Robotics

Seawolves Underwater Robotics Engineering

Seawolf IX

2021 Technical Documentation

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Table of Contents

I. Abstract

The Seawolves Robotics Engineering company has built a new ROV capable of surveying and documenting undersea flora health, removing pollutants and debris, and maintaining healthy waterways. S.U.R.E is headquartered in Wesson, Mississippi, and has over eight years' experience in building ROVs. Over the last year our company members met twice a week for two to three hours a meeting, brainstorming design ideas, building and tooling our latest ROV. Multiple testing and redesigns of tooling were completed to ensure our ROV was a versatile and effective tool to serve waterways around the world, various conditions, and situations. The team members designed several specialized tools to meet the requirements of the RFP. The design of this year's ROV was largely focused on adaptability, reliability, and durability; ensuring the new Seawolf IX was an effective conservation assistant no matter the environment. The S.U.R.E. company is organized into groups responsible for public relations, design, programing, and electronics to ensure maximum productivity. Many tasks require the entire team, which helps to strengthen bonds and communication. The team must work together to ensure that the robot is built on time and safely. 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 IX were strenuously tested to ensure safety and success in the workplace. Seawolf IX is specifically manufactured to meet all the requirements of the missions. This durable ROV is ready for any ocean, river, or lake, and it is prepared to help us all do our part to save our waterways and clean up our planet.

FIGURE 1: THE S.U.R.E. COMPANY (PICTURED LEFT TO RIGHT): SAM BEVINS, GREYSON GRAVES, DALTON WEST, KEVIN MCKONE (MENTOR), TREY DORSEY, MEGAN ARNOLD, VIVIAN GRAY, MATTHEW KING, CAREY WILLIAMSON (MENTOR)

II. Safety Standards and Procedures

At Seawolves Underwater Robotics Engineering (S.U.R.E.), safety standards, protocols, and procedures are of utmost importance. Each member of the S.U.R.E. company is expected to uphold the necessary safety standards to ensure a smooth, safe, and successful engineering process. (S.U.R.E. participates in OSHA safety briefings on slips, trips, and falls before beginning the construction of a new Seawolf drone model to make sure each company member is properly prepared to prevent accidents in the workplace, as well as how to handle such accidents in their unfortunate occurrence). One of the most important factors of maintaining a safe work environment is ensuring that the S.U.R.E workplace remains clean, organized, and tidy; something that S.U.R.E takes very seriously.

FIGURE 2: HARDHATS AND SAFETY KITS

The S.U.R.E. company was tasked with working under the ever changing and restricting recommendations of the CDC to prevent the spread of COVID-19. Every precaution was taken to ensure that each member of the S.U.R.E. company was protected to the highest possible degree, and that each member was responsibly protecting their fellow members as well. The S.U.R.E. company made sure to wear CDC approved masks during each meeting, working session, and gathering, and every member maintained their own separate workstations at least 6 feet away from his or her fellow S.U.R.E. company members. Proper sanitation was held in high importance for the team, as each member was required to use CDC-approved disinfectants before and after occupying their workstations. Perhaps most tedious, each part of the Seawolf IX had to be meticulously sanitized before another member was able to inspect or work on said part. During the unfortunate occurrence of one of our team testing positive for COVID-19, this team member would be unallowed to attend team meetings for at least 14 days. Working from home was also sought after; the S.U.R.E. company was able to complete several tasks from home, which helps reduce the potential for spread of COVID-19.

III. Design and Modelling

Design Rationale

S.U.R.E spent many hours working together to create and assemble *Seawolf IX*. The main aspects of the construction were design, machining, and assembly. Teamwork and diligence were essential during the creation and testing of the ROV. The previous Seawolf model created in 2019 (*Seawolf VIII, Figure 3*) had a cylindrical main body in which all the electronics were housed. The design presented issues because the tubular shape of the body did not efficiently enclose the flat, rectangular circuit boards within. This led to the Seawolf VIII having significant empty space inside. This year, we built a rectangular main body which can efficiently and neatly store and protect the circuitry inside with little wasted space. The rectangular design has a sleeker, more appealing appearance, and the main box is the most durable design we have created so far. The six thrusters ~~guards~~ on the Seawolf IX are angled to provide the ROV with increased range of movement and planes of rotation. Cameras are placed at the front and back of the ROV, and a powerful manipulator is installed at the front. Initially, The *Seawolf IX* was modelled to resemble a sea turtle, both sleek and hydrodynamic as well as durable and resilient. While the sea turtle design was eventually discarded for the rectangular appearance, the idea of a compact, sleek but strong design was certainly retained.

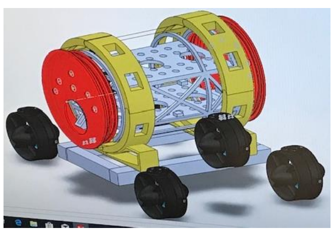

FIGURE 3: THE SEAWOLF V~~X~~III

Modelling

Modelling

Modelling

The *Seawolf IX* was primarily designed in SolidWorks, a CAD program with a near unlimited toolkit to allow full freedom when designing our ROV. Some designing was also done using Blender, a more artistic 3D modelling program. The entirety of the ROV from the main body to the thrusters, and manipulator, was first modelled using these programs before physical construction began. Using this software allowed us to fully account for components needed for construction and assembly of the Seawolf IX, before having to purchase materials that could potentially go to waste. The S.U.R.E. company realizes the near limitless abilities that CAD software provides and placed great importance on learning how to use such programs. SolidWorks has been a monumental tool in our journey to create efficient and streamlined drone designs for various uses. *Figures 4 and 5* show a few CAD designs of the Seawolf IX.

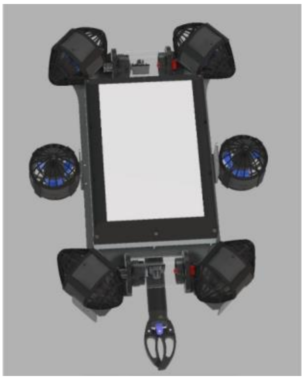

FIGURE 4: SOLIDWORKS MODEL OF SEAWOLF IX

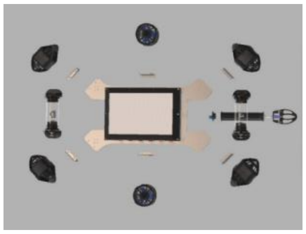

FIGURE 5: EXPANDED VIEW OF SEAWOLF IX

IV. Tooling

Manipulator

The most prominent tool the *Seawolf IX* is equipped with is the *Blue Robotics* Newton Subsea gripper. The gripper opens to a 2.44-inch diameter, and is pressure tested at depths of up to 984 feet. Ultimately, the S.U.R.E. company decided to keep the simple manipulator only, and instead practice on mastery of the controlling of this tool to complete missions effectively. The Gripper (*Figure 6*) is placed at the front of the *Seawolf IX*, slightly to the left, and under the front camera. Placement close to the camera is especially beneficial during missions because having the manipulator within the camera's field of view assists in spatial awareness for the driver and makes it much easier for the driver to see what he or she is doing with the manipulator. This manipulator is simple and user-friendly and is the main tool that will be used in most missions due to its versatility.

FIGURE 6:BLUE ROBOTICS NEWTON SUBSEA GRIPPER

Thrusters

FIGURE 7: BLUE ROBOTICS T100 THRUSTERS

The *Seawolf IX* features six *Blue Robotics* T100 Thrusters (*Figure 7*) placed around the base plate of the ROV. The light weight of the Seawolf IX combined with the powerful T100 thrusters makes this drone the most powerful creation yet from the S.U.R.E. company. 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 0.5A less than the output of a converter. The motor output is software limited to decrease current draw to a total of 16A for all 6 thrusters. 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 VIII* and were extremely satisfied with them. S.U.R.E. chose T100 thrusters for *Seawolf IX* because the ROV is smaller and the T100s do not require as much current as the T200 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 thrusters' ability to propel in two directions gives the *Seawolf IX* total freedom to travel in any direction and provides the ROV with the ability to rotate along all the X, Y, and Z axis, as well as crabbing (strafing) capabilities. The thrusters are encased in custom thruster guards that we created in SolidWorks and 3D printed with ASA filament to perfectly fit the T100 thrusters. These specialized thruster guards are easily assembled, and provide solid protection for the thrusters, as well as preventing anyone from touching the moving blades and injuring themselves. A unique component of our thruster guards is that they guard both the front and backside of the thrusters. While many models of thruster guards only protect the front, or intake, of the thruster, our guards provide protection from both sides; this design is especially important when the thrusters are working in reverse.

Feet

The S.U.R.E. company has experimented with several types of feet designs for the *Seawolf IX* that would be the best fit for the ROV. Four aluminum "Pig's feet" were our starting point. Constructed using round aluminum bar stock machined on a CNC lathe, these feet were

FIGURE 89: COMPLETED FOOT DESIGN

useful and reliable on previous Seawolf models. The "Pig's feet", named for their short, stubby appearance, were not the only ones considered in creation of the Seawolf IX. Sled feet (*Figure 89*) were considered due to their light weight and high surface area which provides increased stability for the ROV. Ultimately, S.U.R.E. designed simple feet in Solidworks that feature a partially hollow design, allowing a single screw to be drilled up through the middle and securing each foot to the ROV. Since the foot (*Figure 98*) has an opening in the bottom that could potentially retain air when the ROV is submerged. We solved this by putting a few holes through the design to let any air escape. This design was easy for the S.U.R.E. company to 3D print due to the simplicity of the design, and printing replacements are cost and time effective.

FIGURE 98: SLED FOOT DESIGN

Cameras

Seawolf IX contains two standard definition CCTV style 1.2mm cameras (*Figure 10*), 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 cameras 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/she is attempting to maneuver the ROV in compact spaces and through debris. The cameras are attached to a servo that allows the pilot to rotate them 180 degrees along the x-axis. This allows the pilot to clearly view his surroundings and greatly minimizes blind spots.

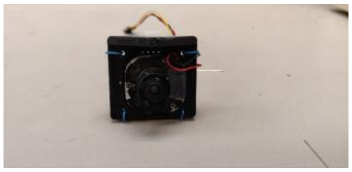

FIGURE 8: CCTV CAMERA

Failed Tooling Ideas

Initially, the S.U.R.E. company worked on several different manipulator tools that could assist in completing the various tasks assigned this year. Prototypical tooling design ideas included those resembling an extending claw grabber (*Figure 11*) that would assist in collecting items from the sea floor. The claw design is based on a hardware tool created to pick up small, hard to grab items and hold them securely. Vacuum manipulators were also considered, capable of pulling debris into their grasp using suction. Ultimately, we found that simplicity of tooling design led to better performance on missions. Complex tooling can increase the chance of malfunction, so a basic manipulator along with adept piloting is more effective and efficient, and less prone to failure or malfunction. While these tools may have helped with certain missions the *Seawolf IX* would encounter, these extra tools also came with weight and buoyancy issues, and essentially caused preparations for missions to be needlessly complex.

FIGURE 9: CLAW MANIPULATOR DESIGN IDEA

V. Electronics

Printed Circuit Boards

The main four-layer board was designed in house, manufactured by Advanced Circuits and is responsible for receiving the supplied 48V DC and filtering the incoming voltage. It also houses the main onboard microcontroller, a Diligent ChipKit Max32. Other items found on this board are an Ethernet Switch, Razr IMU, connections for 4 temp sensors, two connections for servo outputs, connection for the Blue Robotics temp/pressure sensor, lighting outputs, actuator controls, and an ambient temperature sensor. This board is powered by the 5V and 12V DC to DC converters found on the power supply board. It has a 30A fuse for incoming voltage and fuses for both the 5V and 12V supplies.

The power supply Board is a dual layer board that was designed and manufactured in house. This board sits above the Main Board and is responsible for all voltage conversions. This board receives filtered 48V from the Main Board where it is then converted to the required voltages. There is a 5V and 12V DC to DC converter and six 15V DC to DC converters located on this board. It also houses the outputs for each motor. These include a V-out (15V), GND (ground), and PWM (pulse width modulation). A 13-pin connection to the main board receives the PWM signals and passes them to the output pin for the motors.

The video encoder board was purchased and removed from its casing to reduce weight and size. It is powered via the Main 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 ROV.

Tether


FIGURE 10: TETHER

The *Seawolf IX's* tether (*Figure 12*) 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 IX* and the control station. The network router provides standard Ethernet connectivity to all the main parts of the control system. The company uses an Outland's Technology tether, which is neutrally buoyant and durable enough to withstand strong currents and water pressure.

Surface Controls


FIGURE 11: NETWORK ROUTER

The ROV's surface electronics equipment includes an Outland Technologies tether, an Axis IP video decoder, a TV, a network router (*Figure 13*), and a laptop PC. The S.U.R.E. company focuses on keeping the surface control area from becoming too complicated and intricate to provide for fast and easy setup and breakdown processes, as well reducing potential errors and issues during setup.

VI. Materials

3D Printing

3D printing has been a staple of S.U.R.E.'s robotics production for many years now. Several components of the *Seawolf IX* have been produced through 3D printing due to its versatility and customizability. Within the main box of the *Seawolf IX*, we have designed and printed caging to keep the electronics organized and in place within the ROV. Essentially acting as the skeleton of the *Seawolf IX*, this unassuming cage is what holds the ROV together. As mentioned earlier, the thruster guards were designed in house using SolidWorks and 3D printed using extra durable ASA filament. This filament is more rigid than regular PSA filament and provides greater impact protection. The 3D printed feet of the ROV also enjoy the benefits of printing with strong ASA filament. The camera tubing has 3D printed end caps to tightly secure the tubing and prevent leakage. The files for these end caps were acquired from *Blue Robotics*.

Aluminum Base Plate

The foundation of the Seawolf IX is the aluminum base plate from which all parts of the ROV are anchored. Initially, the S.U.R.E. crew attempted to cut the base plate from the side of a washing machine, though this proved unsuccessful, as the washing machine sheeting was too thin to support the ROV. The aluminum was ultimately acquired from eBay and serves as the foundational cornerstone of the entire drone. Aluminum was chosen for its resistance to corrosion due to oxidization, relative lightweight, affordability, and durability. Aluminum is also heat conductive, meaning it does not trap heat withing the *Seawolf IX's* main electrical box, and allows the water outside to cool the inside.

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Main Body Construction and Machining

The bottom portion of the *Seawolf IX's* main box was machined out of aluminum. Connecting to the aluminum base plate, this piece provides the *Seawolf IX* with a rigid armor that protects circuitry and wiring of the ROV. The top half of the box was machined out of HDPE as opposed to aluminum to further reduce the weight of the ROV. S.U.R.E. decided machining would be the superior course of production of the main box as opposed to 3D printing because machining allowed for production of bigger, thicker, more durable parts and could be done in house. The 3D printers at the S.U.R.E. company's disposal are not able to create solid pieces large enough to serve as the main box components; further, 3D printing such thick solid pieces would require a large amount of filament that could be put to better use elsewhere.

Waterproofing

Waterproofing

Several materials were needed to waterproof the *Seawolf IX* because the entire top half of the electronics box is removable. A large, custom fitting O-ring sits between the top and bottom half of the main box. The O-ring is coated with petrolatum jelly to assist in sealing the box, as well as providing additional waterproofing due to petrolatum jelly's hydrophobic characteristics. The tether's outlet to the ROV is also regularly coated with petrolatum jelly. Regular coating is necessary because each disassembly of the ROV may remove some of this coating, so special attention is given to these openings to ensure sufficient coating. On the underside of the *Seawolf IX*, several penetrators run through the base plate and into the main box to allow the thrusters to connect to the power supply. These penetrators are sealed using epoxy. The cameras are encased in clear tubing with endcaps that ingeniously both protect the camera from water at all angles and allow the cameras to maintain a complete field of view. One of the endcaps at the end of each camera tubing has a penetrator allowing the cameras wiring through to the main box of the ROV; these penetrators are also sealed with epoxy.

Marine Foam

A special ~~high density~~high-density marine foam is attached on top of the *Seawolf IX* for added buoyancy. High density marine grade foam is ~~hydrophobic~~ closed cell and does not absorb water. This foam is also extremely resistant to water pressure, and it will not decrease in volume when submerged. The marine foam is attached to the top of the ROV using waterproof epoxy. Between the foam and the top of the ROV we attached an aluminum loop that allows us to connect the tether to the ROV without putting stress on the tether's electrical connectors. (Figure 14).

FIGURE 12: TETHER CONNECTION LOOP

VII. Programming and Software

LabView

At the heart of the control system is a Microsoft Windows 7 laptop running National Instrument's LabVIEW 2017. LabVIEW's Graphical User Interface (GUI) is straightforward and allows commands to be easily employed but is still complex enough to handle the control inputs of our electronic systems. LabVIEW allows the laptop computer to conduct the bulk of data processing, which is preferable to putting the stress on the onboard ROV microcontroller. The LabVIEW software controls our thrusters, cameras, tooling, and the manipulator via an XBOX controller. The Razr IMU (inertial measurement unit) provides ROV positioning feedback to pilot via a horizon indicator in LabVIEW. This IMU includes a triple-axis gyro, a triple-axis accelerometer, and a triple-axis magnetometer.

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Other indicators and controls found in the LabVIEW GUI are thruster power output settings, which allow for finely tuned movements, temperature meters, a depth gauge, actuator controls, and speed controls for the tooling. Additionally, there is an auto hover function using the pressure sensor. The sensor is a Bar30 which can measure up to 300 m and has a depth measurement resolution of 2 mm. This allows for a highly accurate auto depth management.

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Based on input from the XBOX controller (*Figure 15*) and the GUI, LabVIEW determines what action the ROV needs to perform. LabVIEW then issues commands via the tether to the ROV's on-board microcontroller ChipKit Max 32. The Max32 then responds accordingly by directing all of the ROV's components to complete the necessary action.

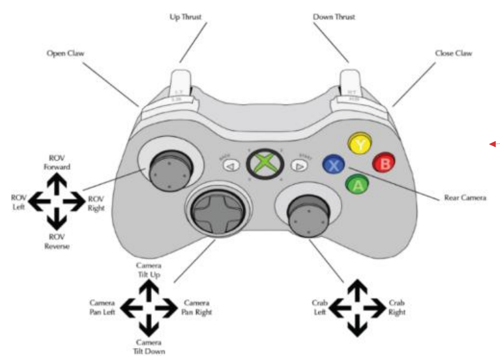

FIGURE 13: XBOX CONTROLLER LAYOUT

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VIII. Buoyancy

The S.U.R.E team had two options when considering the Seawolf IX's buoyancy: we could program the thrusters to a constant hover or add extra materials to the ROV using precise buoyancy calculations to make it neutrally buoyant. Ultimately, we decided that calculating neutral buoyancy would be much simpler, energy efficient, and less prone to malfunction. Making the *Seawolf IX* neutrally buoyant involves finding the ROVs volume and comparing it to its weight. The added high-density marine foam atop *Seawolf IX* allowed the ROV to be slightly buoyant in fresh water. Weigh can also be added to the corners of the ROV opposite the manipulator to even out weight distribution and trim the ROV's buoyancy.

IX. Mission Planning

Mission planning generally began with the S.U.R.E. company brainstorming at a whiteboard to determine a theoretically efficient and effective method to complete each respective mission. For example, planning for the coral replanting mission involved members of the S.U.R.E. company planning the best angle to approach each piece of coral to ensure the manipulator is positioned in front of and below the *Seawolf IX*. In practice, this method proved most successful in completing the coral replanting mission. Furthermore, we learned that after positioning the ROV above and behind the coral, use of the auto-hover function and reducing thruster power output to about 30% greatly assisted with the precise movements needed to collect the coral sample. After collecting this piece, it was effective to increase thruster output and quickly rotate the ROV to locate the coral planting site. Once the planting site is located, thruster power is decreased once again, and auto-hover is used to place to coral in its appropriate site.

The net retrieval mission was a relatively simple mission to plan for. The hardest part of this mission was the fine positioning to initially grab and retrieve the pin. Again, our greatest asset was decreasing thruster power and enabling auto-hover to increase precision when moving and reducing the need to move the ROV vertically. Once we can get a good hold on the pin, it is simply a matter of driving directly backward to pull the pin from the net and allow it to float to the top. We found that once the net is floating, it is most efficient to keep the pin in the manipulator and "spear" the net with the pin. This allows us to retrieve the pin and the net in one trip, greatly reducing mission time.

X. Logistics

Company Organization

The S.U.R.E team is further divided into sub-teams responsible for design, programming, electrical, and public relations, respectively. Each sub-team is made up of a team member best suited to complete their sub-team's specific tasks and responsibilities based on experience and interest. Having a compartmentalized group of team members allows the S.U.R.E. company to progress through the creation and documentation of the *Seawolf IX* most efficiently. Of course, help from a member from a different sub-team is always welcomed at S.U.R.E., as we have learned that when more brain power is applied to solving a problem, a better solution result. We are simply divided to allow all our respective strengths to shine through as much as possible, but any member of the S.U.R.E. company will help his or her fellow member, regardless of sub-teams.

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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 S.U.R.E. company met at least once a week for progress meetings, usually on Fridays, immediately followed by team working sessions. Additional working sessions were held throughout each week to continue creation of the *Seawolf IX*. The creation of the ROV happened in three phases: design, manufacturing, and assembly.

During the first phase, the company began to develop a plan for building the robot. 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 navigate the conditions of various waterways around the globe. Versatility and durability were key components the S.U.R.E. company kept in mind throughout production of the *Seawolf IX* because it was made to be useful in various marine environments, from vast and deep oceans to turbulent rivers.

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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 IX*, as well as the controller. The main body was machined from plastic and aluminum, and various 3D printed components were created.

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The last phase of the construction of *Seawolf IX* was probably the most challenging. The programming, design, and electrical teams worked closely together, combining their work. Once the bottom plate was completed, the company assembled the ROV and began testing it. Several test runs, followed by fine-tuning and careful adjustments were made in the production of an ROV that would help in the continuous battle to save the planet’s waterways from destruction due to pollution.

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Finances

S.U.R.E. Robotics created a budget for the construction of *Seawolf IX* 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 mealtimes. 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 $10,000 which had rolled over from previous years.

S.U.R.E. 2020-2021 Budget		
Cash Income		
Contributions	Amount	Dates
Georgia Pacific	$5,000	October 2020
Georgia Pacific Monticello	$5000	October 2021
Total Money Raised	$10,000	
Expenditures		
Supplies		Cost
3-D Printing		$500
PVC		$90.00
Gripper		reused
T100 thrusters		$714
speed controllers		$150
pressure sensor		$88
Router		$42.67
Electronics		$625
Registration		$400
Travel		$960
Hotels		$2,400
T-Shirts		$168.00
Acrylic Tube		$89.20
Rack		$40.00
Domes		$69.00
Total		$6,357.71

Public Outreach and Corporate Responsibility

The Co-Lin Seawolves hosted the Dauphin Island Sealab March 20 for an underwater robotics workshop. Teachers, parents and students learned the basics of building an underwater robot. All participants who built a robot were able to test their design in a swim pool.

The Co-Lin Seawolves helped Wesson High School Robotics Team, The Bionic Cobras in host a summer robotics camp. The Co-Lin Seawolves have participated in this event for the last 3 years. Junior high students built and competed using LEGO robots in the weeklong camp.

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XI. Conclusion

Testing and Troubleshooting

During the construction of *Seawolf IX*, 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. 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 IX*, learning how to work together seamlessly while the ROV was in operation. We became proficient at connecting the cables within the tether to the television, the monitor, and the power supply. The team created a safety checklist as they worked through complications to ensure a safe ROV mission each time. The various capabilities of the *Seawolf IX* means that a complicated setup process is required to prepare the drone for full functionality, and practicing this setup was just as important as any other aspect of creating, preparing, and operating the *Seawolf IX*.

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Challenges

S.U.R.E. Robotics experienced several challenges in the making of *Seawolf IX*, which forced the team to work overtime and correct these mistakes. One of the major challenges the S.U.R.E. company faced was creating a new design for the ROV that would reduce wasted space within the main box. We essentially had to design a new main electrical box from scratch, which meant we would have less time for actual physical construction of the Seawolf IX. Our previous ROV, the *Seawolf VIII*, had a main box made of plastic tubing, which was easy to assemble, but the New *Seawolf IX* was to have custom fitting machined components, which of course took much of the team's time to design, machine, and assemble.

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A serious issue we faced during testing was we were occasionally getting leakage into the electrical box where the top and bottom halves connected. After taking the ROV out and examining the ROV, a company technician noticed that water had gotten into the base of the ROV. The S.U.R.E. company went to work to figure out what was wrong. Occasionally when we screwed the top half on it would seal unevenly, creating openings between the lid and the bottom that allowed leakage. Thankfully, this was before any electrical components were placed in the ROV, so no shortages occurred. We found that by tightening the screws along the sides of the main box first and then tightening the screws on the corners would seal the *Seawolf IX* securely, and we had no more leaking problems.

When we began performing thruster and camera tests in a larger pool, we encountered a recurring overheating issue. Excessive use of thrusters, especially when rapidly changing directions, caused the ROV to overheat and the thrusters to shutdown to prevent internal damage. We were able to solve this by installing a small fan within the ROV that circulates the internal air to keep the ROV cool. This fan greatly reduced overheating issues and subsequently improved performance of the ROV.

The servos that the front and rear cameras are mounted to occasionally malfunctioned, causing us to lose control of camera movements. We found that reseating the plug to the circuit on each of these cameras restored our ability to control the ROV's cameras.

While attempting practice mission runs, we lost all control of the ROV, unable to control the thrusters, manipulators, or cameras. This was a serious issue that delayed our mission training significantly. Fortunately, while this malfunction was a crippling one, it was relatively easy to fix once the issue was traced. The subcon connector which connects to the tether, runs through the main box of the ROV, and connects to the main power board, was damaged and was not receiving power. This subcon connector is not hard to reach within the ROV's interior, so little disassembly was needed to fix the issue. Thankfully, we did not end up tracing the root of the problem deeper within the electronics of the ROV, which would have taken much more time to locate and correct.

Adding the crabbing function of movement to the ROV also caused many issues. Forward and backward movement as well as rotation were easily achieved, but the front thrusters appeared to be working in reverse when we tried to crab. Tedious electrical work and examination was needed to rewire and calibrate the thrusters so they would move in the appropriate direction in all situations. Further thruster problems were encountered when the rear right thruster would continually quit working. S.U.R.E. went through the trouble of setting up to complete practice missions only to find the thruster was not working. We then ha to disassemble the ROV on the spot to complete the electrical work needed to solve the issue.

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Lessons Learned

The S.U.R.E. company has gone through many changes since its conception. New members join each year as others must move on. The S.U.R.E. company stays committed to recruiting talented, unique, hardworking individuals to create a diverse team. Combining our abilities gives our team a great advantage when it comes to designing a capable ROV. Our team, by our own volition, taught ourselves how to program using LabView and Python, and learned how to design using CAD software like SolidWorks and 3D artistic modelling software like Blender. We learned Google Docs to create spreadsheets that would assist in organizing our responsibilities, budget, and schedule. Most importantly, we learned to work like a team, doing what we can to assist the ROV creation process, and putting our respective skills to their best use. Problem solving was a skill that each member of the S.U.R.E. company had to practice, because learning to assess problems and solve them is the most integral part to ROV construction.

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Future Improvements

Team communication and commitment were unfortunate issues the S.U.R.E. company faced. While each member of the team enjoyed working on the Seawolf IX, many of us had several other responsibilities we had to uphold. A few members of the team were ready to leave school and had gotten jobs, leaving the S.U.R.E. company understaffed towards the end of the production process. Communication issues arose as some team members were failing to respond to group messages on time, leaving other members unsure of their commitment. These issues were serious and detrimental to the team. And improvements must be made to fix these issues. The S.U.R.E. company must be diligent in making sure the recruitment process continues as members have to leave the team, and an emphasis on effective and prompt communication between members is important. An improvement the S.U.R.E. company can make on future iterations of the Seawolf ROV would be a more effective closing and locking mechanism to secure the lid of the box to the bottom piece. The current screws give the *Seawolf IX* a sleek look, but they tend to take a lot of the team's time to unscrew whenever the ROV must be opened. Latching mechanisms may be implemented in the future to reduce assembly time.

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Reflections

Trey Dorsey: “The people I’ve met and the skills I’ve learned have tremendously improved my abilities in the STEM field and has given me an edge in my career.”

Megan Arnold: “This year, I helped to repair the ROV whenever something quit working in it, and it helped me to apply what I have learned in my electronics classes.

Greyson Graves: “As the Technical writer for this project, I was able to learn much in the field of engineering, from electronics to Image recognition technology. I enjoyed my time working with this team and look forward to doing more robotics work in the future.”

Roger Rushing: “This year, I have learned a lot with helping with the robot, and I have really enjoyed working with my team. I can’t wait to see us win the competition.”

Isaac Ebbers: “I have not been a part of the robotics team for very long, but I would love to learn more about the robot and how it works. I will be helping with the operation of the robot.”

XII. Appendix

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

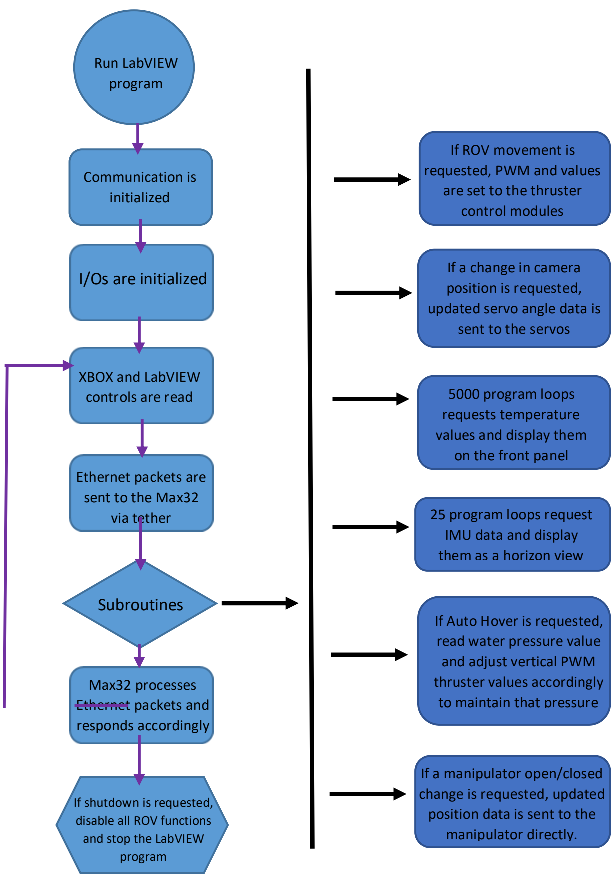
Failed Leak Test:

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"

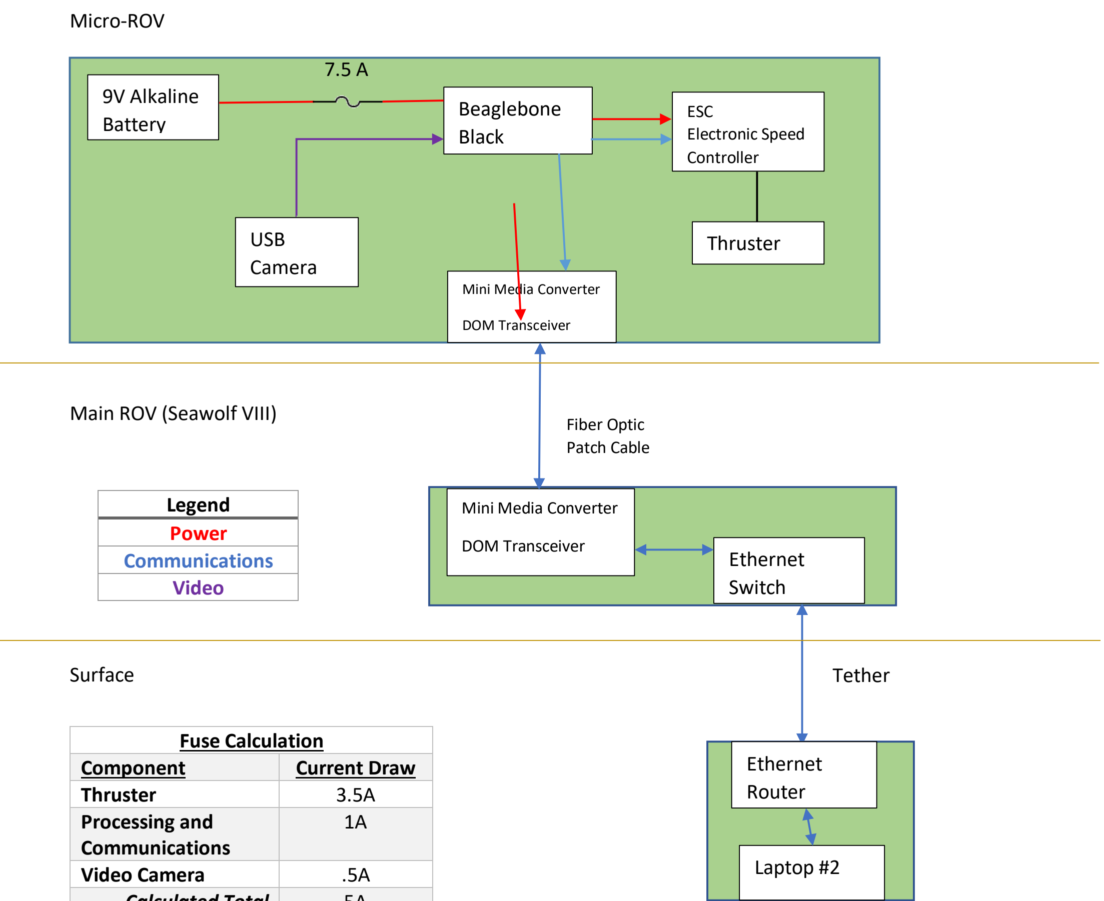
Communication Issues:

1. Co-pilot checks surface computer program for communication issues
2. Co-pilot checks serial connection to ROV
3. Co-Pilot checks if programs are running correctly
4. Pilot checks power supply
5. Tether manager checks tether for imperfections and connections
6. If solution is not found, launch team retrieves ROV

Software Flowchart



System Interconnection Diagram (SID)



Legend
Power
Communications
Video

Fuse Calculation	
Component	**Current Draw**
Thruster	3.5A
Processing and Communications	1A
Video Camera	.5A
Calculated Total	5A
*Fuse Calculation 1.5 * 5A = 7.5A*	
Actual Micro ROV fuse rating = 7.5A	

Acknowledgements

FIGURE 14: *GEORGIA PACIFIC PRESENTS A DONATION OF $5,000 TO THE SEAWOLF ROBOTICS TEAM ON BEHALF OF THE GEORGIA PACIFIC FOUNDATION. PICTURED FROM LEFT:* PICTURED FROM LEFT: DR. JANE HULON SIMS, CO-LIN PRESIDENT; DR. KEVIN MCKONE, SCIENCE DIVISION CHAIR; LUKE HORTON, GEORGIA PACIFIC MONTICELLO PUBLIC AFFAIRS MANAGER; AND ANGELA FURR, FOUNDATION DIRECTOR

S.U.R.E. Robotics Thanks:

Copiah-Lincoln Community College- For providing S.U.R.E.'s healthy learning environment and supporting us through innumerable means.

Georgie Pacific, Monticello Division- For encouraging our company and supporting it financially.

Marine Advanced Technology Education (MATE) Center- For providing a safe competition medium for students to study marine technologies and in turn help them prepare for the real-world work environment through healthy competition.

Brookhaven Country Club- Use of their pool

MATE

Georgia-Pacific

COPIAH LINCOLN COMMUNITY COLLEGE

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