Mount Olive High School

Loggerhead ROV

Canyon

Technical Report - 2019

Mentor

Mr. David Bodmer Project Advisor

Members

JESSICA TIERNEY
CMO (2020)

SOUMYA KHERA
Electrical Engineer (2020)

ABIGAIL FALUOTICO
Electrical Engineer (2020)

KATHLEEN WOOSTER
Design Engineer (2021)

ALEXANDRA EITLEBERG
Electrical Engineer (2021)

SOPHIA OLUP
Design Engineer (2021)

GAVIN PEDERSEN
Design Engineer (2021)

JOSEPH FAUSTINO
Design Engineer (2021)

ROBERT VAN ZEE
COO (2019)

MAXIMILIAN GOEBBELS
Electrical Engineer (2022)

WILLIAM ALBERT
CEO (2020)

FRANK ALFANO
Programming (2020)

MAXWELL FALUOTICO
Programming (2020)

MATTHEW FOLENTA
CTO (2020)

DANIEL FOLENTA
Design Engineer (2021)

NICK FLAMMER
Design Engineer (2021)

LOGGERHEAD ROV

18 Corey Road Flanders, NJ 07836

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ABSTRACT

Loggerhead ROV, operating out of Mount Olive High School in Flanders, New Jersey, continues to create top-of-the-line ROVs (Remotely Operated Vehicles). We are proud to introduce our third ROV, Canyon (Figure 1), and our Micro ROV, Wolverine.

As requested by Eastman and the Marine Advanced Technology Education Center (MATE), Canyon is designed so that it can fully operate in the freshwater environment of Boone Lake and the South Fork Holston River. Our ROV incorporates a custom manipulator system that sits on a Picatinny rail for full modularity. It can collect water samples, determine habitat diversity, recover a Civil War era cannon and lift it to the surface. Our Micro ROV, Wolverine can be deployed to inspect blockages to a drainage pipe and transmit data to the surface. Both our main ROV and our Micro ROV run on custom designed GUI (Graphical User Interface), programs developed in-house by our own computer engineers.

Every part of Canyon has been tested to ensure the design meets the mission objectives simply and effectively. Our company is comprised of 20 industrious student engineers, who together designed Canyon to meet the needs of the RFP (Request for Proposals). Loggerhead ROV takes pride in providing a learning environment for students to grow within our company and beyond.

Figure 1 - Final ROV: M. Folenta

DESIGN RATIONALE

Design Process

Working off last year's ROV, Tammi, we evaluated our adaptability for the 2019 MATE RFP. Missions outlined in the RFP were separated by the action required, such as lifting, moving, and measuring with main objectives being modularity, serviceability, versatility, and manufacturability. Our 8,300 liter test tank, provided a product demo-like testing environment for our initial design options. Results obtained from these tests were analyzed throughout the prototyping process to further improve on our designs and performance.

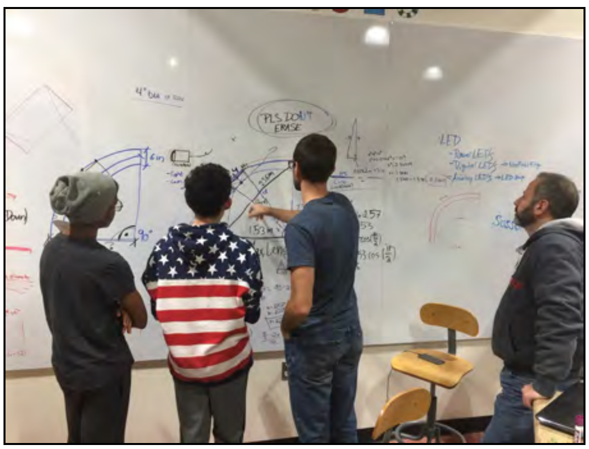


Figure 2 - Students working with mentors to create a formula to determine Micro ROV diameter to length ratio: J. Tierney

Figure 3 - Students sketching preliminary ROV concepts: J. Tierney

Chassis

The chassis was designed in Autodesk Fusion 360, a 3D modeling program used by engineers throughout the world. Designing the chassis using this software allowed us to evaluate many different ROV designs and components without having to build physical models. Once the chassis design was finalized, the design files were exported to our 3D printers for in-house assembly (Figure 4).

Figure 4 - Frame Rendering: M. Folenta

At the core of our chassis is a pressure vessel, serving both as a containment unit and a structural element to our ROV Figure 4. The interior holds a custom 3-stage electronics mounting board set. These components are kept watertight via double o-ring seals on both aluminum end-caps on each end of the vessel's exterior.

Center bracket clamps (Figure 5) secure the pressure vessel and mount both the skids and the Picatinny rails. Aluminum skids provide protection for the underside of the ROV and will stabilize the ROV when working on the bottom of Boone Lake.

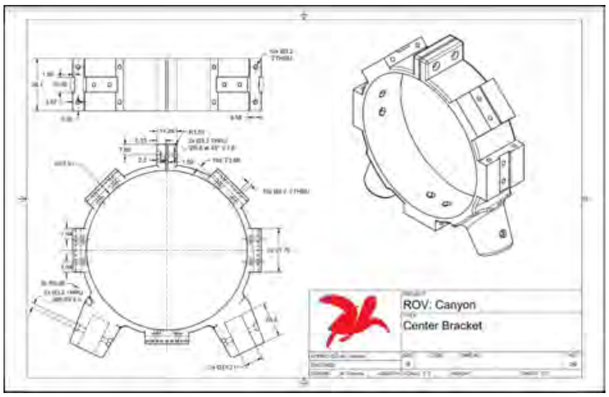


Figure 5 -
Center Bracket Clamps
Drawing: M. Folenta

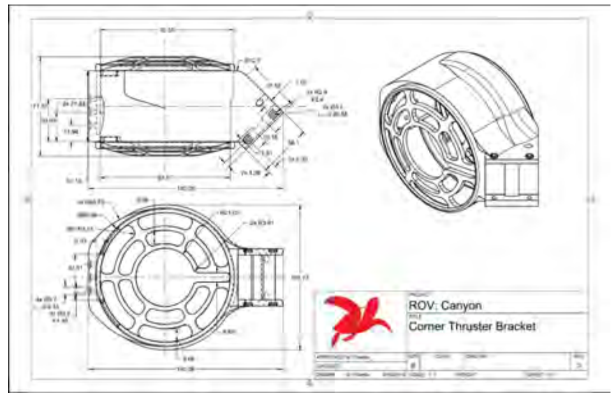


Figure 6 -
Corner Thruster Bracket
Drawing: M. Folenta

Special Features

Picatinny Rail

The Picatinny rail (Figure 7) is a universal mounting platform for end user accessories. The Picatinny rail, originally developed by Picatinny Arsenal in 1992, permits a variety of components to be slid and locked into place easily and quickly. Using three Picatinny rails allows the end-user customization, providing for a more versatile ROV.

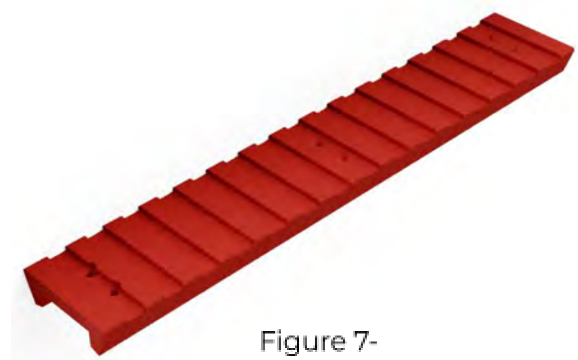


Figure 7-
Picatinny Rail:
M. Folenta

Cannon Salvage Lift Bag and Clips

To salvage the Civil War cannon, we chose to incorporate a lift bag that could be deployed to raise the it to the surface. Three lift bag clips (Figure 8) are attached to the Picatinny rail and positioned between the thrusters. The clips, made of a flexible resin, will naturally open when the bag is inflated. The lift bag is a 6 liter inflatable Osprey Ultralight dry bag, made of 40-denier ripstop nylon for extreme durability.

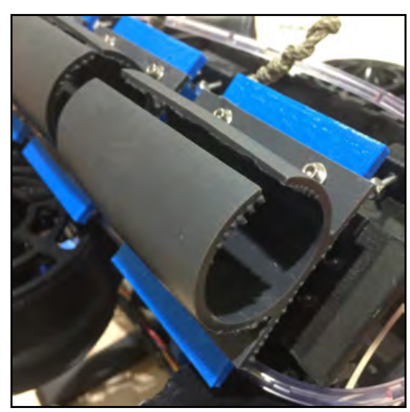


Figure 8 - Flexible
Lift Bag Clip:
R. Van Zee

Manipulator

The manipulator (Figure 9) is engineered to secure and transport objects less than 90 mm in diameter. The attaching bracket is 3D printed out of Formlabs Tough resin to provide the strength needed to transport and recover mission-critical items. The ramp and upper jaw are laser cut out of 6061 aluminum alloy due to its strength-to-weight ratio. The upper jaw is directly attached to a waterproof servo to drive the opening and closing action.

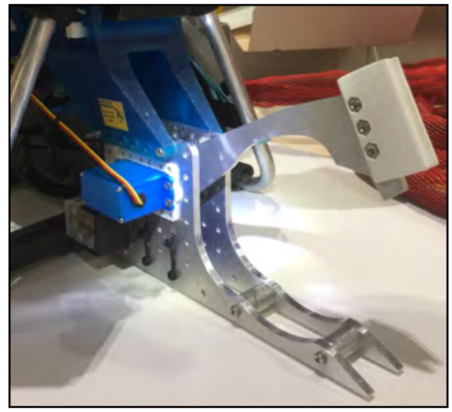


Figure 9 - Manipulator: M. Folenta

Retracting Apparatus for Micro ROV

The retracting apparatus (Figure 10) contains the fiber optic cable on a large spool, which is under spring tension. The Micro ROV's onboard thruster propels itself out of the docking station into the Corex drain pipe. As this forward motion occurs, the fiber optic cable unspools and charges the rotary spring. Once the Micro ROV reaches the maximum distance required, the onboard thruster reverses, pulling our Micro ROV out of the tube. During this travel, the previously charged spool coils the fiber optic cable neatly and securely.

Figure 10 - Retracting Mechanism: R. Van Zee

Micro ROV Designed for Drain Inspection

The Micro ROV is designed with an 8.9 cm diameter by 15.24 cm long acrylic tube to maneuver through the Corex piping as well as navigate the minimum bending radius. Two custom end caps are fitted on either end of the pressure vessel. The Micro ROV is capable of seeking out areas of muddy water by utilizing the front end cap and the on-board camera. The rear end cap aids the Micro ROV back to the docking station when finished.

A dual O-ring seal provides watertight protection for the internal electronics. The front end cap (Figure 11) has a clear acrylic lense fastened to the flat surface for

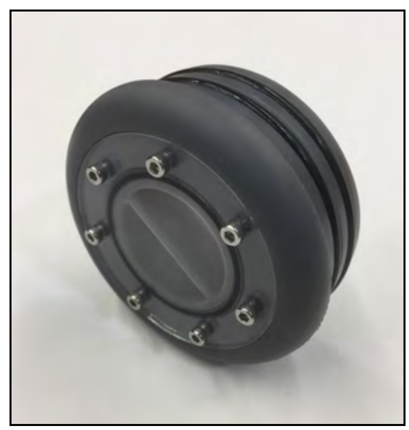


Figure 11 - Front End Cap: R. Van Zee

A prop guard, attached to the rear end cap, is engineered with rounded surfaces, allowing the Micro ROV to be retracted effortlessly and avoid getting stuck on the Corex tubing groves (Figure 12). This prop guard also doubles as a route for the tether to follow when exiting the penetrator located on the rear end cap.

The Micro ROV is powered by eight onboard AA batteries, connected in series, equaling a total of 12 VDC with a 7.5A fuse placed 5 cm from the positive terminal. This eight cell battery pack provides power to a custom built electronic control system that sends video footage and driver control data back to the surface via the fiber optic cable. The fiber optic cable functions as the tether from the main ROV to the micro ROV, transferring data as infrared light.

A spring powered retracting apparatus (Figure 4.3) actively winds up the spring, unspooling the fiber optic cable as the Micro ROV moves forward. When forward motion stops, the Micro ROV is guided back as the cable is spooled.

Figure 12 - Rear End Cap w/ Prop Guard: R. Van Zee

CONTROL SYSTEMS

A new feature for this year's ROV is our custom control system software that allows the pilot improved maneuverability and control of the ROV. To assist the pilot in counting the benthic species, we have developed an image recognition program that captures an image of the species encountered and autonomously determines the number and type of species.

Pilot Station

The pilot station acts as the main server hub for the ROV and Micro ROV. This pilot station has its own custom GUI (Graphical User Interface), and is designed around the ROV's specific functions (Fig. x. By customizing the program, we can easily adapt it to the needs of the ROVs. needs. The pilot station, as well as all of the other programs created this year, are programmed in Python. Python is a programming language that easily interacts with all of the different components we have connected in our Control System. The pilot station sends controller inputs and receives component values, sensor values, and camera feeds from the ROVs. It displays these values on the custom GUI we have created in an organized manner for the pilot to navigate.

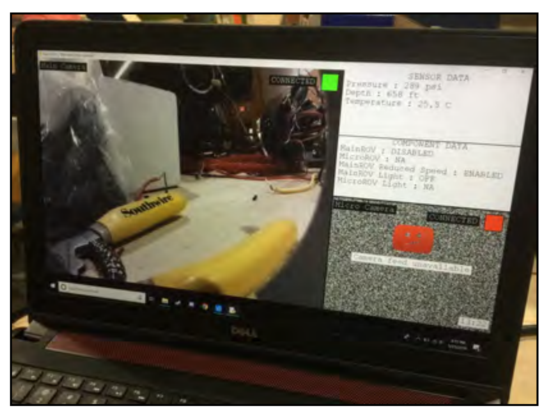


Figure 13 - Pilot Station Console: F. Alfano

ROV

The ROV side of the code is very similar between the ROV and Micro ROV, as they are built using the same base code. The ROV code, at its core, is a program that receives the controller inputs and sends component data, sensor data, and camera feed to the pilot station.

This base code was then modified for each of the ROVs, adding in code to read and move the attached sensors and components.

Image Recognition

The image recognition code is used to count the benthic species and was custom designed for ease of use by the end-user. It was developed in OpenCV-Python, which is a Python-based image processing library that is easy to use and understand. The image recognition program starts by receiving an image from the pilot station. The image is then converted into monochrome. Using this monochrome image, an algorithm finds the shapes by outlining pixels that have the same color intensity, in this case black pixels. Various other algorithms are used to filter out incorrect shapes or errors that program has made. Once it has filtered out all of the false shapes, the shapes are recognized by looking at the number of vertices that the shape has. If it recognizes the shape as either a line, a triangle, a square, or a circle, it counts and displays the total number of each shape to the screen.

Laser Measurement

The laser measurement code is used to measure the cracks on the dam and the overall size of the cannon. Like the image recognition code, it is simple to implement into our pilot station and is written with OpenCV-Python. The laser measurement code uses the lasers mounted on the manipulator at a fixed distance of 2 inches. The code starts by receiving an image from the pilot station and converting the image to HSV (Hue Saturation Value). Then all color from the image is removed except for the color red. The lasers installed on our ROV are red (Figure 14), so the red areas that are left on the filtered image are the two laser points. The program then finds the pixel distance between those two points. The pilot can then click on the image to select the ends of the object they want to measure, and the program finds the pixel distance between those points. Using the pre-measured distance between the lasers mounted on the ROV, the program uses the pixels distances it has calculated to find the real measurement of the object on the screen. It then displays the distance in inches of the object the pilot wants to measure to the screen.

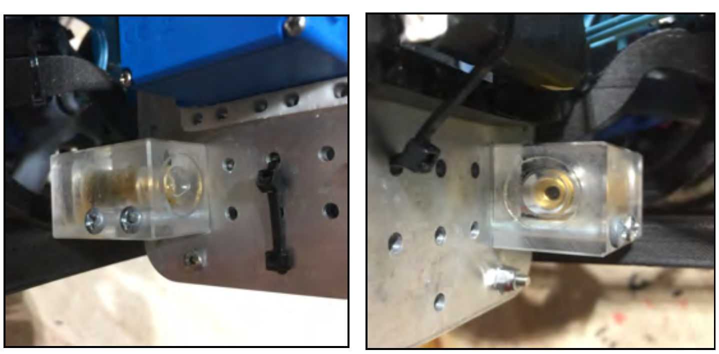


Figure 14 - Custom Laser Mounts: F. Alfano

Build vs. Buy, New vs. Used

Loggerhead ROV has access to an array of manufacturing options such our Markforged (Figure 15) and Formlabs (Figure 16) 3D printers, a laser cutter and a CNC mill that are all utilized throughout our design process. Designing in-house parts allows us to customize each component to the client's specific needs. Commercial off-the-shelf (COTS) parts are used for generic components that were not specifically outlined in the client's RFP. Components such as the lasers, pressure vessel, lift bag, and thrusters were purchased due to the ease of integration into our existing design. An immediate cost-saving initiative we implemented was use of existing, in-house, inventory we have accumulated over the years.

Figure 15 - MarkForged 3D Printer: M. Folenta

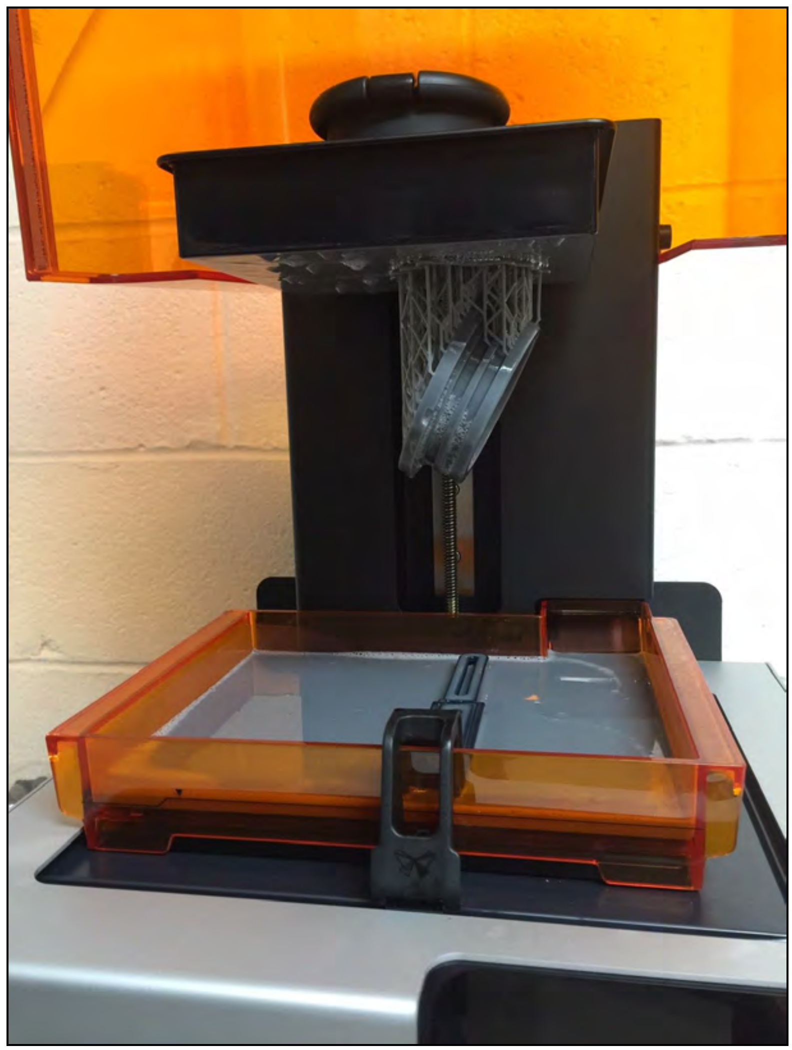


Figure 16 - FormLabs2 3D Printer: R. Van Zee

SID (SYSTEMS INTEGRATION DIAGRAM) FOR MAIN ROV

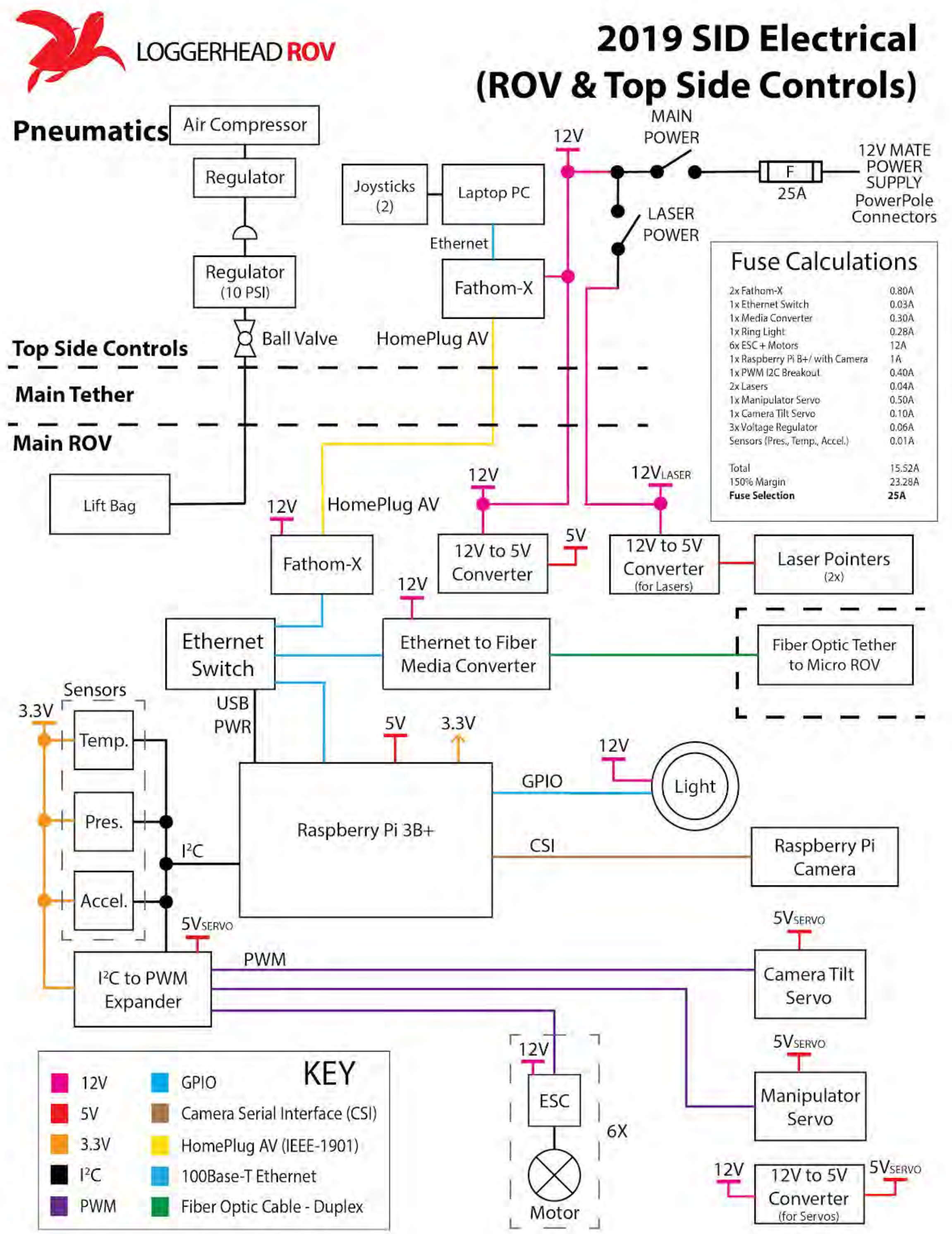
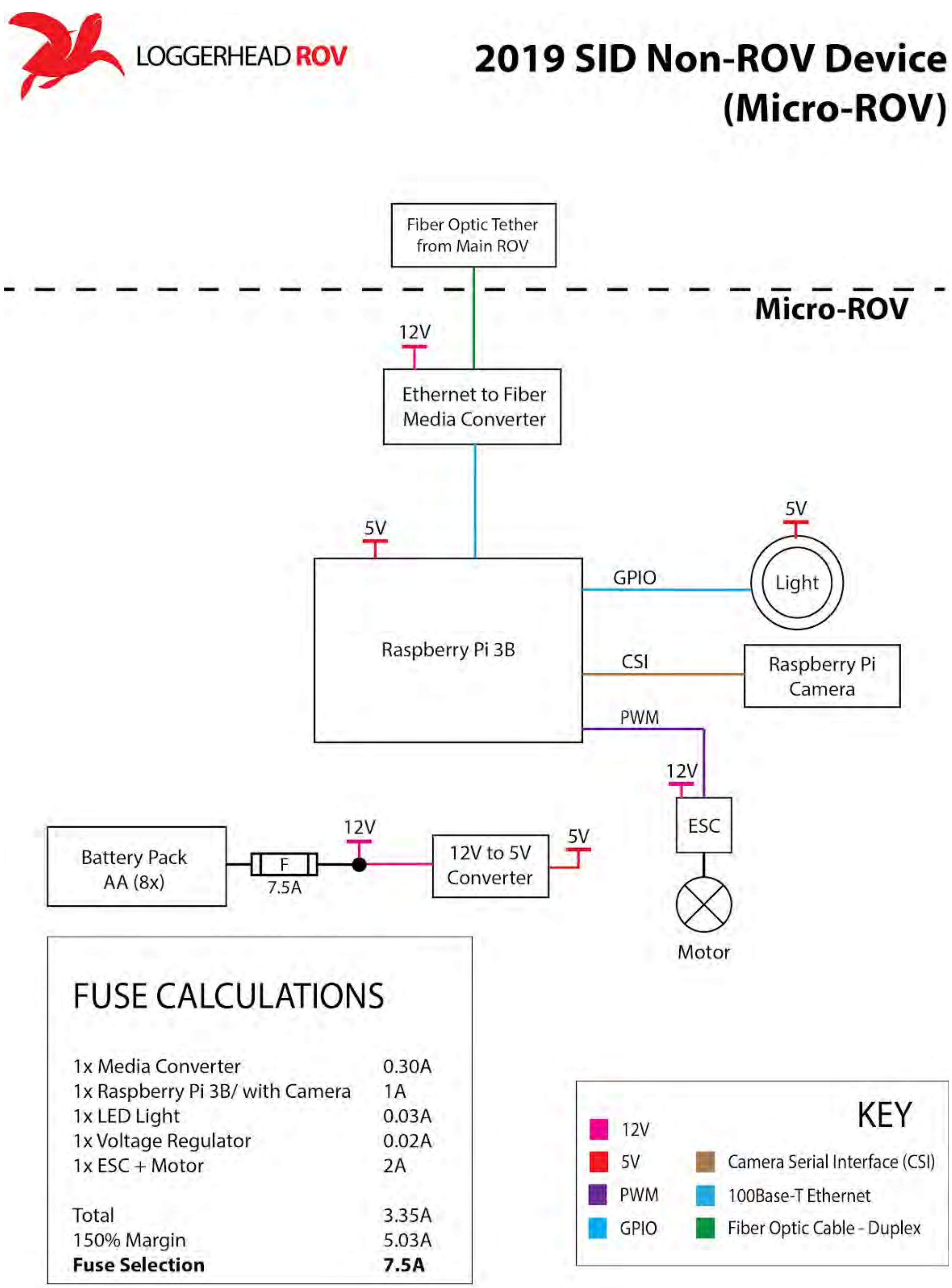


Figure 17 - SID Diagram of Main ROV and
Topside Electrical Systems: S. Khera

SID FOR MICRO-ROV: WOLVERINE



FUSE CALCULATIONS

1x Media Converter	0.30A
1x Raspberry Pi 3B/ with Camera	1A
1x LED Light	0.03A
1x Voltage Regulator	0.02A
1x ESC + Motor	2A
Total	3.35A
150% Margin	5.03A
Fuse Selection	**7.5A**

Figure 18 - SID Diagram of Micro ROV
and Topside Electrical Systems: S. Khera

SYSTEM CURRENT CALCULATIONS/FUSE SELECTION

Main ROV Fuse Calculations	
2x Fathom-X	0.80A
1x Ethernet Switch	0.03A
1x Media Converter	0.30A
1x Ring Light	0.28A
6x ESC + Motors	12.00A
1x Raspberry Pi B+/ with Camera	1.00A
1x PWM I2C Breakout	0.40A
2x Lasers	0.04A
1x Manipulator Servo	0.50A
1x Camera Tilt Servo	0.10A
3x UBEC Power Regulator	0.06A
Sensors (Pres, Temp, Acc)	0.01A
Total Amperage	**15.52A**
150% Safety	**23.28A**
Fuse Selection	**25A**

Micro ROV Fuse Calculations	
1x Media Converter	0.30A
1x Raspberry Pi 3B/ with Camera	1.A
1x LED Light	0.03A
1x UBEC Power Regulator	0.02A
1x ESC + Motor	2.00A
Total Amperage	**3.35A**
150% Safety	**5.03A**
Fuse Selection	**7.5A**

Figure 19 - Fuse Calculations: A. Faluotico

SOFTWARE FLOW CHART

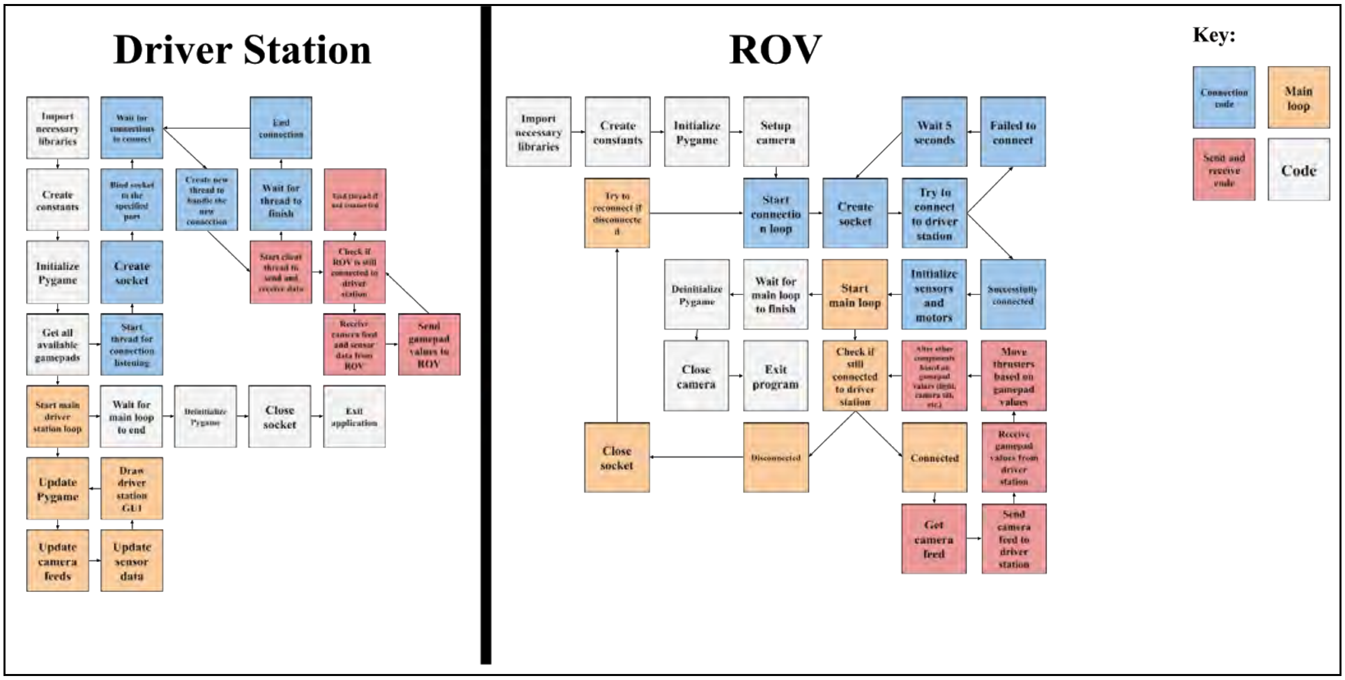


Figure 20 - Software Flow Chart
Diagram: F. Alfano

SAFETY

Safety Features

Our ROV has a number of safety features incorporated into the design. A handle allows operators to safely move the ROV without risking injury. Thruster guards eliminate the risk of debris getting caught in the propellers. Water is able to flow through with minimal obstruction but large objects greater than 12.5 mm are unable to enter the small openings.

To leak test our pressure vessel a vacuum pump creates a depressurized state in the pressure 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. Unwanted stress caused by tugging our tether is mitigated by an installed cord grip and stainless steel leader cable. Finally, our electrical overload failsafe system is a 25A slow blow fuse. The fuse provides protection from overcurrent draw and breaks the circuit if the current draw exceeds the fuse value.

The ROV includes warning stickers on each thruster, the lasers, and the electrical board. The lasers are required to be covered when not in use for protection from damaging light. The software includes arm and disarm features to shut off the ROV in case of emergency. The topside control system is transported in a Pelican case to protect the electronics from shock and water damage. This Pelican case includes 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 over it.

Safety Procedures

PRE FLIGHT SAFETY CHECKLIST

- ❏ Pressure vessel is sealed/pressure tested
- ❏ No electronic wires are exposed
- ❏ ROV connections are seated and secure
- ❏ ROV controls are off
- ❏ Chassis hardware is tightened
- ❏ Deck Crew is clear from ROV
- ❏ Laser covers are in use

TETHER AND TETHER MANAGEMENT SUBSYSTEM

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

ROV POWER UP

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

LAUNCH AND RECOVERY SAFETY CHECKLIST

- ❏ Deck crew wearing closed toe shoes and eye protection
- ❏ Launch team clear of ROV

POST FLIGHT SAFETY CHECKLIST

- ❏ Deck crew ready to receive ROV
- ❏ ROV controls disabled/locked once in the recovery area
- ❏ Recover ROV from water and place on deck
- ❏ ROV is powered off
- ❏ Laser covers replaced
- ❏ Tether disconnected and neatly coiled
- ❏ Rinse and dry ROV for storage

SHOP SAFETY

- ❏ Always wear approved safety glasses or goggles
- ❏ Only OSHA approved safety goggles may be worn with a minimum rating of Z87.
- ❏ Never wear loose clothing or accessories around any power tools.
- ❏ Long hair must be pulled back at all times.
- ❏ Close-toed shoes ONLY!
- ❏ Never use compressed air to clean yourselves or your clothing.
- ❏ 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.

PROJECT MANAGEMENT

Organization, Structure, Planning, and Procedures

In the fall, a schedule was established to maximize training sessions, build sessions and outreach events (Figure 21). During training sessions, returning members taught new members Adobe Illustrator, Fusion 360 and Makerbot. The fall sessions also provided the opportunity to introduce new students to MATE and our company culture (Figure 22) . The team was divided into six different groups. Each group was given a turtle name and a schedule that cycled the group through each department to introduce everyone to all aspects of our company. These training sessions were scheduled right up until the MATE competition manual was released in December. In January, a meeting schedule was established and mandatory company meetings took place to begin the process of designing and building our main ROV.

Green			
Tuesday 9/25			
6:40PM – 7:25PM	Marketing		
7:35 PM – 8:20PM	SOS		
Thursday 9/27			
6:40PM – 7:25PM	Mission Strategy		
7:35 PM – 8:20PM	ROV Piloting		
Tuesday 10/2			
6:40PM – 7:25PM	Control Systems		
7:35 PM – 8:20PM	ROV Design		
Thursday 10/4			
6:40PM – 7:25PM	ROV Design	SOS	ROV Piloting
7:35 PM – 8:20PM	Control Systems	Marketing	Mission Strategy
	Student Choice		

LOGGERHEAD ROV

Figure 21 - Fall Orientation Meeting Schedule

So that all team members stayed on task and our objectives could known throughout our build, students made use of the app, Slack, to communicate at any time, even outside of meetings. Our leadership team provided weekly updates to the Board of Advisors on the status of projects. Each department is lead by a senior member who is responsible for creating clear objectives as well as determine the operational protocol for each group.

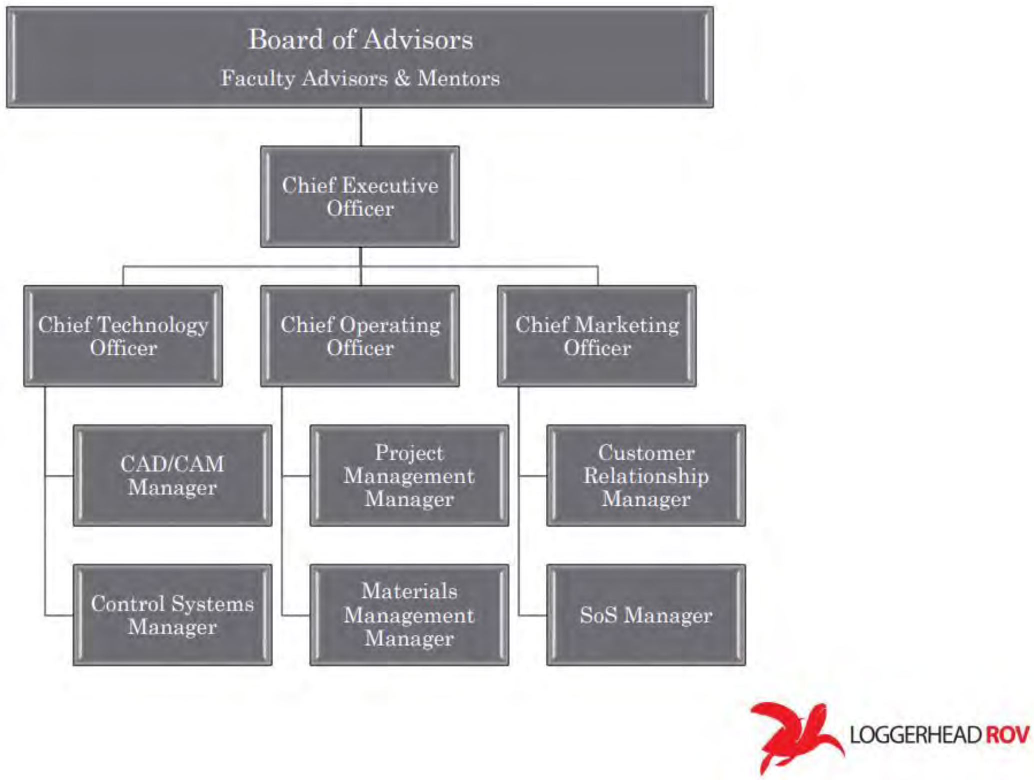


Figure 22 - Loggerhead Company Structure: W. Alberts

CRITICAL ANALYSIS

Testing and Troubleshooting

Loggerhead ROV has an 8,300-liter test tank (Figure 23) in house allowing for continual testing of the operational capacity for each new piece fabricated. An example test we conducted was attaching the lift bag to the cannon in order to determine the proper volume of air needed to lift the cannon. Air was pumped into the lift bag via an air compressor; this took time to figure out just how much air to inflate into the lift bag. In addition, other prototyped designs were tested using the 2018 ROV to identify workable solutions.

Figure 23 - Test Tank Facility: J. Tierney

CHALLENGES

Design Challenges

Identifying an effective design for a lift bag system was a significant technical challenge that our company faced this year. The undisclosed weight and size of the cannon forced us to design for the maximum constraints provided. This resulted in a large lift bag that has to be easily deployable, and safely secured during underwater travel.

Another item that proved challenging was designing a docking station for the Micro ROV. Not finalizing the Micro ROV's design until later in our design process delayed the development of our docking station. Knowing this was an issue, we purposely incorporated a flexible design platform which gave us the ability to quickly adapt the final docking station to accommodate late design changes to the Micro ROV.

Interpersonal Challenges

As our company continues to grow, the integration all of our members into our company is a constant challenge. Providing our members with opportunities to learn and grow while still meeting mission critical deadlines was a challenge for our company. We will look to improve our company in the following areas: active listening, acknowledge others' expertise, cultivate a positive outlook, making each team member feel of value and build relationships not just products.

LESSONS LEARNED

Future Improvements

As our company continues to grow with our recent successes, we were not prepared to address the distribution and monitoring of job assignments in an effective manner. We took time to last fall to reevaluate our company's operational plan and were able to develop and execute an improved management process with the use of assignment charts and improved digital communication. As we look to future, we plan on creating a monthly plan to help our members clearly understand company expectations. Additionally, we plan to inform members on the importance of meeting attendance and punctuality, effective communication between the mentors and the students, and establish clear and concise operational expectations for our members. Our management team will continue to educate ourselves on project management best practices with the goal of improving in this area before the start of next season.

Another challenge that became apparent throughout our year, is our excessive use of 3D printing. We found ourselves 3D printed parts that could have been modeled using other more timely and cost effective mediums rather than 3D printing. By using other materials such as cardboard, we could have developed our prototypes faster and it would have been just as effective with proof of concept. Often, we would find that before a 3D print was completed, we had made iterations to the design rendering the print as outdated. While 3D printing has proven to be an invaluable manufacturing process for our company, we have identified the importance of using simpler methods for initial prototyping to help move our designs forward.

Budgeting and Project Costing

We developed our spending plan by first understanding what our prospective client's needs were and what actions were required of the ROV to complete the required tasks. When deciding where to allocate our company's resources, we decided to allocate a large portion of our funds to the design and control systems subteams so they could have the flexibility to purchase supplies as needed throughout the build process. We understood that our client wanted and expected an ROV designed with durability, flexibility and serviceability. The selection of parts was critical to ensure that our product performed at the highest level. Continuity of product development was crucial throughout the year, so parts were ordered in duplicates as a precaution for unseen issues. For the programming subteam, a smaller portion of our company's budget was required due to open source materials and the integration of low cost prototyping boards for testing our ROV's control software. Our primary sources of income came from the Mount Olive School District, team sponsors, and student families used for purchase tools, supplies, parts for the ROV, 3D printing materials, and covering our competition travel cost.

Loggerhead ROV 2018-2019 Company Budget			
Reporting Period:		**From: 9/1/18**	**To: 4/30/19**
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	$1,500.00
Audio Dynamics	Cash Donation	General	$500.00
Mount Olive Board of Education	Cash Funding	General	$8,000.00
ETGI Waste Disposal	Cash Donation	General	$150.00
Picatinny Arsenal	Parts/Materials	General	$3,000.00
Benjamin Moore Paints	Cash Donation	General	$500.00
Student Team Dues	Cash Donation	General	$1,000.00
Willowgate Cottage	Marketing Materials	General	$150.00
Advanced Digital Data	Cash Donation	General	$1,000.00
The Flammer Family	Cash Donation	General	$250.00
Student Travel Cost (paid by family)	Cash Donation	MATE International Travel	$15,000
		Total Income:	**$31,555.00**
Program Expenses			
Category	**Type**	**Description**	**Projected Cost**
Mfg. Materials	Purchased	ROV Parts	$2,000.00
Hardware	Purchased	ROV Hardware	$750.00
Electronics	Purchased	ROV Electronics	$2,000.00
General	Donation	Business/Marketing Supplies	$300.00
General	Re-Used/Purchased	Tools/Equipment	$1,000.00
General	Re-Used/Purchased	Task Props/Pool Deck Supplies	$400.00
Travel	Hotel Rooms	MATE International Travel Expenses	$7,500.00
Travel	Ground Transportation	MATE International Travel Expenses	$9,700.00
Travel	ROV Tools/Shipping	MATE International Travel Expenses	$500.00
		Total Expenses:	**$24,150.00**

Project Cost						
Description	Type	Category	Vendor	Qty	Unit Cost	Total
Raspberry Pi 3B	Purchased	Electronics	Adafruit	1	$35.00	$35.00
PWM Expander Board	Purchased	Electronics	Adafruit	1	$17.50	$17.50
Fiber Optic Cable	Purchased	Electronics	Amazon	1	$18.00	$18.00
Gigabit Ethernet Media Converter	Purchased	Electronics	Amazon	2	$12.99	$25.98
AA Battery Holder	Purchased	Electronics	Amazon	1	$1.00	$1.00
XtremPro 3-Port Network Switch Hub	Purchased	Electronics	Amazon	1	$13.99	$13.99
2.0 mm Bullet Connectors	Purchased	Electronics	Amazon	1	$8.00	$8.00
25 AMP Fuse	Purchased	Electronics	Amazon	1	$2.00	$2.00
30 AMP In-Line Fuse Holder	Purchased	Electronics	Amazon	1	$1.00	$1.00
3.5 mm Bullet Connectors	Purchased	Electronics	Amazon	1	$6.00	$6.00
Power Regulator (pack of 5)	Purchased	Electronics	Amazon	3	$19.99	$59.97
Laser Switch (pack of 5, using 1)	Purchased	Electronics	Amazon	1	$12.79	$12.79
Master Switch	Purchased	Electronics	Amazon	1	$5.81	$5.81
SFP Slot LC Converter	Purchased	Electronics	Amazon	2	$9.99	$19.98
Raspberry Pi Ribbon Cable Camera	Purchased	Electronics	Amazon	2	$5.95	$11.90
Thrusters (920kv Brushless Motor)	Used	Electronics	Blue Robotics	7	$119.00	$833.00
4" Cast Acrylic Tube (300 MM)	Purchased	Electronics	Blue Robotics	1	$60.00	$60.00
4" Dome end Cap	Purchased	Electronics	Blue Robotics	1	$39.00	$39.00
Fathom ROV Tether	Purchased	Electronics	Blue Robotics	1	$83.00	$83.00
O-Rings (various diameter)	Purchased	Electronics	Blue Robotics	8	$0.50	$4.00
Fathom-X-Single R1-RP	Purchased	Electronics	BlueRobotics	2	$80.00	$160.00
Raspberry Pi Camera	Purchased	Electronics	BlueRobotics	1	$89.00	$89.00
Raspberry Pi Camera w/ Wide Lens	Purchased	Electronics	BlueRobotics	1	$49.00	$49.00
Fast Response Temperature Sensor	Purchased	Electronics	BlueRobotics	1	$56.00	$56.00
Pressure Sensor	Purchased	Electronics	BlueRobotics	1	$88.00	$88.00
ESC w/ Forward/reverse Firmware	Purchased	Electronics	BlueRobotics	7	$25.00	$175.00
Marine Epoxy	Purchased	Electronics	BlueRobotics	2	$6.00	$12.00
Potting Kit	Purchased	Electronics	BlueRobotics	2	$10.00	$20.00
Silicone Grease	Re-Used	Electronics	BlueRobotics	3	$3.00	$9.00
Fathom X	Re-Used	Electronics	BlueRobotics	2	$80.00	$160.00
Vent (Pressure Vessel Penetrator)	Purchased	Electronics	BlueRobotics	2	$8.00	$16.00
6mm Penetrators (Red)	Purchased	Electronics	BlueRobotics	8	$4.00	$32.00

Formlabs Grey Pro	Purchased	Electronics	Formlabs	1	$130.00	$130.00
Formlabs Tough Resin	Purchased	Electronics	Formlabs	1	$218.00	$218.00
Formlabs Grey Resin	Purchased	Electronics	Formlabs	1	$150.00	$150.00
Formlabs Black Resin	Purchased	Electronics	Formlabs	1	$150.00	$150.00
Formlabs Flexible Resin	Purchased	Electronics	Formlabs	1	$88.00	$88.00
Joystick	Re-Used	Electronics	Logitech	2	$39.99	$79.98
Makerbot PLA Filament	Purchased	Electronics	Makerbot	3	$48.00	$144.00
Markforged Filament	Purchased	Electronics	Markforged	1	$282.00	$282.00
Tether Cord Grip	Purchased	Electronics	McMaster-Carr	1	$3.50	$3.50
Fiber Optic Cord Grip	Purchased	Electronics	McMaster-Carr	2	$3.50	$7.00
Custom Aluminum End Cap	Donated	Electronics	CDS	1	$100.00	$100.00
Wolverine Polycarb Tubing	Purchased	Electronics	McMaster-Carr	1	$30.00	$30.00
Hardware McMaster (misc.)	Purchased	Electronics	McMaster-Carr	1	$100.00	$100.00
1/2" Aluminum Tubing	Purchased	Electronics	McMaster-Carr	1	$15.00	$15.00
Neoprene Rubber Strip	Purchased	Electronics	McMaster-Carr	1	$0.55	$0.55
Pneumatic Tubing	Purchased	Electronics	McMaster-Carr	1	$24.00	$24.00
12"x12"x1/8" 6061 Aluminum Sheet	Purchased	Electronics	McMaster-Carr	2	$27.00	$54.00
Rotor Spring	Purchased	Electronics	McMaster-Carr	1	$69.00	$69.00
Lasers	Purchased	Electronics	Quarton	2	$25.00	$50.00
Lift bag	Used	Electronics	Ramsey, Inc.	1	$16.00	$16.00
Raspberry Pi 3B+	Purchased	Electronics	Raspberry Pi	1	$35.00	$35.00
646WP Servo	Purchased	Electronics	ServoCity	1	$51.00	$51.00
HS-5055MG Servo	Purchased	Electronics	ServoCity	1	$30.39	$30.39
Ring Light	Purchased	Electronics	Superbright LEDs	1	$11.95	$11.95
Single Light	Purchased	Electronics	Superbright LEDs	1	$2.99	$2.99
Tether Wire - 10 awg Red/Black Silicone, High Flex	Purchased	Electronics	Turnigy	2	$53.40	$106.80
Tether Wire - 12 awg Silicone, High Flex	Purchased	Electronics	Turnigy	2	$47.25	$94.50
Tether Wire - 16 awg Silicone, High Flex	Purchased	Electronics	Turnigy	2	$24.50	$49.00
Tether Wire - 18 awg Silicone, High Flex	Purchased	Electronics	Turnigy	2	$12.75	$25.50
					Total Cost	**$4,202.09**

OUTREACH

With our program now in its third year participating in the Marine Advanced Technology Education Competition, we are paving the way for future generations of Mount Olive High School students to discover how marine technologies such as ROVs can help solve real world problems facing today's marine environments. We believe that hard work, determination, and passion will lead us to being successful stewards of our global ecosystems and marine resources. We not only need to engineer solutions for our clients but also lead by example and educate them about the importance of caring for our oceans and water supplies (Figure 24).

Figure 24 - Delivering donations to Sea Turtle Recovery: R. Van Zee

REFLECTIONS

Robert Van Zee - Senior Team Member

To me, Loggerhead ROV is an opportunity to experience different aspects of engineering, and express my ideas in science and technology. I have grown in many ways on this team, one of which is my presentation skills and public speaking skills, they have been vastly improved and I now have more confidence when speaking. I also have grown in terms of my knowledge of engineering, and the different parts contained within an engineering project of this scale. I learned the different steps taken into consideration when designing a product as well as how to troubleshoot different problems that arise.

Soumya Khera - 2nd Year Team Member

The MATE Loggerhead experience means a lot to me. This team gave me a chance to directly be involved in technical and non-technical projects that interest me. By being a member on the team, I've gained technical and non-technical skills (design, electrical, programming and marketing). I've also gained company like experience, similar to what I will encounter in the future. I've learned how to manage deadlines, work with people who have a different mindset than I do and solve company challenges.

Jessica Tierney - 2nd Year Team Member

The MATE Loggerhead experience means opportunity to me. It gives me the chance to learn what I would not learn in class and to expand my skill set. Through MATE, I have learned how much I love marketing and marine science and I now know want to pursue it in college. Without MATE, I would have never even considered those fields. MATE has also taught me to be a better public speaker and how to solve real life issues such as those regarding our natural resources.

ACKNOWLEDGEMENTS & RESOURCES

Loggerhead ROV would like to extend our sincerest thanks to our supporters:

- The MATE Program for giving us resources that have contributed to a successful year and a successful future
- Mount Olive High School/Mount Olive Board of Education for their continued support
- Mr. David Bodmer, Ms. Susan Mills, Mr. Allan Dunster, Mr. Matt Dunster, Mr. Gregg Turi, Ms. Jen Kalkunte, Mrs. Megan Boyd and Ms. Jessica Van Zee for being the best mentors ever!
- Mr. Albert and Mr. Khera for their time
- Bermuda Institute of Ocean Sciences (BIOS) for hosting us and teaching us about the importance of marine life conservation
- Villanova University- School of Engineering
- Picatinny Arsenal
- Chameleon Design Solutions
- Siemens for machine time and materials
- CDS Graphics for their help with apparel and decals
- Monmouth University
- Advanced Digital Data Systems
- Benjamin Moore Paints
- Special Technical Services
- Environmental Transport Group, Inc.
- Willowgate Cottage
- Ocean Alliance SNOTBOT
- Blue Robotics
- Ben J. Hicks, Photography
- The Flammer Family
- Audio Visual Dynamics (AVD)
- And last but not least, our lovable Loggerhead mascots, Canyon and Wolverine, who we hope to see released into the big blue ocean soon!

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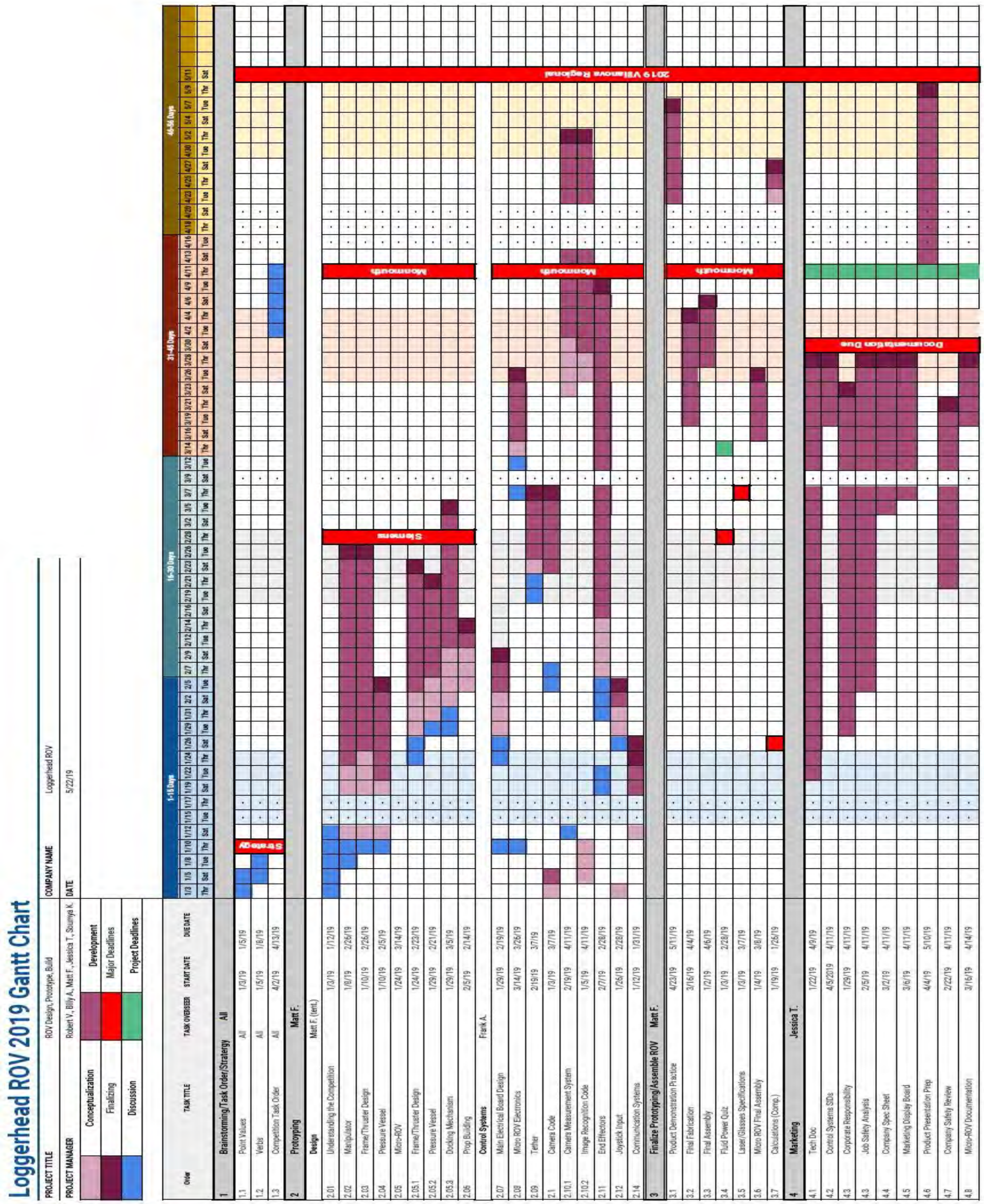
Appendix A
2019 Loggerhead ROV Gantt Chart



Appendix B

ROV Electrical Board Technical Drawing