SURE Robotics

Seawolves Underwater Robotics Engineering

Seawolf VII

2018 TECHNICAL DOCUMENTATION

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I. Introduction

A. Abstract

Seawolves Underwater Robotics Engineering (S.U.R.E.) has created an underwater robot controllable via remote that meets the requirements issued by the Applied Physics Laboratory at the University of Washington. Over a course of seven months, the company created and strenuously tested the ROV deemed *Seawolf VII*. The S.U.R.E. team, consisting of ten persons, has produced an efficient and reliable robot with the capability of executing specific tasks. These tasks include locating aircraft wreckage and extracting the engine, installing or recovering a seismometer, and installing a tidal turbine and instrumentation to monitor the environment.

The S.U.R.E. team *(Figure 1)* is organized into groups responsible for public relations, design, programing, and electronics to ensure maximum productivity. Each sub-team has specific jobs as well as tasks that require the entire team, which helps to strengthen bonds and communication. Safety is important to the company and each member is taught how to properly use equipment and conduct themselves in a working environment. The design, programming, and electrical components of *Seawolf VII* were strenuously tested to ensure success.

Seawolf VII is specifically manufactured to meet all the requirements of the missions. The main frame of the ROV is made of HDPE marine grade high-density polyethylene. The circuit boards, which were designed in house, are contained in cast acrylic tubing and the robot has a total of four thrusters.

The following report explains in detail the process and elements that went into the design and manufacturing of *Seawolf VII*.

Figure 1: S.U.R.E. Company Members (L to R) Front: Kevin McKone (Mentor), Erin Lowe, Cooper Earls, James Douglas, Robert Case. Back: Carey Williamson (Mentor), Charles Smith, Joseph Crouse, Ernest Smith, James Kuriger. Not Pictured: Dezirae Katt, Kenneth Starkey.

II. Safety

A. Safety Reasoning

Seawolves Underwater Robotics Engineering (S.U.R.E.) maintains high safety standards. Safety is the most important factor in the workplace and each company member is taught proper safety precautions and is expected to uphold them. S.U.R.E. was required to participate in an OSHA safety briefing on slips, trips, and falls at the beginning of the construction of the robot to make sure each company member was trained on proper safety standards and the prevention of accidents in the workplace. By not only having an organized workspace but also company members who are trained in proper safety behaviors, the S.U.R.E. corporation ensures a safe and efficient working environment.

B. Safety Standards

During the construction of the ROV, *Seawolf VII*, the team was required to meet certain safety standards. When power equipment was in use, each person was required to wear eye and head protection, as well as appropriate footwear and clothing. Proper safety equipment is provided for each worker and basic safety rules are hung throughout the workplace. First Aid kits are also readily available *(Figure 2)*. When working with circuits and live wires company members wear proper clothing and make sure the electrical components are shut off. Each company member is expected to withhold the safety standards of S.U.R.E.

Figure 2: Safety hats and kits

C. Safety Properties

The underwater robot *Seawolf VII* was built with safety in mind. The design has many safety features such as thruster guards covering the external thrusters, rounded frame edges to prevent injury while handling the ROV, and waterproof electrical tubing for the housing of the circuit boards and electrical components. The frame of the ROV is made with HDPE, which is strong and durable. The bottom of *Seawolf VII* is flat to ensure stability when out of the water and/or being transported.

Before submersion and use of the ROV, the team goes through the safety checklist (Appendix part A) to make sure each component of the robot is fully functional and there is a low risk of mechanical issues. During the use of *Seawolf VII*, the robot continuously sends reports to the pilot. These reports tell the pilot if the robot is functioning properly. If the robot dysfunctions, the pilot can remotely shut it down.

III. Design Rationale

A. Overview

S.U.R.E spent many hours working together to create and assemble *Seawolf VII (Figure 3)*. The main aspects of the construction were design, machining, and assembly. Teamwork and diligence were essential during the creation and testing of the ROV.

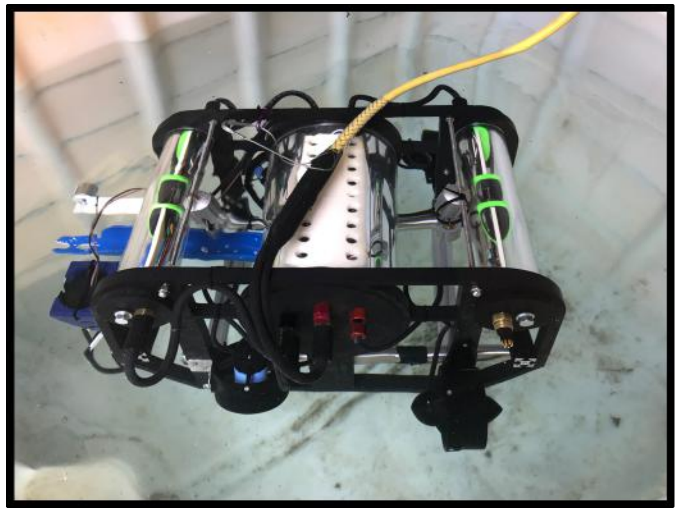


Figure 3: Seawolf VII

B. Design

Several aspects of *Seawolf VII* were inspired by *Seawolf VI*, S.U.R.E's previous ROV, which the company had great success with. The design of *Seawolf VII* was also significantly influenced by the requests of the University of Washington. The design team created the ROV and tooling with great care, ensuring it would go above and beyond when completing the missions required of it. *Seawolf VII* is compact and light *(Figure 4)*, built for maneuverability around aircrafts and debris. The ROV was built with tooling to deploy lift bags and move heavy objects to the surface. Tools can also be quickly switched out, allowing for easy shifts from on mission or task to another.

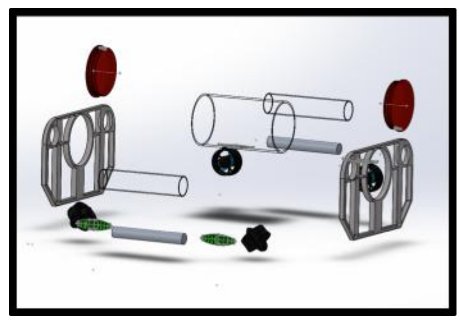


Figure 4: Exploded view of basic components of Seawolf VII including frame, thrusters, end caps, and electronic housing tubes

S.U.R.E. had great success with Blue Robotics thrusters on *Seawolf VI* and chose to employ Blue Robotics again on *Seawolf VII.* These thrusters are elegantly designed and cost friendly. The company previously used T200 thrusters for *Seawolf VI* but opted for T100 thrusters on *Seawolf VII* because the ROV is more compact and does not require as much power. These thrusters still provide plenty of power to maneuver the ROV through strong currents as it installs tidal turbines.

Figure 5: Largest Acrylic tube showing shelving and one of the circuit boards.

The design team opted to use acrylic tubing to house the electrical components of *Seawolf VII* because it created a sleek and compact design that was unlike any previous ROV models the company had produced. All end caps of the acrylic tubes contain O-rings, which guarantee a waterproof seal.

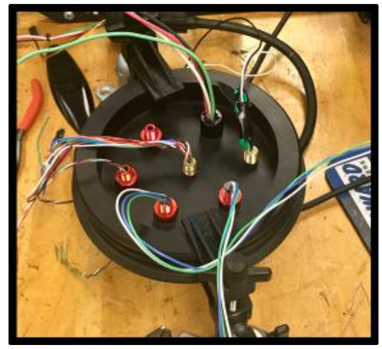


Figure 6: End cap of largest acrylic tube showing wiring

The tether of *Seawolf VII* connects to the electrical elements through the end cap of the largest acrylic tube. This tube houses all major electronics. Circuit boards are held in place inside the ROV by 3D printed shelves made of acrylonitrile butadiene styrene (ABS) *(Figure 5)*. The company chose this material because it is a strong and inexpensive plastic. The frame and end caps of the ROV are made of HDPE *(Figure 6)*, which was milled in house using a CNC mill.

C. Machining

The ROV was designed in SolidWorks and milled using a 3-axis Haas Computer Numerical Control Mill (CNC) *(Figure 7)* utilizing MasterCam software. The frame of the robot was milled and the end caps turned on a manual lathe by Copiah-Lincoln students. Acrylic tubing was fitted for the end caps before the electronic components could be installed.

Figure 7: The frame of the ROV being milled using the CNC by a Copiah-Lincoln student

D. 3-D Printing

Several components of *Seawolf VII* were constructed using 3D printing. All shelving for the electronics were printed using ABS plastic. These shelves were designed and printed after the electronics of the ROV had been determined. Camera/lighting mounts housed inside the acrylic tubes were also 3D printed.

IV. Buoyancy

Seawolf VII was designed to be its own source of buoyancy. While the completed design was in SolidWorks, the surrounding material was changed to water to find the center of buoyancy. The material of the robot itself was then changed to HDPE to find its center of mass. Finding the distance between the center of buoyancy and the center of mass helped S.U.R.E. conclude the amount of stability needed for the ROV. This, along with a vat test and pool test, helped determine that to be neutrally buoyant, *Seawolf VII* would need to weigh approximately 14 kg. The completed robot with tooling would weigh 13.45 kg and .75 kg of mass would be added to the frame to compensate for any extra buoyancy. Experience has shown that the ROV needs to have a low center of mass to increase the stability of the vehicle. The low center of mass coupled with a higher center of buoyancy resulted in a stable ROV. Using the mass properties identified and the understanding that additional tooling would be included later, S.U.R.E confirmed that this design would be stable and fit the needs of the University of Washington and the Pacific Northwest coast.

V. Thrusters

Figure 8: T100 Blue Robotics Thrusters

S.U.R.E. selected Blue Robotics T100 thrusters *(Figure 8)* for *Seawolf VII.* This model of thrusters was preferable due to increased functionality, reduced finances, self-lubrication, and size. Each motor is run on an individual DC to DC converter due to current limitations. The motors run on 15V DC which is supplied to them via the converters. Each motor is capable of drawing 11.5A, which is roughly the output of a converter. The motor output can be limited to decrease amps, but the lower voltage does have a higher current consumption. A power budget was calculated using P=I*V=48V*30A, providing the total power usage allowed for the robot. This helped the company decide that these motors could be effectively used. The company previously used Blue Robotics T200 thrusters on *Seawolf VI* and were extremely satisfied with them. S.U.R.E. chose T100 thrusters for *Seawolf VII* because the ROV is smaller and does not need as much power to maneuver it. These Blue Robotics thrusters are also much more economical and user friendly than *Seawolf V's* Crust Crawler thrusters. T100 thrusters use water as a lubricant which is cleaner and simpler than using grease. The thrusters are compact and work well with the small size of the robot; one thruster weighs only 120g in water. The ROV has 4 thrusters: 2 horizontal for forward, reverse, and turning motions, and two vertical for up, down, and crabbing motions. Each thruster receives input via Blue Robotics penetrators. Several previous *Seawolf* models have used bulkheads, but using penetrators has improved overall performance and cost.

VI. Tooling

A. Overview

The S.U.R.E. company created a series of specialized tools which diversify the abilities of *Seawolf VII*. Tooling of the ROV includes a multi-tool, a frictionally assisted rotating tool (F.A.R.T.), an electromagnet, and a lift bag. All tooling is located at the front of the ROV for optimal visibility and maneuverability. These tools set *Seawolf VII* apart as it's called upon to assist in the needs of the University of Washington and the Pacific Northwest coast.

Figure 9: Multi-Tool with attachment

B. Multi-Tool

The multi-tool *(Figure 9)* has many uses, hence the name. The main function of the tool is to transport an Acoustic Doppler Velocimeter. It was designed in a way that the user can interchange parts and use the tool for other purposes, especially in transporting materials.

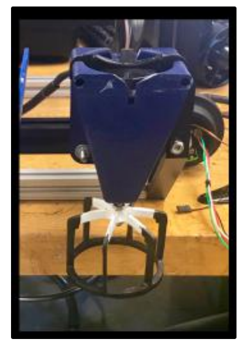


Figure 10: F.A.R.T

C. F.A.R.T.

The frictionally assisted rotating tool (F.A.R.T.) *(Figure 10)* serves as a leveling tool and employs a 12V DC motor with a custom slotted handle attachment that rotates leveling screws. It utilizes a specially cut PVC cap to turn the screws.

D. Electromagnet

The electromagnet *(Figure 11)* was installed on *Seawolf VII* to assist in the movement of debris during missions. It holds a hook to the ROV until the pilot turns it off, releasing the hook and debris attached to it.

Figure 11: Electromagnet

E. Lift Bag

The lift bag *(Figure 12)* sits deflated on the top of *Seawolf VII*. After debris have been hooked to the ROV using the electromagnet, the lift bag is engaged by a company member using a hand pump. The lift bad pulls the debris up from the ocean bottom, allowing the ROV to maneuver it to the desired location.

VII. Materials

A. HDPE

S.U.R.E. chose HDPE marine grade high-density polyethylene as the material for the ROV frame and end caps. The design team chose this material because of its superior strength, flexibility, and weight. With the hazards found in port environments, HDPE provides a high strength vehicle, and produces a product that is capable of withstanding substantial amounts of stress. It is also able to withstand extreme temperatures, which can be an issue in the waters off the Pacific Northwest coast. HDPE material is also flexible, can be easily milled, is naturally light in weight, and is almost neutrally buoyant, which reduces stress on the frame and thrusters. Because it's a form of plastic, HDPE resists the rust and corrosion that salt water creates and is also efficient in fresh water.

Figure 12: Lift bag with hook attachment

B. Acrylic Tubing

All electronic components of *Seawolf VII* are housed in three acrylic tubes *(Figure 13)*. The company chose acrylic because of its durability and clarity. It is also more lightweight and scratch resistant than other plastics and glass. Acrylic is a thermoplastic; it can withstand a fair amount of pressure and cold temperatures. The clarity of the tubing allows the ROV cameras to have excellent visibility and the company can easily check wiring inside the ROV without taking it apart.


Figure 13: HDPE frame of Seawolf VII showing acrylic tubing

VIII. Electronics

A. Power Control Board

This four-layered board was designed in house and purchased from a manufacturer. The power control board *(Figure 14),* located in the electronics bay of the ROV, receives the 48V DC from the power supply while filtering the current. All ROV tools and components are routed through this board. It houses three 5V switching circuits, three 12V switching circuits and two H-bridges. Three DC to DC converters output 5V, 12V, and 15V. The outputs for the thrusters consist of a 15V out, ground, and pulse width


Figure 14: Power Control Board

modulation (PWM) which comes from the onboard BeagleBone Black. The power control board also has a 30A fuse for incoming current and fuses for both the 5V, 12V, 15V circuits.

B. Video Encoder

This board was purchased and removed from its casing to reduce weight and size. It is powered via the power control board and has two cameras connected to it. The video encoder allows for display of the ROV's two cameras. The encoder also contains a slot for a micro SD card that permits recording and downloading of video footage from the robot. This can be useful for documenting work and finding aircraft debris in the waters of the Pacific Northwest.

C. Cameras

Seawolf VII contains two standard definition CCTV style 1.2mm cameras *(Figure 15),* one located in the front of the ROV and the other in the rear, each in its own acrylic tube. This gives each camera plenty of room for a full range of motion. Both camera receive power from the power control board. Live video footage is sent through the tether of the ROV to a router, allowing the pilot visibility. As the surface controls are powered on, the video decoder connects to the ROV's video encoder board via the Ethernet communications link. This signal is then displayed on the TV. Having two cameras allows the pilot increased visibility as he is attempting to maneuver the ROV in compact spaces and through debris.

Figure 15: One of two cameras housed in Seawolf VII

D. Tether

The tether provides power, GND, and Ethernet communications to the robot via 8 and 3 pin Seacon bulkheads. There is a 30A in-line fuse within 30cm of the surface power supply. Both ends of the tether have strain relief provided by carabineers secured to *Seawolf VII* and the control station. The network router provides standard Ethernet connectivity to all the main parts of the control system. The tether also supplies air to the lift bag via an air tube. The company uses an Outland's Technology tether *(Figure 16),* which is already neutrally buoyant and durable, making it ideal for use in the Pacific Northwest coast.

Figure 16: Tether

E. Depth/Pressure Sensor

The depth/pressure sensor on *Seawolf VII* is made by Blue Robotics and uses a penetrator designed to be water proof. The sensor also allows the ROV to hover at a specific depth while installing Acoustic Doppler Velocimeters and can assist in leveling out an OBS.

F. Surface Controls

The ROV's surface electronics equipment includes an Outland Technologies tether, an Axis IP video decoder, a TV, a network router *(Figure 17),* and a laptop PC.

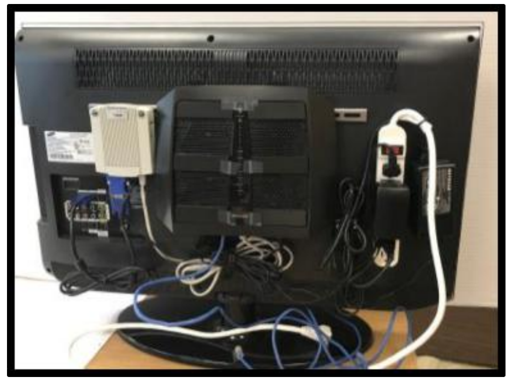


Figure 17: Router attached to TV where video footage is viewed

IX. Software

The control center of the ROV is a HP Pavilion laptop running Python 2.7.14. Within the python code, several libraries are used. Most notably is the pygame library. Calling classes from pygame allows the company to program a PlayStation 4 controller to control functions of the ROV. These functions include mapping joysticks to the ROV mounted thrusters, setting buttons on the controller *(Figure 18)* to control servo movement, and performing on/off functions for lights, electromagnet, and the F.A.R.T. Additionally, the team utilized the pygame library in building a rudimentary GUI, which gives the pilot a visual reference for thrust and the ability to quickly determine the on/off state of the ROV's different abilities.

The free software PuTTy allows the team to make a serial connection to the ROV mounted BeagleBone Black. If the surface laptop is the control center, the BeagleBone Black (BBB) would be a substation. The BBB uses a AM335x 1GHz ARM Cortex-A8 processor with 512 MB DDR3 RAM and two PRU 32 bit microcontrollers. Also, it has ethernet, USB, and micro USB ports along with two 46 pin headers. Contained with these pins are several ground, 3.3V, and 5V connections along with GPIO, PWM, and I2C pins. Mounted in the electronics bay of the ROV, BBB has been flashed with a Linux image, Debian version 9.2. Under this operating system, the ROV operating program was written in Python 2.7.14, and made extensive use of Adafruit libraries. The Adafruit libraries allow the user to program the use of PWM and GPIO pins located on the BeagleBone Black. These PWM and GPIO pins are used to control the thrusters, lights, camera, servos, electromagnet, and F.A.R.T. The ROV's onboard pressure sensor is run through the BBB's I2C pin suite.

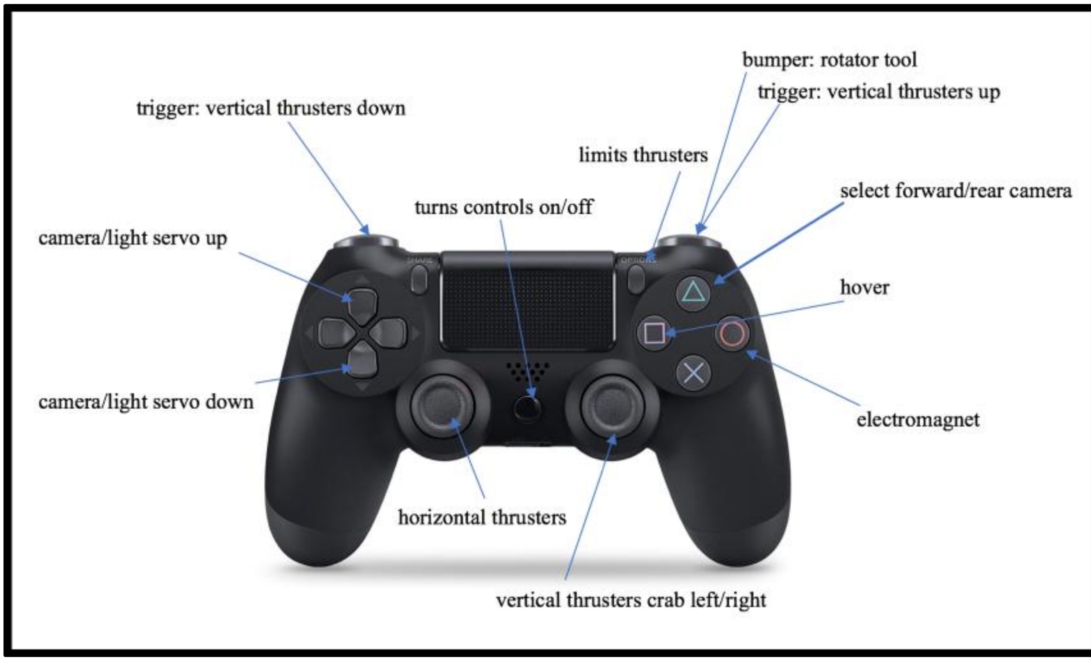


Figure 18: PlayStation 4 controller programmed for ROV with button functions

X. Logistics

A. Company Organization

S.U.R.E has four sub-teams. These four teams are responsible for design, programming, electrical, and public relations, respectively. Company members are placed in each sub-team based on their experience and interests. Having mini teams within the company allows the members to focus and specialize on certain parts of the construction and documentation of the ROV.

B. Project Management

S.U.R.E Robotics created a schedule at the first of the year for the team to follow to make sure all deadlines were met well before their due dates. The schedule was written on a board in the meeting room where all members could see it clearly and refer to it easily. The team met twice a week for three hours throughout the 2017-2018 year, during which they designed, manufactured, and constructed *Seawolf VII*. The creation of the ROV happened in three phases: design, manufacturing, and assembly.

During the first phase the company began to brainstorm and plan. A schedule and budget were created and S.U.R.E. decided on what materials to use for the new ROV, keeping in mind the conditions and tasks the robot would encounter as it preformed the missions required of it. With these aspects in mind, the design team formulated a blueprint for the ROV and created a model using SolidWorks. Through much trial and error, they designed a compact and sleek ROV with the maneuverability and versatility to execute the tasks expected of it in the Pacific Northwest coast.

After the initial design process, the electrical team used the blueprints of the ROV as a guide while creating the circuit boards and other components. The programming team began to create the program needed for *Seawolf VII*, as well as the controller. The frame of *Seawolf VII* and the end caps were milled, and the acrylic tubing obtained.

The last phase of the construction of *Seawolf VII* was probably the most challenging. The programming, design, and electrical teams worked closely together, combining their work. After the frame was milled, the company assembled the ROV and began testing it. There were many factors that had to be tweaked and refined as the company created an ROV to meet their standards.

C. Finances

S.U.R.E. Robotics created a budget for the construction of *Seawolf VII* by comparing budgets from years past and predicting likely expenses for the new ROV. This budget includes all expenses for the creation of the ROV as well as travel expenses for all company members and food costs for when the company works extra hours during meal times. The budget also considers the amount of money made during fundraisers and the money donated to the cause. The company started with a balance of twelve thousand dollars, which had rolled over from previous years.

Budget:

S.U.R.E. Robotics' 2017-2018 Budget			
Sarting Balance: $12,338.76			
Budget Category	**Item and Description**	**Type**	**Amount**
Cash Income			
	Georgia Pacific Contrabution	Donation	$ 5,000.00
	FTC Fundraiser	Fundraiser	$ 1,994.00
	Tim Jones Donation	Donation	$ 250.00
	FTC Fundraiser	Donation	$ 220.00
	Robotics Fundraiser	Fundraiser	$ 623.00
	Co-Lin Homecoming Funraiser	Fundraiser	$ 68.00
Total Earned			$ 8,155.00
Expenses			
Robot			
	Polymer HDPE Sea Plastic Sheet	Purchased	$ 100.00
	Thrusters and Speed Controllers	Purchased	$ 750.00
	Cast Acrylic Tubing	Purchased	$ 100.00
	Sheetrock Screws	Purchased	$ 5.00
	Threaded Rod	Purchased	$ 10.00
	Propellers	Purchased	$ 10.00
	Fastners	Purchased	$ 15.00
	USB-RJ45 Adapter	Purchased	$ 10.00
	3.3 Volt Linear Voltage Regulator	Purchased	$ 2.00
	Circular Saw	Purchased	$ 30.00
	Vent and plug/ cable penetrator	Purchased	$ 50.00
	Tripple Axis Accelerometer	Purchased	$ 15.00
Food			
	Snacks and meals	Purchased	$ 200.00
Travel			
	Transportation	Purchased	$ 4,000.00
	Room and Board	Purchased	$ 3,750.00
	Underwater Intervention Expo	Purchased	$ 217.00
Miscellaneous			
	S.U.R.E tshirts	Purchased	$ 250.00
	Registration for MATE competition	Purchased	$ 300.00
Total Estimated Spending			$ 9,814.00
Total Balance Left Over			$ 10,679.76

XI. Conclusion

A. Testing and Troubleshooting

During the construction of *Seawolf VII*, each working part was tested before being connected to the ROV. After the robot was complete, the company began to run tests to check all working parts. Thrusters, cameras, tooling, and waterproofing were tested before the submersion of the ROV in SolidWorks to a depth of 20m. The first test in water was done in a large vat. One company member held the robot in place underwater while another controlled the ROV. Thruster capability was tested as well as waterproof seals. After the ROV was determined fit for deeper water, it was taken to a local pool and tested to a depth of 3m. During this time, the company perfected the set up and take down of *Seawolf VII*, learning how to work together seamlessly while the ROV was in operation. The team created a safety checklist (Appendix A) as they worked through complications to ensure a safe ROV mission each time.

B. Challenges

S.U.R.E. Robotics experienced several challenges in the making of *Seawolf VII*, which forced the engineers to re-evaluate the issues and utilize problem solving techniques to determine needed modifications. Setbacks are expected in the making of a robot, and this one was no exception. One problem the company faced involved the O-rings. O-rings of the correct size were ordered but because of shipping delays, did not arrive on time. The company found some O-rings but they were either too large or too small. The small ones allowed water into the ROV and the larger ones made it impossible to place the end caps onto the acrylic tubing. The problem was solved by making the acrylic tubing bigger so the larger O-rings could be used, ensuring a waterproof seal on the ROV.

The main challenges for the company came after the robot was assembled. During the initial power up of the ROV, one of the first issues was with the video camera. It had been installed incorrectly and the video feed was sideways. This was a simple fix. The design team had to take that section of the robot apart and turn the camera the correct way. Another issue S.U.R.E Robotics encountered was with the DC to DC converters that power the thrusters. The thrusters would not power up because of a floating ground. The company had to re-evaluate the situation and solved the problem by tying the input ground to the output ground using a jumper wire.

C. Lessons Learned

S.U.R.E. is made up of members from all different backgrounds with different experiences. Having a diverse company allowed for each member to learn about things they had never done before. Engineers were required to learn how to program using Python and to effectively use other systems such as SolidWorks, PowerPoint, and Excel. Members learned how to work as a team to be more efficient, leaving less room for errors. The company had to problem solve constantly, which was great experience for S.U.R.E. members. Through community outreach the company built relationships with the people around them and demonstrated how important robotics and engineering skills can be.

D. Future Improvements

One of the biggest issues this year for the company was poor time management. Because of this, the company was forced to work overtime during a course of five days to meet the requirements in time. To avoid this problem in the future, measures will be put into place to ensure each member is held accountable for completing the tasks required of them.

Another improvement that would greatly enhance the quality of the ROV would be to have easier access to the circuit boards. The way the robot was designed places all the main electrical components in one center acrylic tube. This created a unique and sophisticated look, but hindered accessibility to the circuit boards. The circuit board set-up could be enhanced by having cords that held them in place and stabilized them. The ROV would also be improved by creating larger lighting holes, allowing cables to pass though more easily.

E. Reflections

Ernest Smith (CEO): "I enjoyed all aspects of designing, manufacturing, and assembling a robot this past year. I was able to apply the programming and physics classes I took a Copiah-Lincoln Community College to real world problems, which was a neat experience."

Joseph Crouse: "This past year I have learned many things that will be beneficial in my future career. I was taught how to use SolidWorks and became very efficient at it. I gained experience in the drafting shop using a robotic mill and all kinds of drills and machinery. I also learned about circuit placement and usage. I loved being on the team."

Austin Kuriger: "Working on the robotics team this year has been really fun! I have enjoyed learning the process of creating an ROV and have gained a lot of experience from it."

Erin Lowe (CFO): "Being the technical writer, I was required to know enough about what everyone was working on to document it. This gave me some knowledge about each aspect that goes into the building of an ROV. I learned things about engineering this year that I know will be helpful as I continue my education."

XII. Appendix

A. Safety Checklist

Set Up Procedure:

1. Check that all company members are wearing safety glasses and closed-toed shoes
2. Check work environment and ROV for any hazards (sharp edges, untidy cables, et/slippery area)
3. Check that power supply is off
4. Inspect electrical components and connections for water proofing
5. Connect surface computer to router
6. Connect coder to router
7. Connect tether to router
8. Connect tether to power supply
9. Connect tether to ROV
10. Connect power strip containing surface laptop, TV, router, power supply to external power supply

Initial Power Up:

1. Co-pilot powers on TV, router, and surface laptop
2. Co-pilot announces "power is on" as 48V power supply is turned on
3. Tether manager affirms electronic status lights are correct and alerts pilot and co-pilot
4. Launch team places ROV in water and keep it immobile
5. Launch team checks for leaks in the ROV (If leaking, refer to "Failed Leak Test")

Launch:

1. Launch team releases ROV as co-pilot starts timer
2. Tether manager calls out "ready"
3. Pilot takes control of ROV and begins mission tasks
4. If communication with ROV is interrupted, refer to "Communication Issues"

Retrieval:

1. Pilot steers ROV to pool side for launch team to retrieve.
2. Co-pilot calls "Ready to remove ROV"
3. Launch team removes ROV from water and tether manager calls "ROV is out of pool"
4. Co-pilot stops timer

Shut down:

1. Co-pilot calls "shutting down" before powering off ROV.
2. Co-pilot shuts down surface laptop, router, TV and power supply
3. Tether manager disconnects tether from ROV.
4. Team packs all gear

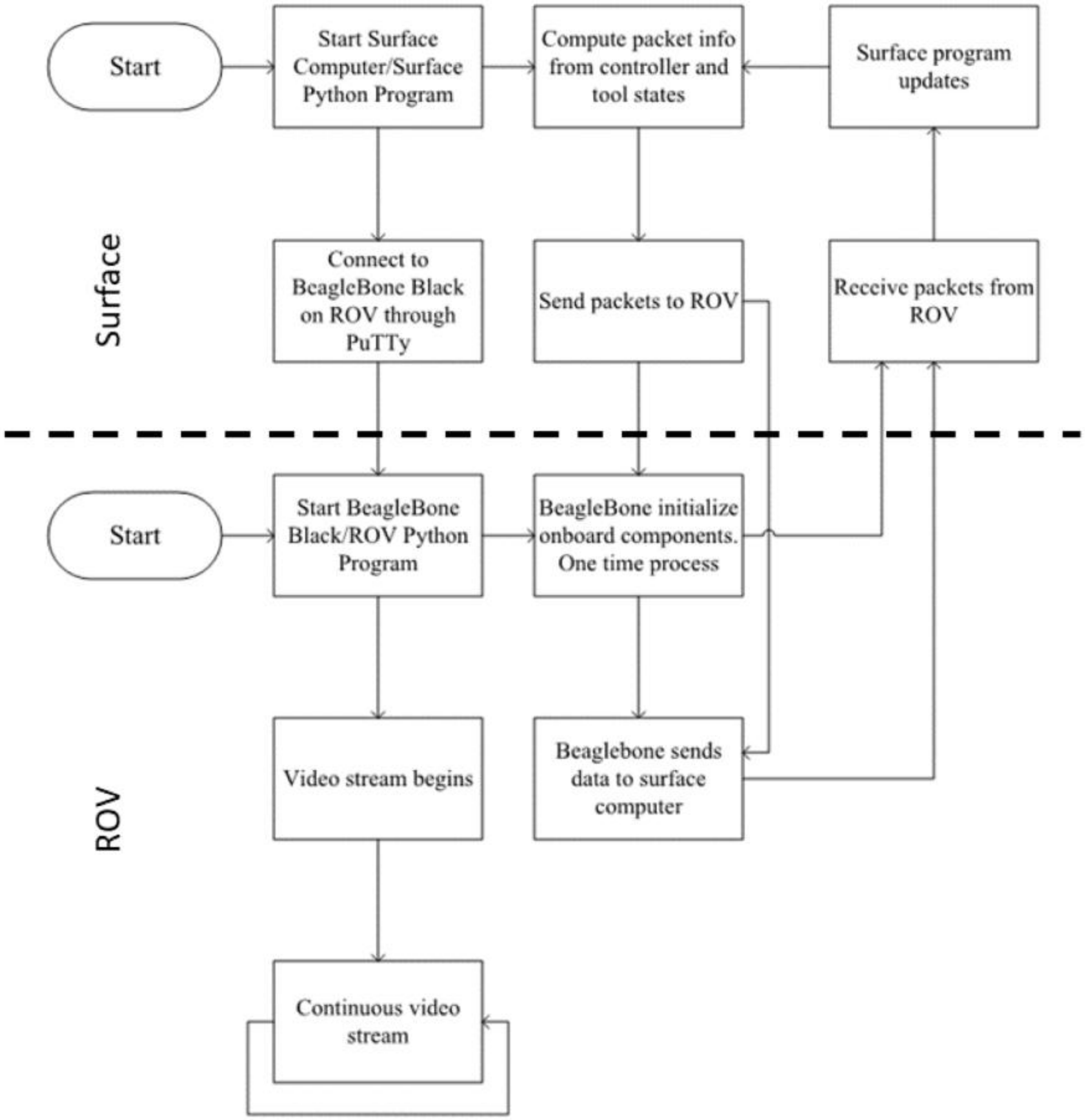
Failed Leak Test:

1. Pilot brings ROV to pool side
2. Co-pilot calls "shutting down" and powers off ROV
3. Launch team retrieves ROV and begins troubleshooting
4. If problem is solved, begin process again with "Initial Power Up"

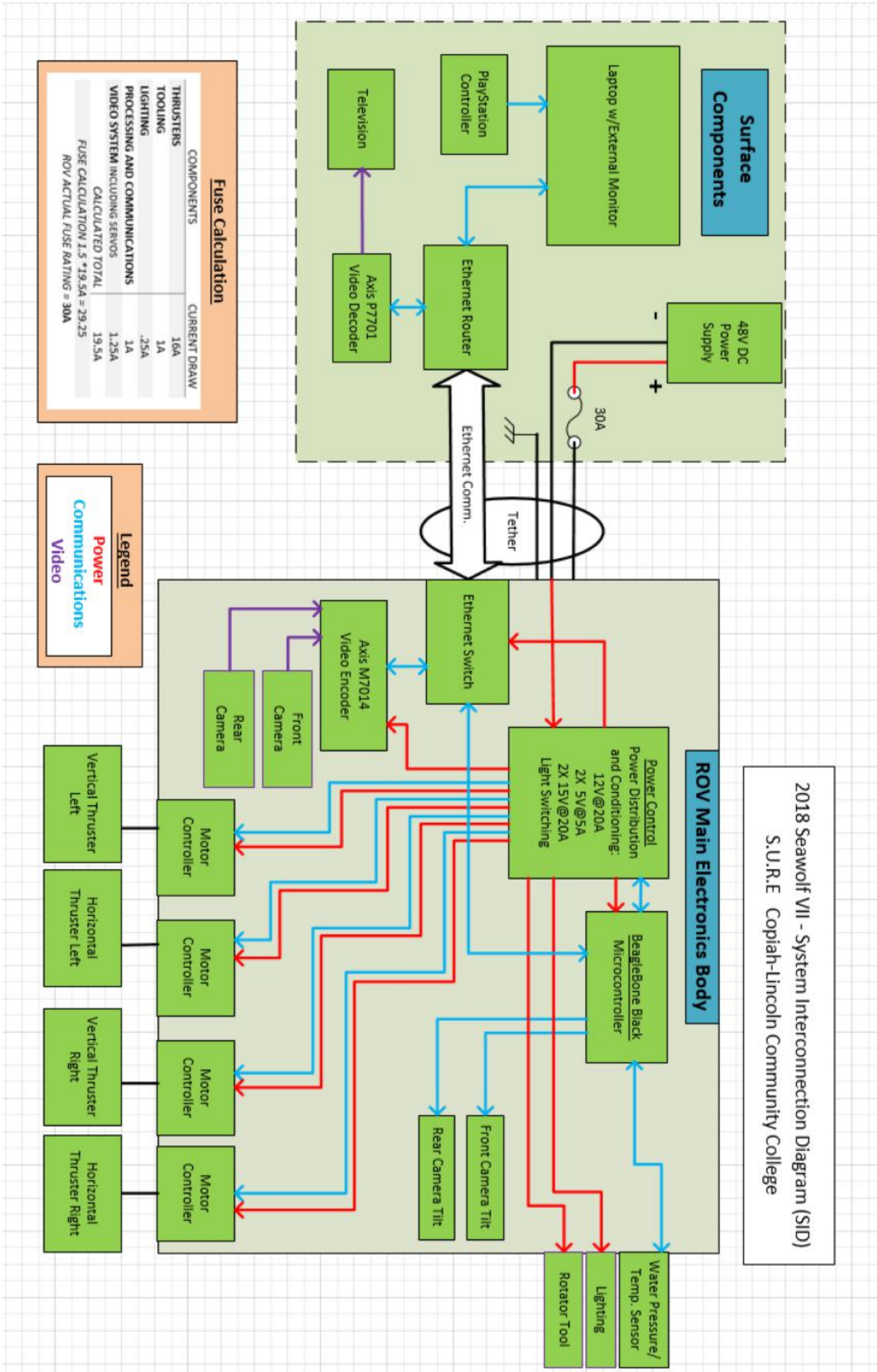
Communication Issues:

1. Co-pilot checks surface computer program for communication issues
2. Co-pilot checks serial connection to ROV and
3. Co-Pilot checks if programs are running correctly
4. Pilot checks power supply
5. Tether manager checks tether for imperfections and connections

B. Software Flowchart



C. System Interconnection Diagram (SID)



D. Acknowledgements

Figure 19: Doug Hoy, director of Georgia-Pacific Monticello LLC Public Affairs/Communications, presents a donation of $5,000 to the Seawolf Robotics Team on behalf of the Georgia Pacific Foundation. Pictured from left: Dezirae Katt (Graphic Design), Doug Hoy, and Joseph Crouse (Construction Engineer/ Pilot).

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MATE

Georgia-Pacific

COPIAH LINCOLN COMMUNITY COLLEGE

Tim Jones

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