LOGGERHEAD **ROV**

Mount Olive High School
18 Corey Road
Flanders, New Jersey 07836

2018 Technical Documentation

Photo Credit: S. Mills

Team Members (From Left to Right):

Damon Johnson	Design Engineer (2018)
Billy Albert	Software Engineer (2020)
Garrison Case	CTO (2018)
Lauren Turi	CMO (2019)
Matthew Folenta	Design Engineer (2020)
Thulasi Varatharajan	Design Engineer (2019)
Katie Weatherwax	CEO (2018)
Erin Perry	CFO (2018)
Megan Perry	Electrical Engineer (2020)
Soumya Khera	Marketing & Comm. (2020)
Brooke Bennett	Marketing & Comm. (2019)
Jessica Tierney	Safety Officer (2020)

Mentors

Mr. David Bodmer	Project Advisor
Mr. Gregg Turi	Electrical Engineer
Mr. Allan Dunster	Electrical Engineer
Mr. Matt Dunster	Mechanical Engineer
Mr. Stephen Geiger	ROV Design Mentor
Mrs. Susan Mills	Marketing Advisor

ABSTRACT

Entering our second year, Loggerhead ROV, operating out of Mt. Olive High School in Flanders, New Jersey, continues to create top-of-the-line ROVs (Remotely Operated Vehicles). This year's ROV, Tammi (Fig. 1), can salvage vital components from submerged aircraft wreckage using an integrated lift bag system, retrieve ocean-bottom seismometer (OBS) instruments and help provide renewable energy through tidal turbine deployment. This is accomplished through sophisticated onshore control systems, custom mission specific tools, and advanced onboard electronics for manipulation and wireless communication.

Tammi builds upon last year's modular six thruster vectored design with a sleek chassis to promote ease of use and on-the-go changes if necessary. The chassis includes a custom manipulator system, acoustic emitter, and an integrated lift-bag inflation and quick release system, all designed by our student engineers. Our company consists of 12 skilled and passionate students who are eager to learn, and who throughout the year were able to design the ROV to meet the needs of the RFP (Request for Proposals). Through the use of the cloud based CAD (Computer Aided Design) software Fusion 360, we were able to design our ROV piece by piece collaboratively. Each component was tested to ensure the design met preset specifications for its effectiveness at completing the mission objectives. Loggerhead ROV takes pride in providing students with the experience they desire and opportunities to grow within our company.

Figure 1 - ROV Tammie Photo
Photo: B. Albert

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PROJECT MANAGEMENT

To prepare ourselves for success this season, Loggerhead ROV began meeting in early August of last year. At that time company positions were discussed and assigned to individuals based on qualifications. Our summer meetings ran for two hours to allow us to take inventory, organize our shop, restock supplies and discuss build schedules for the coming season. Throughout the fall and before the season started, meetings were held to introduce our new students to MATE and our company culture. We used that time to train all members and provide the necessary skills needed to use the software, tools, and components that we work with, and to establish tentative work deadlines and schedules. When the RFP was released in December we began meeting three times per week for two hours to discuss strategies and design ideas. To accommodate our large group and their varied schedules we held meetings after school, evenings and weekends. Lunch meetings during school hours allowed company executives to plan future company meetings and adjusted milestones as needed. Mandatory company meetings took place to relay this information and gain input from the rest of the company.

Another tool we used to stay organized throughout the design process was Fusion 360, a cloud based CAD (Computer Aided Design) software. This was done so that every student engineer had access to all of the files from anywhere, including from home. We also broke into project groups based on a student's interests and skills. This allowed us to allocate our resources to effectively meet day-to-day operations. Each student was able to access 3D printers required for prototyping and testing different components to address each mission. We also introduced a 'subteam' breakdown in which students chose one or more areas to focus on. Areas of concentration would include design, electrical, programming, marketing and communications. Individuals worked with the group(s) they were most interested in and comfortable with. Each student engineer was given the opportunity to choose which projects they wanted to partake in. This choice ensured that each student would be working with enthusiasm and passion to effectively complete the ROV.

To manage these groups and maintain order throughout the company, individuals were selected to lead each subteam and were responsible for monitoring the progress of daily operations. These directors are responsible for creating objectives to accomplish each meeting and determine the protocol for each subteam.

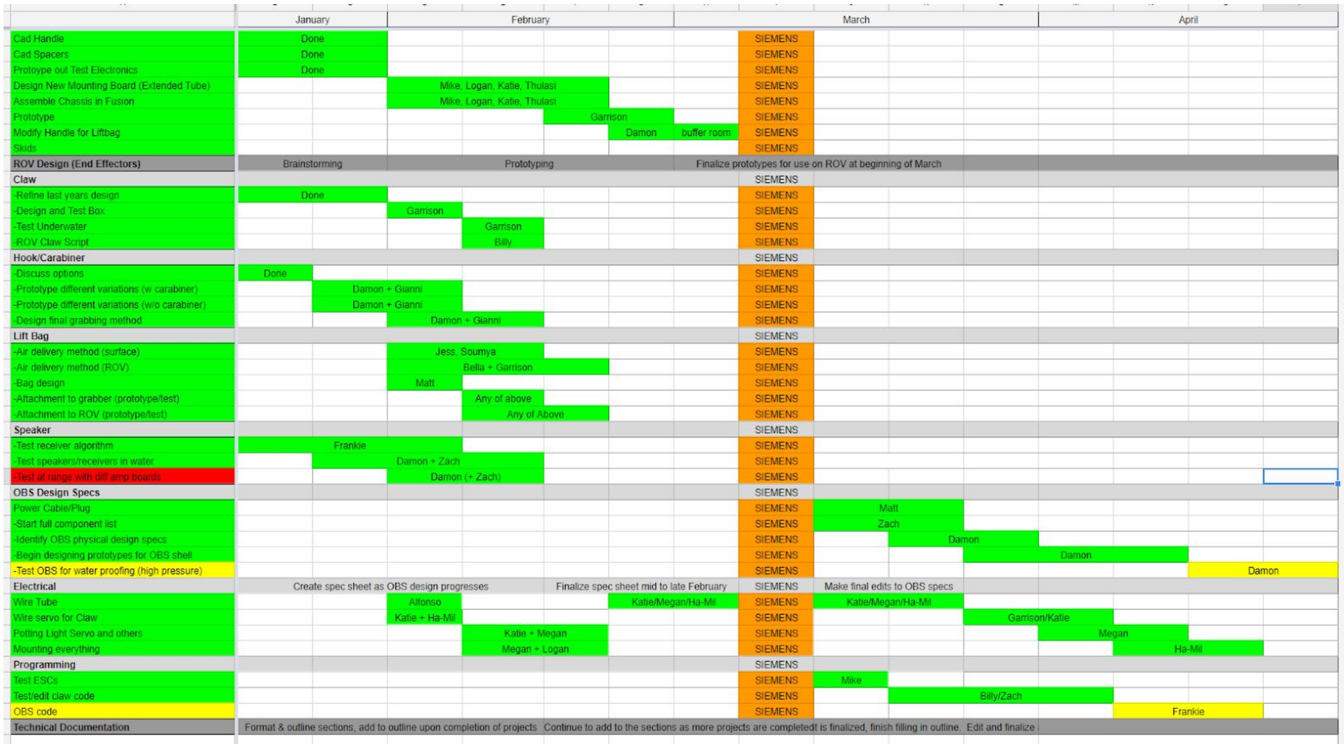

Figure 1.2 - Design Gantt Chart
Google Sheets: M. Folenta

DESIGN RATIONALE

Figure 1.3 - ROV
Photo: B. Albert

We designed with two principles in mind; *design intent* and *modularity*. Design intent is the concept of designing components that can be readily updated and modified over time to fit our client's particular needs. Modularity allows design intent to be easily implemented and allows for easy replacement and extension of parts. This approach reduces turnover time between prototypes and ultimately allows for a more positive ROV operator experience. Modularity also allows for changes to be made in the future and increases the potential for growth; the ROV can tackle an entirely new challenge by simply mounting a new end effector and adjusting the buoyancy, making the robot more versatile in a wide range of applications.

We analyzed each mission and identified the individual steps the ROV must complete to successfully accomplish the actions within each mission. Our engineering leadership then assigned specific design tasks to each member to evenly distribute the design workload. This allowed us to accomplish the missions outlined in the Request for Proposals (RFP) as smoothly and efficiently as possible.

Throughout our product development we performed experiments testing multiple variables to optimize our designs. Taking advantage of our tank, we were able to test prototyped concepts in a simulated product demo environment. We then were able to take the results of these tests back to the whiteboard, often using aids such as matrices to organize our variables and options to further improve on our designs and performance.

Frame

The chassis of the ROV (Fig. 2.1) consists of three center brackets that secure the pressure vessel (See Fig. 3.1 below), a custom electronics mounting board, interchangeable thruster mounts, and a handle that also serves as a lift bag transport and release system. The frame as a whole is designed to be compact to meet the sizing specifications in the RFP and the size restrictions required for operating in the environments of each mission objective, such as during aircraft recovery operations. The center brackets (Fig. 2.2) are designed to hold the thruster mounts in place and incorporate threaded rods to allow for extra mounting points for the rest of the chassis. A natural clamping feature ensures the pressure vessel is held in place and cannot be rotated providing advantages in both size and customizability that could not be achieved with alternative chassis solutions. Made from production-grade ASA (Acrylonitrile Styrene Acrylate) thermoplastic using FDM (Fused Deposition Modeling) technology, the center brackets are durable, yet flexible enough to maintain a secure hold on the pressure vessel, with silicone inserts being used to prevent movement when handling the ROV. ASA plastic also has the benefits of being lightweight and high strength. These traits allow the ROV to execute a wide

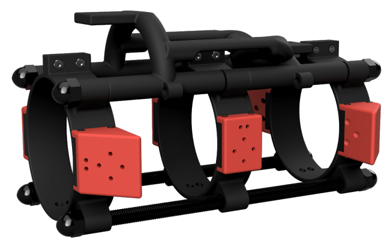

Figure 2.1 - Frame
Rendering: G. Case

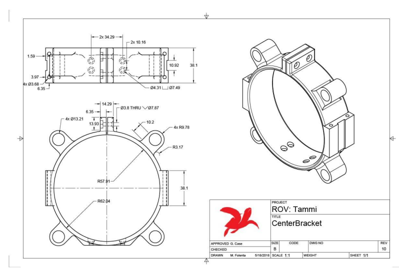

Figure 2.2 - Center Bracket
Drawing: M. Folenta

variety of operations and allow it to handle the stresses associated with missions, such as working with Ocean Bottom Seismometer (OBS) units and handling underwater tidal turbines. These brackets are custom designed to satisfy the need for modularity and interchangeability, as there are no products on the market that can accommodate the pressure vessel and the various actuators of the robot.

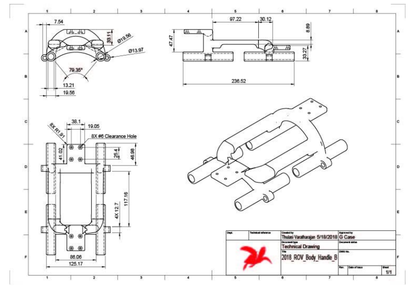

Figure 2.3 - Handle
Drawing: T Varatharajan

The handle (Fig. 2.3) is seamlessly integrated with our lift bag system, allowing the ROV to passively release the lift bag as it is filled with air and rises. Considering the buoyant forces generated as the lift bag inflates, it is placed on top of the ROV, ensuring that the center of buoyancy remains above the center of mass (providing an adequate righting moment throughout ROV operations). The handle made from ASA is designed to accommodate this lift bag placement, as well as serving its function as a safe way to carry and lift the ROV (Fig. 2.3).

In order to optimize our lift bag and its deployment method, we identified the main variables that affect its performance and consistency. By setting up multiple matrices of different options, we were able to work our way through each stage of variation of the lift bag and its deployment method. One of these key changes was the direction of the handle. Choosing to put the more elevated side of the handle towards the front or rear of the ROV altered the dynamic of its deployment by moving its center of buoyancy.

The skids (Fig. 2.4) borrow many concepts from last year's design, but are printed as one part to eliminate stress concentrations that were present in the previous design. They are printed from PLA (Polylactic Acid) to allow for in-house manufacturing, especially considering the similarities in material densities and strength properties when compared to ASA.

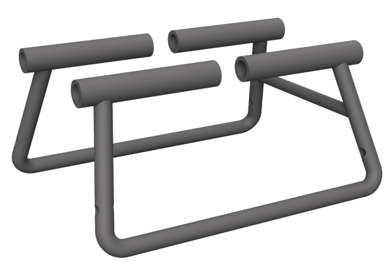

Figure 2.4 - Skids
Rendering: G. Case

In our tests, we discovered that the ROV had a natural tendency to pitch upwards and roll to the side when placed in water. We determined that this was due to the center of buoyancy being below the center of mass of the ROV. We took steps to lower the center or mass, as well as raise the center of buoyancy to allow these vectors to 'pull' on each other instead of 'push' on one another. We included an opening for a threaded rod insert on the lower half of the skids, on which we could place adjustable weights to fine tune the buoyancy characteristics of the ROV.

Pressure Vessel

Our pressure vessel (Fig. 3.1) and electronics were purchased from outside sources due to the difficulty of manufacturing them ourselves. The electronics mounting board, however, was designed in house (Fig. 3.2). In our previous model, we were unable to fit all of our desired electronics into the main pressure vessel and had to use separate housing. This drove us to design a dual layer electronic board that allowed us to effectively maximize our available surface area to mount additional electronics. The two platforms include cutouts for easier access to the end cap standoff mounts and more cutouts to enable wires to not be confined to one side of the plate. These two layers are connected by two end plates with circle cutouts for wires. The front endplate also has an attached camera mount that was made using the BlueROV camera mount CAD file and a cutout for easier access to the SD (Secure Digital) card in the Raspberry Pi. The rear end plate differs in that it screws into standoffs that screw into our tube end cap. For added support, two convex columns were added in the center.

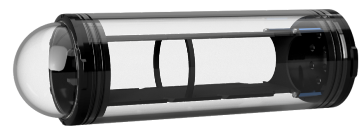

Figure 3.1 - Pressure Vessel Rendering: G. Case

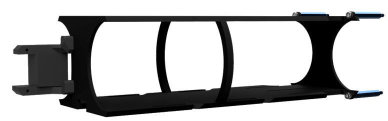

Figure 3.2 - Electronics Board Rendering: G. Case

Actuators

Our thruster setup (Fig 4.1) is designed to operate in a multitude of configurations and can be set up to accommodate anywhere from four to eight thrusters to add or remove axes of motion as necessary. The thruster mounts have the option of being normal to the tube or at a 45 degree angle along the XZ-plane. The normal mounts allow for vertical motion while the 45 degree mounts allow for all motion along the XZ-plane due to the vectoring produced by the non-parallel thrusters. Using a combination of these mounts in an 8 thruster setup, the ROV can move along 3 planes and can rotate about all 3 axes. This

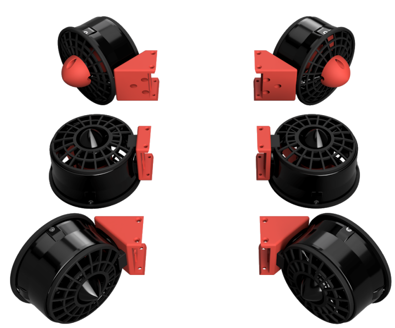

Figure 4.1 - Thruster Mounts Rendering: G. Case

however, was unnecessary for our needs, and was more complicated to maintain and install, so we decided on a 6 thruster setup, which allows for 3 planes of motion and 2 axes of rotation. This proved to be a more balanced approach to the thruster configuration, and allowed us to have an extended range of motion on the ROV without using excessive amounts of space being taken up within the electronics board and on the ROV itself.

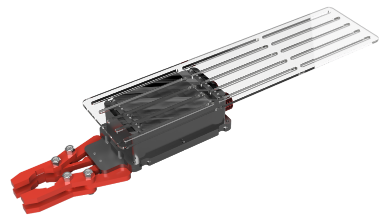

Figure 4.3 - Manipulator Rendering: G. Case

Our end effector this year consists of a manipulator and a sealed servo housing (See Fig. 4.3). The manipulator is a two finger design that uses a four bar system to keep the fingers parallel, allowing the user to grip and handle a wide variety of objects. Through various research and testing, it was decided that a two finger design operating through a parallel linkage would provide a strong balance between simplicity, ease of manufacture, and capability. The design took inspiration from existing claws, such as the VEX Robotics Claw Kit, and built upon them to suit the needs of the ROV, allowing more effective completion of missions. The joints on the claw are fastened by shoulder screws to reduce friction and prevent the claw from sticking or skipping throughout its travel. The housing contains a servo positioned horizontally with a set of bevel gears to save space. This enclosure is sealed to allow for a redundant layer of water resistance and to prevent objects such as fingers and particulates from getting caught in or interfering with the gears and mechanisms.

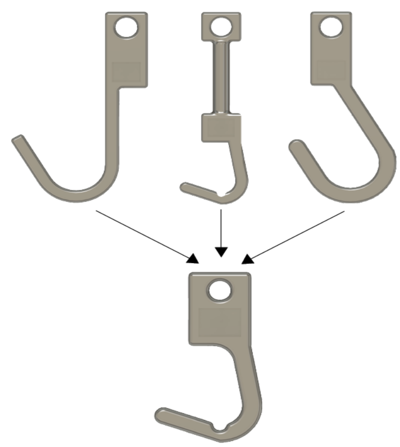

Figure 4.4 - Hook Evolution Diagram: E. Perry

The claw is designed in parallel with this year's lift bag system to ensure each part functions with one another properly and to prevent extra changes from being made after the fabrication of these parts. The hook included in the lift bag system focuses on attaching and removing the lift bag during aircraft recovery reliably. Several prototypes of the hook were created, and ideas were consolidated into one final design (Fig. 4.4). After testing these prototypes we altered the geometry of the claw to better secure the hook. The claw has a

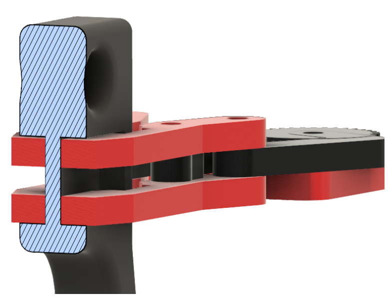

Figure 4.5 - Hook Section Analysis Rendering: G. Case

pattern inset (Fig. 4.5) that matches the hook used in the lift bag system which ensures a consistent, firm grip that prevents the hook from slipping.

The end effector is mounted on a slotted plate made from laser cut acrylic that allows the claw's position to be adjusted to the user's preferences. This slotted design also provides opportunities to add new end effectors as needed to tackle challenges other than those provided in the RFP. We laser cut our end effector mount out of acrylic, as it is easy to work with considering the simplicity of the part and is durable enough to withstand the forces carried through the manipulator.

Build vs. Buy, New vs. Used

We decided to build a majority of our ROV's parts as opposed to purchasing them. Tammi's design required many specially designed parts that could not be accommodated by items on the market. We felt that building parts from scratch gave us a higher return on time investment and allowed us to optimize our robot for its specific purposes. Building parts saved us time, as we did not have to wait for purchased parts to arrive by mail. The largest benefit of designing custom parts is the ability to adapt the design to accommodate new parts as requirements develop. Buying parts limits the ability to change individual elements of the design, as each purchased part is static and offers little in terms of modification. Designing our own parts allows the ROV to be designed in a more fluid manner, with parts being highly customisable, and multiple design paths available, allowing the ROV to fit a range of applications instead of a specific use case.

Although we designed many of the parts for the ROV in house, we also incorporated multiple parts that were purchased. Keeping in mind both budget and time constraints, we turned to existing items available on the market when appropriate. For example, the pressure vessel, electronics, and thrusters were all parts that were easier to purchase, due to a combination of cost, quality, or other factors. Conversely, the tether, center brackets and thruster mounts were all parts that have had lasting benefits and justified the time spent designing them to fit our specific needs for the RFP.

Many of our part designs are iterations of designs from the previous season, with changes made to accommodate this year's challenge. We recognized the time that could be saved by reusing existing designs instead of creating and testing new designs, and decided to focus on improving our existing design rather than starting from scratch. The time that we saved by doing this enabled us to improve the ROV's stability and structural integrity and to consolidate parts into a simple, refined design that has less points of failure and is more versatile overall.

SID (Systems Integration Diagram)

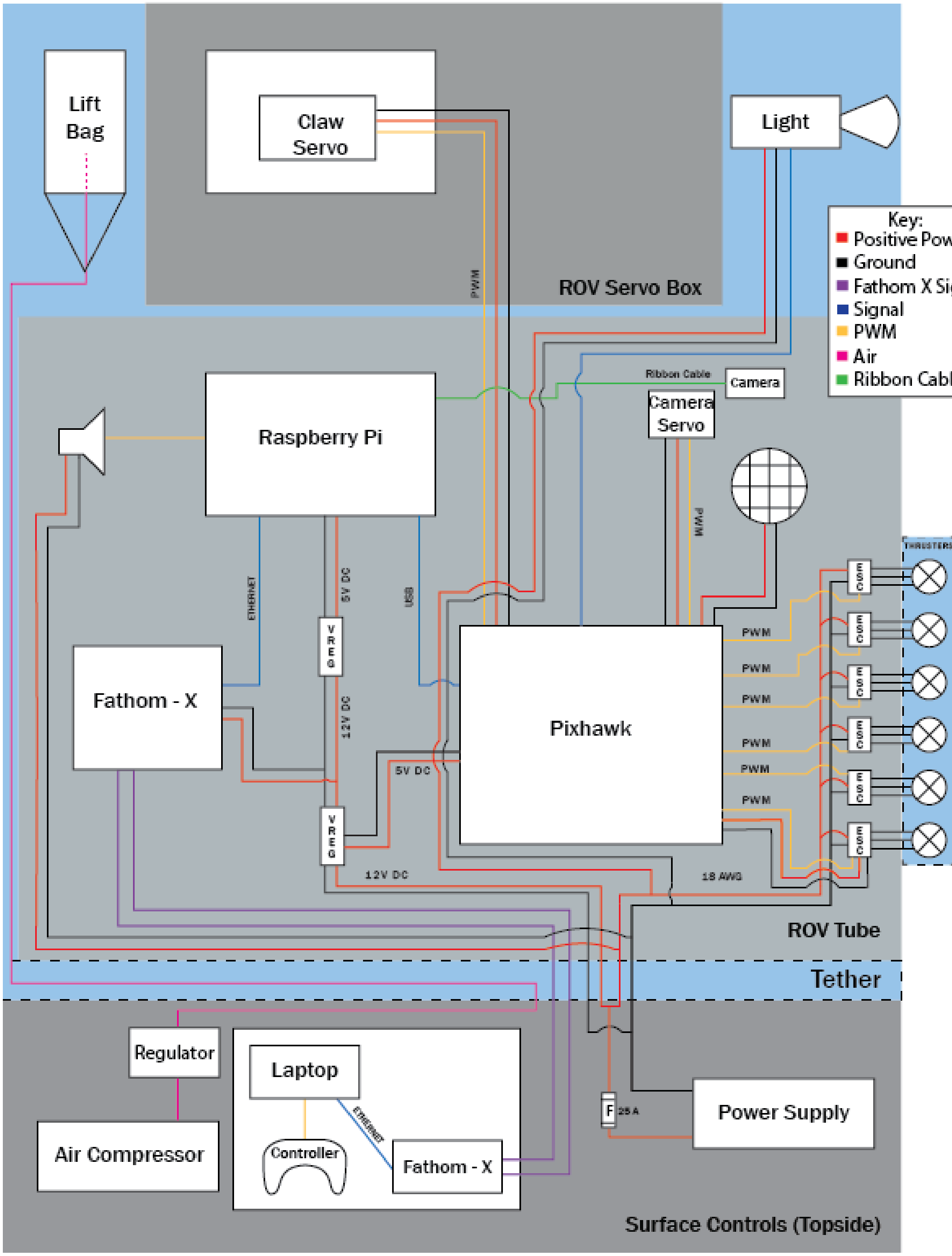

Figure 5.1 - SID Diagram of ROV and Topside Electrical Systems: K. Weatherwax

System Current Calculations/Fuse Selection

Description	Qty	Iq (typ) (A)	Iq (max) (A)	System Iq (typ) (A)	System Iq (max) (A)
Raspberry Pi 3 (with Camera)	1	0.6	1.0	0.6	1.0
PixHawk & Fathom-X (Both)	1	0.38	0.5	0.38	0.5
UBEC (Voltage Regulator)	2	0.05	0.05	0.1	0.1
LED Light - White	1	0.25	0.5	0.25	0.5
Speaker/Buzzer	2	0.02	0.025	0.04	0.05
Thruster (T100) + ESC (Speed Controllers)	6	1.0	2.0	6.0	12.0
Total System Current				7.37	14.15
Supply Current with 150% overrating					21.225
System Fuse Selection (rounded to next standard)					25 Amp

Software Flow Chart

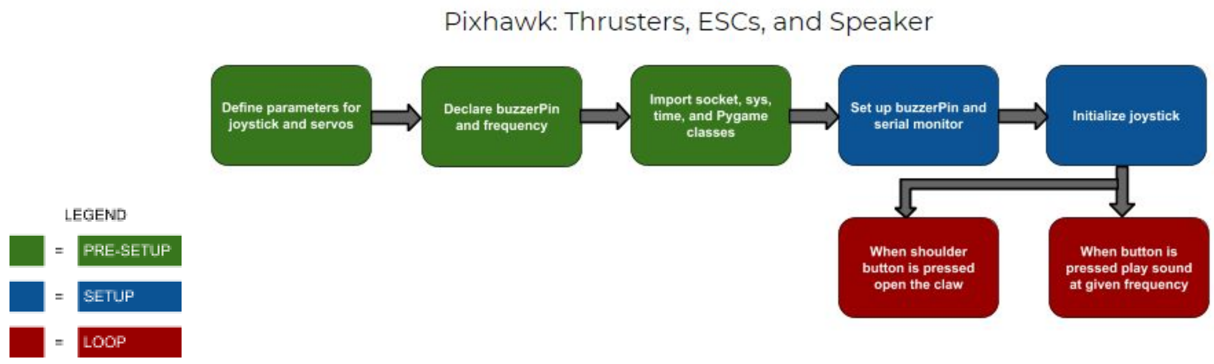

Figure 5.2 - Software Flow Chart Diagram: B. Albert

SAFETY

Safety Features

To ensure that our ROV met the safety requirements for this year's challenge, we have included numerous safety features. The most obvious feature is the handle that we incorporated into our design for safe carrying and transportation, as seen in Figure 2.3. This allows operators to handle the ROV without having our hands near any dangerous moving parts. In addition, we eliminated the risk of debris getting caught in the propellers by installing IP20 Propeller Guards. Water is able to flow through with minimal obstruction but large objects greater than 12.5 mm are unable to enter the small openings. Furthermore, we included an additional aluminum vessel which encases the servo and gears used to manipulate the claw, preventing debris from jamming the gears or any possible injuries.

Our pressure vessel testing system is a pump that creates a vacuum in the vessel to 103.4 kPa (15 PSI) below atmospheric pressure. The pressure must remain above 100.0 kPa (14.5 PSI) for at least 15 minutes to be water ready. The ROV is equipped with a strain-relief carabiner attached to the tether to ensure that if the tether is tugged on, the force is applied to the carabiner and the wires inside will not be affected. Finally, our electrical overload failsafe system is a 25 amp slow blow fuse to protect our electronics from current overdraw, specifically from inrush current during the initial power up of the ROV. The fuse provides protection from overcurrent draw and will break the circuit when the current draw exceeds the preset threshold.

The ROV includes warning stickers on each thruster as well as around any possible pinch and electrical hazards. The software also includes quick arm and disarm features to shut off the thrusters in case of emergency or electrical failure. The topside control system is transported in a Pelican case to protect the electronics from shock and water damage. This Pelican case includes a tether strain relief to prevent damage to the wires. Our tether is colored red to ensure that those on the pool deck are aware of its presence, thus reducing the risk of tripping around it. Additionally, our thrusters have current limits that are custom set within the ROV control software to prevent electrical overloads.

PRE FLIGHT SAFETY CHECKLIST

- ❏ Electronics pressure release valve is closed
- ❏ Electronics canister is sealed/pressure tested
- ❏ No leaks emitting from electronics canister
- ❏ No electronic wires are exposed
- ❏ Underwater connections are seated and secure
- ❏ Main ROV controls in off or neutral position
- ❏ Chassis hardware is tightened
- ❏ Deck Crew is clear from ROV

Safety Procedures

TETHER AND TETHER MANAGEMENT SUBSYSTEM

- ❏ Tether is untangled and connect tether to ROV control box
- ❏ Inspect tether for visible damage, replace if damaged
- ❏ Check that the tether is neatly coiled for deployment

ROV POWER UP

- ❏ All electronics have power
- ❏ Hands clear of ROV before arming
- ❏ Thrusters respond to controls
- ❏ Emergency stop system tested

LAUNCH AND RECOVERY SAFETY CHECKLIST

- ❏ Deck crew wearing closed toe shoes
- ❏ Deck crew wearing eye protection when required
- ❏ Two member launch crew ready

LAUNCH ROV USING HANDLES

- ❏ Launch team clear from ROV

PERFORM MISSION TASKS

- ❏ Deck crew ready to receive ROV
- ❏ ROV controls disabled/locked once in recovery area
- ❏ Recover ROV from water and place on deck

POST FLIGHT SAFETY CHECKLIST

- ❏ ROV is powered off
- ❏ Tether disconnected and neatly coiled
- ❏ Rinse and dry ROV for storage

SHOP SAFETY

- ❏ Always wear approved safety glasses or goggles in designated areas and/or when working with the ROV and/or hand/power tools.
- ❏ Only OSHA approved safety goggles may be worn with a minimum rating of Z87.
- ❏ Never wear loose clothing around any power tools. Roll up sleeves to your elbows and hide sweatshirt hood-strings to avoid getting them caught in a tool.
- ❏ Remove any accessories such as ties, watches, bracelets, or any other jewelry. These items can get stuck in a tool and cause serious injury.
- ❏ Long hair must be pulled back at all times.
- ❏ Close-toed shoes ONLY!
- ❏ Never use compressed air to clean yourselves or your clothing. It can result in internal rupture.
- ❏ Always know what the escape plan is in case of a fire, evacuation emergencies, etc.
- ❏ Always wear long pants to avoid lacerations to your legs.
- ❏ Keep hands away from all moving parts of machinery

Marauder Innovation Learning Lab (MiLL) Housekeeping

- ❏ Always make sure that power tools are completely stopped before cleaning it.
- ❏ Always keep the tools clean of metal chips and oils that may cause damage to the tool.
- ❏ Use a brush and/or vacuum to remove any chips; NOT your hands. Clean oily surfaces with a cloth.
- ❏ Make sure that there is no oil, grease, or chips on the floor to avoid slipping.
- ❏ Clean up all metal chips on the floor with a broom or vacuum.
- ❏ Do not leave tools or any other items lying around. Put everything back in its proper place once you are done.

- ❏ First Aid kit is easily accessible and displayed in a visible location.

CRITICAL ANALYSIS

Testing and Troubleshooting

In the Fall of 2017, Loggerhead ROV installed an 8,300 liter test tank (Fig. 6) which enables us to prototype and test the operational capacity of each new piece we fabricate. Following onsite testing, we then took the ROV to the Aquatic Center at Monmouth University to test at the full operational water depth. We met with Professor James Nickels, a college level mentor, to get feedback on our product. Upon returning, we continued onsite testing in preparation for our product demonstration. The following strategy was used for troubleshooting; when a problem was identified, student engineers worked to develop a solution, and when necessary, reached out to more knowledgeable sources including the internet, product manuals, and mentors.

Figure 6 - Test Tank Facility Photo: B. Albert

3D modeled and 3D printed prototypes were used to evaluate and test the design options. These were placed on existing ROVs and tested in our tank to identify which design was most efficient. This method was utilized in each subsystem's testing phase, for example in our lift bag testing scenarios, where we prototyped several hooks of varying geometries and sizes, and tested them for fit and ease of use. Once this was determined, we made minor modifications to further optimize the design. In addition, in evaluating the lift bag mounting clip design, we tested multiple systems, including a physical clip versus a magnetic based release, as well as different geometries of each. After testing, we were able to identify an effective design for the mission.

During the development of our OBS, we hypothesized that the change in medium from air to water would distort the frequency. In order to program the system correctly, these frequency shifts need to be accounted for. We developed an experiment to test the concept using speakers, microphones, and a sink. We determined the sound waves did not experience, but a significant drop in intensity, with the final signal being very faint even at a short distance. These discoveries were the foundation for our final design by keeping the starting and ending medium constant and by using amplifiers to pick up on the frequency even after its intensity drop.

Despite having a tank available at our school, some of our designs needed to be tested in a larger and deeper environment. A nearby school allowed us to use their swimming pool, which not only was significantly larger than our tank, but was about three times as deep. This pool allowed us to experiment with how our ROV and all its elements would behave at the required depth. We were able to collect better data, such as the optimal PSI to deploy our lift bag system to lift debris and the engine.

Challenges

As described above, identifying an effective design for lift bag mounting clips was a significant technical challenge that our company faced this year. Ideating for the original designs proved to be a challenge within itself, but after testing multiple systems and multiple geometries, we were finally able to identify an efficient, streamlined system that we implemented into our product.

We had a large amount of leadership positions which caused more confusion than organization because many duties overlapped. Without clear direction, it became challenging to be productive. After participating in the MATE Pennsylvania Regional, we reduced our leadership system to four key roles for the international competition in Seattle.

Lessons Learned

Last year we had little to no trouble with buoyancy; the ROV was in a drivable condition from the start. This year, with the reorganization of the electronics board and the modifications done to the end effector, we quickly discovered that buoyancy adjustment was going to be a necessary feature to be competitive this year. We learned about the concepts of center of buoyancy vs center of mass, as many adjustments were necessary to reach optimal buoyancy.

Our company size proved to be a significant challenge this year. With so many eager student engineers, it was difficult to effectively distribute the work. Often, there were idle hands for which we could not provide work for. After experiencing these issues, we broke into sub teams to better organize our members based on their personal interests. This approach proved to be incredibly effective and helped to disperse the work more efficiently throughout the team. We required clear communication to ensure everyone was kept up to date on company events and progress. We learned that using Google Classroom is another effective method for sending out updates to the whole company and remaining organized.

While participating in the many aspects of our company, students learn a wide range of technical and business skills to help them in their future endeavors. For example, students learn CAD, design principles and the design process through Autodesk Fusion 360, which is heavily relied on for the creation of our ROV. Students also learn basic engineering concepts and mechanical terminology as they work. Throughout our prototyping and manufacturing process, students are exposed to the principles of additive manufacturing through 3D printing their pieces from a variety of materials. Programming our ROV and controls system, students gain exposure to programming concepts, and the programming language Python, which is commonly used in industry. Students on marketing are able to work with Adobe Illustrator to design graphics and the display board. Students also learn marketing strategies and how to run a successful business through each aspect of the competition.

FUTURE IMPROVEMENTS

One aspect of our project management we plan to improve in the future is our time management. We found ourselves occasionally losing track of time, whether it be due to inclement weather or an excessive desire for perfection in our projects. There were times when our entire team was meeting despite not having any open project requirements or work that needed to be done. Therefore, in future years, we plan to have a more rigid schedule and deadlines that will be strictly enforced. In June, we hold an “End Of Year” meeting to reflect on our season and talk about our experiences as a company. All of the points in this document will be addressed and will be corrected for the next season.

ACCOUNTING

Loggerhead ROV 2017-2018 Company Budget			
Reporting Period:		**From: 9/1/17**	**To: 6/30/18**
School Name:	**Mount Olive High School**		
Loggerhead ROV Program Director:	**David Bodmer, Lead Advisor**		
Income	**Type**	**Category**	**Amount**
Bodmer Family	Parts/Materials	General	$500.00
Chameleon Design Solutions	Cash Donation	General	$1,000.00
DRT Transportation	Cash Donation	General	$750.00
Mount Olive Board of Education	Parts/Materials	General	$8,000.00
Pettit Paints	Cash Donation	General	$500.00
Picatinny Arsenal	Parts/Materials	General	$3,000.00
Triangle Services	Cash Donation	General	$1,000.00
Student Team Dues	Cash Donation	General	$1,000.00
Willowgate Cottage	Marketing Materials	General	$150.00
Terry and Meeta Thomas	Cash Donation	General	$4,000.00
The Weatherwax Family	Marketing Materials	General	$170.00
Harrington Trust	Cash Donation	General	$500.00
Multi Utilities Ventures, LLC	Marketing Materials	General	$250.00
		Total Income:	**$20,820.00**
ROV Build Expenses			
Part Description	**Type**	**Category**	**Budgeted Value**
ROV Watertight Enclosure			
Buoyancy Foam	Purchased	Mfg. Materials	$47.00
Enclosure Tubing	Purchased	Mfg. Materials	$20.50
BlueRobotics T100 Thruster	Purchased	Electronics	$714.00
Electronic Speed Controllers	Purchased	Electronics	$150.00
1/2-13 Cap Nut Black	Purchased	Hardware	$3.39
1-1/2 x 6 Stainless Steel Tailpiece	Purchased	Hardware	$6.62
3/10 Flat Head Socket Cap	Purchased	Hardware	$0.46

4/40 Thin Nylon Insert Nuts	Purchased	Hardware	$0.99
4-40 Flat Head Socket Cap	Purchased	Hardware	$3.39
6/32 Thin Nylon Insert Nuts	Purchased	Hardware	$3.73
6-32x3/4 Stainless Steel Socket Head Screw	Purchased	Hardware	$0.93
6/32x9/16 Flat Socket Cap	Purchased	Hardware	$0.81
			$951.83
ROV Manipulator			
Acrylic	Purchased	Mfg. Materials	$50.00
Aluminum Box	Purchased	Mfg. Materials	$150.00
Aluminum Lid	Purchased	Mfg. Materials	$50.00
Cable Penetrator	Purchased	Hardware	$12.00
HS-5086wp Servo	Purchased	Electronics	$48.00
O-Rings	Purchased	Hardware	$0.50
Plexi Glass Lense Cover	Purchased	Hardware	$10.00
Servo Gear/Bevel Gears	Purchased	Hardware	$20.65
Servo Set Screw Shaft Coupler	Purchased	Hardware	$4.99
Zinc Plated Nuts And Screws	Purchased	Hardware	$25.00
		Sub Total:	**$371.14**
ROV Electronics			
Power Supply	Purchased	Electronics	$144.00
Buzzer	Purchased	Electronics	$2.00
Ethernet Cable	Purchased	Electronics	$3.00
Fathom-X Tether Interface	Purchased	Electronics	$159.00
Pixhawk	Purchased	Electronics	$199.00
Raspberry Pi	Purchased	Electronics	$45.00
Speed Controllers	Purchased	Electronics	$150.00
Raspberry Pi Camera	Purchased	Electronics	$45.00
Cable Penetrators	Purchased	Electronics	$44.00
Tether	Purchased	Electronics	$218.00
Buzzer/Speaker	Purchased	Electronics	$18.00
Speaker	Purchased	Electronics	$5.00
Voltage Regulator	Purchased	Electronics	$1.00

Microphone	Purchased	Electronics	$3.00
Arduino	Purchased	Electronics	$16.00
		Sub Total:	**$1,052.00**
3D Printed Manufactured Parts			
Makerbot Tough PLA	Purchased	Mfg. Materials	$225.00
		Sub Total:	**$225.00**
Auxiliary Parts			
Lift Bag	Purchased	General	$5.00
Pneumatic Tubing	Purchased	Mfg. Materials	$20.00
		Sub Total:	**$25.00**
		ROV Total:	**$2,624.97**
Project Costing			
	Type	**Category**	**Projected Cost**
ROV Parts	Purchased	Mfg. Materials	$1,000.00
ROV Hardware	Purchased	Hardware	$300.00
ROV Electronics	Purchased	Electronics	$1,400.00
Business/Marketing Supplies	Donation	General	$300.00
Tools/Equipment	Re-used/Purchase	General	$500.00
Mission Props/Pool Deck Supplies	Re-used/Purchased	General	$400.00
MATE PA Travel Expenses	School Transportation	Travel	$0.00
Fall Eco Trip - University of Miami *	Hotel	Travel	$4,400.00
Fall Eco Trip - University of Miami *	Flights	Travel	$3,600.00
Fall Eco Trip - University of Miami *	Ground Transport	Travel	$1,100.00
Fall Eco Trip - Divers Paradise	Tour	Travel	$2,150.00
Fall Eco Trip - Biscayne Institute	Tour	Travel	$2,000.00
Fal Eco Trip - Kayak Tour	Tour	Travel	$1,050.00
MATE International Competition	ROV/Tools Shipping	General	$900.00
MATE International Competition*	Hotel	Travel	$3,100.00
MATE International Competition*	Flights	Travel	$6,000.00
MATE International Competition*	Ground Transport	Travel	$1,200.00
MATE International Competition	Faculty Travel Expenses	Travel	$5,400.00
** Indicates student/family paid*		**Total:**	**$34,800.00**

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- Mount Olive High School/Mount Olive Board of Education for their support to providing our company with the sufficient workspace and monetary donations
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- Biscayne Bay National Park for hosting us and teaching us about the effects of human activity on the environment with regard to sea turtles and other aquatic species
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- And last but not least, our lovable mascot Tammi, who we hope to see released into the big blue ocean soon!

RESOURCES

- Bodmer, David. (MATE Project Advisor)
- Dunster, Allan. (Electrical Engineer, MATE Mentor)
- Dunster, Matt (Mechanical Engineer, MATE Mentor)
- Turi, Gregg (Electrical Engineer, MATE Mentor)
- Geiger, Stephen (Marine Engineer, MATE Mentor)
- Nickels, James (Professional Resource)
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