Underwater Research Robot Company

Alpena High School Underwater Robotics Club

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The UR^2 Team:

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Abstract

The Underwater Research Robot Company (UR2) considers our highest priorities to be safety, innovation, and environmental preservation and research. Our team is comprised of seven skilled students, ranging from ninth to twelfth grade, who are dedicated to helping the Boone Dam of Eastman Tennessee.

Our remotely operated vehicle (ROV) is the culmination of years of experienced innovation and troubleshooting, resulting in many professional grade features. Some of these features include a Pixhawk Flight Controller, a 3D printed biconvex frame design, and a three-directional mechanical grabber. Our control system; a Raspberry Pi processor networked to a Windows based topside computer that uses an Xbox 360 controller to move our thrusters, is a new design located in an acrylic enclosure that is both a housing unit and a buoyancy tube. These controls are connected to our Pelican Case control box through a fifteen meter long braided nylon mesh tether.

To aid in maximum speed and control while maneuvering underwater, our Acrylonitrile Butadiene Styrene (ABS) frame features four T-100 thrusters, with two positioned vertically and two positioned horizontally. In addition to having our frame's corners rounded, we use a high resolution camera that can view 180 degrees to ensure the safety of any marine life we may encounter. Keeping the ideals of our company in mind - safety, innovation, and conservation - our ROV is built to solve any problem it encounters.

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Understanding the ROV

The Underwater Research Robot Company (UR^2) is committed to fulfilling all research needs. Operating in the Boone Damn of Eastman Tennessee, one of our greatest challenges, the UR^2 team has embraced the demanding tasks that accompany working on this job site. Our team is uniquely qualified to develop a remotely operated vehicle that can operate in the sometimes confined and often precarious conditions created while working in ports and the delicate ecosystems of rivers and lakes. Our engineering team has developed an ROV that can assist with the identification and repair of the Boone Damn to help uphold safety and reliability to the surrounding communities; build, release, and recover an a Micro ROV to help inspect and pinpoint any exigencies with the pipe line; accurately measure and record the lengths of a Civil War cannon then safely recover the artifact; safety releasing fish fry; providing correct data of organism count; and finally collect water quality samples for analysis.

In the development of our current robot, the Wildcat 4.0, our engineers focused on designing an ROV that was capable of completing research related tasks and industrial related work.

Our frame, is composed of ABS, which provides the durability needed for the high and low temperatures ranges. We have worked with many different framing materials, but our research has shown that the versatility and ease of use of ABS yields the result for manipulation. The ROV's biconvex design houses an on-board watertight enclosure to confine all electronics and electrical connections to one area of the ROV. The enclosure also holds a 180 degree camera, electronic speed controllers (ESCs), and an auxiliary processor. Our 180 degree camera and mission specific tools allow us to install equipment, identify debris, and collect samples accurately and efficiently. Through encasing all of the electronics in our enclosure, we were able to reduce the weight and width of our tether. Overall, our design focused on developing an ROV that is hydrodynamic, compact, and light weight in order to easily transport it in any work environment while also working swiftly. UR^2 is committed to providing reliable and useful research platforms capable of ensuring our clients with accurate and trustworthy data. The Underwater Research Robotics Company has a robot that will answer your needs.

MATE

NATIONAL MARINE SANCTUARIES

THUNDER BAY

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NOAA

U.S. DEPARTMENT OF COMMERCE

Underwater Research Robot Company

Acknowledgements and References

Thank you very much to:

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· Thunder Bay National Marine Sanctuary
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· Marine Advanced Technology Education Center
· Solid Works Corp
· All the volunteer divers and NOAA staff members that make everything possible.

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"The Engineering Design Process." *Science Buddies, edited by Debbie Stimpson, Science Buddies, 2002-2018, www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess. Accessed 10 Apr. 2018.*

"Underwater Robotics Competition." *Marine Advanced Technology Education Competition Website, MATE, https://www.marinetech.org/rov-competition-2/. Accessed 3 Oct. 2017.*

All pictures of team members used in this technical documentation were taken by Savannah Thomson and Karli Myers.

This year, our team came together to build a ROV that was superior to our previous models which would allow us to advance in the rankings. In order to accomplish all the tasks that come with building a ROV and preparing for competition, our team held weekly Tuesday, Thursday, and Saturday meetings starting in the beginning of November of 2018.

Even with a team as small as ours, there are often few at meetings when some members have to miss for other extracurricular activities, so to keep all team members up to date on what has been done on the robot and what still needs to be started or finished, we maintain a board in our workshop of all the tasks and their current completion status. This allows members who have missed a meeting not to waste time trying to complete a job that has already been finished without them knowing.

Our team also has a team Google drive that all members have access to. This team drive contains a meeting schedule, a copy of the technical documentation for editing, and other resources for reference. This team drive allows everyone on the team to stay up to date as well as stay informed on what has been going on at meetings.

Our whole team is involved in the design and engineering of the ROV, but in order to complete the tasks at hand each member specialized in a specific department. For example, the software department has a lead member who could answer questions from other members on the specific topic of software. The other departments included electrical, marketing, and engineering. On a day to day basis, team members reported to their department head in order to figure out what needed to be accomplished for that meeting. Breaking our team down into departments of three to four team members each allowed for tasks to be completed more efficiently.

When a problem arose, our mentors encouraged us to problem solve as a team, but when we needed the extra help we utilized community members such as Paul Coleman, a local coding expert. We also used internet resources such as Sparkfun and Ardusub for coding tips and aid. Since our robot includes Blue Robotics parts, we also used their website for reference. Our team has accumulated a lot of experiences and knowledge over the years, but we still reach out for help when absolutely necessary to complete a task.

(Above) Eva Lusardi checks the enclosure pressure while Wenton Harris records the measurements.

(Above) Eva Lusardi, removes parts from the wildcat 3.0 to repurpose on the wildcat 4.0

(Above) Josh Beatty collaborates with Karli Myers.

Each year we employ the engineering design process to improve and develop a more advanced and reliable ROV. We used this process again to guide us through every step of the project:

Define the Problem

Do Background Research

Specify Requirements

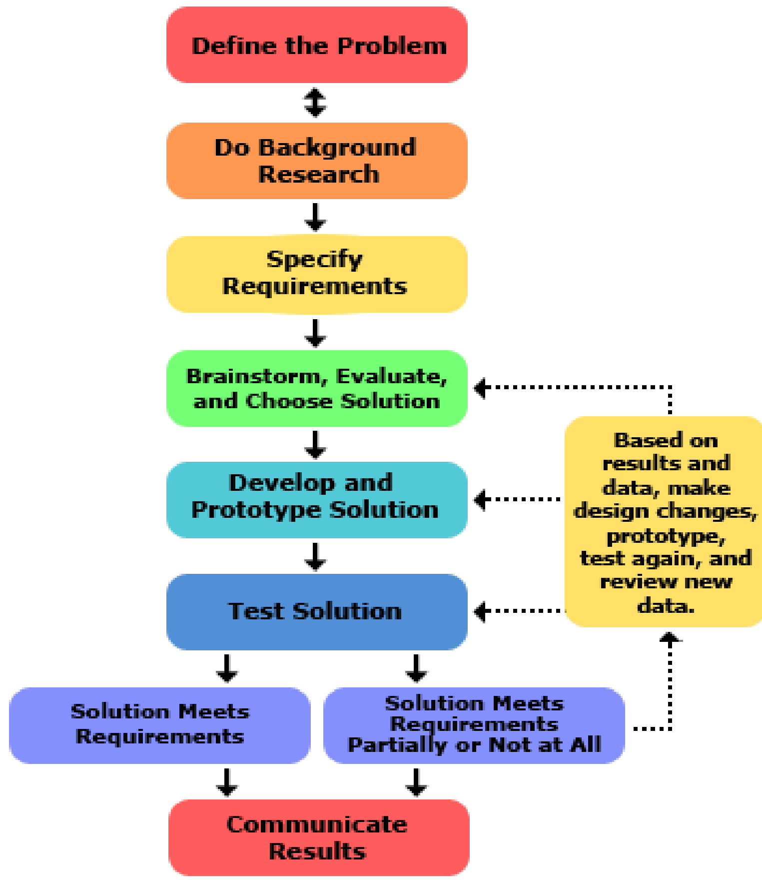
Brainstorm Solutions

Choose the Best Solution

Do Development Work

Build a Prototype

Test and Redesign



The UR² Company has experienced many successful research projects and competitive achievements, but in order to be more successful, we challenge ourselves with new ideas and technologies. The Wildcat 4.0 is our most sophisticated and site specific ROV that we have ever developed. The Boone Damn requires not only a vehicle that is equipped to complete the required tasks, but a vehicle that meets criteria for both weight and size.

In order to meet these requirements; our design team had to start from the bottom up. This required creating a hydrodynamic and compact frame, reliable control system, and the development of very unique job site tools. Our frame is designed out of ABS plastic. In past years we have chosen to use High-Density Polyethylene (HDP) at the cost of being confined to a more bulkier and square frame. However, this year we chose to use ABS plastic to expands our horizon and design a more original and unique frame. This new and improved frame is more hydrodynamic than ever, due to the biconvex shape of it which allows water to flow through more easily. This frame designs also includes an on-board watertight enclosure, where all electronics and electrical connections are enclosed on the ROV. This allows for the tether width to be reduced and total weight of the tether to be significantly decreased. Our overall design focused on developing an ROV that is hydrodynamic, compact, and light. This design provides for easier transportation in any work environment.

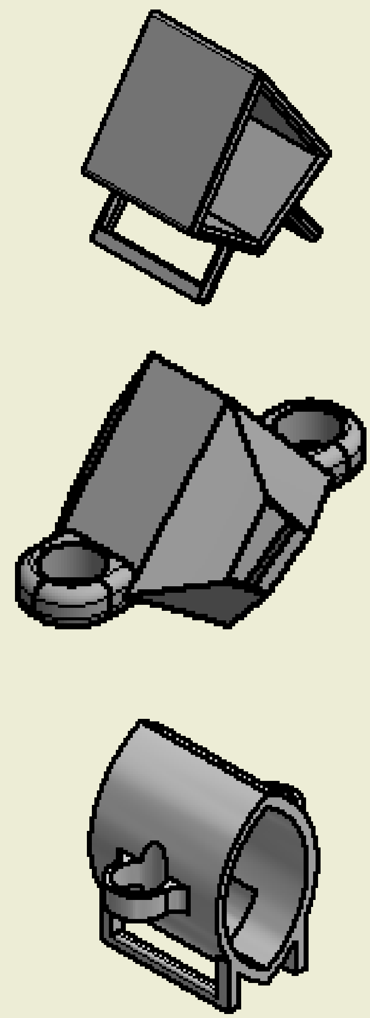
To compliment our highly diverse robot, our engineering team has developed job site specific tools to complete the required tasks: an accurate linear measuring device and our uniquely designed Micro ROV.

Frame Design:

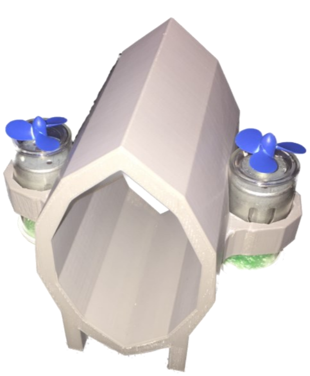
The goal of this year's frame improvement was to develop a frame shape that was more hydrodynamic and decreased the drag. In the design process of our frame, we started with ideas and rough sketches from team members. These sketches were drawn out with paper and pencils to get an idea on what to later draw in the CAD software. While sketching the frame, we tried to prioritize the idea of keeping it as hydrodynamic as possible. We decided on a frame design that was meant to be as vertically hydrodynamic as possible while focusing less on forward and backward movements. Once the design was selected we began to model it through Autodesk Inventor. During the CAD process, we also worked with Amit Dev to tweak the frame and improve the hydrodynamics. We modeled multiple prototypes until we created our current frame.

One of the main challenges that came with the frame design was the thruster placement. We wanted optimal thrust while keeping hydrodynamic shape. During the second draft we designed exterior thruster compartments for our vertical thrusters. These compartments ran from back to front flush with the main frame. While revising during the fourth draft we sized down the compartments. We did this because the ROV would be lighter and we get the same result with the ROV's hydrodynamic goal. Once the design was finalized, the frame was printed at a ¼ scale, with ABS plastic, to visualize the robot and to test the hydrodynamics on a smaller scale. After finalizing the design on a smaller scale, the final step was to print our frame at full scale to use for the competition.

We printed a quarter scale of the frame design to help us decide the what level of fill to print the frame. The initial test on the quarter scale from showed the ten percent fill created way too much buoyancy. Coupled with the added buoyance of the enclosure we need to either print the frame at a higher fill percentage or add more weight. We researched the cost of printing a solid fill frame and the price ranging from $900.00 to $1,500 for a complete rendering. That price was out of our budget, so we decided to print it ourselves and attempt to adjust the buoyance.



This is the Wildcat 4.0 design evolution. As the design process went on the style of the robot changed slightly with each draft. We first started out with a diamond shaped which then grew into biconvex design.



What we learned from the quarter frame prototype was that if we drilled small air holes in the frame it will flood and the air will be removed. It is the same idea of drilling the wholes in a PVC style frame to neutralize the buoyance so that we could have more control over the buoyance.

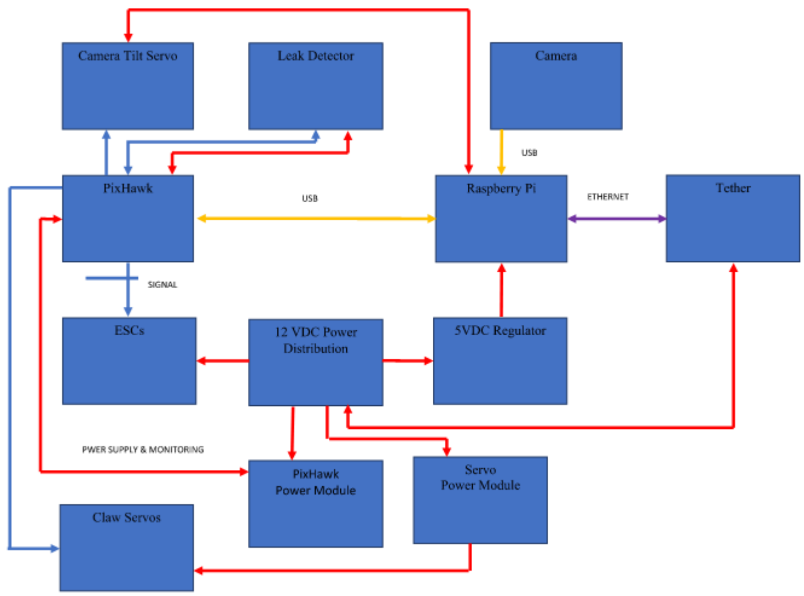
Control System

The Raspberry Pi system accommodates us with a reliable processor control that was within our budget. The code and the PixHawk converts the analog input from the joystick to the electronic speed controllers needed to input power to the T100 thrusters. Working with QGroundControl- a drone flight software, on a surface laptop, we are able to use an XBox Controller to control the thrusters, camera, and manipulator. This system is compact and reliable, allowing our robot to operate quickly and efficiently. The program has allowed us to experiment with different programming commands to adjust our control program to fit the needs of the mission requirements.

Use the XBox game control provides a level of operation familiarity to the pilots. The controller is economical and far cheaper to buy than to build. Also, it is durable and field tested to sustain a high degree of usage.

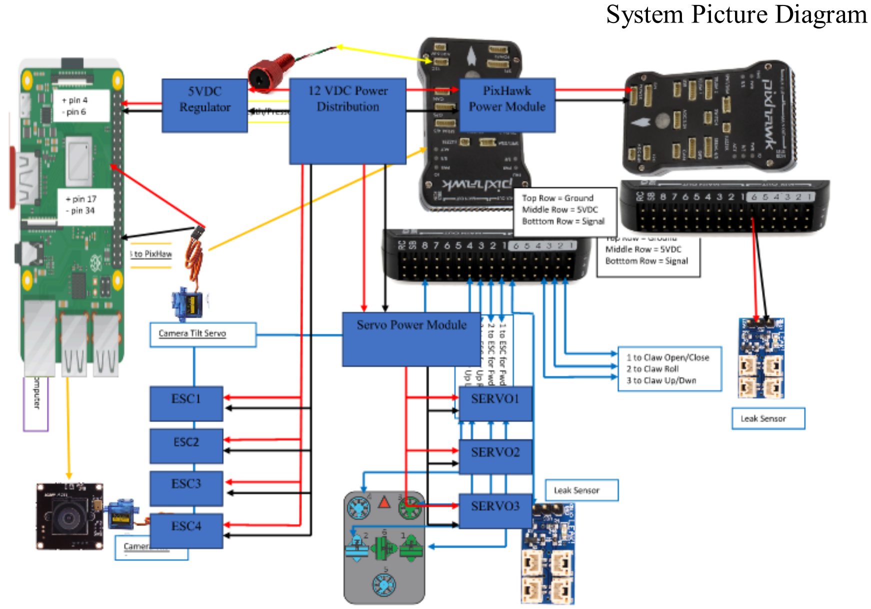
The entire system is built into a Pelican waterproof case. The case is large enough to accommodate all the control equipment with room to expand to adapted to future missions. When closed the case is easy to transport and makes our ROV highly mobile for shipboard missions or land paced operations. We have even using in the winter on a sheet of ice in the middle of a lake.

System Block Diagram



With the loss of both of our software programmers graduating this year, our mentor Mr. Coleman helped us develop two different flow charts that diagramed the command signals. By creating these flow charts we were able to develop a more concrete understanding of the control system. The above diagram is a block diagram of the control units and below is a pictured diagram. Both provide a easy way to follow a signal for trouble shooting and system understanding.

System Picture Diagram



Tether

This year's mission criteria made us rethink and consider ways to make the ROV lighter, since it is the heaviest part of our ROV. To reduce its weight we reduced the number of conductors that we use in the tether. We also researched different conductor materials for the theater, in hopes to find something with high levels of pure copper and low levels of voltage drop. We decided on the Blue Robotics Shielded Fathom Tether, which has a shorter tether length of 15.24 meters. We also removed some data lines from our control system to lose more extra weight and prevent a voltage drop along the tether. Our goal for next year is to have a detachable tether that will allow us to store and travel with the ROV more efficiently. We attached our tether SID document that out line the conductors.

This is our current complete package of ROV and control case. The tether is hardwired on both the ROV and the control case.

Image Shape Detector

Working with our software mentor, Chris O'Brien, we have attempted to develop a program that will complete the shape recognition task of the mission. The Image Shape Detector will detect basic shapes in a captured image. It uses the Aforge.Net Frame work which is an open source framework designed for developers and researchers in various computer applications including image processing. The program is written in C#.

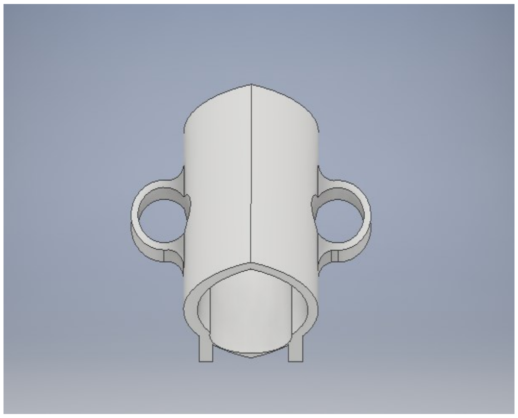
The following are the steps to process the image and give a count of each image.

1. Click the Start Button.
2. Software captures image from feed from ROV.
3. Process image to make it easier to determine shapes by filtering colors into black and white image.
4. Use the BlobCounter Class to analyze the image. The Class counts and extracts objects.
5. Detect Circles by comparing the edge distance from the shapes center. If the distances are within a certain allowance, the count as a circle.
6. Detect Quadrilaterals by finding the corners and verifying the shape edges are not too far from the lines connecting the corners. If the variance is small, then count the shape.
7. Determine in quadrilaterals are either squares or rectangles by comparing the length of the sides. If the sides are equal, then count as square. Otherwise, count as a rectangle.
8. Detection of Triangles by counting the vertices and variance of the edge of the shape and the triangle based on the points. If the point count is 3 and the edge variance is small, the count as a triangle
9. Display results on the screen.

At this point we are still developing this application, but have not been able to make it reliable. We are hoping to have all the bugs worked out for the Regional Competition.

Propulsion Design

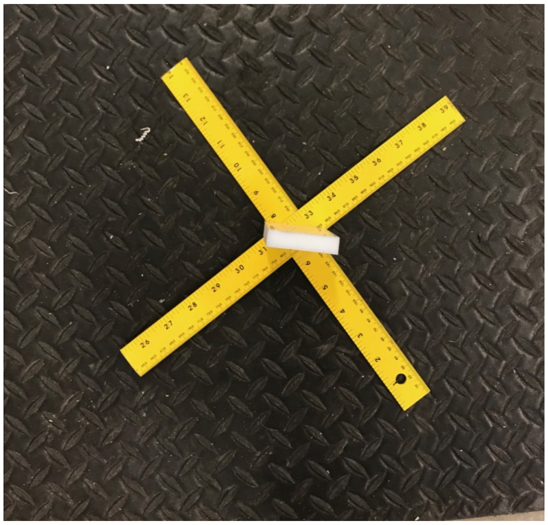
In the past, propulsion has been the one area that we spent the longest time developing because we needed thrusters that had more thrust. The conversion to the Blue Robotics T100s has solved our thrust issues, but created a variety of other time consuming design problems. To use the T100 thrusters, they need ESCs (electronic speed controllers) that are not waterproof. Our first attempt to waterproof the ESC was to encase them in acrylic. This worked, but it was very messy and did not produce a professional looking solution. To create a more professional look, we upgraded to using an electronics enclosure in our frame that housed the ESC's so they were all combined into one area neatly. Two of the thrusters are located in the upper back of the frame for forward and backward motion as well as turning left and right. The other two thrusters are located on the midsection of the ROV between the enclosure and edge of the frame for upward and downward motion. These four locations allow for optimum maneuverability and speed.



We designed our frame to be as hydro dynamic as possible, in the process we placed our thrusters to best accommodate our design and to achieve strong propulsion.

Linear Measuring Devices

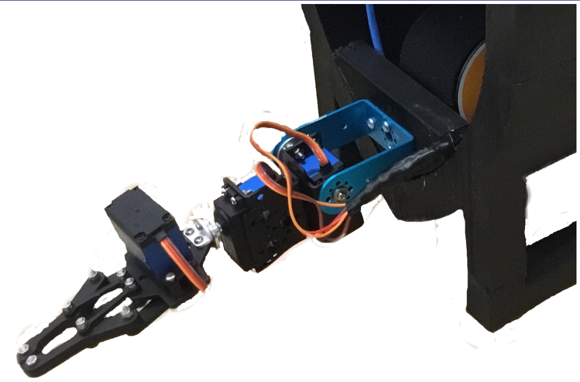
Using our experience from previous MATE international competitions where measuring was required, we created a new and improved liner measuring device. Until recently, we have struggled with measuring and could never figure out an efficient way to collect data. When studying the mission, we innovated a design that utilizes the straight and clean edges of the tape on the dam mission prop. This year, we decided to create a measuring device using two 35cm segments cut out of a meter stick. We positioned and fused these two segments into a crossed pattern in order to easily measure cracks at any angle. The Wildcat 4.0's manipulator will then be able to grasp the handle located at the center of the measuring device, and rotate the device when necessary. This measuring device ensures our ability to measure the longest of cracks at 35cm quickly and accurately.



The simplistic design of our measuring device makes it easy to work with and extremely reliable.

Mechanical Grabber

We equipped our ROV with a three-directional mechanical grabber. This design allowed our grabber to work in three points of rotation. Shortly after our regional event the grabber experienced a catastrophic failure that rendered it inoperable. Faced with a budget decision to repair or adapt, the team decided to adapt. Our team has a research ROV that we use for our cooperate outreach projects that is equipped with a mechanical grabber. We removed the grabber and adapted it to our competition ROV in order continue to prepare for the competition. Our ROV is currently equipped with the Blue Robotics Newton Subsea Gripper, a reliable aluminum grabber that has a liner actuator inside. This linear actuator uses a single PWM signal to open and close the claw to the maximum width of 7cm. The extension of this claw allows us to take hold of all objects throughout our mission. Along with the extended range of motion, this actuator also allows a grip strength of 124 newtons which is much stronger than previous years. This strength ensures reliability when carrying heavy objects from the pool floor to the surface. Overall, this grabber reduces time and difficulty when completing the mission.

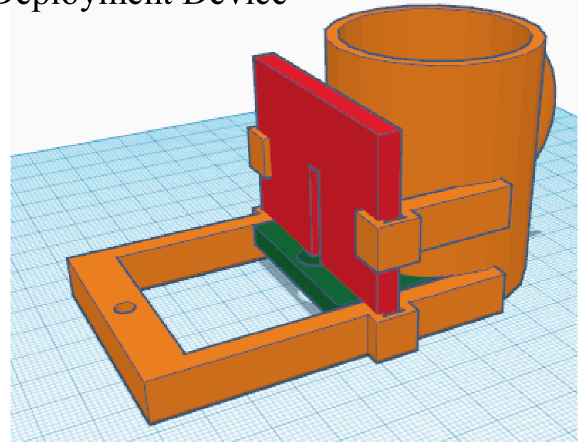


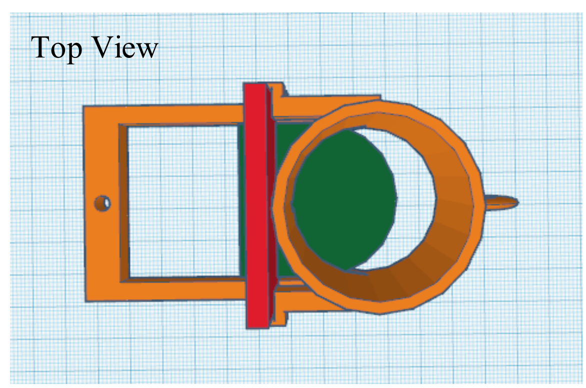
Our three-directional mechanical grabber was built specifically for this year's mission tasks for the placement of the caulk and delivery of the live trout.

Fish and Grout Deployer

Finding a fish deployer that can also act as a grout deployer was very important to our team this year. Being able to use the same tool for different tasks help save money while also being efficient. The design we chose for our deployer is made out of 3D printed ABS plastic (The same material as our robot frame). We then connected a 1/4in fitted piece of polycarbonate sheeting to the side of the 3D printed cylinder. This sheet moves up and down feely on the side of the cylinder depending on the amount of force pushing up on it. When the force hits the sheet, it moves up and allows the bottom of the cylinder to disengage from its position, allowing materials inside the cylinder to fall out.

Deployment Device





Pictured above is our fish and caulk deployer is a scaled down version of our actual fish deployer we use to release brown trout on a reef in Thunder Bay.

Micro ROV

- Frame is composed of a 2mm gridded stainless steel material for a strong support structure.
- Two drive wheels are created from two Blue Robotics T100 thruster motors.
- Control system is comprised of an Arduino processor with two electronic speed controllers.
- Colored camera with LED lights provides for clear vision to inspect enclosed piping.
- 15m tether with built in retractor.

The intended design idea behind our micro-ROV was to think about a vehicle that would move quickly, be direct, and would have a minimal impact on our overall development budget. We went through our leftover parts and pieces, gathered what we thought would be useful, and started making prototypes. We developed three micro-ROV in all. The first was a traditional ROV design with four thruster we created with some left over motors and an extra control box we had from a teacher workshop we hosted. We took our original ROV frame design, reduced the size to twenty-five percent and 3D printed the frame. The second came from our inner-LEGO and is a small tank driven robot that we sealed motors into a tradition LEGO tank-type vehicle. This worked as well and cost almost nothing, but it was a slow. The third design focused on using parts from our pervious ROV control system of Blue Robotic T100 motors and Arduino control system.

The next step was determining which vehicle would best complete the mission. All the vehicles fit our original design criteria, but only one was capable of meeting the time requirements for the mission. We decided to go with our third design because of speed and the Arduino allowed us to adjust vehicle control through the manipulation of the operation program.

Located at the back of the Wildcat 4.0 is our Micro ROV's docking system. The diameter on the circular docking system is 5 inches. This design will allow for an easy deploy for inspection into the drain pipe.

The control box for the Micro ROV is equipped with a to 360 joystick. Inside of the control box is the Micro ROV's monitor and power cord that plugs into the on surface battery. Also located inside of the control box is the red board

Camera Design and Placement:

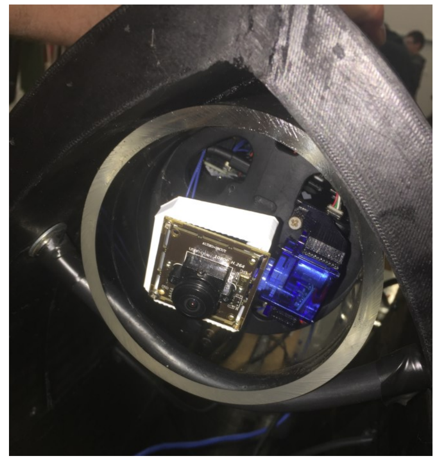
Mounting the cameras has always been one of the last things we attempt to do on the ROV. Our new 180 degree camera is placed at the front of our waterproof enclosure, which is shaped like a dome, giving us a full view of the area we are working on in front of the vehicle. Last year we had trouble with finding space for the camera and it was difficult to mount.

This year, we made our own camera mount with a 3D printer. The camera sits on the 3D printed mount and is attached to a servo that allows this 180 degree viewing angle. Unlike other years where we had multiple cameras because we needed to see tools inside the ROV, this year we have designed our ROV so that all the tools are in front of the ROV and in perfect viewing angle of the ROV.

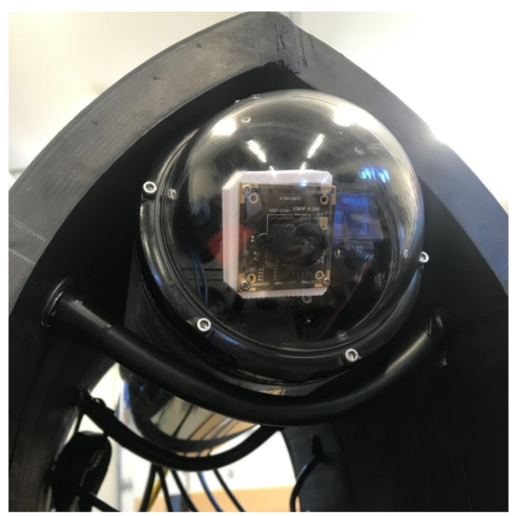
Using one camera instead of multiple cameras eliminated costs of purchasing other cameras, and it also reduced the weight of the camera cords. Those two variables benefitted both the budget and the weight requirement.

Another exciting new element this camera has is that it is run through the raspberry pi on board our ROV. The camera's monitor then becomes the computer the pi is connected to, and this has the capability to produce the position of the ROV on the screen as well as what cardinal direction the vehicle is moving in.

Being the one of the last components taken care of in previous years, the camera normally got the least amount of design consideration because we are trying to get the ROV in the water to perform test runs. This year however, we realized the importance of our camera design and made it one of our number one priorities.



Using a servo mounted camera provides the pilot with a great degree of view. Having the whole unit contained in the enclosure proved to have some technical challenges, but eliminated any need for waterproofing. This greatly increases reliability.



The location of the dome on the front of the ROV allows the camera to see all our mission specific tools.

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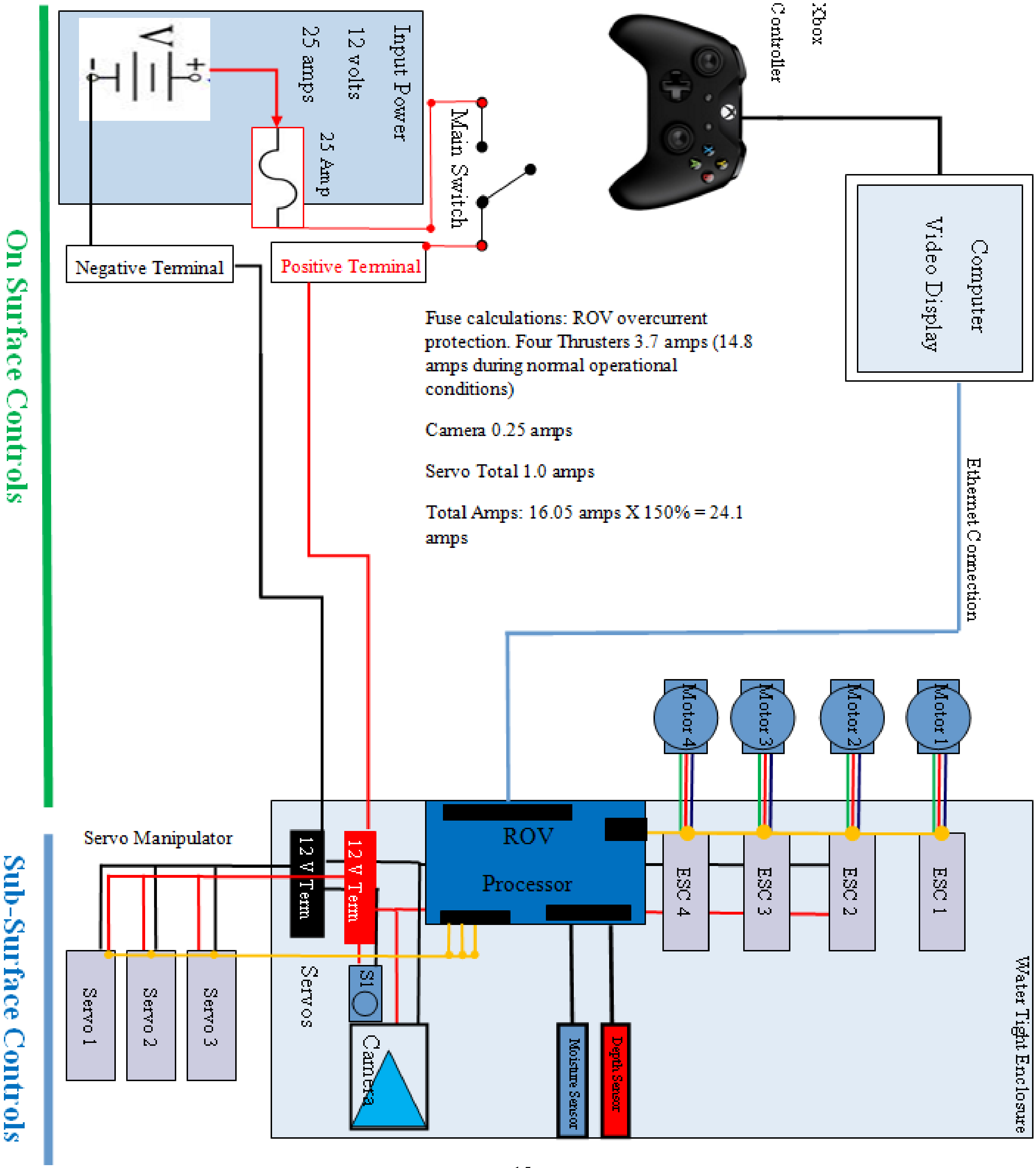
System Integrated Diagram (SID)



Company Safety

The Underwater Research Robot Company's goal is to provide a safe and positive working and learning environment. Each company member must practice the three safety rules we came up with together as a team. First, proper clothes must be worn while working on and with the ROV. This includes safety goggles, closed toed shoes, and long pants when working with cutting tools, soldering equipment, and industrial glues. The second rule is that no company member works on the ROV while it is connected to power in order to avoid any mishap that ends in injury. Our last safety rule is to clean-up after yourself. The rare injuries that have occurred in the past involve someone slipping or tripping on something that was left on the floor and not put away. It can be as simple as pieces of PVC tubing that are left on the floor for someone to slip, fall, and injure themselves.

At our company work space, we work to maintain a safe and friendly work environment. Robot Factory Research teams have their own assigned area to store equipment and projects.

Our motto is that a safe company is a happy company and a happy company leads to positive productivity. We have a great company, but if we don't have everyone on the team working together, that puts us at a disadvantage. This is why it is important for us to have consistent safety practices. Our Safety Check Sheet (Page 17) is an example of our dedication to maintain a safe working environment. Also, we have appointed our CEO as our safety officer. She has our company's permission to stop work at anytime if an unsafe condition starts to arise.

As a company, we wanted to ensure that safety extended not only to our working environment but onto the actual ROV itself. The vehicle incorporates two strain reliefs that prevent the tether from being ripped out. The first strain relief is located on the back of the ROV and is a simple carabineer clip that clips on to a cable thimble. This set up attaches to all the wires coming out of the enclosure preventing strain. The second strain relief is attached to the side of the control box so the tether is securely attached. The ROV also has an in-line fuse that is positioned 30cm from the point of power. Both of the top thrusters are surrounded with yellow and black warning tape as a visual warning to anyone around the ROV. In addition, all of the thrusters have a 3D printed guard over them so that no fingers can enter the vicinity of the propeller. Finally, all of the ROV's edges are rounded so there is no risk of anyone cutting themselves while picking up or working with the frame.

Our goal is to make every member of our company aware of situations that may lead to an injury or damage to equipment.

UR² Safety Check-off Sheet

Checklist Items	YES	NO	Action Required
Electrical schematics & power distribution diagrams	☐	☐	☐
Technical report	☐	☐	☐
RANGER CLASS SAFETY CHECKLIST (safety inspection)	☐	☐	☐

Part 2: Physical

Checklist Items	YES	NO	Action Required
All items are secure to ROV and will not fall off	☐	☐	☐
Hazardous items are identified and protection provided	☐	☐	☐
Propellers are enclosed inside the frame or are shielded that they will not make contact with items outside of the ROV	☐	☐	☐
No sharp edges or elements on the ROV that could cause injury to personnel or damage to pool surface	☐	☐	☐

Part 3: Electrical

Checklist Items	YES	NO	Action Required
Single attachment point to power source	☐	☐	☐
25 amp single inline fuse, no frays in tether or conductors.	☐	☐	☐

Testing and Troubleshooting

A problem we faced this year came with wiring the enclosure. With so many wires involved in ensuring the Pi and Pikhawk received power and proper connection, it is always difficult trying to figure out exactly how many wires are necessary. Once we did figure out how many wires we needed, the next step was to actually start wiring. We got halfway through the wiring process only to find that the wires had been cut too short and could not be used in the enclosure. In addition to the short wires, we consistently re-wired our camera, control system, and power supply to make modifications and this led to us misplacing the wires at times. We often had to look at our diagrams and assess whether or not our wiring was correct.

The next problem we faced was programming. Developing a more mature control system has brought the team many challenges. The first problem having to learn how to code in Python because, we had never worked with a Raspberry Pi operating system. Due to unfortunate outside factors, coding with Python revealed to more time consuming than we had anticipated.

So in light of this situation, we decided to switch over to Q-Ground control; a drone software system. By using Q-ground control we were still able to use our Xbox controller, Rasberry Pi and Pixhawk. In general we did not lose any additions to the control system we wanted, but we gained some unanticipated functions we would not have had access to if we had used Python. Because Q-Ground control is run off of a lap top, we gained a monitor with high quality display and an easier system of trouble shooting and detection problems with the software system. Because of the type of lap top we were donated to use was a windows, we gained Speech Application Programming Interface, this feature notifies the pilot of how much gain the Rov is at when being operated.

Setting up the Q-ground control was not simple. We learned how to wire the new system by placing all the hardware on a practice board. By having all the wires spread out and neatly organized, it was easier to learn where everything belonged in the enclosure.

Thanks to the practice board, testing, and research, we were able to finish the wiring and develop a software that worked. This accomplishment was extremely important to our team because last year we were not able to overcome this challenge. Learning from our mistakes and solving these technical challenges at the beginning of the season heartened our team for the year and boosted our confidence in our abilities.

(Above) Wenton Harrison trouble shoots problems brought about by the Micro ROV.

Challenges

Three of our greatest challenges were working to on the Micro, working around everyone's schedules, and trying to compensate for lost time due to the government shut down and terrible winter weather.

All of our team members are involved in other academic activities and sports so our meetings had to take place in the evenings. Additionally, due to multiple different sports practice times, even meeting at night can make having everyone together at one time next to impossible. This makes it extremely difficult to develop and share ideas so, while we try not to miss sporting events or extracurricular activities, we often have to miss other activities in order to meet the overwhelming responsibilities and needs of engineering an ROV.

(Above) Abby O'Brien check the enclosure for any air leaks.

One of the most difficult technical challenges facing the team this year was the Micro ROV. Initially we knew that we wanted to try and manufacture a system run by fiber optics, but we were challenged by how we would accomplish that. To better understand the Micro ROV we watched the MATE Facebook live stream on the Micro ROV and its tasks to understand the basics. This allowed us to understand the design of the Micro and what we needed to accomplish to build the fiber optic system.

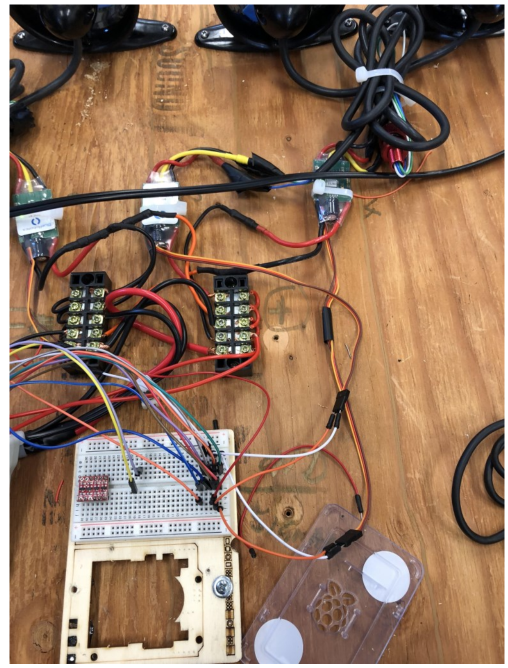
We then gradually worked our way up to an fiber optic system by building an Ardu Sub system. Taking the time to build the Ardu Sub system helped us understand what kind of we were working with and how to build it. It was critical that we understand as much as possible about the Micro ROV as there is not a lot of project research available to the public that outlines Micro ROVs. Unfortunately, we did not fully accomplish the Fiber optic system due to time. Because our work shop is at Thunder Bay National Marine Sanctuary we lost a substantial amount of work time due to the government shut down. In addition to this the horrific winter weather experienced by Northern Michigan caused us to miss ten practice days. Overall, the Micro ROV was the hardest part of this years mission because of the leap we took to run a system of fiber optics. But in the end knowledge and experience was gained and that is an accomplishment in itself.

(Above) Mady Gohl resets the orientation of the ROV.

Lessons Learned

The first lesson we learned this year, on the technical side, was to carefully monitor the power wires in our ROV. After a power malfunction last year that resulted in several blown fuses and an incapacitated ROV during competition, we learned that we needed to assess the power wiring in our enclosure and control box. This long process gave us time to re-learn the basics of power systems and better our wiring in general. It also taught us to never trust a first-time wiring job and to always double check everything. This year, we feel much more confident in the wiring of our robot and can safely say that it will not be stopped by a blown fuse.

On an interpersonal level, our team learned the lesson that effective communication is essential to being able to build a well designed ROV. As mentioned previously, our team members are extremely involved in other community activities on top of ROV. This meant that sometimes team members had to miss a meeting, or even multiple meetings in a row. There were also times certain team members had to leave a meeting early or come to a meeting late. With so many people coming and going at all times, it became difficult to know what had already been done and what was still left to do. In order to combat this, our company created a board and wrote down everything that still needed to be done. Notes could also be left on the board to clarify any topic or specify who should be completing a task. Once a task was completed, it was crossed off and the next task was started.



Since wiring is such an important part of building an ROV, our team has learned to become extremely conscious of making sure all wires are properly connected.

Reflection

Overall the Wildcat 4.0 is a well designed ROV with top notch maneuverability, efficiency, and speed, but as with any robot, there is always room for improvement. In the future we would like to design a frame that has easier access to all of its parts. The ribbed design of this years frame was excellent for housing the acrylic enclosure, but it also meant that anytime we wanted to adjust other parts, such as the mechanical grabber or thrusters, the whole frame had to be dismantled. If we could design a frame that did not need to be dismantled to modify its parts, that would save our team time that could be used towards other efforts.

Another non-technical improvement that our team would like to enact is a stricter schedule. This competition season, our team spent a lot of time experimenting with different parts and tools we could potentially use on our robot, and because we spent extra time experimenting, that set us back on finalizing the tools we were going to use. The setback of completing our robot meant that it was not ready to start practice mission runs in the pool by the date we had previously planned on. Having more time in the pool to practice the mission would be preferable for future competition seasons so that our pilots feel completely prepared to take on the product demonstration during the competition.

Underwater Research Robot Company

Underwater Research Robotics is a non-profit educational research company. Our team's goal is to construct an ROV that is functional and cost effective. The money to purchase new parts was obtained through private donations totaling $1,500. There were also other private donations including the laptop and pool time. We only spent a total amount of $723 on new parts. Because our team is now going on eight competition seasons, we have accumulated a multitude of parts available for reuse. The total value of reused parts on this years ROV is $1,435. The total value of our complete ROV unit is $2,006.

Category	**Description**	**Cost or Value**	**New or Reused**
ROV Structures	ABS Frame	$125	New
	Enclosure and Electronics tray	$252	Reused
Propulsion	4 T100 Thrusters	$440	1 New and 3 Reused
Electronics	4 Electronic Speed Controllers	$100	Reused
	Raspberry Pi	$40	New
	Pixhawk	$85	New
	Xbox controller	$25	Reused
	3 Servos	$150	New
	180 Wide view Camera	$65	Reused
	Wiring	$50	Reused
	Arduino Uno	$30	Reused
	4 Penetrators	$16	New
Tether	Mesh Casing	$53	Reused
	Fantom ROV tether cable	$20	Reused
Mission Tools	Micro ROV	$50	New/Reused
	Grout and Fish Deployer	$10	New
	Measuring Device	$10	Reused
	Lewansoul LeArm Robotic Arm	$130	New
Miscellaneous	Pelican Case	$160	Reused
	Diving Weights	$50	Reused
	Laptop	$200	Reused

The costs below include other competition season expenditures that were not used in the manufacturing of the ROV.

Category	Description	Cost or Value	New or Reused
Extra Parts	4 Test Servos	$72	New
	Backup Pie Board	$55	New
Competition Costs	Competition Registration	$150	n/a
	Printed Poster Board	$25	New
Travel Expenses	Great Lakes Regional Competition is in the same town as our workshop	$0	n/a
Other Expenditures	Pool time	$900	n/a

The table below displays a financial summary report

Purchased Items	$723
Value of Reused Items	$1,435
Total ROV Value	$2,006
Total Competition Expenses	$3,208

The table below displays a donation and funding report

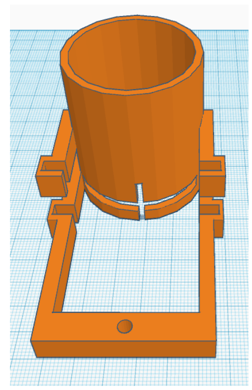
Air Designs Donation	$500.00
Upham Foundation Donation	$1,000.00
NOAA (Inkind: Faculties and Utilities) Donation	$10,000.00
2017-2018 Financial Donation Total	$1,500.00
2017-2018 Inkind and Donation Total	$11,500.00

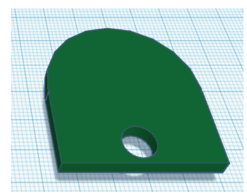
Build vs. Buy

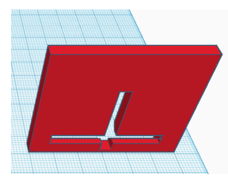
When we were contemplating how to design a mission tool the first thing we think about is, how can we build it? As a company we believe that you develop a better understanding when you build vs buy. For example, instead of buying a tool to deploy the fish, we first consider our options by outlining the design criteria to develop a project cost. We create drawing and ideas select a few to develop a simple prototype. In developing the tool we look at want could we purchase to save time or is there even anything out on the market that could do the job. In this design we chose to build because nothing existed that would help us with completing the task.

In using the fish deployer, we partnered with our junior Ranger ROV team, Hur-On the Bottom, for some friendly design competition. This saved us time and money for both teams reducing the number of team members working on the project for both teams. The results of the collaboration created a dual purpose deployer that not only deploys the grout, but the live fish as well. The act of us designing this gives us the benefit of designing the tool to fit out robot, not the robot to fit the tool.

Evolution of the Deployment Device







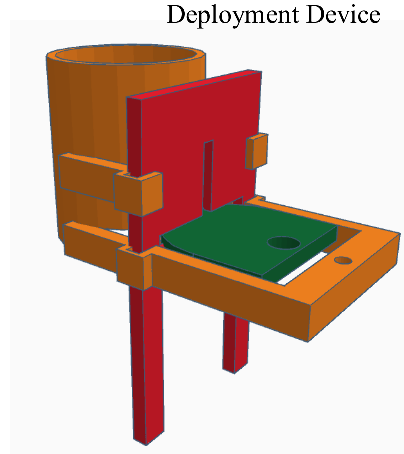
The main body started as a large plastic cup, but it required a way to trigger the bottom to open. The design was created by Sam Cook an Eighth grader from the other team. The bottom was a trap that pulled forward when activated from below. The problem was you had to sit the deployed on the ground to get it activated.

New vs. Reused

When we do decide to purchase tools, we buy it for its reliability. Such as the Raspberry Pi, and Pixhawk. The benefit is buying these items guarantees us efficiency and reliability. In the development of this year's robot the budget was a main point of focus. When deciding what to reuse, we select the tools that have proved to be reliable and efficient. We reviewed and found that reusing the Ethernet cable, Xbox controller, Laptop, Teather, T100 Thrusters, Enclosure, Dome, Camera, Pelican box, manipulator skeleton and temperature probe would save our company a substantial amount. The only time our team invest into new tools is when we want to make an advancement as a company or replace a tool that is damaged. For example, our team invested in a new depth sensor and leak detector to improve upon our robots safety features. These were purchase item simple because they were safety items and we wanted to eliminate any malfunction risks.

Joint Team Revision

Deployment Device



The legs on the trigger plate allow the cargo hopper to be placed directly over the target providing room to fill the crack with grout.

Negwegon State Park Project

One of our newest projects is the Newegon Project. The main goal of this project is to spread knowledge of the historical significance of Negwegon State Park. Negwegon State Park is one of the last undeveloped State Parks in the country. Within this natural gem is the home to many rock formation that are believed to have been built during the last Ice Age, or 9,000 years ago. In collaboration with Michigan Sea Grant, our team has worked to map and created a 3D diagram of this area to put in the local museum, Jesse Besser Museum, to promote Native American History and Culture.

Abby O'Bryan (Above) with Hannah Hazewinkle, Thunder bay National Marine Sanctuary's Great Lakes Stewardship Initiative leader, and Brandon Schroeder, Sea Grant Extension Educator at Michigan State University explore and survey Negwegon State Park.

The Brown Trout Project

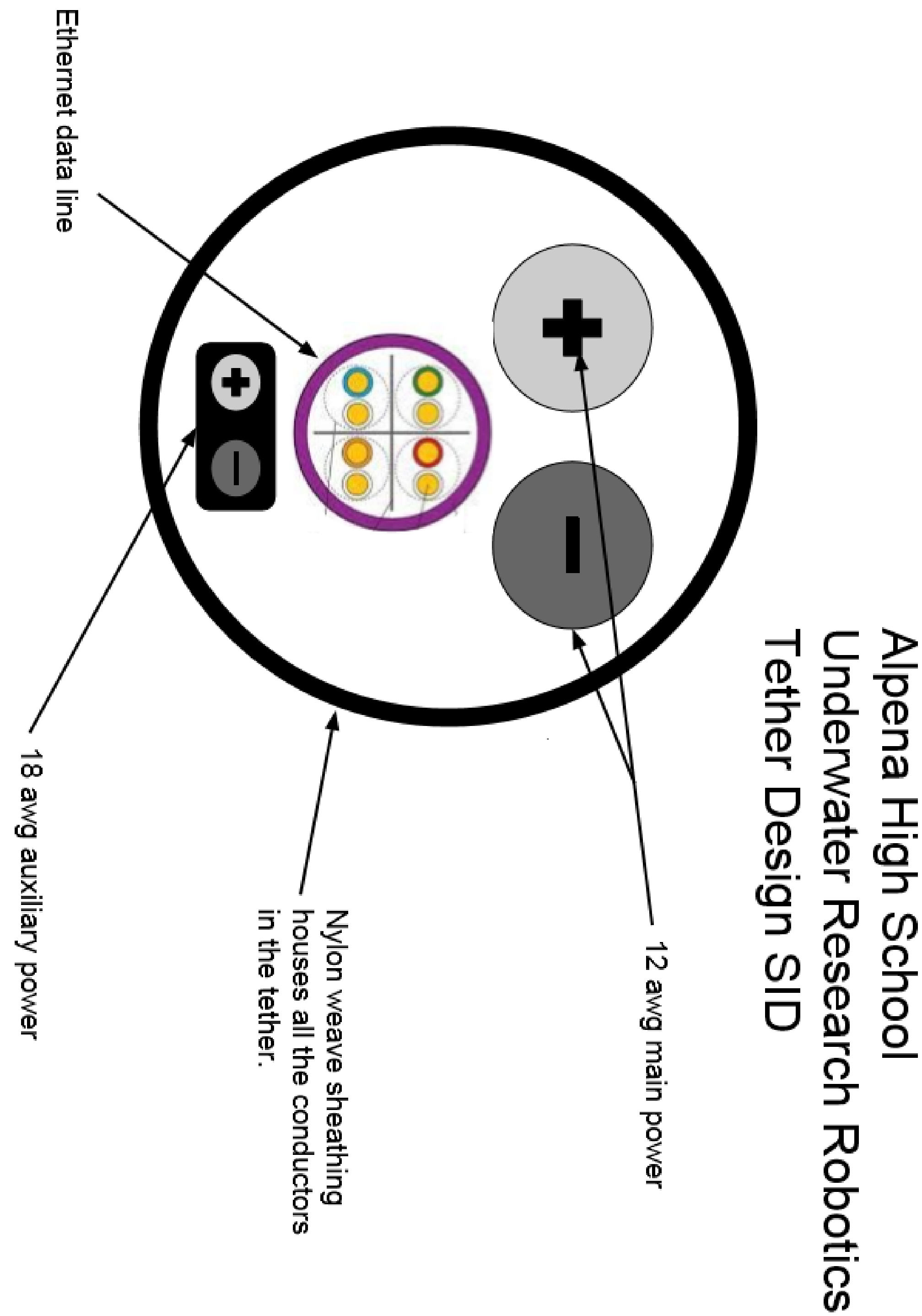
As a team we produced a fish deployer system that would deploy Brown Trout to a reef located at the bottom of Thunder Bay. We contacted the Department of Natural Resources and told them about our project, from there we had received permission to transport these Brown Trout fry. Our Brown Trout we're originally raised in tanks located at Ella White Elementary in Mentor Robert Thomson's classroom. This collaboration allows our team to introduce ROV's into a classroom atmosphere. The children in this class climb aboard the Lady Michigan and use our EDU (educational) ROVs to release the fry onto reef in Thunder Bay. Because of hard work and collaboration from our team, we deployed the fish safely to the reef.

Photo of brown trout fry in Mr. Thomson's 5th grade classroom.

Overall

Our team values community outreach. It is our number one priority to give back the community. We hve experienced many unique experiences because of the support from our community partners. Just recently we received an opportunity to cooperate our one of our project with Dr. Robert Ballard and learning how he is using autonomous ROVs to collect data in the Channel Islands. We are truly grateful and want to pay our gratuities in full by giving back.

(Above) Savannah Thomson and Joshua Beatty presenting to, Matt Brookhart, regional director of the National Oceanic and Atmospheric Administration's Office of National Marine Sanctuaries, John Armour, director the Office of National Marine Sanctuaries, and Rear Adm. Tim Gallaudet, NOAA's assistant secretary and acting undersecretary of commerce for oceans and atmosphere, show off their ROV and discuss their community outreach.


Alpena High School
Underwater Research Robotics
Tether Design SID
Ethernet data line
12 awg main power
Nylon weave sheathing houses all the conductors in the tether.
18 awg auxiliary power