Innovations for Inshore:

ROV Operations in Rivers, Lakes, and Dams

2019 MATE International

ROV Competition

Technical Documentation

Sea Dragons

Port Townsend WA

Member Name	Company Roles
Ella Ashford	CEO, Pilot, Electrical and Software Engineer
Logan Flanagan	Head of R&D and Data Analysis
Nathaniel Ashford	CFO, Pilot and Mechanical Engineer
Everest Ashford	Safety Captain and Tether Manager
Ayden Ratliff	Head of Marketing, Engineer and Pilot
Gabriella Ashford	Admin Mentor
Otto Smith	Programming Mentor
Betsy Blinks	Editor Mentor
Eric Ashford	Woodworking Mentor

MATE ROV COMPETITION 2019

The Sea Dragons are affiliated with the Port Townsend STEM Club

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1. Abstract

The S.S. Dragon, a remotely operated underwater vehicle (ROV), is designed by the Sea Dragons to meet the request for proposals (RFP) submitted by MATE and the Eastman Company through this year's challenge: ***Innovations for Inshore***. This vehicle is reliable, robust, and efficient, enabling it to navigate in freshwater environments and meet all industrial needs in Kingsport, Tennessee.

The Sea Dragons' goal is to provide public safety by performing surveys and routine repair work on Boone Dam. Environmentalism is a top priority for the Sea Dragons and therefore they demonstrate their ability to conduct both biological and chemical sampling to ensure a healthy ecosystem. Kingsport is also steeped in historical sites. The S.S. Dragon is equipped with tools to aid in the recovery and preservation of historic artifacts. This company accomplishes these tasks and more through a solid business model, innovative designs, and community engagement.

The S.S. Dragon incorporates two cameras, six thrusters, a custom manipulator and unique mission specific tools. The vehicle's frame is constructed from recycled aerospace grade carbon fiber, making it durable and lightweight. The S.S. Dragon is equipped with an intuitive control system whose secret lies in a simple but efficient Arduino controlled design. The Sea Dragons ensure a reliable ROV that is capable of any industrial, environmental and preservation task. The Sea Dragons have been acknowledged by the Environmental Protection Agency for their innovative ROV design as well as their environmental stewardship.

2. Project Management

At the start of the season, experienced members prepared a solid business plan to lay the foundation for success. Additionally, the Sea Dragons used a scheduling software called Smartsheet to streamline the design process. Smartsheet increased the accountability of company members by using a tracking system that follows a job's progress. The CEO can get status updates on a project and even send out reminders to keep everyone on track. By recording sponsors, expenses and projects, Smartsheet enabled the company to easily make a budget, timeline, and strengthen company structure.

Task Name	Status	Additional Information	Due Date	Project Lead	Assistant
+ Business				Ayden Ratliff	
+ Competition Prep				Ella Ashford	
+ Robot Build				Nathaniel Ashford	
− R&D				Logan Flanagan	
Micro ROV	Complete	Complete but needs testing	05/23/19	Logan Flanagan	Nathaniel Ashford
Image Recognition	Progressing	Explore OpenCV software	05/23/19	Logan Flanagan	Ella Ashford
Measuring Tool	Progressing	Needs testing of designs	06/15/19	Nathaniel Ashford	Everest Ashford
Tire Recovery Tool	Progressing	Needs testing of designs	06/15/19	Everest Ashford	Ayden Ratliff
Lander	Progressing	Design fuctional but more work needed	06/15/19	Ayden Ratliff	Ella Ashford
Temp Sensor	Progressing	Functional but needs to be calibrated	06/15/19	Ella Ashford	
+ ROV Design					
Control System	Progressing	Troubleshoot noise problem		Ella Ashford	
Carbon Fiber Frame	Complete	Send thank you to PC and CRTC	05/10/19	Ella Ashford	Nathaniel Ashford

Figure 1: Excerpt from the Sea Dragons planner showcasing the breakout of tasks
Credit: Ella Ashford

2.1 Timeline

A year round schedule was maintained by the company which factored in outreach (corporate responsibility), research, design, and competition preparations. In total, company members completed over 1,500 hours of outreach and 1,000 hours of ROV related projects.

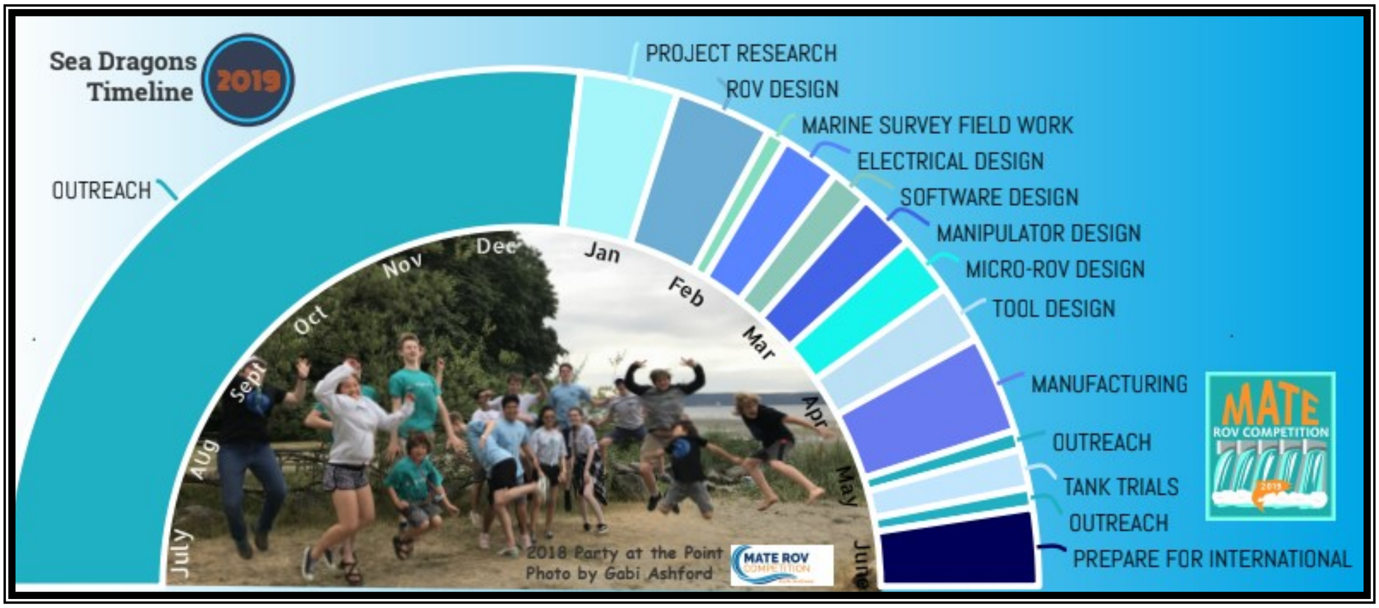


Figure 2: Timeline of company activity from July 2018 to June 2019
Credit: Ayden Ratliff

2.2 Company Assignments

Each member has a role in the company that enables them to lead an engineering project. Project leads are in categories such as ROV tools, mechanical design, electrical, software and Micro-ROV. Project leads will report the weekly progress to the CEO as well as record their work in the engineering notebook. These assignments create an understandable chain of command that is implemented in the shop as well as in the field. Additionally, company members are in charge of the business. Through roles such as the CEO, CFO and Head of Marketing, progression of funding, documentation and company leadership is ensured.

Figure 3: Left to Right - Logan, Everest, Ella, Nathaniel, Blake (supporter), Ayden
Photo Credit: Gabriella Ashford

Company Roles:

- Ella Ashford: CEO (Chief Executive Officer), Electrical, and Software Engineer
- Logan Flanagan: Head of R&D, and Data Analysist
- Nathaniel Ashford: CFO (Chief Financial Officer), Lead Mechanical Engineer, and Pilot
- Ayden Ratliff: Head of Marketing, Pilot, and Engineer
- Everest Ashford: Safety Officer and Tether Manager

3. Design Rationale

The S.S. Dragon ROV was built to meet the requirements of the request for proposal (RFP) submitted by MATE and the Eastman Company.

When creating the ROV, the Sea Dragons used industrial design concepts such as *Lean Thinking* to streamline the design process through assembly line efficiency. An engineering notebook was kept to record, evaluate, and select design ideas. Meetings were conducted using Roberts Rules of Order to increase the effectiveness of communication between engineering departments.

The S.S. Dragon design optimizes size and weight while maintaining a durable structure. By utilizing a carbon fiber frame, the S.S. Dragon aims to withstand environmental stresses such as ultraviolet light, biological growth, and corrosion. Thruster placement ensures maneuverability in the strong currents of rivers and lakes. Six powerful thrusters provide stable lift when completing tasks such as dam maintenance and historic artifact recovery.

By incorporating a combination of custom manufactured components and tested commercial products, the S.S. Dragon ensures a reliable design that best balances the needs of the company's clients. The ROV and crew have fifteen hours of pool mission practice time and over twenty hours of real world industrial survey experience. To test their ROV design the Sea Dragons partnered with the Port of Brownsville in Washington State to survey a historic fuel dock for rust and cracks, enabling the company to apply core ROV systems out in the field. The Sea Dragons ensure an environmentally conscious design by using recycled aerospace grade carbon fiber on their ROV. The S.S. Dragon design and the Sea Dragons have been recognized by the United States Environmental Protection Agency, for their environmental stewardship and innovative designs.

Figure 4: Photo of the complete S.S. Dragon vehicle

Photo Credit: Ella Ashford

3.1 ROV Frame

The goal of the S.S. Dragon frame is versatility, durability, and reliability. Designs were created using a combination of Solidworks and Rhinoceros, which are CAD (Computer Aided Design) programs that allow engineers to digitally build ROV models. To create an efficient ROV, concepts such as drag, weight, and size are important in the overall design. The frame was built to be small and compact. This is favorable for transportation as well as ease of deployment. Structural integrity is vital, especially since the ROV's main function is field work. Excess material was eliminated from the frame to reduce drag and weight. The S.S. Dragon design balances weight and structural integrity by cutting out unnecessary material from the frame. These gaps in the frame use strong geometric shapes such as triangles so that structural strength is optimized (Figure 5 & 6). The most unique feature of the S.S. Dragon frame is the recycled aerospace grade carbon fiber plain weave that is the basis of the design. Many different materials were tested during the construction of the S.S. Dragon, but carbon fiber was chosen for its high strength to weight ratio, durability, and the positive environmental impact of the manufacturing techniques (Figure 7). A Waterjet was used to cut the frame, and smaller power tools were used to further customize it to the company's needs.

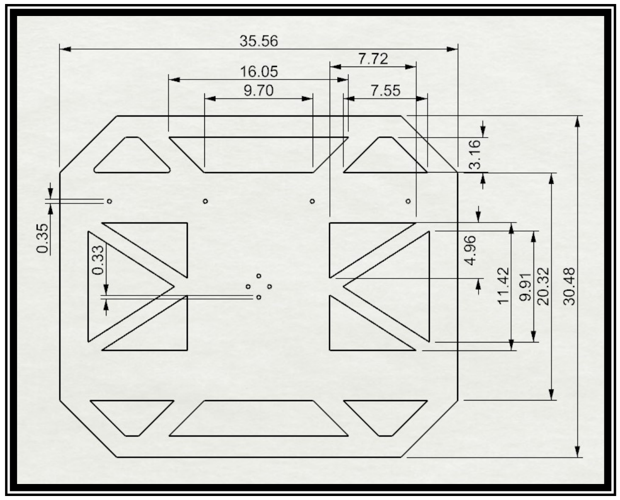


Figure 5: Mechanical drawing of side panel
Credit: Logan Flanagan

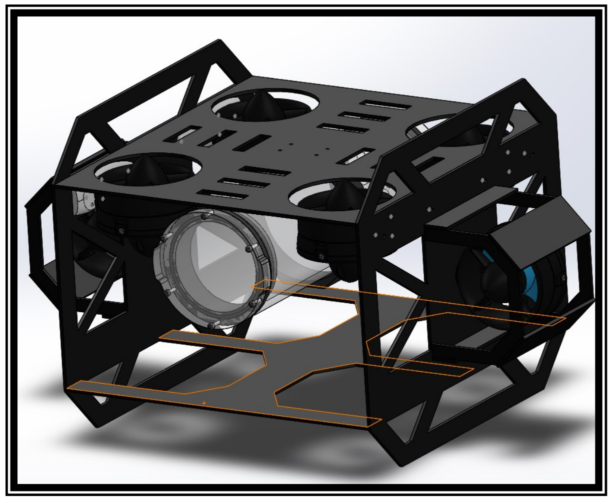


Figure 6: CAD model of the S.S. Dragon
Credit: Ella Ashford

Manufacturing Techniques and Materials						
Material:	**Aluminum**	**Polyethylene**	**Plywood**	**Carbon fiber**	**Polycarbonate**	**LEGO**
Availability:	Easily available	Easily available	Easily available	Not easily available	Less available	Easily available
Ease of manufacturing:	Difficult to cut on bandsaw	Easy to cut on bandsaw	Easy to cut on bandsaw	Very difficult to cut	Difficult to cut on bandsaw	Easy to manufacture
Optimal tool:	Bandsaw/jigsaw	Bandsaw	Bandsaw/jigsaw	Waterjet	Bandsaw	Bandsaw
Weight - grams per cubic cm:	2.7	0.95	2.5	2.2	1.2	Varies
Additional notes:	Strong, water-proof, heavy	Sturdy, light-weight, semi-soft	Soaks up water, increases weight	Very strong, lightweight, time consuming	Professional, brittle	Very easy to build with, weak

Figure 7: Chart outlining the manufacturing techniques and materials used in the design process.
Credit: Nathaniel Ashford

3.2 Buoyancy

An industrial ROV needs to be under the complete control of the pilot. To achieve this vital feature, buoyancy must be calculated and implemented based on the tasks the ROV is expected to complete. There are several features of the S.S. Dragon that affect its buoyancy: A positively buoyant electronics canister, the negatively buoyant carbon fiber frame, the positively buoyant polystyrene foam, and the negatively buoyant metal rebar weights. The metal rebar and polystyrene foam are used to trim the ROV's buoyancy. Closed cell polystyrene foam is used for flotation, as it does not compress under pressure, and the metal rebar is painted to prevent rust. A spring scale was used to measure forces of positive and negative buoyancy. Archimede's Principle was applied to create a slightly positively buoyant ROV, to assist in the recovery of heavy objects such as the cannon and trash rack mission tasks.

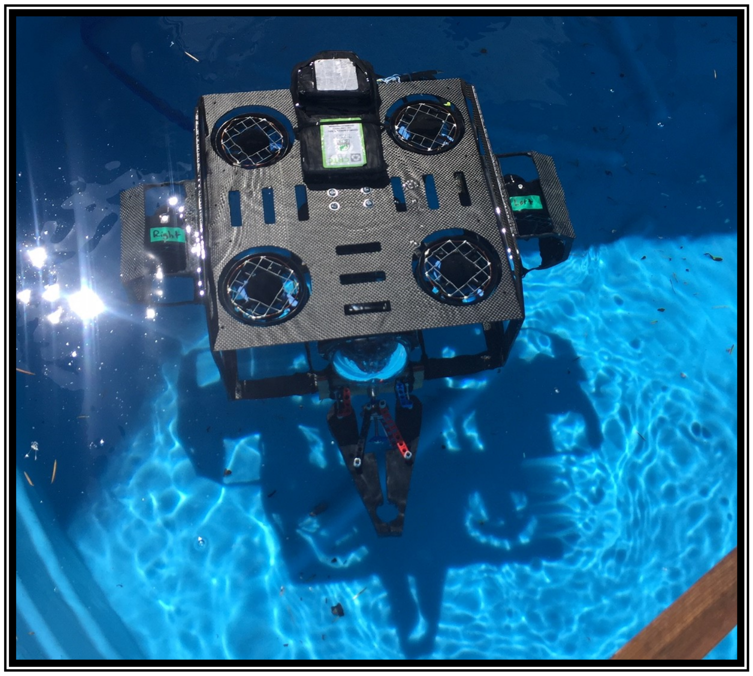


Figure 8: Trimming buoyancy on the S.S. Dragon
Photo Credit: Ella Ashford

3.3 Tether

The S.S. Dragon tether has a power cable consisting of 12 gauge speaker wire and two CAT5 cables for signal wires. These cables are housed in a protective mesh. The tether is 15 meters long and has an overall diameter of 13 mm. When designing the tether, the goal was to make a thin lightweight system that would be snag resistant. Small floats are attached to the tether, enabling it to be slightly positively buoyant and to avoid getting tangled in mission models. By having the cables inside a plastic mesh, it also diminishes safety hazards like tripping. A metal tether thimble is used to apply strain relief. This is a heavy duty system that insures the safety of the wires, the watertight canister, and the frame.

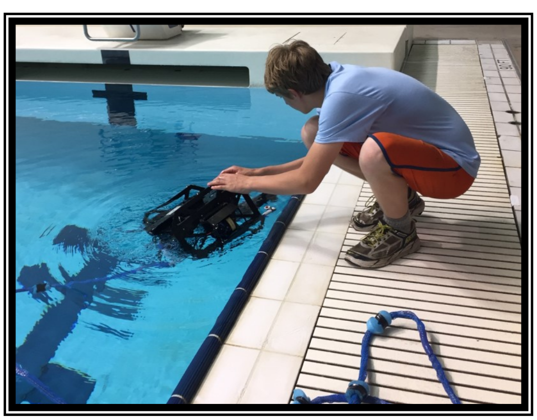


Figure 9: Tether Manager recovering the ROV
Photo Credit: Ella Ashford

Figure 10: Tether
Photo Credit: Ella Ashford

Figure 11: Metal tether thimble
Photo Credit: Ella Ashford

3.4 Propulsion

The S.S. Dragon utilizes six T-100 thrusters commercially sold by Blue Robotics. These reliable brushless motors balance efficiency and power. There are two lateral thrusters on the ROV. They are placed on the outside of the frame so they are far away from the ROV's center of rotation. This enables turning to be fast and responsive. Custom thruster guards were built into the frame to protect these lateral thrusters from damage. Four thrusters placed on the top of the ROV create vertical thrust for lift. It is important that industrial ROVs have a steady and powerful lift, enabling them to conduct restoration, surveying and construction. The four thrusters are attached evenly around the center of mass on the ROV, increasing the stability and creating powerful lift for smooth completion of tasks such as cannon recovery and dam construction efforts.

3.5 Watertight Enclosure

Determining electronics placement on ROVs is a difficult task. Engineers have to decide if they want a robust permanently sealed design, or a modifiable system that can be adjusted if necessary. Though both are important for different tasks, the S.S. Dragon implements a system that can be modified. For this year's proposal, ***Innovations for Inshore***, it was determined that because of the broad range of environmental factors being encountered, it was important that flexibility in design was maintained.

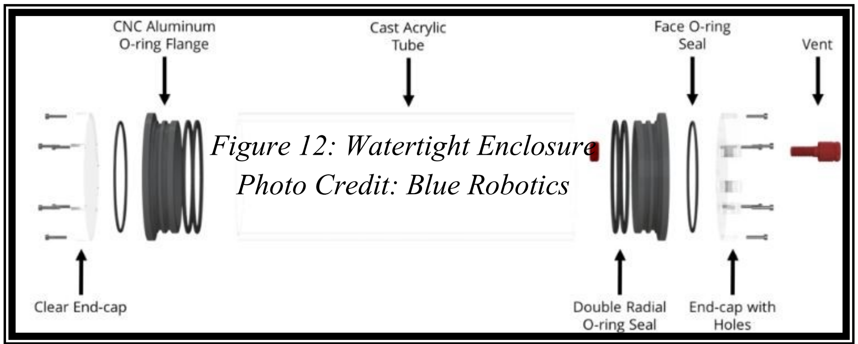


Figure 12: Watertight Enclosure
Photo Credit: Blue Robotics

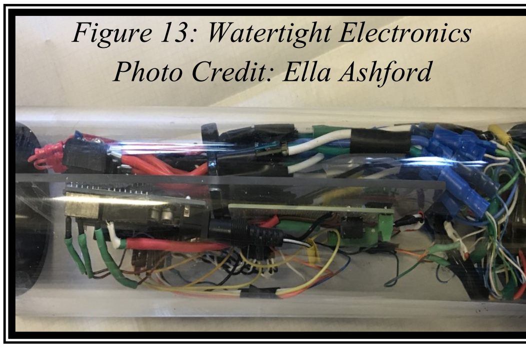


Figure 13: Watertight Electronics
Photo Credit: Ella Ashford

Originally the company prototyped many different watertight enclosures. One of the designs used silicon as a gasket, but after pressure testing, the design failed at two meters of depth. The second design used two O-rings set into a round ABS pipe. Unfortunately, the ABS warped when using a lathe to cut the O-ring slots, making the design not viable. The final idea was to use metal or acrylic material when manufacturing the watertight enclosure. The company did not have adequate tools or resources to complete the job themselves, removing that as an option. It was determined that the best solution was to purchase a commercial product to house electronics. After extensive research was conducted, a Blue Robotics Watertight Enclosure was used to enable easy access to electronics. Unlike a permanently sealed design, which cannot be reopened, this particular type of watertight enclosure can be opened and modified at any time.

After analysis of the various canisters, the company decided on the 4" Series which has an inner diameter of 10.16 cm. This size perfectly fit the electrical system and matched the size requirements of the frame. This system has interchangeable fitted endcaps that use double O-rings on a flange to create a watertight seal. The endcap is aluminum based, and has 14 holes that are compatible with cable penetrators for the tether and thruster cables.

3.6 Electronics

The S.S. Dragon’s electrical system was built to be simple, reliable, and field repairable. The marketability of an ROV depends on how easily clients can operate and repair systems. An analog system was implemented to meet the design features specified by the company.

Onboard the ROV, housed in the watertight enclosure, is a custom polycarbonate insert that supports electronics. This system has an Arduino Uno that converts analog potentiometer (joystick) signals to PWM (Pulse Width Modulation) signals. The Arduino Uno is onboard the ROV to reduce the number of signal wires that need to be sent up the tether. As the Arduino system boots, it correlates the starting position of the surface potentiometers (joysticks) with a PWM signal of 1500 microseconds, which is the thruster stop position. A single axis is used on the joysticks, which makes operating the ROV more intuitive for pilots.

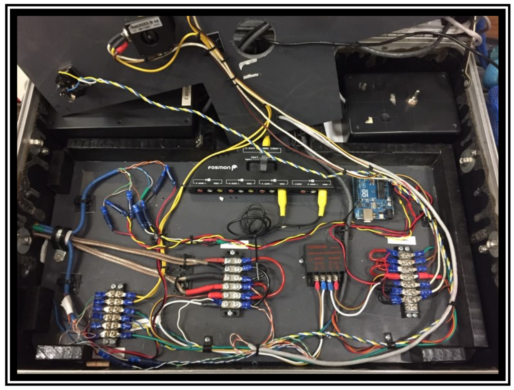


Figure 14: Layout of surface electronics
Photo Credit: Ella Ashford

As the joystick is moved, the analog signal changes, and the Arduino matches this signal within the PWM range set in the software. Pulse width accuracy was checked and confirmed using an oscilloscope. The Basic ESCs used in the system are commercially sold electronic speed controllers. ESCs are critical to many ROV electrical systems. Without them, three phase thrusters would not receive commands. On the S.S. Dragon system, they are mounted securely on a custom polycarbonate insert. It is important that they are appropriately spaced to avoid overheating and electrical shorts. Many refits were necessary to gauge the distance which would preclude interference. A power distribution block was implemented to organize power and ground wires. This is important because in the event of electrical failure, fewer connections will result in faster troubleshooting. Bullet connectors are used to connect the output to the thrusters, in this way all electronics can be disconnected and the whole system can be removed from the ROV if necessary.

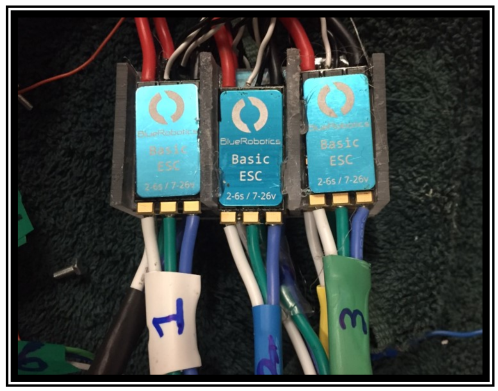


Figure 15: Mounting system for ESCs
Photo Credit: Ella Ashford

Another organizational feature in the ROV electrical system is the use of a Perma-Proto board. Perma-Proto boards are thin circuit boards similar to a breadboard. These boards were used to create a custom circuit that eliminates the need for excess analog signal wires, power wires, and PWM wires. Screw terminals are used to receive signal wires from the tether, which are neatly organized and labeled. The Perma-Proto board implements several resistors and capacitors, to help stabilize signal and combat voltage drop. The Perma-Proto board is critical in keeping onboard electronics neat and presentable. The screw terminals also assure that thin wires, which can be susceptible to breakage, are held firmly and securely in place.

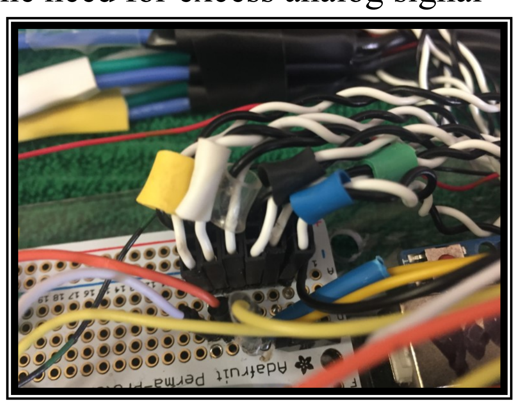


Figure 16: Perma-Proto board inputs
Photo Credit: Ella Ashford

3.7 Cameras

When operating in oceans, lakes, or rivers, ROV pilots rely on video feed to navigate in complex environments. Having a reliable camera system is especially important for this year's proposal, ***Innovations for Inshore***. ROVs needs to have sharp precise vision to complete specific tasks.

The S.S. Dragon is equipped with four cameras. Many different systems were tested and analyzed including a GoPro, reverse analog cameras, USB digital cameras and E-sky front facing analog cameras. After environmental testing, stress testing and logistics planning, the E-sky front facing camera was selected, as it best balances price and video quality. One wide angle E-sky camera is tilted for a full view of the manipulator, and the second is used for general navigation. The two additional cameras are used as a backup and for mission specific tasks. All cameras are mounted inside the main electronics enclosure. The dome acrylic endcap effectively widens the camera view resulting in a broader field of vision. The camera system is inexpensive, reliable and easily replaceable.

Figure 17: Camera System
Photo Credit: E-sky

3.8 Control Box

The topside control station is one of the most important design features of any ROV. Professional control stations must strike a balance between having all the right components, while maintaining simplicity for pilots. The S.S. Dragon control station aims to satisfy both of these criteria and has undergone multiple testing phases in different environments. To ensure durability, all electronics are housed in a multi-layer plastic case that was built to protect the joysticks and monitor, during both transportation and deployment of the ROV. There is a removable polycarbonate panel that separates raw electronics from piloting components. All wires in the case have adequate strain relief and are neatly labeled for ease of troubleshooting. Pilots interface with a single monitor, three joysticks and two switches on the second level of the control box. A color monitor is powered by the MATE regulated AC power strip. A single large screen, 48cm by 38cm is implemented to insure maximum clarity and visual range. A video feed switcher is used to change the view between multiple cameras onboard the ROV. The S.S. Dragon control system uses a unique collaborative design for pilot operation. By splitting up tasks between multiple pilots, there is less multitasking and more precision by each operator. In this system two pilots control the ROV thrusters. The co-pilot is in charge of decent and ascent of the ROV, while the main pilot controls the ROV's direction. A third pilot controls the Micro-ROV and the manipulator. Because of the large screen, it is easy for all pilots to see the video feed. This and many hours of practice, has trained the pilots to be adept at communication and operating the ROV together.

Figure 18: Field testing the control box
Photo Credit: Ella Ashford

3.9 Software

When writing software for the S.S. Dragon control system, the goal was to create a simple and modifiable design. To achieve this goal the Arduino IDE is used to write code that converts analog signals from the controllers to PWM (Pulse Width Modulation) signals for the thrusters. Comments in the code are used to aid troubleshooting and make modifications more streamlined. The software was created so that all company members could understand the system and it would be easy for clients to modify.

```
void loop()
{
  int joystick; // value recieved from joystick controller
  joystick = analogRead (A5 ); // reads joystick for side thruster
  T1.writeMicroseconds (map(joystick, 0, 1023, 1300, 1700)); // compairs and matches values from joystick
  joystick = analogRead (A3); //repeat for each set of thrusters and joystick
  T2.writeMicroseconds (map(joystick, 0, 1023, 1300, 1700)); // Limit thrusters to 1300 to 1700 for safety
  //UP and DOWN
  joystick = analogRead (A0); // reads joystick for thruster
  T3.writeMicroseconds (map(joystick, 0, 1023, 1400, 1600)); // compairs and matches values from joystick
  T4.writeMicroseconds (map(joystick, 0, 1023, 1400, 1600)); // compairs and matches values from joystick
  T5.writeMicroseconds (map(joystick, 0, 1023, 1400, 1600)); // compairs and matches values from joystick
  T6.writeMicroseconds (map(joystick, 0, 1023, 1400, 1600)); // compairs and matches values from joystick
  delay (1000);
}
```

Figure 19: Main loop in the ROV Control Code
Credit: Ella Ashford

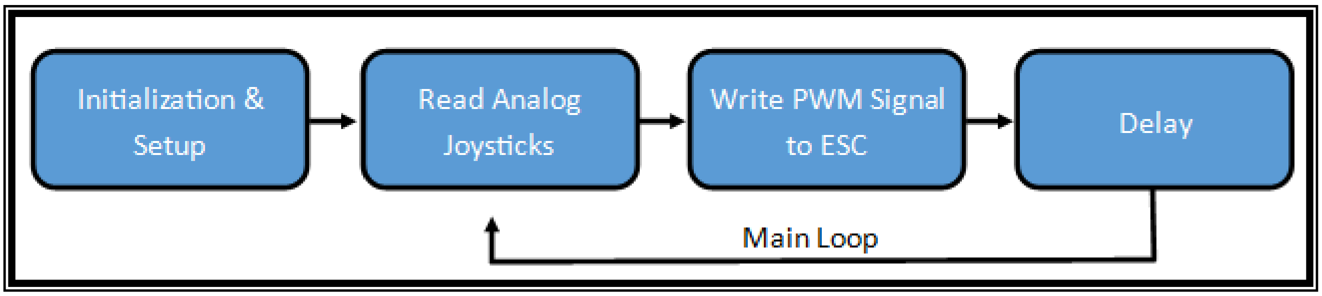


Figure 20: Software Block Diagram
Credit: Ella Ashford

3.10 Manipulator

The S.S. Dragon's manipulator went through many revisions to reach a suitable solution to meet this year's proposal. Manipulators need to have a sturdy design, a strong grip, and need to meet specific mission objectives. Both hydraulic and electrically powered manipulators were tested. Though the hydraulic design was less prone to failure, it was heavier, created a larger tether, and had a weaker grip. The electronic design was lightweight, had a powerful grip, and added no additional size to the tether. The electrically powered manipulator was chosen as the main design, but the hydraulic version is kept as a back up system.

The manipulator is driven by a linear actuator (a geared motor that drives a piston). The linear actuator is a commercially purchased product but the internal gears and electronics were modified to fit the S.S. Dragon's manipulator design. The actuator drives two grippers, a custom design built to grip a variety of mission tasks. The grippers have a 1.27 cm round slot for grabbing PVC targets such as those found on the trash rack replacement task. The slot was designed to fit a wide range of targets, and a silicon liner helps provide traction when retrieving slippery models. By adding the silicon to the grippers, the efficiency of mission recovery was exponentially increased.

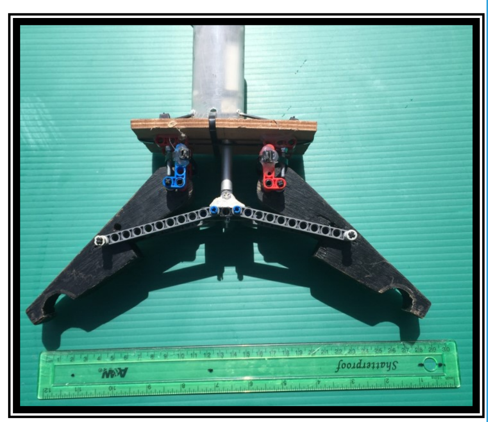


Figure 21: Manipulator
Photo Credit: Nathaniel Ashford

4. System Interconnection Diagrams

ROV Overcurrent Calculations

4 Camera Systems (.03 amps each) = .12amps

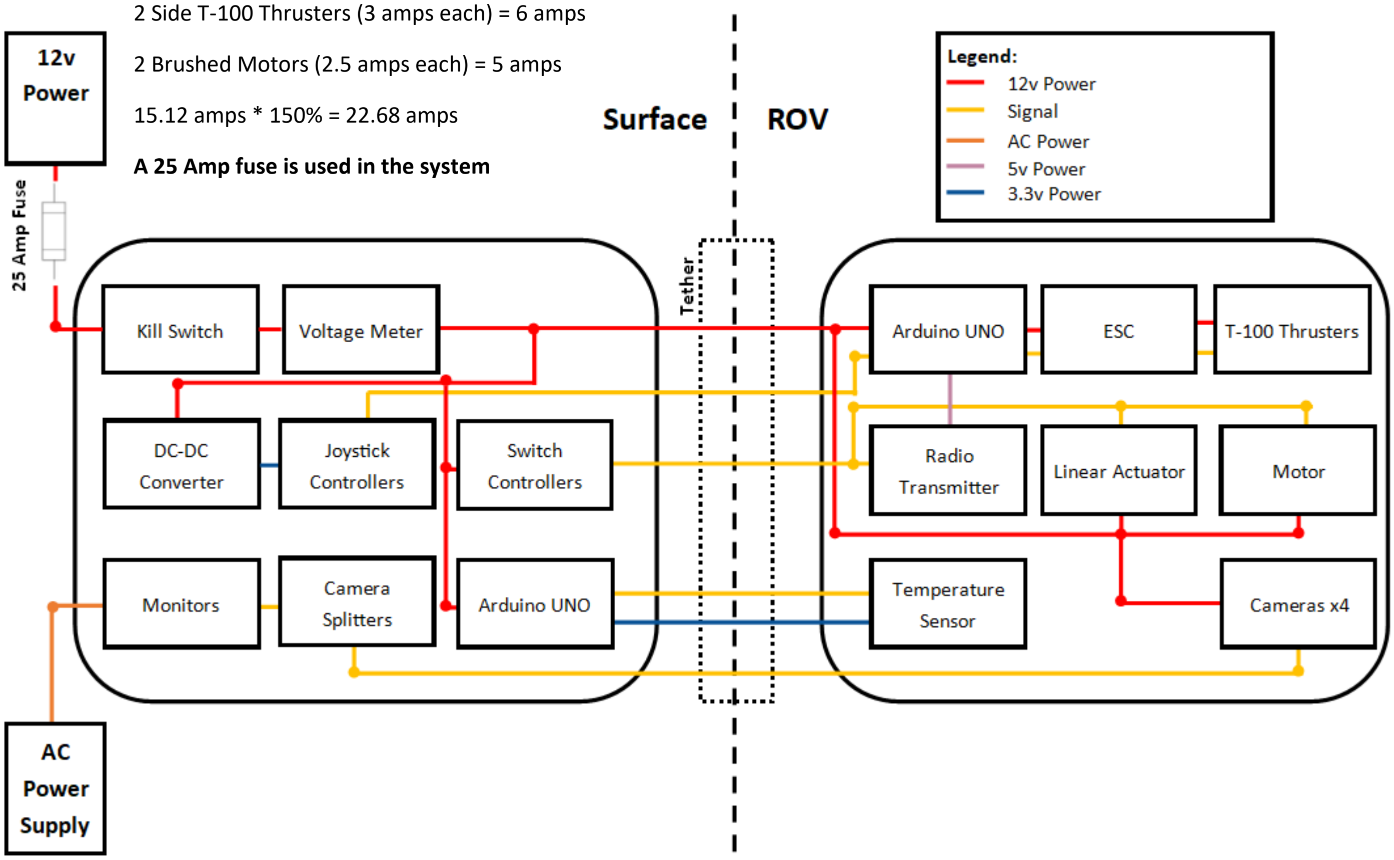
4 Up/Down T-100 Thrusters (1 amp each) = 4 amps

2 Side T-100 Thrusters (3 amps each) = 6 amps

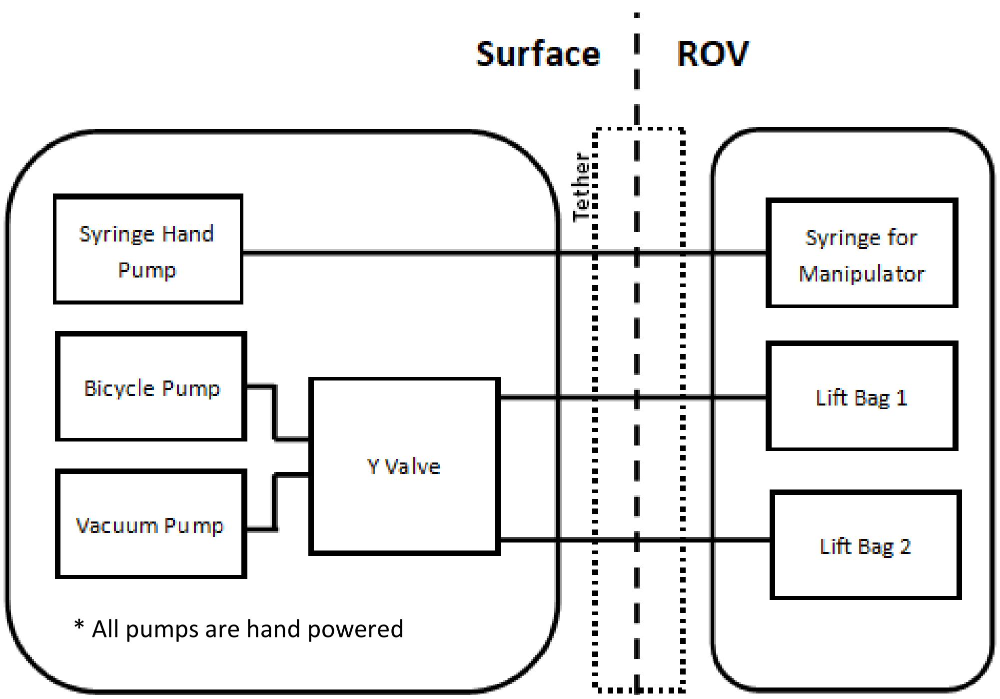
2 Brushed Motors (2.5 amps each) = 5 amps

15.12 amps * 150% = 22.68 amps

A 25 Amp fuse is used in the system



Fluid Power Diagram



5. Mission Specifics

Engineers need to think beyond just the frame and system designs, to the tasks the ROV is expected to complete. These missions often require specialized tools, sensors, or extensions to ensure reliable and efficient completion of tasks.

5.1 Lift Bag

Lift bags are commonly used in the industry to aid an ROV in the recovery of heavy, large or cumbersome cargo. In this year's proposal, ***Innovations for Inshore***, companies must recover a Civil War Cannon that can be large and extremely heavy. Though the S.S. Dragon is a powerful design that can lift many heavy objects, it is more efficient, safer, and reliable to use a lift bag in this task. The lift bag was designed to optimize recovery time. A watertight gear bag is used to capture air and a specialized attachment allows the ROV an easy grip point. A single Y valve is used to switch between a hand pump and a vacuum pump that controls the amount of lift force.

Figure 22: Lift bag
Photo Credit: Ella Ashford

5.2 Grout and Fry Deployment System

The ability to multitask with an ROV is an important feature, especially when completing challenging tasks such as transporting fish fry and inserting grout. By designing a specialized tool for the S.S. Dragon, these two independent tasks are able to be accomplished simultaneously. The design implements ABS pipe and a trapdoor system to release the fry and grout. The ROV carries the tool down to its target, sets it down and then pulls one of the two trapdoors to release either the fry or the grout. This method saves time, as the ROV doesn't need to come back to the surface to reload and prepare a payload for the next task.

Figure 23: Deployment system
Photo Credit: Ella Ashford

5.3 Cannon Shell Sensor

Detection and marking of the cannon shells is one of the most important and dangerous tasks in this year's RFP (Request for Proposal). This task involves testing shells for metals that indicate explosive materials. It is of utmost importance to mark them correctly so that EOD (Explosive Ordinance Disposal) technicians can remove and dispose of them safely. The S.S. Dragon is able to determine metal composition by using a neodymium magnet (a strong rare earth magnet) driven by a spring loaded sensing tool. This system was invented by company members to be simple, accurate, and efficient. In this system, a neodymium magnet is fastened to a spring that has a orange indicating tab set on the opposite end. When the ROV approaches a metal shell the magnetic attraction triggers compression in the spring and pulls down the indicator tab.

Figure 24: Shell sensing system
Photo Credit: Ella Ashford

5.4 Micro-ROV

Industrial Micro-ROVs can be difficult to design and build. Engineers have to take into consideration size limitations, mission specific goals, and the difficulty of navigation in a small space. It is especially challenging to conduct dam surveys using a Micro-ROV, as it is dark and narrow, and searching for muddy water flow can be difficult. The S.S. Dragon Micro-ROV accomplishes this task by navigating through a 15 cm pipe and finding a visual target representing muddy water flow. Six major design prototypes were eliminated before reaching the final Micro-ROV. Many different shapes and materials were experimented with. Prototypes were built out of soda cans, whiteboard erasers, PVC, and even LEGOs. The final Micro-ROV is round to avoid getting snagged or caught. A single thruster is used to propel the Micro-ROV through the pipe. A USB camera is used to detect the muddy water flow. The Micro-ROV uses a fiber optic cable to transfer video data to the surface monitor. Fiber optic cables are more reliable than copper cables, as they send signals faster, don't have noise interference, and are used in many industrial ROV designs. The most unique part of the S.S. Dragon Micro-ROV is the wireless transmitter and receiver used to send signals to the thruster. This wireless system is a hacked car fob commonly used to open cars or garage doors. A custom relay board system is used to switch between signals that control the forward and reverse motion of the thruster.

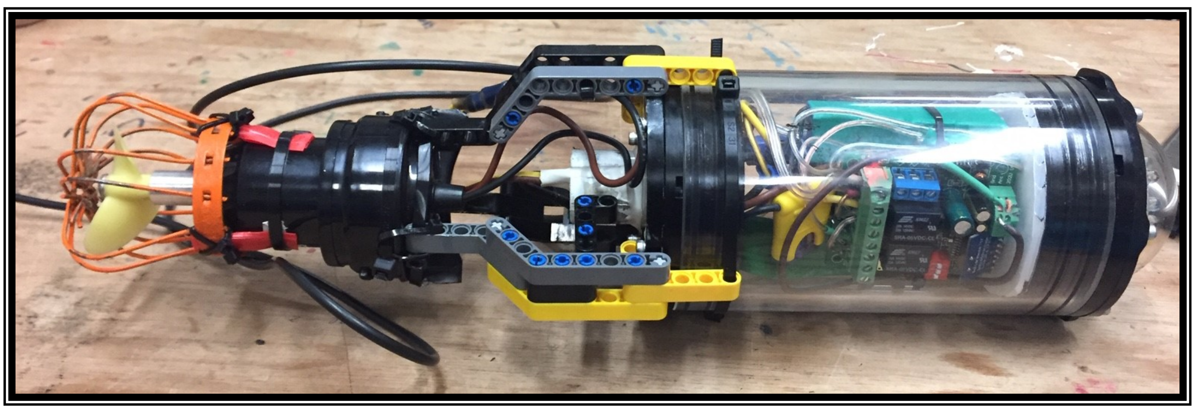


Figure 25: Micro-ROV Design
Photo Credit: Ella Ashford

5.5 Temperature Sensor

The S.S. Dragon was built to be a well rounded ROV that can complete a variety of tasks. An important part of the environmental task is the ability to use sensors to determine information. In this case, an analog temperature sensor is used to gauge information about the environment in the South Fork Holston River. An analog temperature sensor does not use mercury, thermistors or bimetallic strips to measure the ambient temperature, but instead uses voltage. As temperature increases, so does the voltage across a diode. These sensors amplify the voltage, so that it is proportional to the temperature as it changes. The sensor used in the S.S. Dragon system is programed with an Arduino code that correlates the voltage output of the sensor to Fahrenheit measurement. An algebraic formula converts it into Celsius. Both Fahrenheit and Celsius measurements are displayed for the pilot.

Figure 26: Waterproofed Temp Sensor
Photo Credit: Ella Ashford

6. Design Choices (Build vs. Buy / New vs. Reused)

When building an industrial grade ROV, a company must consider the tradeoffs when buying components versus manufacturing components, and when reusing components versus buying new components. The Sea Dragons pride themselves on both manufacturing many of their own components such as the ROV frame and manipulator, as well as implementing commercial products in an efficient way. The Sea Dragons try to reuse components to reduce expenses and environmental impact, but often it is necessary to invest in new equipment or components.

This year, R&D work was focused on improving ROV tools. This included prototyping the Micro-ROV, building a temperature sensor and creating custom tools. These projects required new products be purchased and experimented with. In contrast, many of the main ROV components were reused. This includes the watertight enclosure, thrusters and cameras. Several components had to be replaced, such as the monitor, Arduinos and control box.

Listed below are some of the design choices that had to be made to ensure reliability and efficiency of the ROV.

Build vs. Buy & New vs. Reused Chart						
Component	**Build**	**Buy**	**New**	**Reused**	**Modified**	**Justification**
Frame	✓		✓			Carbon Fiber, Custom Designed
T-100 Thrusters		✓		✓		Reliable, Efficient
Enclosure		✓		✓		Waterproof, Reliable
E-sky Camera		✓		✓		Good Quality, Inexpensive
Manipulator	✓		✓			Customizable, Mission Specific
Linear Actuator		✓	✓		✓	Modifiable, Geared Motor
Joysticks		✓		✓		Simple, Inexpensive
Monitor		✓	✓			Good Video, Large Screen
Grout and Fry Deployment System	✓		✓			Custom Design, Mission Specific, Modifiable, Reliable
Temp Sensor		✓	✓		✓	Precise, Customizable
Micro-ROV	✓	✓	✓	✓	✓	Lots of different components used in design
Lift Bag	✓		✓			Custom Design, Mission Specific
LEGO Components		✓		✓	✓	Easily Customizable
Control Box		✓	✓		✓	Modified to fit design
Fiber Optic Cable		✓	✓		✓	Modified to fit design
Tether		✓	✓		✓	Purchased tether wires
Arduino		✓	✓			Reliable Systems

Figure 27: Chart outlining major company decisions in build vs. buy & new vs. used
Credit: Ella Ashford

7. Safety

Good safety practices allow the Sea Dragons to work in a productive environment while developing innovative solutions. Safety is always the first priority, and serves as the backbone of the Sea Dragons. This company's philosophy is summarized with the acronym RESCUE, which stands for Respect, Experience, Safety, Cleanliness = Underwater Exploration. This acronym serves as an important reminder that to have a successful and productive mission, all the RESCUE criteria are relevant.

Figure 28: RESCUE poster designed by the Sea Dragons
Credit: Ayden Ratliff

The Sea Dragons apply their safety philosophy to their ROV design by incorporating features such as handholds, thruster shrouds and a kill switch. These safety features help prevent jobsite accidents, prevent damage to the ROV and create a productive work environment. A list of ROV specific safety features is included in Figure 29. Additionally see Appendix 1 on page 24 for the Sea Dragons' Safety Checklist, which was developed with feedback from all company engineers.

ROV Safety Features	
Safety Features	**Description**
Warning Labels	Bright colored warning labels are used to mark potentially hazardous parts of the ROV.
Thruster Shrouds	Custom thruster guards are designed using CAD modeling to protect thrusters from damage caused by hitting objects.
Thruster Guards	Thrusters are guarded per MATE specifications using IP20 standards to protect company members from spinning propeller blades.
Rounded Edges	All corners are rounded to prevent cuts and scrapes. Zip ties are cut with a flush cutter and dulled for safety.
Strain Relief	A tether thimble is used for strain relief on the ROV.
ROV Transport Cart	A ROV transport cart is used to improve organization and reduce strain on company members. The transport cart is equipped with a first aid station.
Handholds	Handholds on the ROV provide a safe place to retrieve the ROV.
Kill Switch	A power kill switch enables the ROV to be safely powered off.
Fuse	A fuse is used to prevent damage to electronics during an electrical short.

Figure 29: ROV Safety Features Chart and descriptions
Credit: Everest Ashford

8. Critical Analysis

8.1 Testing

- ***Complete Design Testing:*** The S.S. Dragon was tested in several different environments to determine if additional improvements were needed. The S.S. Dragon first underwent a series of buoyancy tests in a small pool with a depth of 1 meter. The purpose of the test was not only to determine neutral buoyancy but to establish a waterproof design. After the ROV passed these tests it was moved to a larger pool with a depth of 2 meters. In this pool, practice product demonstrations were conducted to test the feasibility of tools and ROV efficiency. Having the ability to practice and troubleshoot in a pool is invaluable for testing ROV and training of pilots.
- ***Micro-ROV Testing:*** The Micro-ROV was the most extensive prototyping and testing project. There were six major revisions of the design and countless pressure tests at different depths. Because the system was a custom design, the biggest concern was water leaking into the watertight enclosure onboard the Micro-ROV. Throughout the testing process there were many flooded prototype enclosures. The testing procedure for enclosure leakage included have a desiccant packet to indicate moisture levels and testing the component at different depths for different lengths of time. After repeated testing of different materials and prototypes, a combination of Blue Robotics components and custom designs were successfully merged to reach the current design of the Micro-ROV.

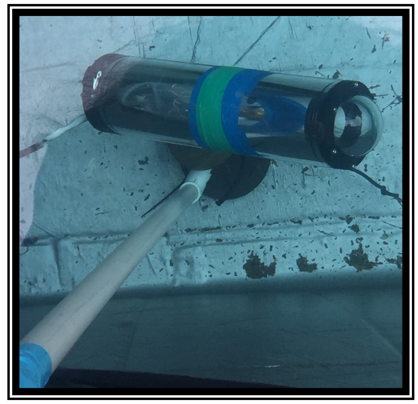


Figure 30: Pressure testing
Photo Credit: Ella Ashford

8.2 Troubleshooting

- ***Electrical System Noise:*** When the electrical system was first designed, there was a major setback. This setback was caused by noise in the electrical system that resulted in thruster variability and loss in control. The noise resulted in sensitive wires picking up signals from each other. An oscilloscope was used to find where the noise was coming from. Once it was identified that the PWM signals were creating noise over all signal wires, capacitors were used to act as a filter on the line. Turning down the power on the T-100s also helped. This taught the company the importance of good troubleshooting. A checklist has been implemented to streamline troubleshooting.
- ***Fry and Grout Deployment System:*** When designing the Fry and Grout Deployment System, the goal was to deploy both the fry and the grout. Originally, the plan was to drop the grout into the void before deploying to the fish fry. Unfortunately, it was discovered that as soon as the grout was deposited into the void, this changed the buoyancy of the system, making it extremely positively buoyant. This made it nearly impossible to try and accurately place the fry in the target. After lots of buoyancy calculations and testing, the problem was still not solved. Then the company realized that they could flip the problem upside down literally! By releasing the fry first, the buoyancy did not change and both tasks could be accomplished.

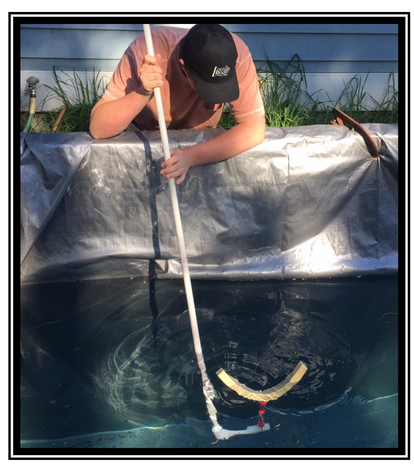


Figure 31: Calculating buoyancy for the deployment system
Photo Credit: Ella Ashford

8.3 Challenges

- ***Technical Challenges:*** A very significant technical challenge faced this year was the implementation of a fiber optic tether on the Micro-ROV. Over fifty hours of research, testing and prototyping was spent on this challenge. The project was draining emotionally, financially and logistically. Through research, company members learned that there are commercially sold fiber optic USB cables that are small, relatively inexpensive and lightweight. This design did have several features that needed to be modified before it could be implemented. The major modification was disconnecting power wires that ran alongside the fiber optic cable. This was a delicate process, as certain components needed to be disconnected and others needed to be reconnected. Even after studying the industrial circuit diagram, several expensive mistakes were made. When the cable first arrived company members rushed the modification process. This, in combination with the product provider not giving accurate information on the spec sheet, lead to a severing of the optical cable, destroying the whole system. Company members learned the importance of a steady work ethic and making detailed electrical schematics. The second attempt was successful, after a better documented product was used and company members were more methodical in the modification process.

Figure 32: Modifying the fiber optic cable
Photo Credit: Ella Ashford

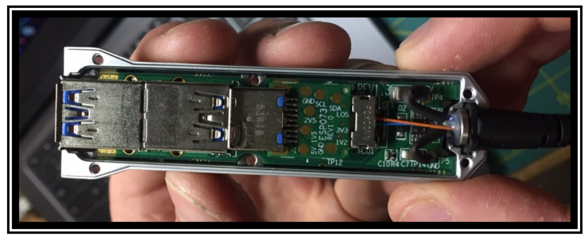


Figure 33: The delicate fiber optic system
Photo Credit: Ella Ashford

- ***Interpersonal Challenges:*** The Sea Dragons have members within the company ranging in age from sixth grade to twelfth. The company also coaches younger MATE teams. This broad age difference leads to a unique set of strengths and challenges. At the beginning of the MATE season, company members worked long days with few breaks. A lot was expected of younger members. This lead to company members experiencing burn out and interpersonal conflicts. The company re-evaluated the team environment to make it a more positive experience for all members. To work cohesively as a team, generous break schedules were set and members played teamwork games. This insured that members could feel they contributed no matter their age or developmental skills. As a result, the company members grew together, overcame personal differences, and became better communicators with one another.

Figure 34: Completing teamwork games
Photo Credit: Gabriella Ashford

8.4 Lessons Learned

- ***Technical Lessons Learned:*** Measure twice cut once is a common saying in the engineering world, but that doesn't lesson its importance. When designing the carbon fiber frame, a miscommunication with the CAD designer and engineer resulted in the side panels having several misaligned holes. Though the problem was fixable, it confirmed that having strong communication and company structure was essential to the engineering process.
- ***Interpersonal Lessons Learned:*** Learning to persevere in the face of failure is a tough lesson to learn, but essential to the MATE competition learning process. When experiencing electrical mishaps or team disagreements, it is critical to first separate yourself from the problem, and be willing to look at it as an opportunity to learn. The company learned to evaluate what went wrong and how to fix the problems in the future. Company members worked to support one another, aiming for clear communication at all times.

Figure 35: Supporting each other
Photo Credit: Gabriella Ashford

8.5 Development of Skills

By preparing for the 2019 MATE event, the company's skills were strengthened by learning how to form community partnerships. This year the Sea Dragons worked with Peninsula College (PC) and the Composite Technology Recycling Center (CRTC) to build the S.S. Dragon. Company members learned many new skills by working alongside college students in an industrial setting. It was beneficial for the company to learn industrial safety procedures, machine shop skills and work ethic, while improving problem solving skills.

Because the Sea Dragons used this partnership to design a professional grade ROV, they are now working within the community to volunteer their services in the marine industry. The company was commissioned by the Port of Brownsville, in Washington State to inspect an historic fuel dock for environmental damage. As a result of working in the marine industry, company members have developed a more sustainable business model and built professional skills within the company. These partnerships even enabled the Sea Dragons to be recognized by the Environmental Protection Agency (EPA) for their sustainable practices and environmental work in the Puget Sound. Additionally, the Sea Dragons were officially endorsed by the Port Townsend Mayor and City Council.

Figure 36: Working with CRTC and PC
Photo Credit: Gabriella Ashford

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

The U.S. Environmental Protection Agency
Commends

Ella Ashford

for outstanding achievement in environmental protection services

March 2019
President's Environmental Youth Awards
United States Environmental Protection Agency

Figure 37: Each student received a certificate from the EPA
Photo Credit: Gabriella Ashford

Figure 38: Recognition at City Hall
Photo Credit: Gabriella Ashford

9. Future Improvements

The S.S. Dragon meets all design criteria set forth by the company, but as with any long-term engineering project, there is always room for improvement. In the future the company would like to move away from analog systems, instead implementing digital controls. This would eliminate noise problems and continue to improve efficiency. After experimenting extensively with fiber optic systems, the company is interested in making the main ROV tether fiber optic as well. This would increase tether signal speed and clarity. Below are some additional points that company members think should be improved upon:

Ella Ashford: "*As the CEO I feel that there is still room for improvement in our project management. This year we implemented an engineering notebook and digital scheduler to streamline our design process. This was a huge improvement but we need to do a better job keeping up to date in the engineering notebook. Additionally, the company could do a better job budgeting expenses and finding sponsors that will support the program year after year."*

Logan Flanagan: "*I think that our company can improve communication on the pool deck during product demonstrations. In many cases background noise keeps the pilots and tether manager from communicating effectively. This causes problems like having to speak very loudly to be heard since the pilots are facing in a different direction. This problem may be able to be solved by creating certain simplified commands to aid in direct communication."*

Nathaniel Ashford: "*As the Lead Mechanical Engineer I see that we can improve upon the tools our ROV uses to complete specific mission tasks. For example I would like to see more sensors utilized to learn more about the environment in which the ROV is being operated. I am interested in experimenting with magnetometers, depth sensors and vision recognition. I think that having an audio system on the ROV would be beneficial as you can hear when you hit the bottom or collide with an object."*

Ayden Ratliff: "*As the Head of Marketing one thing that I would like to improve is how we display our company, from our team shirts to our poster display. I think that the way we present our company is really important. Next year I would like to encourage the team to step up the aesthetics on the poster display, improve logo design on team uniforms and create additional marketing materials such as brochures."*

Everest Ashford: *"Though our team has many shop specific safety procedures, I want to help improve our field safety procedures. This includes having a more efficient safety checklist for pool demonstrations. Our team has been working for industrial ports, and I feel that we need to better prepare safety equipment for working on boats, docks and beaches."*

10. Finance

At the beginning of the season the company created a budget for ROV expenses and travel expenses. The budget is based on expenditures from previous years and project cost projections. The CFO maintains a record of expenses throughout the year by keeping track of purchases on the Smartsheet planner. By fundraising within their community, the company was able to raise enough to cover all expenses up to the regional competition. The company is currently in the process of fundraising to cover the expenses associated with the 2019 MATE International ROV Championships.

10.1 Budget

Sea Dragons Budget January 1 2019 - June 30 2019				
Income				
Local fundraiser				$2,000.00
Online fundraiser				$965.00
Master Gardener Grant				$750.00
Kiwanis				$150.00
PNW MATE Regional Competition Award				$1,000.00
Total Income				$4,865.00
Expenses				
Category	Type	Description	Projected Cost	Budgeted Value
Hardware	Re-used	Joystick controls	$60.00	$0.00
Hardware	Re-used	Household Monitor	$25.00	$0.00
Hardware	Re-used	Blue Robotics T100 Thrust-	$720.00	$150.00
Hardware	Re-used	Watertight enclosure and	$450.00	$0.00
Hardware	Re-used	General mechanical parts	$222.00	$0.00
Hardware	Re-used	General materials	$145.00	$0.00
Hardware	Re-used	General electrical parts	$215.00	$0.00
Hardware	Purchased	tool mechanical parts	$225.00	$225.00
Hardware	Purchased	tool / micro-rov electrical	$615.00	$615.00
Hardware	Donated	frame materials	$1,610.00	$0.00
Travel	Purchased	Transport to Regionals	$100.00	$100.00
Travel	Purchased	Lodging at Regionals	$326.00	$326.00
Travel	Purchased	Food at Regionals	$300.00	$300.00
Travel	Purchased	Transport to Internationals	$3,500.00	$3,500.00
Travel	Purchased	Food at Internationals	$1,000.00	$1,000.00
Travel	Purchased	Lodging at Internationals	$500.00	$500.00
Hardware	Re-used	General sensors	$60.00	$0.00
Hardware	Purchased	General lab supplies	$1,000.00	$1,000.00
Hardware	Purchased	ROV sensors	$118.00	$118.00
Total Income				$4,865.00
Total Expenses				$7,834.00
Total Expenses-Re-used/Donations				$3,507.00
Total Fundraising Needed before Internationals				$2,969.00

10.2 Project Cost

SEA Dragons Costs
January – June 2019

*FMW- Fair Market Value

Category Totals	Cost (USD)	Status	FMV* (USD)
Carbon Fiber frame	$0.00	Donated	$1,610.00
Acume Marine Plywood	$0.00	Donated	$25.00
L-brackets and Hardware	$0.00	Donated	$5.00
Paint	$10.00	New	$10.00
Penetrating Epoxy	$45.00	New	$45.00
Painting Supplies	$0.00	Reused	$5.00
Closed Cell Foam	$0.00	Reused	$5.00
Rebar	$0.00	Reused	$5.00
Frame/Buoyancy total	$55.00		$1,710.00
Joysticks	$0.00	Reused	$60.00
12 to 5 Volt Converter	$0.00	Reused	$10.00
Electronics Bus Bars	$0.00	Reused	$20.00
Wiring	$0.00	Reused	$20.00
4" Watertight Enclosure	$0.00	Reused	$200.00
Penetrators	$0.00	Reused	$60.00
Epoxy Supplies	$20.00	New	$20.00
Connectors	$20.00	New	$20.00
2 Batteries	$0.00	Reused	$260.00
2 Arduino Uno	$50.00	New	$50.00
Breadboard	$0.00	Reused	$5.00
Capacitors	$0.00	Reused	$10.00
Fuse and Fuse Holders	$10.00	New	$10.00
Anderson Connectors	$10.00	New	$10.00
Temperature sensor	$3.00	New	$3.00
Hardware Case	$0.00	Reused	$10.00
Polycarbonate	$0.00	Reused	$10.00
Copper tube	$15.00	New	$15.00
Electronics total	$128.00		$793.00

Category Totals	Cost (USD)	Status	FMV* (USD)
6 T100 Thrusters	$0.00	Reused	$720.00
6 T100 Thruster ESC	$0.00	Reused	$156.00
1 spare T100/ec	$150.00	New	$150.00
Shrouding	$0.00	Donated	$50.00
Thrusters total	$150.00		$1,076.00
Tether total	$20.00	New	$20.00
Tether Strain Relief	$10.00	New	$10.00
Tether total	$30.00		$30.00
Reverse Car Camera	$0.00	Reused	$15.00
Front Car Camera	$0.00	Reused	$15.00
Video RCA Switch	$11.00	New	$11.00
2 Monitors	$30.00	New	$30.00
Camera total	$41.00		$71.00
Linear Actuator	$90.00	New	$90.00
Geared motor	$30.00	New	$30.00
Pump motor	$0.00	Reused	$25.00
Lego Technic Parts	$0.00	Reused	$5.00
Acume Marine Plywood	$0.00	Donated	$25.00
Aluminum	$0.00	Donated	$30.00
Manipulator total	$120.00		$205.00
Plywood	$0.00	New	$5.00
Linear Actuator	$100.00	New	$100.00
Lego Parts	$0.00	Reused	$10.00
Electronic Connections	$5.00	New	$5.00
Batteries	$30.00	New	$30.00
Tools total	$135.00		$150.00

Category Totals	Cost (USD)	Status	FMV* (USD)
2 Fiber Optic tethers	$300.00	New	$300.00
Micro ROV thruster	$0.00	Reused	$25.00
Car FOB Kit	$15.00	New	$15.00
3" Watertight Enclosure	$0.00	Reused	$190.00
2 USB cameras	$60.00	New	$100.00
AA Battery holder 2 pack	$10.00	New	$10.00
2 circular LED lights	$10.00	New	$10.00
4 channel DC relay module	$7.00	New	$7.00
Micro ROV total	$402.00		$657.00
Fiber Optic cable	$109.00	New	$109.00
Desoldering pen	$10.00	New	$10.00
Analog to Digital converter	$16.00	New	$16.00
Digital to Analog converter	$14.00	New	$14.00
R & D total	$149.00		$149.00
Shipping	$300.00	new	$300.00
Pool Liner	$0.00	Donated	$120.00
Travel	$3,600.00	new	$3,600.00
Accommodations	$826.00	new	$826.00
Meals and Entertainment	$1,300.00	new	$1,300.00
ROV cart	$118.00	New	$118.00
Cart First Aid Kit	$0.00	Reused	$50.00
Cart Tools	$0.00	Reused	$30.00
Cart PPE Kit	$0.00	Reused	$30.00
Cart Battery Safety	$0.00	Reused	$30.00
Shop supplies	$1,000.00	Reused	$1,000.00
Overhead total	$7,144.00		$7,404.00
ROV Grand Total	$1,210.00		$4,753.00

11. References:

Extensive research on ROV components was conducted before purchasing products. Many new skills were learned through this research that greatly contributed to the education of company members. Here are the essential references used by the company:

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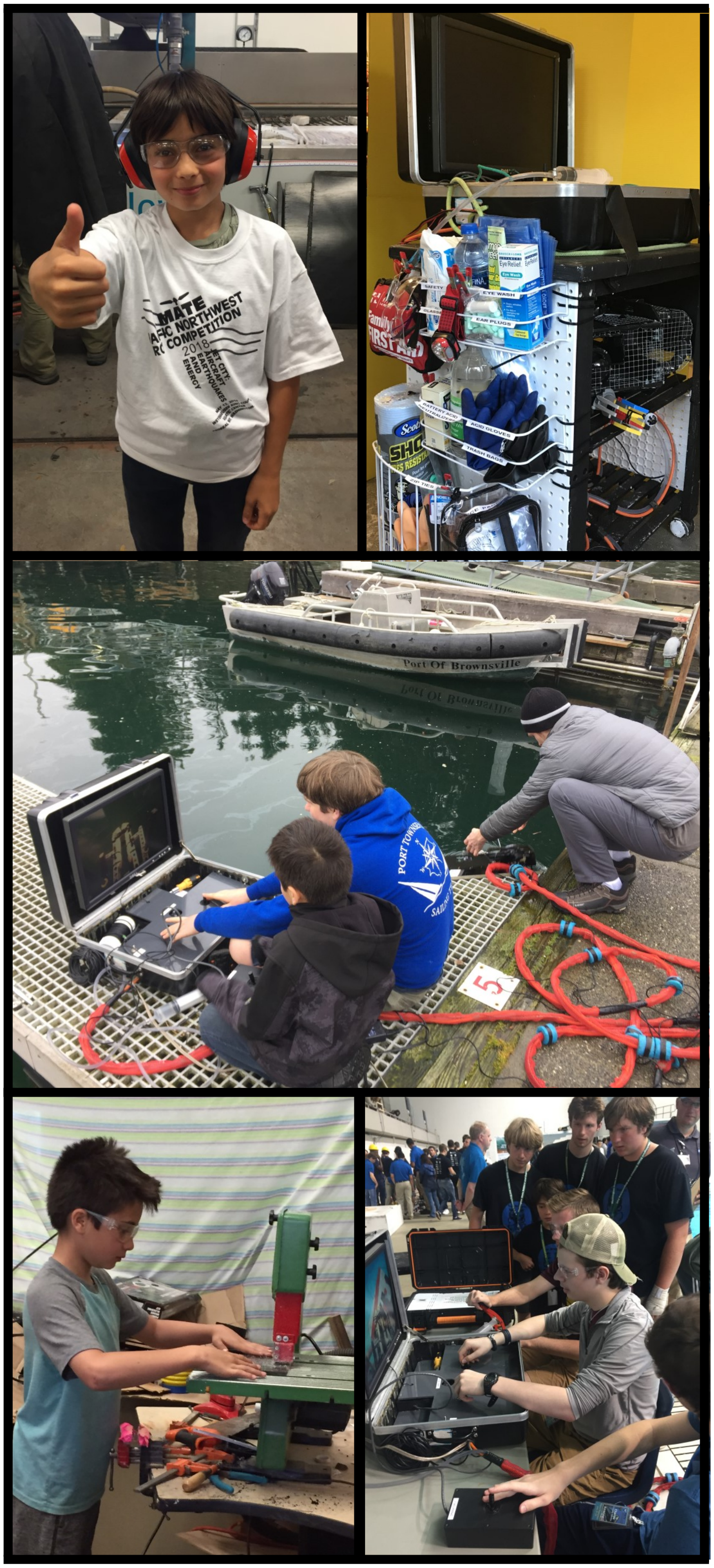
12. Acknowledgments:

The Sea Dragons would like to give a special thank you to our sponsors and supporters listed below!

Sea Dragons Sponsors & Supporters: *Peninsula College, Composite Recycling Technology Center, PT STEM Club, NOAA, Admiral Ship Supply, Port Townsend NAPA, Applied Education Foundation, Pacific Northwest MATE ROV Competition, Marine Technical Society, Solidworks, Port Townsend Garden Center, Valley Nursery, Shold's Landscape Products & Garden Center, Brent & Becky's Bulbs, Safeway, Port Townsend Henery Hardware, PT Computers, Townsend Electric, MATE Center, Quimper Mercantile Company, AMW, WEHOP, Port Townsend Food Coop, PT Leader, Port Townsend QFC Deli, WSU Master Gardeners Foundation, Kiwanis, City of Port Townsend, Mary Robson, Eric Ashford, Aaron Tinling Kim Jacoban, Heather Flanagan, Gabriella Ashford, Colin Kahler, James Russel, Vera Williams, Phil Williams, Harry Bohm, Emerson Stipes, Otto Smith, Betsy Blinks and the community of Port Townsend.*

Appendix 1: Safety Checklist



Sea Dragons demonstrating their safety practices

Photo Credits: Sea Dragons