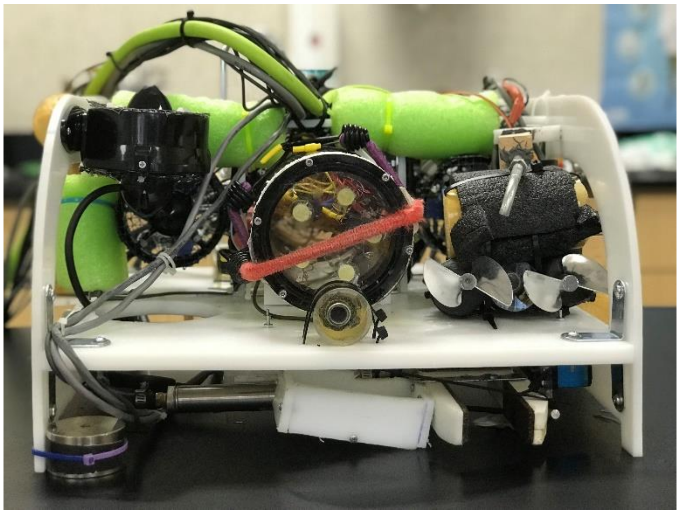
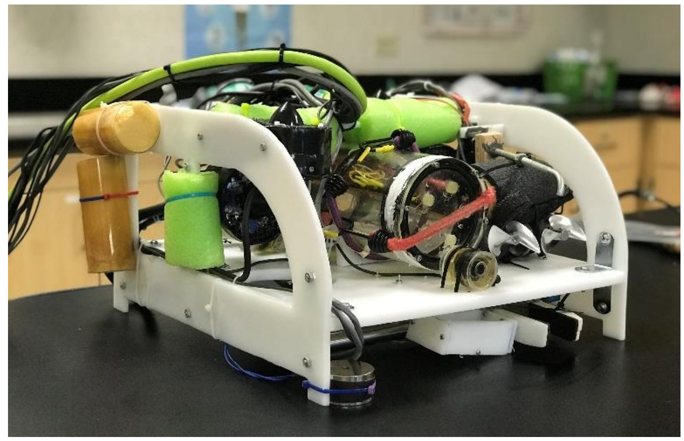
Extreme Ocean Observing Systems Repair Company

EOOSRC

Technical Report





COMPANY MEMBERS
Hans Baschy (12th) - CFO, Chief Mechanical Engineer, Pilot Lars Baschy (10th) - Head of Safety, Tether Manager Shannon Woodside (12th) - CEO, Chief Electrical Engineer, Analyst, Editor
TEACHERS/ ADVISORS
Rose Justi - Project Instructor Stephanie Woodside - Overseeing advisor and photographer

Eastern Tennesee: Ensuring Public Safety, Maintaining Healthy Waterways, and Preserving History

Mountain Oaks School

San Andreas, California 95245

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Abstract

Extreme Ocean Observing Systems Repair Company (EOOSRC) has been committed to marine health and submerged system repairs for seven years. This year we are assisting Eastman in doing "Good for Good" in Eastern Tennessee. Eastman, an ecofriendly plastic manufacturing company based in Tennessee, has become involved with the Tennessee Valley Association's (TVA) "Boone Project" and operations at the South Fork of the Holston River. Boone Dam requires inspection and repair, especially after the 2014 sinkhole. Seventy years of deterioration has created several safety hazards, endangering the public and Eastman's employees. The South Fork of the Holston River, where Eastman's manufacturing runs through, is home to several benthic species and a Civil War cannon. Eastman requires help to monitor water quality, collecting samples, locating species, determining their diversity, and restocking rainbow trout. Eastman also asks for assistance recovering the Civil War cannon, a crucial step at preserving history. We are also asked to locate and mark any unexploded cannon shells. Once marked, an explosive ordinance unit can remove the shells, protecting the public. As a company involved in underwater operations, we jumped at the opportunity to aid Eastman in operating sustainability.

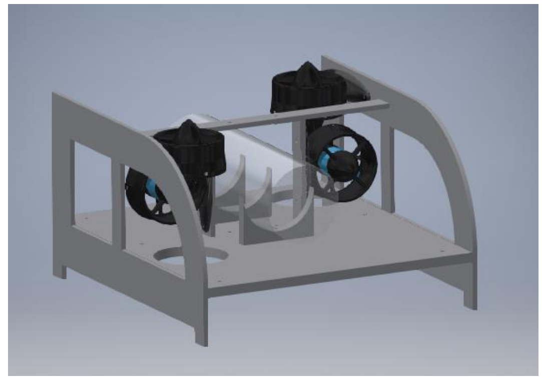
To accomplish these requests we have constructed a specialized underwater remotely operated vehicle (ROV). Our ROV, *The Enterprise*, has a High Density Polyethylene (HDPE) frame for durability and strength. It is equipped with powerful thrusters and versatile tools. With all *The Enterprise's* design features, EOOSRC is ready to assist Eastman inspect and repair dams, protect healthy waterways, and preserve history.

System Design

While designing *The Enterprise* we considered several aspects to create a functional and effective ROV for Eastman. *The Enterprise* was first modeled in the computer-aided design (CAD) software, *Autodesk Inventor*. Its shape was chosen to best accommodate our underwater enclosure, thrusters, and tools. Our frame measures 41.91 cm x 39.37 cm x 24.13 cm, fitting within the size parameters. Planning our ROV with CAD software allowed the company to review and adjust *The Enterprise* until it efficiently suited Eastman's requirements. EOOSRC created about five different CAD versions before choosing the final design. While building, EOOSRC considers three main factors: commercial, original and reused components. We prefer to build the majority of our components by hand to maximize the potential of each item. However if we feel we lack expertise in an area, we purchase commercial items such as our thrusters, microprocessors and underwater enclosure. In the past we constructed our own underwater enclosure, but repeated leaks led us to choose a commercial product. Additionally, we reuse previous commercial and original components for economic reasons, tool performance, and the environmental benefits of waste reduction. However, when this is not an option, we upgrade our tools, fixing problems with the previous versions.

System Design

The Enterprise is constructed from HDPE, a strong and versatile material. Four Blue Robotics thrusters allow quick maneuverability with small power consumption. These thrusters also grant the lift capability of 46.28 Newtons. An underwater enclosure is centrally mounted on the frame, housing electronic speed controllers used to control our thrusters. The air inside the underwater enclosure acts as positive buoyancy, counteracting most of *The Enterprise's* weight. Four cameras provide clear video feed of all operations. *The Enterprise* has five payload tools: a mini ROV, a claw, a temperature sensor, a carrier, and an electromagnet. Our mini ROV, *The Shuttlecraft*, swiftly detaches from *The Enterprise* with a rotation of a hook. Hand-waterproofed motors easily allow *The Shuttlecraft* to travel through a drain pipe and determine the muddy water flow. The claw operates on a pneumatic actuator, opening and closing at the press of a foot pedal. A servo grants precise rotation useful for specific tasks: repairing trash racks, collecting water samples to measure pH and phosphate levels, determining habitat diversity, restoring fish habitats, and recovering a Civil War cannon. In order to maintain healthy water quality, EOOSRC measures the water's temperature in Celsius with a temperature sensor and presents the reading on a digital meter. The carrier is a HDPE rectangular box safely transporting trout fry and inserting grout into cracks of Boone Dam. Its position next to the claw allows its contents to be released at the rotation of the claw's servo. The electromagnet, activated by a switch, lifts metal objects to determine the location of metal cannon shells. EOOSRC achieved a combination of ingenuity, dedication and patience to build a ROV capable of accomplishing Eastman's proposals.

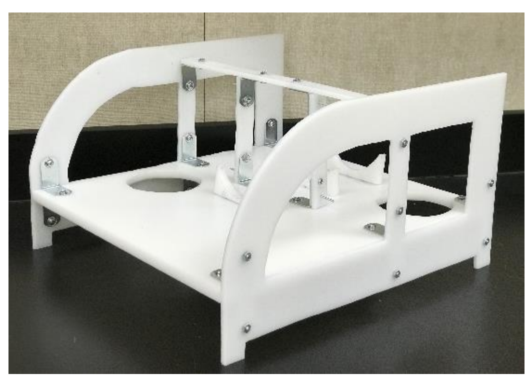


CAD Diagram of The Enterprise

Design Rational

Structure

The Enterprise's frame is made out of High Density Polyethylene (HDPE). Not only is HDPE a strong and durable material, it is also recyclable. EOOSRC stands with Eastman in creating ecofriendly products. *The Enterprise's* frame consists of nine main parts. Two curved rectangular sheets act as the frame's sides. Specially designed cutouts reduce bulk and create handles for easy transportation. A horizontal sheet is secured between the two sides. It is positioned 6.35 cm from the bottom, granting space to mount the claw, carrier, electromagnet and lower camera. To ensure the force from our up and down thrusters are not blocked, two 9.65 cm



Side view of The Enterprise's Frame

diameter cutouts are below the thrusters' positions. A narrow strut runs across the width of the frame, supporting the sides' upper sections. Secured equidistantly below the strut are two vertical beams. These beams, which further support the frame, act as mounts for the driving thrusters. Additionally, three support beams are specifically designed to support our 4 inch diameter underwater enclosure. Right angle brackets and bolts connect every junction, providing a secure bond. When constructing the frame we were careful to create precise cuts. We sanded and polished all edges of the frame to increase aesthetics and remove any sharp spots. *The Enterprise's* frame was designed in CAD software, guaranteeing a well-developed ROV to meet Eastman's requirements.

Buoyancy/ Ballast

EOOSRC combines rigid foam, pool noodles, and rebar to create a slightly positive buoyancy system for *The Enterprise*. These products are effective, inexpensive, and easy to install. They are properly secured, simply with cable ties. A slightly positive buoyancy system allows an object to stay in position without sinking or traveling upwards too quickly, a crucial operational factor. If and when *The* Enterprise begins to travel upwards, we can easily maintain position with our up and down thrusters. EOOSRC has experienced situations with both positive and negative buoyancy. Overly positive buoyancy causes the ROV to constantly float upward and negative buoyancy prevents the ROV from easily returning to the surface. Poor buoyancy dramatically reduces maneuverability and stops EOOSRC from accomplishing our clients' needs.

Propulsion

The Enterprise is equipped with four Blue Robotics thrusters, two T100s and two T200s. These thrusters, specifically designed for underwater vehicles, were chosen for their efficiency and easy maneuverability of *The Enterprise*. Our T100 thrusters are vertically mounted on each side of the ROV's frame, granting up and down movement. The T200 thrusters are positioned on the middle struts of the frame for forwards and backwards movement. We decided to use T200 thrusters as they improved our directional mobility. Originally we used T200 thrusters for up and down as well but found the increased use of amperage would shut off our system. Using a combination of both T100 and T200 thrusters allows us to maximize the potential of *The Enterprise's* maneuverability. All together, these thrusters make our ROV effective at completing operations at Boone Lake and the South Fork of the Holston River.

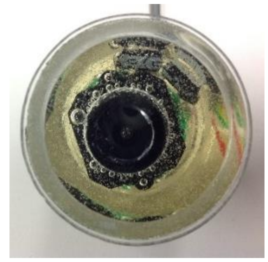
T200 Thruster

T100 Thruster

Design Rational

Cameras

For visual feedback of Boone Lake and the South Fork of the Holston River, *The Enterprise* is equipped with four X10 video cameras. After first securing the cameras' lenses onto circular acrylic sheets, we waterproofed the cameras by filling 3.81 cm tall acrylic cylinders with epoxy. Our driving camera is centrally mounted at the front of *The Enterprise*. Our second camera is placed below the frame's horizontal sheet and its 60 degree field of view displays the claw, carrier, temperature sensor, and electromagnet. Another camera, placed on the left of *The Enterprise's* frame, is used to survey Boone Dam and benthic species of the Holston River. Additionally, the camera aids the driver in orientation. *The Enterprise's* final camera is placed on the *Shuttlecraft* to view muddy water flow within the drain pipe.



Waterproofed X10 Camera

Monitoring System

The Monitoring System, housed inside a watertight utility case, consists of three monitors, an amperage meter, a Video Graphics Array (VGA) converter, the control base, the pilot box, and the mini ROV controller. The monitors are attached on the lid of the case, along with the galvanized meter. We have one large monitor to display our driving camera and two smaller monitors to see our tools and *The Enterprise's* surroundings. The large monitor is mounted in the center of the case's lid while the smaller monitors are mounted on the bottom corners. We installed the VGA converter in the lower half of the case. It is used to convert analog feed from our X10 cameras to a VGA output for display on the large monitor. Alongside the VGA converter, we positioned the control base, pilot box, and mini ROV controller. We designed this system for fast, easy setup and cleanup. The Monitoring System takes up very little space for easy transportation from location to location.

Detachable Connector

The Monitoring System

Tether

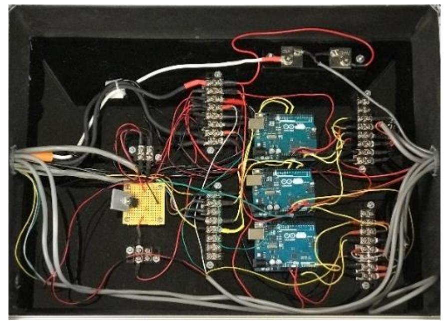
The Enterprise's tether includes 25 power and signal conductors, four camera cables, and pneumatic tubing. The tether is properly secured at the center of the frame's upper horizontal strut providing strain relief. We designed the tether to be detachable from the monitoring system with a 19 pin circular connector and two power connectors. This ability is more than convenience as it further protects the tether from being pulled during operations. Flotation is added to create a neutrally buoyant tether preventing drag on the ROV. The tether is neatly bundled with cable ties.

Design Rational

Electrical System

We designed our electrical system to operate *The Enterprise* with maximum efficiency. It includes our control base, pilot box, mini ROV controller, and underwater enclosure. When building our system we placed emphasis on simplicity and accessibility, ensuring easy understanding, reduction in electrical problems and easier troubleshooting.

The control base is the hub of the electrical system, linking all our connections together. It is housed in a 45.72 cm by 33.02 cm by 15.24 cm watertight box. Inside are three Arduino Uno R3s, a shunt, a voltage regulator, and terminal blocks. The Arduino Uno R3s interpret signals coming from the pilot box and mini ROV controller to send commands to the ROV. These microprocessors allow us to easily control our thrusters, and servos. Using multiple Arduino's simplifies programs thus making troubleshooting easier. The shunt allows the galvanized meter located in the monitoring system to read amperage, preventing system overloads and blown fuses. As our servos run on a maximum of 6 volts of direct current (DC), we built a voltage regulator to reduce our 12 volt DC power supply. It is constructed off a breadboard converting power with a potentiometer and capacitor. To absorb heat a small aluminum square was added to the regulator. All connections leaving the control base to the ROV runs through our tether.


Inside of Control Base

The pilot box was built to best maneuver *The Enterprise* during Eastman operations. To simulate "tank-drive" control with our driving thrusters, we are using two joysticks. When traveling forwards, both joysticks are pushed upwards. While turning, the joysticks are pushed in the opposing direction of the other joystick. To go up and down, we are using one potentiometer. In previous years, EOOSRC discovered having the up and down thrusters on different controllers caused tilting. By syncing our thrusters to one controller, we achieved precise vertical movement. A second potentiometer is used to pivot the servo on the claw. This ability allows us to perform various tasks at specific angles. The temperature meter is also positioned on the pilot box so the driver can easily record the temperature sensor's reading.


The Pilot Box

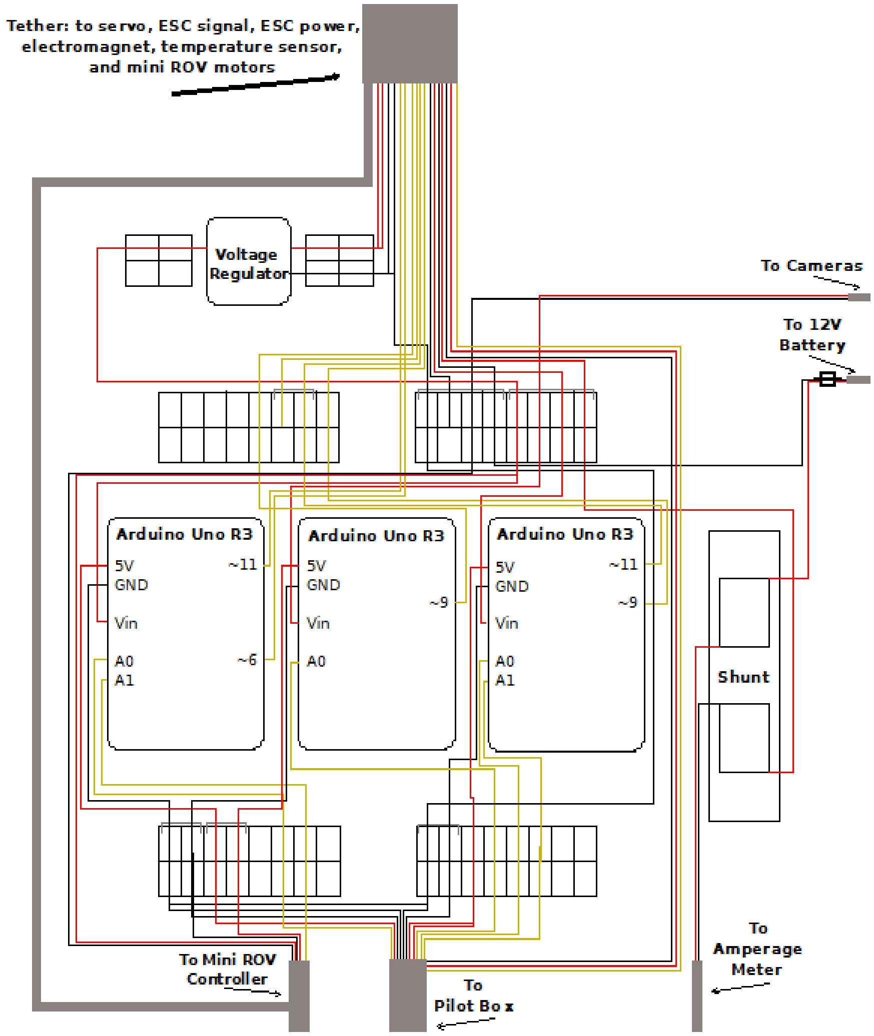
The mini ROV controller includes a potentiometer and three on-off-on switches. The potentiometer, positioned on the top of the box, operates the servo used to release *The Shuttlecraft* from *The Enterprise*. Each motor on *The Shuttlecraft* is controlled by a switch. Using switches allows full thrust in all directions resulting quick movement from *The Shuttlecraft*. The third switch is used to turn our electromagnet on and off. We chose to place the electromagnet's switch on the mini ROV controller rather than on the pilot box so the driver could focus on hovering over the cannon shells.


Mini ROV Controller

Design Rational

A 12 inch long by 4 inch diameter Blue Robotics underwater enclosure houses our electronic speed controllers (ESCs). The ESCs are connected to Arduinos through the tether. They receive signals from our Arduino program informing them how much DC should be converted to AC (alternating current) to run the motors at the desired speeds. In the past we built our own underwater enclosures, unsuccessfully waterproofing them. Rather than place all the ESCs back onto the surface, we decided to use a professionally designed enclosure. Having the ESCs underwater reduces bulk on the tether, creating a more mobile ROV. The enclosure has two end caps with O-rings on either side. To make sure of zero leaks, we permanently sealed one end. On the remaining end cap, wires run through three holes. We sealed the holes with marine adhesive, expandable foam, and rubberized spray. For additional moisture control we added desiccant packs and a humidity detector.

Underwater Enclosure

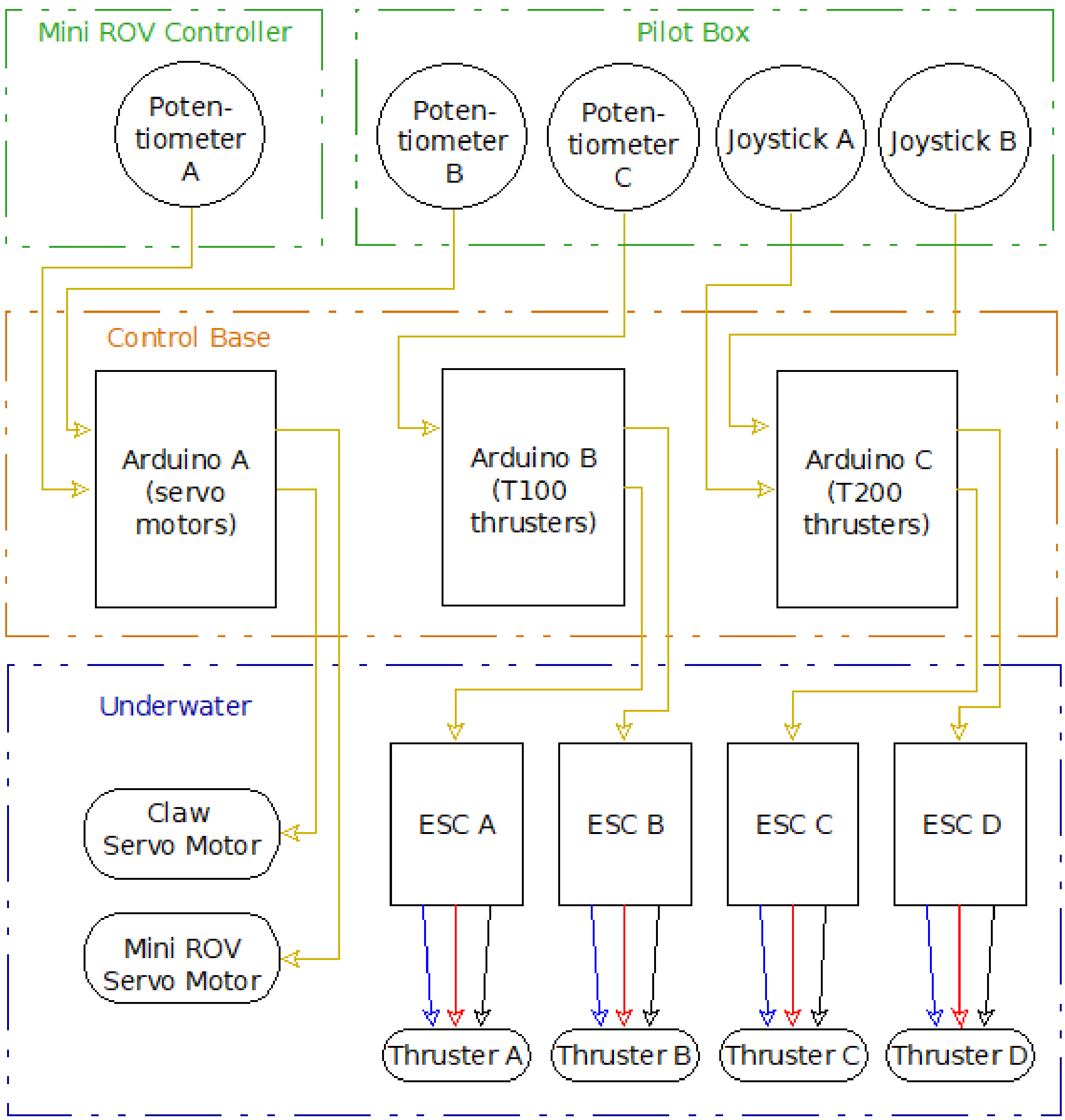


Electrical Schematic of Control Base

Design Rational

Arduino Software

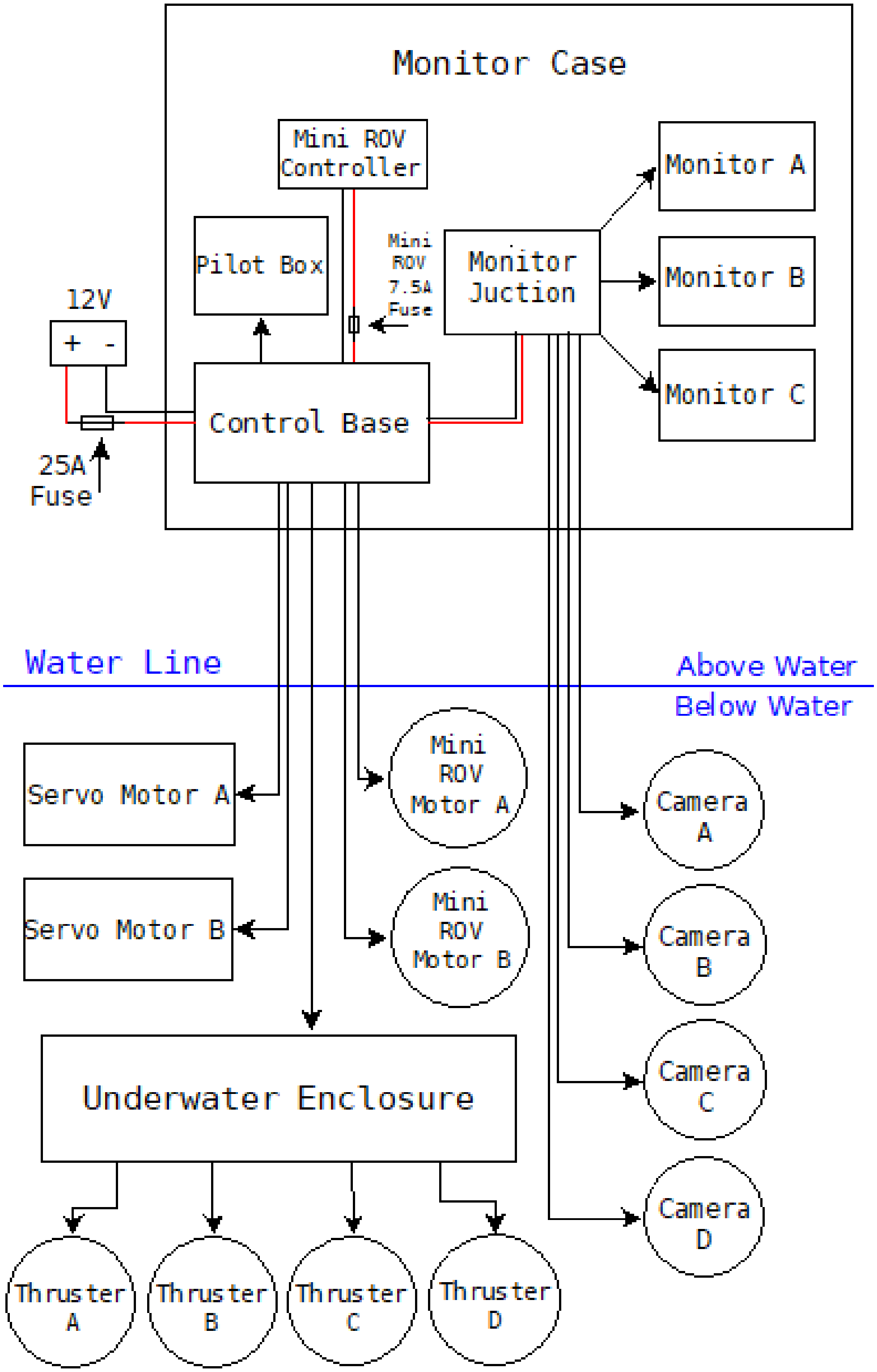
We are using three Arduino Uno R3s to precisely control *The Enterprise*. The Arduinos interpret signals sent from the pilot box and the mini ROV controller. Two of the Arduinos are used to control our thrusters. Through the ESCs, the Arduinos transmit how much power to send to the thrusters. We separated the thrusters onto different Arduinos after concluding they worked more efficiently. The third Arduino interprets signals coming from potentiometers to control our two servo motors. The Arduino allows us to convey how many degrees the servo motors turn relative to the potentiometers' positions.



Software Flow Diagram

Design Rational

System Interconnection Diagram



ROV Fuse Calculations			
Component	**Current Draw**	**Qty.**	**Total**
T100 Thruster	3.75	2	7.5
T200 Thruster	4	2	8
Servo	0.1	2	0.2
Electromagnet	0.84	1	0.84
Temperature Sensor	0.5	1	0.5
Camera	0.4	4	1.6

Total Current	18.64
Overcurrent Protection	18.64 x 150% = 27.96
ROV Fuse	**25 Amp**

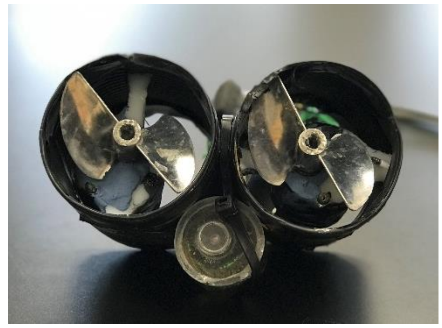
Mini ROV Fuse Calculations			
Component	**Current Draw**	**Qty.**	**Total**
Electric Motor	2	2	4

Total Current	4
Overcurrent Protection	4 x 150% = 6
Mini ROV Fuse	**7.5 Amp**

Payload Tools

Mini ROV, *The Shuttlecraft*

EOOSRC's miniature ROV, *The Shuttlecraft*, was designed to navigate a 6 inch diameter drain pipe at Boone Dam. *The Shuttlecraft* must locate muddy water flow exposing dam failures for the safety of the surrounding community. It is equipped with two electric motors and an X10 camera, standing 11 cm. The motors, hand-waterproofed with 3-in-1 oil, rubber spray, and molding clay, are shrouded in two cans. These cans prevent the motor's thrust from bleeding to the side in an unproductive way. The driving motors are angled so while traveling forwards, *The Shuttlecraft* tilts upwards reducing the need for an up and down motor. The can structure provides spaces to mount the camera and buoyancy. The camera is positioned underneath the motors for central vison while *The Shuttlecraft* is moving. *The Shuttlecraft* was designed to be slightly buoyant aiding upwards movement. *The Shuttlecraft* detaches from *The Enterprise* with a metal hook rotated by a servo. The tether is removable from *The Enterprise* with a 19 pin circular connector. *The Shuttlecraft* is controlled with its own controller (previously described in the electrical system).



Front View of The Shuttlecraft

Top View of The Shuttlecraft

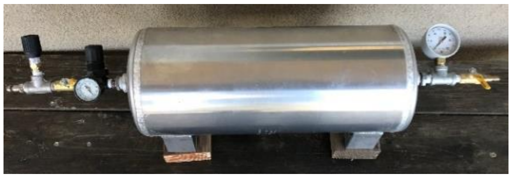
Claw

Several of Eastman's operations require multiple manipulation tasks. For this purpose, we designed a rotational, pneumatic claw. A spring-loaded pneumatic piston is connected to the lower jaw of the claw. While relaxed, the jaw stays open, and is positioned over the object of interest. Once positioned correctly, a foot pedal is pressed, channeling air pressure from our pre-filled pressure tank down a system of hoses and into the pneumatic cylinder, closing the jaw. To release the object, a second foot pedal is pressed allowing the pressure to escape the system. Without the pressure, the spring in the cylinder can return to its original position, opening the jaw. A servo motor, mounted on the right of the claw, pivots the claw with a turn of a potentiometer. This ability allows *The Enterprise* to access objects in hard-to-reach places.

The Claw

Payload Tools

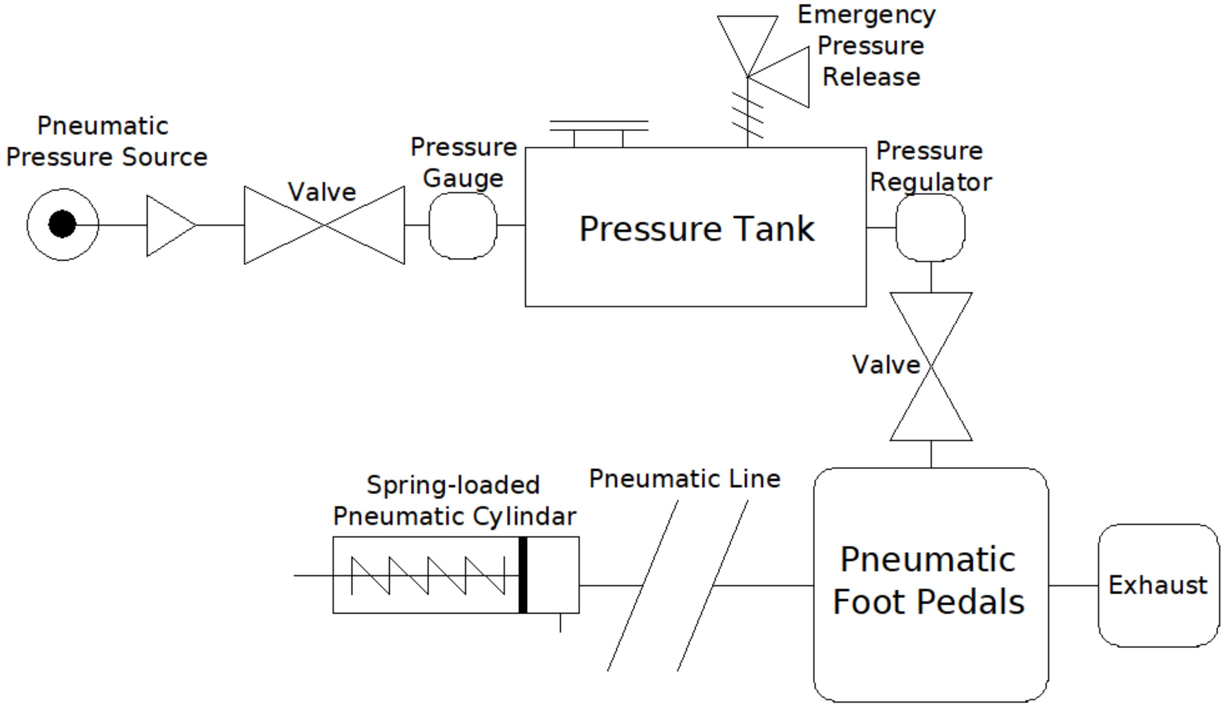
Claw Pneumatic System



Pressure Tank

The Enterprise's pneumatic system was designed with an emphasis on safety and ease of use. We are using a certified pressure tank to hold 80 pounds per square inch (psi) of pressure. The pressure released from the tank is regulated to 40 psi, the MATE safety standard. For additional safety, our tank is equipped with valves, two pressure gauges recording both 80 psi and 40 psi, and an emergency pressure release. Two pneumatic foot pedals are used to send and release pressure in the claw's pneumatic piston. When the left pedal is pushed, air is sent to the piston, closing the claw's jaws. To relieve pressure within the cylinder, the right pedal is pressed. The use of the pneumatic foot pedals allows the driver to operate the claw, increasing efficiency. Additionally, combining jobs is especially helpful as EOOSRC is a smaller company this year.

Pneumatic Foot Pedals

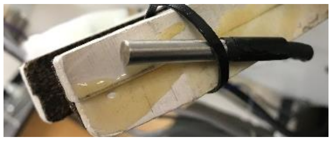


Pneumatic Flow Diagram

Payload Tools

Temperature Sensor

EOOSRC is assisting in data collection for studies documenting the water quality of the South Fork Holston River. To measure the water's temperature, *The Enterprise* is equipped with a temperature sensor. It is positioned on the tip of the claw for access to the claw's servo. The rotational axis is useful for determining the temperature of specific areas. The sensor accurately presents a reading in Celsius on a digital meter in the pilot box.

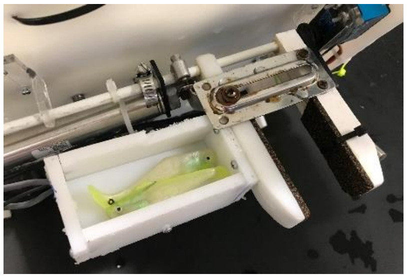


Temperature Sensor

Carrier

To restore the rainbow trout habitat in the South Fork Holston River, EOOSRC created a tippable aquarium safely transporting trout fry. We are also using the carrier to insert grout into cracked sections of Boone Dam. Making use of the claw's servo mechanism, a HDPE box with a buoyant lid was mounted to the left of the claw's lower jaw. While the claw is level, the lid presses against the bottom of *The Enterprise*, preventing the carrier from opening. Once in location to release the fish or insert grout, the servo is turned, tilting the carrier. Since the lid is buoyant, it opens. The fish are free to swim away and the grout goes into place.

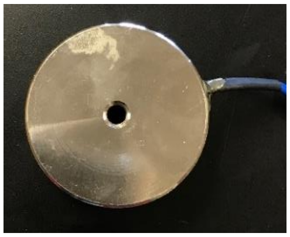
Closed Carrier



Fish inside Carrier

Electromagnet

To determine the location of any unexploded cannon shells left behind from the Civil War, we are using an electromagnet. Activated by a switch, the electromagnet produces a force of 50 Newtons. When marking metal and non-metal debris, the electromagnet is positioned directly above. If the item is metal, the electromagnet sticks. In this process, EOOSRC efficiently confirms and marks any cannon shells at the South Fork of the Holston River.



Electromagnet

Safety Importance

A major necessity for any company dealing with engineering, construction equipment, electricity, or pneumatics is safety. EOOSRC is no different. We believe through safe practices, proper knowledge, and personnel initiative, safety accidents can be avoided.

All safety accidents are the result of human errors. Accidents deemed as equipment malfunctions are caused from failure to properly inspect and repair equipment. For these reasons, EOOSRC is committed to making safety the responsibility of everyone:

- Equipment is always turned off and unplugged after use. They are maintained to keep in good condition.
- Power cords and other cables are always kept out of any common walking space.
- The workspace is always kept clean and orderly.
- All members wear Personal Protective Equipment (PPE) at all times while within the workspace.
- Long hair must be pulled back.
- Rings, bracelets, necklaces or dangling earrings are not allowed.

Members must:

- Understand the dangers incorrect methods and behaviors pose, to themselves and to others.
- Always use the proper equipment.
- Never rush.
- Always pay attention to the condition of equipment, the cleanliness of the workspace, surroundings and behavior of other personnel.
- Ask for help, if help is required. Never attempt a two-person job alone.
- Follow all safety procedures when travelling to other areas.

EOOSRC also encourages its members to take the initiative of informing personnel of any unsafe methods or behaviors. When an error is made, we continue forward with a positive attitude to prevent further mistakes.

New members are taught:

- The EOOSRC philosophy.
- How safety accidents affect everyone and the project.
- The proper use of equipment from qualified members or an instructor.

Additionally, new members must pass general safety and equipment safety tests, ensuring their understanding of safe methods.

Safety precautions are also practiced on our ROV:

- The pneumatic system can be completely depressurized through one valve, ensuring swift release if a part fails, or if injuring someone becomes a possibility.
- Our pressure tank is certified and stamped by the DMT (Department of Motor Transportation).
- Our pressure tank is strapped down during operations to prevent injury.
- The fluid power safety quiz was passed with a score of 100%.

Safety Importance

- Every thruster is encased in a guard with 6 mm shrouds, to prevent hand or finger injuries.
- Warning labels are applied to all spinning parts, further preventing hand injuries.
- A 25A fuse is placed within 30 cm of the battery connection.
- All electrical connections are properly sealed and secured.
- Our underwater enclosure can withstand pressure at 4 meters.

To further ensure safe practices we developed safety checklists:

Physical Safety

- ☐ All items attached to the ROV are secure and will not fall off.
- ☐ Hazardous items are identified and protection is provided.
- ☐ Propellers are enclosed inside the frame of the ROV and shrouded to prevent contact with items outside of the ROV.
- ☐ No sharp edges or elements of the ROV design can cause injury to personnel or damage to the pool surface.

Electrical Safety

- ☐ Single attachment point to power source.
- ☐ Standard 30 amp male Anderson Power Plug to connect to MATE power source.
- ☐ 25 amp single inline fuse or circuit breaker within 30cm of attachment point.
- ☐ No exposed copper or bare wire.
- ☐ No exposed motors.
- ☐ All wiring is securely fastened and properly sealed.
- ☐ Surface controls: All wiring and devices are properly secured and control elements are mounted with wiring inside an enclosure.
- ☐ Underwater connections must be sealed with silicone sealant and shrink tube.
- ☐ All taping is self-vulcanizing.
- ☐ NO male to male connectors.

Tether Safety

- ☐ Tether is properly secured at surface control point and at ROV.
- ☐ Any splices in tether are properly sealed.
- ☐ Tether is neatly bundled around a spool.
- ☐ The team knows NEVER to step on the tether.
- ☐ Tether should ALWAYS be buoyant.
- ☐ The team has a tether manager.

Personal Safety

- ☐ All team members wear required PPE.

Project Management

To ensure *The Enterprise* was finished on time, EOOSRC created monthly deadlines. Shown below is our calendar:

August	September	October	November	December	January
1st meeting; Discuss future ROV ideas	ROV designs/ ideas	Briefing released; Cut out frame	Assemble frame; Mount motors and enclosure; Test basic system	Mini ROV designs	Test electronics; Mini ROV frame; Tool designs
February	**March**	**April**	**May**	**June**	
Assemble Mini ROV frame; Plan pneumatic system	Finish electronics, tools, and other components	Finish up ROV; Test and troubleshoot ROV; Practice in pool	Testing and pool practice; Regional Competition	Testing and pool practice; International Competition	

Members showing interest in particular types of engineering were assigned to head those sections: CAD diagrams, frame, mechanics, programs, and electronics. Assigning members to manage each section allowed EOOSRC to complete each of *The Enterprise's* components on time. EOOSRC's project log is shown below:

Aug 24, 2018	First meeting; Discussions and plans for future ROV (entire team)
Sep 14, 2018	Talked about ROV designs; Discussed potentially buying a GoPro camera (entire team)
Sep 21, 2018	Looked at each teammate's frame design and sketched out a frame incorporating all of them; Talked about camera (entire team)
Sep 28, 2018	Voted on initial frame; Further planned ROV (Brandon, Orion, and Shannon)
Oct 5, 2018	Frame design finalized; Researched and ordered frame materials; Debated whether to purchase camera (entire team)
Oct 12, 2018	Received frame materials; Started sketching design onto frame material; Mission briefing released
Oct 19, 2018	Finished sketching design onto frame material; Started cutting out frame
Oct 26, 2018	Cut out frame material; Smoothed out all rough edges on frame pieces cut
Nov 2, 2018	Finished cutting frame materials (Hans, Orion, and Shannon); Assembled frame (Orion and Shannon)
Nov 9, 2018	Mounted thrusters and enclosure onto frame (Brandon, Hans and Shannon); Looked into mini ROV
Nov 16, 2018	Tested ROV in water (entire team); Did more research on mini ROV; Ordered materials for mini ROV

Project Management

Nov 30, 2018	Mounted claw onto frame (Brandon, Hans and Shannon); Ordered more materials for mini ROV
Dec 7, 2018	Waterproofed mini ROV motors (Hans and Shannon)
Dec 14, 2018	Tested mini ROV motors (entire team); Built mock tool for fish transportation mission; Discussed missions; Researched materials
Jan 11, 2019	Mounted and tested T100 up/down thrusters (Brandon, Hans, Shannon)
Jan 18, 2019	Tested faulty mini ROV motor and found a spare replacement (Brandon); Worked on mini ROV design (Shannon); Made carrier (Hans)
Jan 25, 2019	Started sketching mini ROV design onto material (Hans and Shannon); Looked into battery for mini ROV (Brandon); Orion quits
Feb 1, 2019	Cut out side pieces for mini ROV (Hans); Tested 3rd mini ROV motor and began wiring (Shannon)
Feb 8, 2019	Cut out middle sheet for mini ROV (Hans and Tristen); New team member and Brandon quits
Feb 12, 2019	Began assembling mini ROV frame (Hans); Started working on underwater enclosure (Shannon); Looked at pneumatic foot pedals to control claw (Hans and Shannon); Researched propellers for mini ROV
Feb 19, 2019	Finished assembling mini ROV frame (Hans); Wired underwater enclosure (Shannon)
Feb 22, 2019	Worked on pneumatic system (Hans); Began mounting mini ROV motors (Shannon and Tristen)
Feb 26, 2019	Mounted mini ROV propellers to 2 motors (Hans); Secured carrier (Hans); Made device to hold amperage meter (Shannon); Began adding new ESC to underwater enclosure (Shannon)
Mar 1, 2019	Worked on pneumatic foot pedals (Hans); Started building mini ROV control box (Tristen); Finished wiring underwater enclosure and began waterproofing (Shannon); New member
Mar 5, 2019	Worked on mini ROV frame (Hans); Finished sealing underwater enclosure (Shannon); Wired additional Arduino for up and down thrusters (Shannon)
Mar 8, 2019	Worked on pneumatic foot pedals (Hans); Secured motors on mini ROV frame (Hans); Wired and tested mini ROV motors (Hans and Shannon); Assembled underwater enclosure and mounted it onto frame (Shannon); Fastened tether with strain relief to ROV (Shannon); Began layout for detachable tether (Shannon)

Project Management

Mar 12, 2019	Passed Fluid Power Quiz; Mounted and tested electromagnet; Added buoyancy to mini ROV (Hans); Secured amperage meter to monitoring system (Shannon); Tristen drops out
Mar 15, 2019	Tested buoyancy on mini ROV (Hans); Began mount for mini ROV (Hans); Completed inner side of detachable tether (Shannon)
Mar 19, 2019	Worked on mount for mini ROV (Hans); Finished outer side of detachable tether (Shannon); Added buoyancy to ROV (Hans); Worked on tech report
Mar 22, 2019	Worked on mini ROV and mount (Hans); Worked on tether and condensed size (Shannon)
Mar 26, 2019	Connected and tested pneumatic system (Hans); Finished tether (Shannon); Worked on mini ROV mount (Hans);
Mar 29, 2019	Tested electrical system-- troubleshooted servo problem
Apr 2, 2019	Tested underwater enclosure and found leaks-- worked to fix; Redesigned mini ROV (Hans); Began layout for mini ROV controller (Shannon)
Apr 5, 2019	Found more leaks in underwater enclosure and fixed; Worked on mini ROV and added buoyancy (Hans); Finished mini ROV controller (Shannon)
Apr 9, 2019	Tested and worked on underwater enclosure; Finished mini ROV; Worked on tech report
Apr 12, 2019	Tested and worked on underwater enclosure; Worked on tech report
Apr 23, 2019	Testing and troubleshooting
Apr 26, 2019	Testing and troubleshooting
Apr 27, 2019	Testing ROV at Watsonville Pool
Apr 30, 2019	Testing in pool
May 3, 2019	Testing in pool
May 6 - 9, 2019	Testing in pool
May 11, 2019	Monterey Bay ROV Competition
May 14, 2019	Discussed International Competition-- ROV plans, travel expenses
May 28-June 14, 2019	Practice for International Competition
June 19 - 23, 2019	MATE International Competition

Testing and Troubleshooting

We created several prototype CAD models of *The Enterprise* to decide the best frame. Modeling the frame allowed us to calculate the amount of material used thus finding the frame's mass. It also permitted the shape and size to be examined as well as finding places for the thrusters, tools, and underwater enclosure.

We thoroughly tested all of *The Enterprise's* individual systems prior to being mounted. This ensured proper performance and made troubleshooting easier. After the frame was completed, we first established thruster function and correct placement. Then we confirmed the effectiveness of our cameras and monitors. Lastly our underwater enclosure was tested for leaks. Before powering the system, all programs and their signals were verified. For every tool, we tested both mechanical and electronic functions. Before sending pressure to the pneumatic cylinder, we ensured the claw's pressure tank was regulated to 40 psi. We also made sure the claw's servo could support the weight of both the claw and carrier. While building the carrier, we manually simulated a rotational function to test the design. The sensor and digital meter of the temperature sensor were checked for accuracy. We tested the electromagnet's strength by simulating cannon shells. We also checked to see if it disrupted the cameras' feed. All individual components of *The Shuttlecraft* were tested before assembly. All electrical components were measured with a multi-meter to scan for problems and prevent current overloads.

While troubleshooting, EOOSRC has learned to fully examine the situation. For each scenario, we created a series of particular questions. For example, when the servo on the claw stopped working we followed a linear system:

- Does the servo have power?
- Did the voltage regulator malfunction and overload the servo?
- Did the wiring become an issue?
- Was there a problem with the detachable connector or tether connections?

In the end we found the connection between the servo and tether had corroded blocking the signal to the servo. We have also experienced a long, troubleshooting battle with *The Enterprise's* thrusters. Last year we purchased four Blue Robotics T200 thrusters as opposed to T100 thrusters. Research showed the thrusters' increased force would better maneuver the ROV. However we found these motors drew too much amperage causing our system to shut off. Our goal this year was to fix this issue. We first tried limiting power sent to the thrusters through the Arduino program. Although this worked, the thrusters barely propelled our ROV. We decided to purchase two T100 thrusters and attempt a fifty-fifty ratio. The results were much better but we occasionally encountered system shutoffs. After consideration we decided to separate the thrusters' signals onto two different Arduinos. Finally, we had successful results.

EOOSRC has shared our troubleshooting experiences with our fellow Scout team. We know troubleshooting is difficult making it crucial to share the techniques we have learned over the years.

Challenges

EOOSRC's first mini ROV proved to be a challenge. While designing *The Shuttlecraft* we had difficulty finding the correct parts: motors, sealant, propellers, and frame. Our first significant complication involved our motors. Originally thought to be a waterproofing malfunction preventing the motor's axel from spinning, we found the motor as simply faulty. Thankfully, we found a replacement motor used on a previous ROV. The *Shuttlecraft* was initially assembled on a frame. However the frame was designed to fit within a 6 inch x 6 inch space, not a 6 inch circle. We did not account for the curvature of a circle leaving us with a major problem. Quick thinking allowed us to assemble *The Shuttlecraft's* components among one another reducing the need for a frame. We have also been plagued by repeated leaks in our underwater enclosure. After several years of unsuccessfully building our own watertight enclosures, we decided to use a professional enclosure. This has proved to be a very difficult challenge as we did not anticipate water leaks from a professionally designed enclosure. Weeks of testing and troubleshooting with different types of sealants finally eliminated water penetration.

This year EOOSRC experienced a new kind of challenge: a skeleton team. Starting out as a crew of five, we immediately lost a member due to illness. We pushed forward but eventually some of our members began missing meetings and stopped completing assignments. This was a difficult situation because as a team one person's actions effect everyone. Within a few months two members quit leaving us a team of two and unable to compete. Job positions had to be shuffled and remaining members had to work twice as hard to finish the project. Luckily a sibling of one of our members agreed to join the company granting us the opportunity to compete. Another company challenge involved not having a robotics instructor who retired two years ago. Although the company understands several engineering aspects, we occasionally encountered situations leaving us unsure what methods to follow. This uncertainty dramatically delayed some decisions pushing our timeline a little behind.

Lessons Learned

This year we learned to build a mini ROV. Although originally thought to be simple, we found constructing a mini ROV involved detailed planning. We found most techniques learned to build ROVs conflicted with our limited space. For example, buoyancy usage needed to be reevaluated. Because of the extensive weight of the motors, we discovered more buoyancy was necessary. In our experience buoyancy never played an important role in product design. Innovative placement and alteration allowed us to reach our slightly-positive buoyancy goal.

This year we learned to improve several of our robotics skills. We gained more knowledge in troubleshooting methods. We learned to better understand computer code and how to use pneumatic foot pedals. Additionally, since our mini ROV required waterproof motors, we educated ourselves in sealing micro motors.

Lessons Learned

This year we learned to deal with interpersonal issues. EOOSRC experienced issues with members not showing up and neglecting to finish their assignments before eventually quitting. Dealing with these members was difficult for everyone but we gained valuable life skills. We had to keep moving forward and make decisions. Lack of communication decreased productivity but we learned to be patient and empathetic. We learned the real value of a team and the importance of dependability and communication.

Future Improvements

EOOSRC would like to produce a smaller and more compact ROV for increased mobility. Additionally, we would like to construct our own underwater enclosure despite past issues. Even though we purchased a commercial model to reduce leaks, we encountered several. Therefore in the future we would like to build an enclosure that does not take precious weeks to resolve water leaks. This year we successfully built our first mini ROV and would enjoy the opportunity to make improvements: designing a CAD model and using our school's laser cutter to create a frame. We would like to learn more about mini ROVs and potentially make smaller versions.

ROV pool practice time is often an issue in our experience, as well as being an issue quite hard to solve. As we do not have a pool at our school, we cannot regularly test the ROV. Having more time to test the ROV in the water resolves any issues and increases overall performance of the driver and team.

Accounting

EOOSRC budgeted $1200.00 for purchases needed in construction of *The Enterprise*. To organize the decision making process, we divided the budget into subcategories: frame, electrical, mechanical, monitoring, mini ROV, and miscellaneous. Shown below is our budget planning:

<table>
<tr><th>Category</th><th>Type</th><th>Description</th><th>Projected Cost</th><th>Budgeted Value</th></tr>
<tr><td colspan="4"></td><td>$1,200.00</td></tr>
<tr><td>Frame</td><td>Purchases</td><td>HDPE, screws, brackets</td><td>$100.00</td><td>$100.00</td></tr>
<tr><td rowspan="2">Electrical</td><td>Purchases</td><td>Electronic components of ROV</td><td rowspan="2">$150.00</td><td rowspan="2">$150.00</td></tr>
<tr><td>Reused</td><td>Arduinos, tether</td></tr>
<tr><td rowspan="2">Mechanical</td><td>Purchases</td><td>Thrusters, air lines</td><td rowspan="2">$200.00</td><td rowspan="2">$250.00</td></tr>
<tr><td>Reused</td><td>Thrusters, gears, pneumatic mechanisms</td></tr>
<tr><td rowspan="2">Monitoring</td><td>Purchases</td><td>GoPro camera</td><td rowspan="2">$250.00</td><td rowspan="2">$250.00</td></tr>
<tr><td>Reused</td><td>Monitors, cameras, case</td></tr>
<tr><td>Mini ROV</td><td>Purchases</td><td>HDPE, motors, propellers, sealant</td><td>$100.00</td><td>$100.00</td></tr>
</table>

Accounting

Miscellaneous	Purchases	T-shirts, registration, marine lubricant, adhesive	$300.00	$350.00
	Reused	Powerpole connectors		

We kept our expenses under budget thanks to resourcefulness, reusing items, and originality while constructing tools. In total, *The Enterprise* cost $887.59 to complete, leaving $312.41 in reserve. The total cost including reused and donated items is $2746.25. Shown below is EOOSRC's 2018-2019 project costs:

Category	Item	Supplier	Type	Qty.	Cost Per Item	Extended Cost	Total Balance
							$1,200.00
Frame	20" x 16" x 1/2" Cutting Board HDPE	Tap Plastics	Bought	1	$28.89	$31.13	$1,168.87
	18" x 21" x 1/4" HDPE Smooth Sheets	Tap Plastics	Bought	1	$16.80	$18.10	$1,150.77
	Zinc-Plated Steel Comex Bracket	McMaster Carr	Bought	25	$1.00	$25.00	$1,125.77
Electrical	25 AMP DC Panel Meter	All Electronics	Bought	1	$12.00	$12.00	$1,113.77
	25 AMP Shunt	All Electronics	Bought	1	$10.85	$10.85	$1,102.92
	Arduino Uno R3	Arduino	Reused	2	$35.00	$70.00	$1,102.92
	SRA Black Aluminum Case 18.1" x 13" x 6"	Amazon	Reused	1	$33.43	$33.43	$1,102.92
	Electric Lifting Magnet	Amazon	Bought	1	$18.59	$19.59	$1,083.33
	Basic 30A ESC (w/ forward/reverse firmware)	Blue Robotics	Reused	5	$25.00	$125.00	$1,083.33
	Standard Power Connector	Mouser Electronics	Bought	1	$18.00	$18.00	$1,065.33
	Detachable Circular Connector Male	Mouser Electronics	Bought	1	$20.56	$20.56	$1,044.77
	Detachable Circular Connector Female	Mouser Electronics	Bought	1	$26.92	$26.92	$1,017.85
	Spare O-Ring Set (4" Series)	Blue Robotics	Donated	1	$3.00	$9.30	$1,017.85
Mechanical	T100 Thrusters	Blue Robotics	Bought	2	$119.99	$239.98	$777.87
	T200 Thrusters	Blue Robotics	Reused	2	$169.00	$338.00	$777.87
	Savox Waterproof Steel Gear Servo	Savox	Reused	2	$88.14	$176.28	$777.87

Accounting

	Pneumatic Air Line 1/4" 10 Meters	Amazon	Bought	1	$15.90	$15.90	$761.97
	Parker Stainless Steel Single Acting Air Cylinder	Amazon	Bought	1	$22.56	$22.56	$739.41
	3 Gallon Aluminum Air Tank		Reused	1	$75.98	$75.98	$739.41
	10ft 1/4" 200 PSI Air Hose	McMaster-Carr	Reused	1	$6.70	$6.70	$739.41
	Utah Pneumatic Air line 1/4" 10 Meters Nylon Tube	Amazon	Bought	1	$15.90	$15.90	$723.51
	Anarobe Foot Pedals	Anarobe	Donated	2	$100.00	$200.00	$723.51
	Metalwork Brass Hose Barb 4 mm x 6 mm Reducer	Amazon	Bought	1	$9.99	$9.99	$713.52
	Plastic Hose Barb Reducer	Amazon	Bought	1	$8.23	$8.23	$705.29
Monitoring	15" x 24" x 36" Pelican 1730 Watertight Protector Case	Pelican Cases	Reused	1	$600.00	$600.00	$705.29
	Dell Monitor Screen		Reused	1	$50.00	$50.00	$705.29
	Docooler 5" LCD Car Color Rear View Monitor	Amazon	Reused	2	$24.99	$49.98	$705.29
	X10 Video Camera	X10	Reused	4	$25.00	$100.00	$705.29
Mini ROV	Uxcell DC Electric Gearbox Motor 333RPM	Amazon	Bought	2	$17.82	$35.64	$669.65
	7.5A Fuses	Amazon	Bought	1	$5.95	$5.95	$663.70
	In-line Fuse Holder	Amazon	Bought	1	$8.87	$8.87	$654.83
	Powerwerx Powerpole Connector	Powerwerx	Bought	1	$14.99	$14.99	$639.84
	Detachable Circular Connector Male	Mouser Electronics	Bought	1	$20.56	$20.56	$619.28
	Detachable Circular Connector Female	Mouser Electronics	Bought	1	$26.92	$26.92	$592.36
Misc.	Loctite PL Marine Fast Adhesive Sealant, 3 Ounce	Amazon	Bought	1	$8.97	$9.62	$582.74
	Permatex Liquid Electrical Tape	Amazon	Bought	1	$10.33	$10.33	$572.41
	Anderson Powerpole Connectors	Powerwerx	Reused	1	$23.99	$23.99	$572.41

Accounting

	MATE Competition Registration	MATE	Bought	1	$200.00	$200.00	$372.41
	Team Shirts	Amazon	Bought	3	$20.00	$60.00	$312.41
						Total Remaining Balance	$312.41
						Total Amount Spent	$887.59

Shown below is EOOSRC's planned International Competition expenses:

Category	Description	Budgeted Value	Total Balance
			$5,000.00
Transportation	Vehicle rental, gas	$2,000.00	$3,000.00
	Train tickets	$1,000.00	$2,000.00
Housing	Hotel rooms	$1,000.00	$1,000.00
Food	Lunches, dinners	$500.00	$500.00
Miscellaneous	Registration	$100.00	$400.00
		Total Remaining Balance	$400.00

Acknowledgments

Extreme Ocean Observing Systems Repair Company would like to thank everyone who made this experience possible. Firstly we express our gratitude to Rose Justi, our project instructor, and Stephanie Woodside, our overseeing advisor and photographer, for their incredible guidance and assistance. We are extremely thankful to the MATE Center and its staff for creating and coordinating this event. We thank Kingsport Aquatic Center for hosting the international competition. To MATE Monterey Northern California, its staff, Matt Gardiner, and Watsonville High School for organizing the regional competition. To all the engineers, scientists, and divers volunteering for these events. A very special thanks to Mountain Oaks Charter School for support, funding, providing a makerspace and water tank; additionally granting scholarship money to help fund international competition travel expenses. A big thank you Monika Riedel for creating a GoFundMe page further helping fund travel expenses. We also want to thank everyone who donated money through GoFundMe. None of this would have been possible without the generous contributions we received. Thank you to Catherine Steyer and MaryAnne Garamendi for allowing us to practice our ROV in their pools. To Alex Woodside, a former team member, for technical help. We also would like to thank BIOLOG Inc. for donating the pneumatic foot pedals. Most importantly we thank our parents for taking us to meetings, transporting us to competition, and for their outstanding support and encouragement throughout this amazing journey.

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