Underwater Research Robot Company

Alpena High School Underwater Robotics Club

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Mentor	Robert Thomson
Mentor	Katie Thomson

Abstract

The Underwater Research Robot Company (UR^2) considers our highest priorities to be safety, innovation, and environmental preservation and research. Our team is comprised of fourteen determined and skilled students, ranging from ninth to twelfth grade, who are dedicated to helping the Applied Physics Laboratory at the University of Washington preserve the resources of the Pacific Northwest.

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 ribbed frame that holds an acrylic enclosure, and a three-directional mechanical grabber. Our control system, a Raspberry Pi processor 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 High Density Polyethylene frame features four T-100 thrusters, with two positioned vertically and two positioned horizontally. In addition to having our frame 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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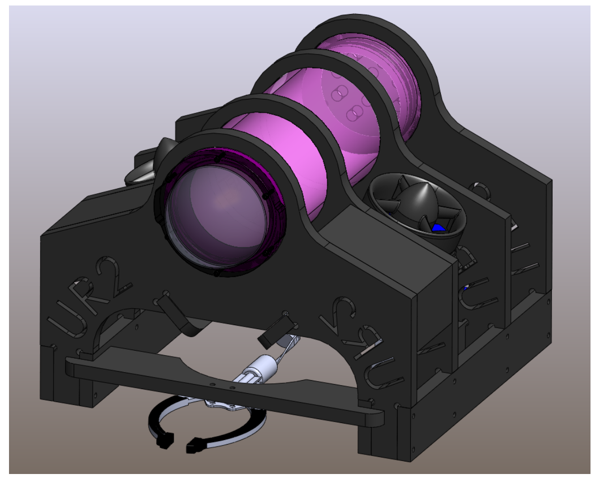
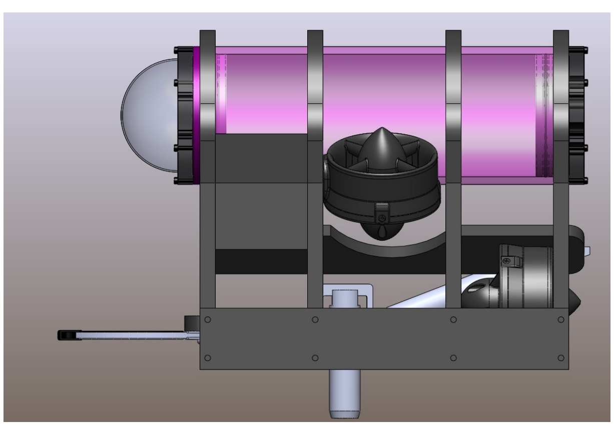
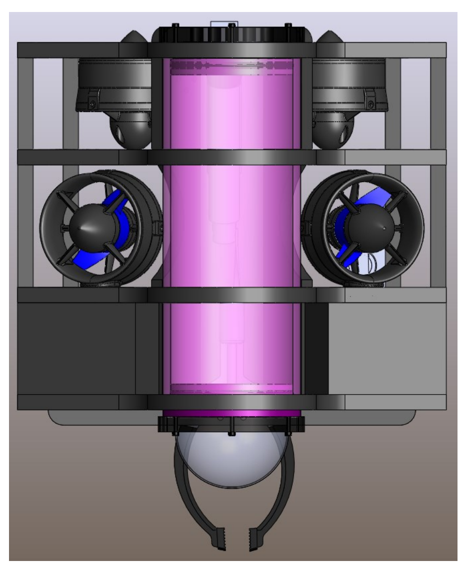
Wildcat 3.0



Front View



Side View



Top View

Underwater Research Robot Company

Understanding the ROV

The Underwater Research Robot Company (UR^2) is committed to fulfilling all research needs. Operating in the Puget Sound of Seattle, Washington, 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 lakes and bays. Our engineering team has developed an ROV that can assist with the identification and removal of crashed aircraft to help restore the natural habitat of the crash site; build, release, and recover an Ocean Bottom Seismometer (OBS) to help monitor the earthquake activity in the Puget Sound; install a tidal turbine at the optimum location to help generate renewable energy in the area as well as install an Intelligent Adaptable Monitoring Package (I-AMP) to monitor the area; and finally collect eelgrass samples for analysis.

In the development of our current robot, the Wildcat 3.0, our engineers focused on designing an ROV that was capable of completing research related tasks and industry related work.

Our frame, designed out of High-Density Polyethylene (HDPE), will not expand or contract under extreme temperature changes like normal plastics. We have worked with many different framing materials, but our research has shown that HDPE has yielded the best results. The ROV's ribbed design houses an on-board watertight enclosure in order to confine all electronics and electrical connections to one area on the ROV. The enclosure holds a 180 degree camera, electronic speed controllers (ESCs), and the auxiliary processor. Our 180 degree camera and mission specific tools allow us to install equipment, identify debris, and collect samples accurately and efficiently. Encasing all of our electronics in the enclosure, we were able to reduce the weight and width of our tether. Our overall design focused on developing an ROV that is compact and light in order to easily transport it in any work environment. UR^2 is committed to providing reliable and useful research platforms capable of ensuring our clients accurate and trustworthy data. The Underwater Research Robotics Company is the answer to your research needs.

Acknowledgements and References

Thank you very much to:

Our SolidWorks Mentor

- Quade Kimball

Technical Advisors

- David Cummins: Alpena Community College
- Martha Schumann: Uber Technologies Inc.
- Paul Coleman

Team Support

- Thunder Bay National Marine Sanctuary
- QSR Outdoor Sports Inc.
- Marine Advanced Technology Education Center
- SolidWorks Corp
- All the volunteer divers and NOAA staff members that make everything possible.
- All the MATE Volunteers who dedicate their time to ensuring a safe and fun competition.

References:

"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 Tara and Karli Myers.

This year, our team came together to build an ROV that was superior to our previous models and would allow us to advance in the rankings.

With a team as large as ours, there are often meetings where 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 including what still needs to be started or finished, we maintain a board in our workshop of all the tasks along with 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 google team 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 informed on what has been going on at meetings.

One of the benefits of having such a large team is that we can all specialize in certain aspects to better the productivity in the team. The team is divided into three main areas. The software team is comprised of four members with Katie Nicholson at the head. The software team is in charge of all the coding along with wiring involved in the ROV. The engineering team is comprised of six members with Savannah Thomson as the Lead. These team members are responsible for all the hardware in the ROV, mission specific tools, and the overall design of the ROV. The final team is the editorial team lead by Tara Myers. Comprised of three members, the editorial team is responsible for the technical document, the marketing display, the quality of all safety documents necessary for competition, along with any media outreach pieces. To oversee all progress taking place is our CEO Elizabeth Thomson. She works within all three teams when her advice is required. It is our CEO's job to know all current information about specific requirements and deadlines.

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. Since our robot includes Blue Robotics parts, we also used their website for reference. Our team has accumulated a lot of knowledge over the years, but we still reach out for help when absolutely necessary to complete a task.

(Above) Katie Nicholson and Lizzy Thomson adjusting the mechanical arm.

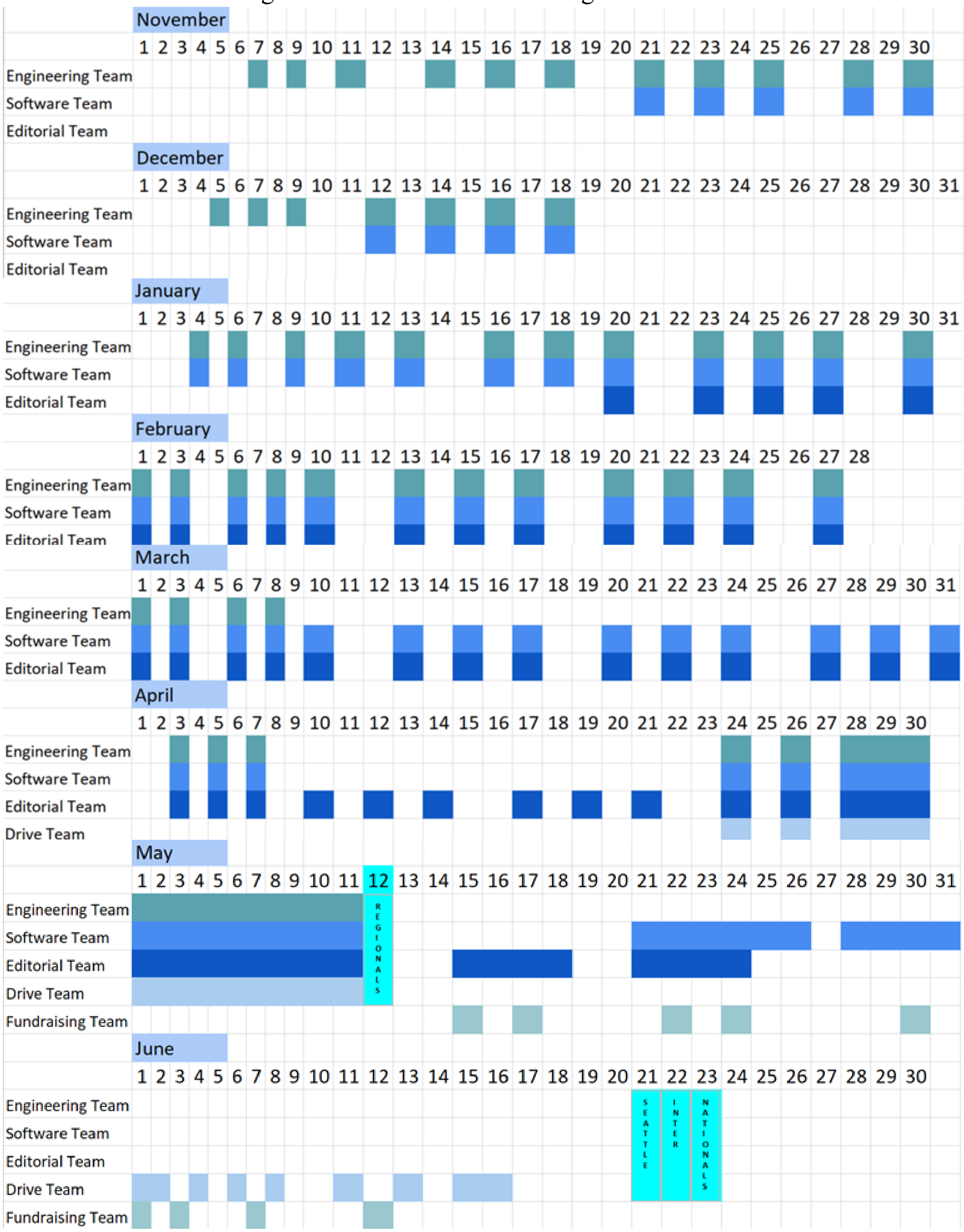
(Above) Tara Myers and Elizabeth Thomson updating the Google team drive.

(Above) Ian Shriner and Savannah Thomson collaborate with Paul Coleman.

Underwater Research Robot Company

Project Management: The Schedule

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 since the beginning of November of 2017. We also added a tentative meeting schedule for our June meetings.



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

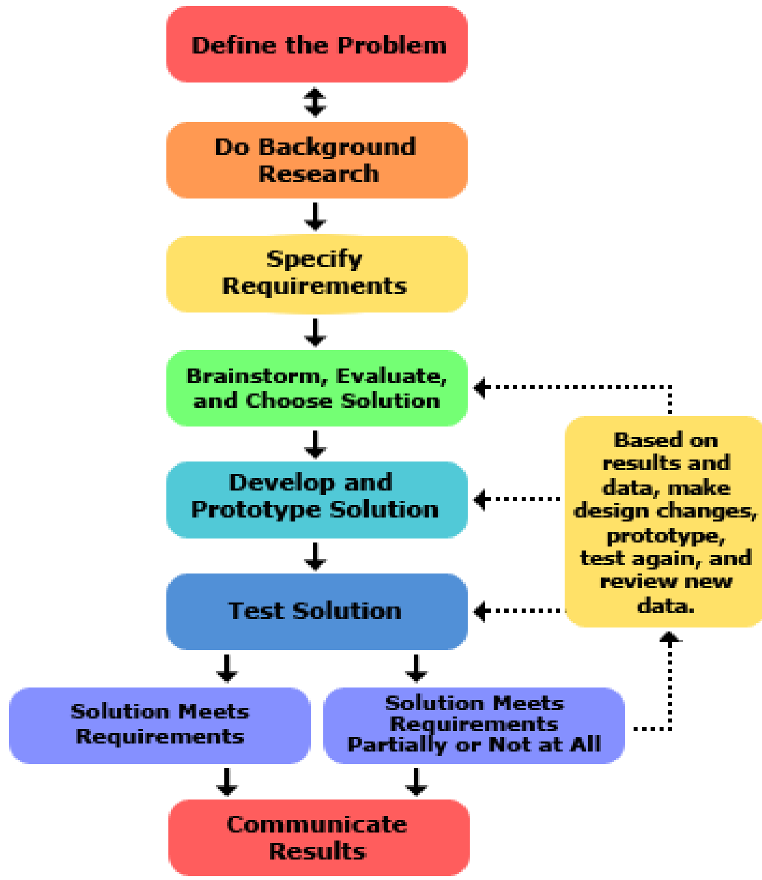
Brainstorm Solutions

Choose the Best Solution

Do Development Work

Build a Prototype

Test and Redesign



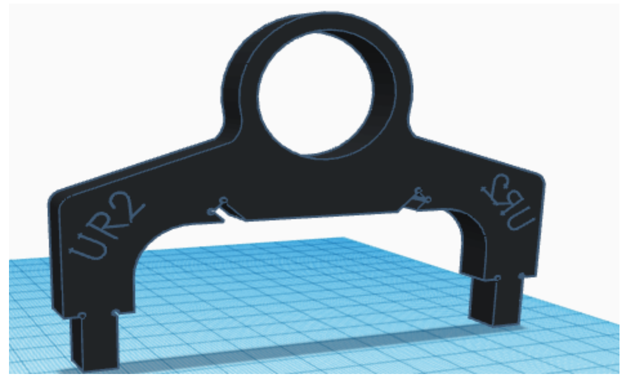
The UR² Company has experienced many successful research projects and competitive achievements, but in order to be more successful, we challenge ourselves with new ideas and technologies. The Wildcat 3.0 is our most sophisticated and site specific ROV that we have ever developed. The Puget Sound requires not only a vehicle that is equipped to complete the required tasks, but a vehicle that meets the criteria for both weight and size.

In order to meet these requirements; our design team had to start from the bottom up. This required a compact frame, reliable control system, and the development of very unique job site tools. Our frame is designed out of High-Density Polyethylene (HDPE). HDPE will not expand or contract under extreme temperature changes like normal plastics, and it also allows for easy modifications. With the addition of an on-board watertight enclosure, 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 is significantly decreased. Our overall design focused on developing an ROV that is compact and light. This design provides for easier transportation in any work environment.

To complement 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 OBS.

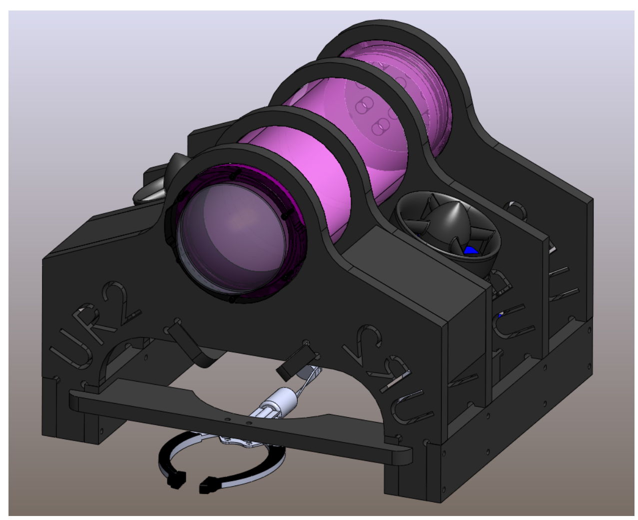
Frame Design:

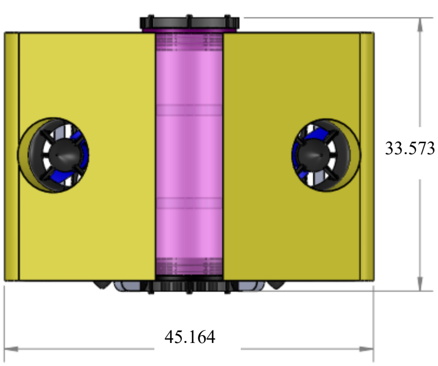
In the design process of our frame, we worked with a local fabrication company. The process began with a paper and pencil design to get a rough sketch of shape and size. Then we started modeling in SolidWorks to develop our original 3D frame design. We worked with a product engineer, Quade Kimball, who helped us design and modify our drawing. We wanted to design the ROV by developing it based on the mission criteria, and we chose the construction material High Density Polyethylene (HDPE) because it can be used in a variety of climate conditions.



The backbone of the ROV is these four rib structures that we designed to decease the amount of material being used, decrease cost, and give the ROV a stable structure to attach tools needed to complete the mission tasks.

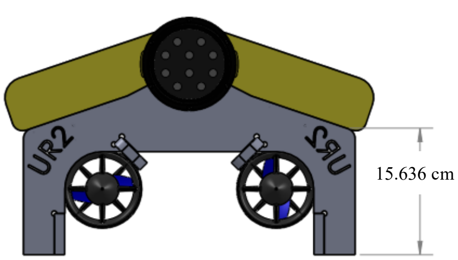
The frame design this year greatly differs from previous years as it was fabricated in pieces that can be assembled and disassembled. Unlike last year’s design, the frame is not a square format. Instead, the four ribs of our ROV wrap around the enclosure in the center of the frame to make the ROV more aerodynamic. Designed to be positively buoyant to ensure completion of the tasks, our ROV has two vertical thrusters placed at a 45 degree angle on both sides of our enclosure in the top along with two horizontal thrusters placed in the back of the ROV. We designed this frame to be slightly larger than the debris piles, that are required to be moved off the engine, so that way our ROV would be able to maneuver the debris piles efficiently and not lose balance in the water.





The final design phase of the Wildcat 3.0 frame structure was to attach as many of the necessary parts needed to make the ROV operational. Our technical mentor, Quade Kimball, provided software support and technical support in order to create a 3D rendering of the ROV before cutting any material.

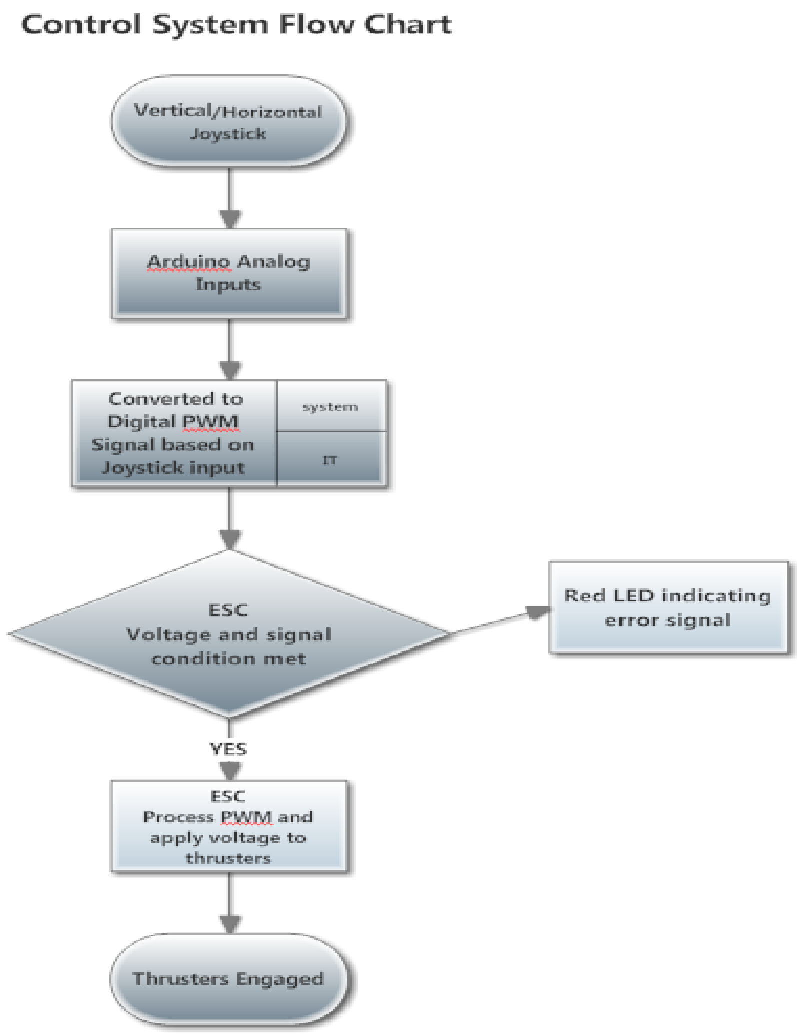
The frame is designed to fit within a 60cm diameter so that the Wildcat 3.0 is easily maneuverable and transportable from one location to the next.



Tether

This year's mission criteria made us rethink and consider ways to make the ROV lighter. The heaviest part of our ROV is the tether and to reduce the weight require a change in size and number of conductors that we use in the tether. We never considered changing the material the conductor was created from so we researched conductor material that had a high level of pure copper and a low level voltage drop. We decided to use Blue Robotics Shielded Fathom Tether, shorten the tether length to 15.24 meters, and remove some data lines from our control system to lose most of the extra weight and prevent a voltage drop along the tether.


(Above) Katie Nicholson testing the camera for a proper image production.

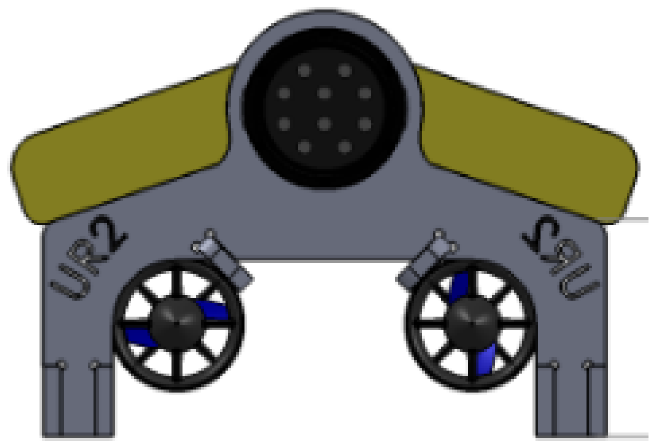


Control System

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 and camera. This system is compact and reliable, allowing our robot to operate quickly and efficiently. Additionally, reusing our Pelican waterproof case makes our ROV transportable, durable, and easy to modify. These new controls allow our pilots to drive the ROV to full capacity and make their job easier with the simplicity of the Xbox controller.

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 electronic housing 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 back of the frame for forward and backward motion as well as turning left and right. The other two thrusters are located on the top of the ROV between the enclosure and the edge of the frame for upward and downward motion. These four locations allow for optimum maneuverability and speed, which is critical when competing against the clock in product demonstrations. These thrusters allow our vehicle to maneuver effectively through the product demonstration landscape and achieve our goals.



We designed our frame to allow for the support to attach the T-100s in positions to proved the most efficient ROV control possible.

Linear Measuring Device

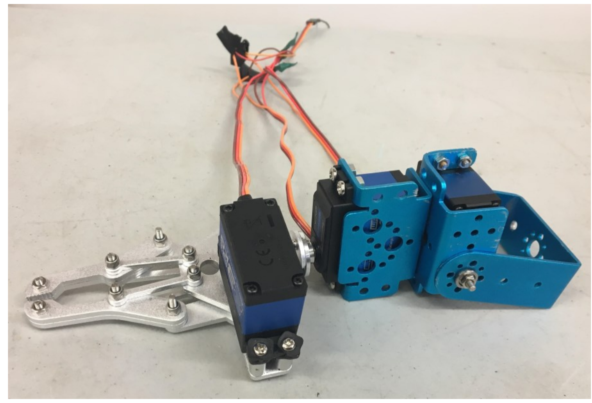
Using our experience from previous MATE International Competitions where measuring was required, we created a new and improved linear measuring device. Until recently, we have struggled with measuring for many years and could never figure out an efficient way to collect data. Now, we have designed and prototyped what we believe to be our best attempt at measuring yet. The designers had tried everything from string to motors when deciding how to measure the distance, but realized that they should just go back to the basics. The designers Ava Shriner and Karli Myers settled on taking an ordinary tape measure and attaching a curved metal rod to the first 15 centimeters, which allowed the hook to be strong and from its placement on the ROV it can be easily seen by the camera which makes the data accurate. We tested it out on our practice props to be sure it would work and found that it was successful.

The simplistic design of our measuring device makes it easy to work with and extremely reliable for measuring the distance from the base of the tidal turbine and measuring the distance the Acoustic Doppler Velocimeter is suspended at from the seafloor.

Mechanical Grabber

The ROV is equipped with a reliable aluminum grabber that has 3 servos attached to it. The three servos allow the grabber to maneuver on three different axis'. The open/close, up/down, and side to side functions all work together to move the grabber in a 360 degree motion to help us complete tasks. The three servos are Lewan Soul servos that are rated for 20 kg of pressure. This is especially helpful when trying to attach lift bags to the engine and debris. Rather than the entire robot moving the mechanical grabber acts like a human arm. The "joints" of the mechanical grabber allows easier access points to difficult tasks.

With the three different servos, it makes it much easier to complete the mission and it makes the ROV much lighter, which will allow us to fit into the weight requirement for the extra points. Also, with our arm's dexterity, it reduces our reliance on our entire ROV to have to move in order to use the grabber. Now, with the three servos, we can reduce the time and difficulty to complete the mission.

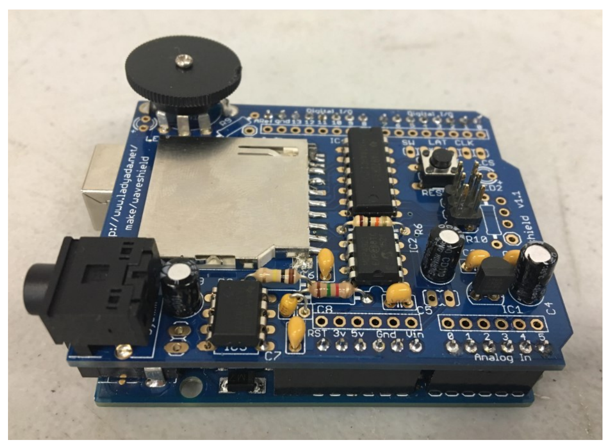


The servos on our mechanical grabber are much stronger than last years design and will not strip while to lifting heavy objects.

Ocean Bottom Seismometer

Our Frequency-Selective acoustic release Ocean Bottom Seismometer (OBS) is comprised of many elements. The first is a PVC housing with an Arduino Uno. The Arduino holds a code that allows us to transmit signals to send an acoustic pulse. From there it is connected to a microphone that will be listening for a specific frequency that will be emitted from our ROV and is received by the OBS and results in the release.

As soon as the frequency is received the servos connected to the Arduino will be activated, releasing the cable connector in its holder, sending the necessary part of the OBS to be ushered to the surface by the Wildcat 3.0 and collected at the surface by our poolside manager. The anchor of the OBS is constructed of PVC and bricks which effectively grounds the OBS. This allows us to work and become familiar with acoustic projects, while giving us maximum points for our OBS.



This Arduino uno holds the code for transmitting a specific frequency to release the OBS.

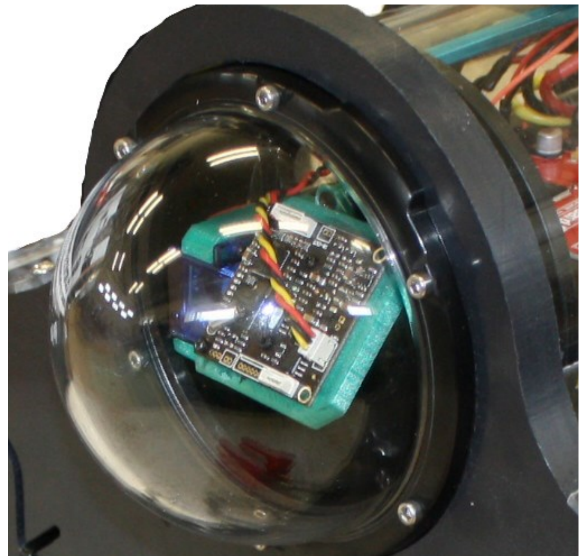
Camera Design and Placement:

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 for the 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.



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.

Lift Bag:

The design of our lift bag this year is simple, yet effective. We took a triple layer pipe and attached an endcap to one end and a tri-hook to the other end. The tri-hook is made out of a coat hanger that we bent into the tri-hook format and weighted down so that the hook does not shift in the current of the water. We were inspired to use this design from the competition five years ago when our team used a similar lift bag format. We chose to use the pipe because it is light and naturally buoyant, so we can get the most lift with the least amount of weight. The lift bag rises to the surface using a bike pump.

To complete the mission properly, we designed two lift bags. The first lift bag is designed with only one pipe which we use for lifting debris from the bottom, and the second lift bag is designed with two pipes so that we can ensure it is capable of bringing the engine to the surface.

Build vs. Buy
New vs. Reused

Build vs. Buy:

The Underwater Research Robotics team focuses on the cost to build vs the cost to buy. If we can build a part at less than what it cost to purchase the item, than we try to build it, but we also consider the weight, timeliness, and reliability of the item we are building before we initiate building because we do not want the expense of repairing or replacing a part if it breaks. We purchased our Blue Robotics T100 motors because building the motors would be very difficult, and we would not be able to seal the housing to meet MATE’s safety standards for the competition. We designed and built our frame from stock HDPE plastic rather than buy material to assemble a frame. We were able to partner with a local manufacturing company that let us use their CNN's machine to cut the frame parts. This saved us time and money. We purchased the majority of our control system components and assembled it ourselves. This saved us money and allowed us to have a deeper understanding of each component and its function. The most costly component of our robot is the computer used to interface with our on-board Raspberry Pi processor. We did not have the time to set up the surface control processor before the Great Regionals. In an effort to save time and avoid assembling, a process that was not reliable because of time constraints, one of our mentors donated an older Mac laptop to the company.

(Above) Blue Robotics T100 Thrusters allow the ROV to move efficiently through the water when competing. Photo curtsey of Blue Robotics.

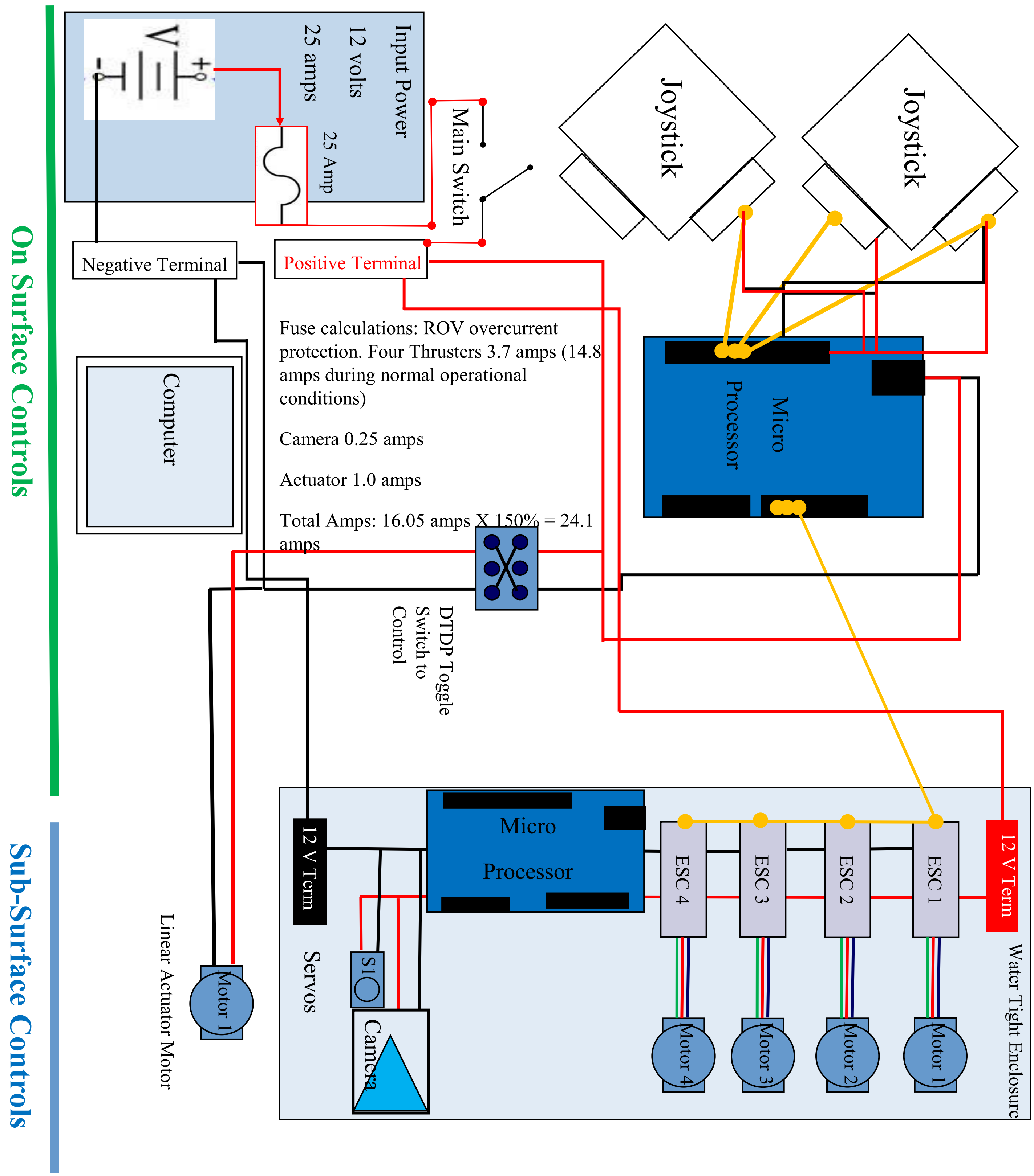
New vs. Reused:

This year we updated our control system. The older control system we use to mentor and teach a new Ranger team. We helped the new team use parts from our 2016 ROV to develop a robot the was capable of competing at the Ranger level. This allowed them to save hundreds of dollars on new parts. The T100s that we repaired from last year we left on the old ROV and purchased new. We reused two of the T100s and purchased two new ones. We also purchased all new ESC for this year’s build and left the old ESC on the 2017 robot. We left the 2017 robot in working condition to test props while preparing this year’s ROV for competition. Having competed for several years at the International level has allowed us to build a large surplus of tether material and electronics to reuse without the need to buy new materials which overall saves our company money.

(Above) Blue Robotics ESC’s allow the ROV to receive the appropriate signals requires for the ROV to maneuver in the water . Photo curtsey of Blue Robotics.

Underwater Research Robot Company

System Integrated Diagram (SID)



Fuse calculations: ROV overcurrent protection. Four Thrusters 3.7 amps (14.8 amps during normal operational conditions)

Camera 0.25 amps

Actuator 1.0 amps

Total Amps: 16.05 amps X 150% = 24.1 amps

Underwater Research Robot Company

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 any time if an unsafe condition starts to rise.

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 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 Arduino and Pi 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, being that we had never worked with a Raspberry Pi operating system before, was learning how to code in Python. While it was difficult, the Python language proved to be valuable for our team because of its straightforward syntax and language.

After mastering Python, we discovered that the Pi had trouble receiving input from the Xbox Controller. We learned this by writing and rewriting code that would move the thrusters and as soon as we added in the controller variable, it would fail. With the help of Martha Schumann - a programmer from Uber - we discovered that our Pi was having trouble maintaining the frequency needed to activate the thrusters.

Next, 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.

Katie Nicholson (above) working with the Pi and thrusters

Challenges

Two of our greatest challenges were working to on the OBS and working around everyone's schedules in order to meet this goal of creating a better engineered ROV.

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.

One of the most difficult technical challenges facing the team this year was the OBS. Initially we knew that we wanted to try and manufacture an acoustic release system, but we were challenged by how we would accomplish that. To better understand the OBS we watched the MATE Facebook livestream on the OBS and a manual release first to understand the basics. This allowed us to understand the design of the OBS and what we needed to accomplish to build the acoustic release.

We then gradually worked our way up to an acoustic release system by building the manual release, the reed switch release, the wireless release, and then finally tackling the acoustic release. Dabbling in all the release mechanisms helped us understand what kind of system we were working with and how to build it. It was critical that we understand as much as possible about the OBS systems as there is not a lot of project research that requires an acoustic release system and how to build one underwater. It was definitely our biggest challenge because it was out of our element and required us to do a lot of critical thinking and problem solving before we even began building.

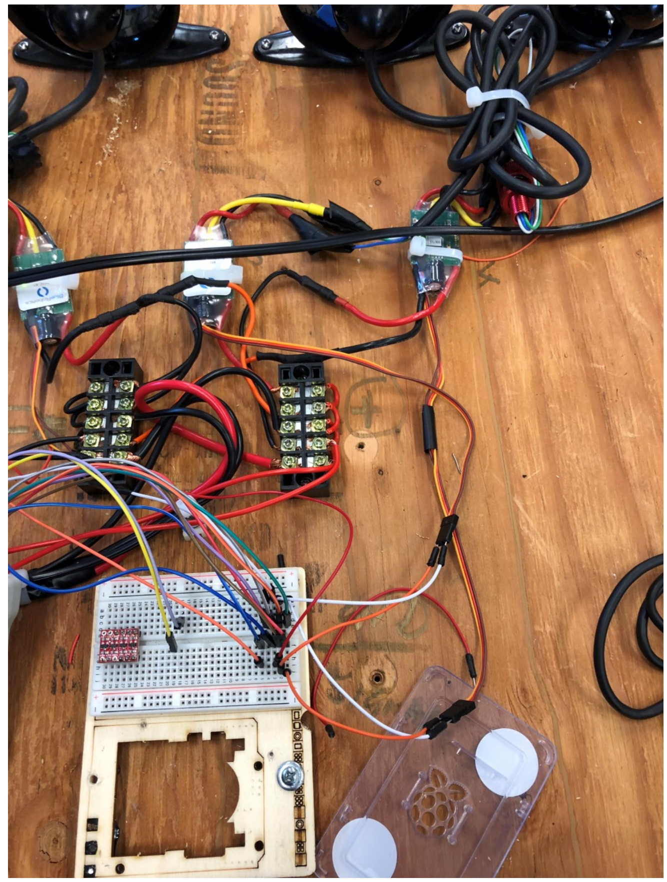
(Above) Ian Shriner and Savannah Thomson work on a manual release prototype for the OBS.

(Above) Katherine Nicholson reads up on how to transmit and receive frequencies for the acoustic OBS release.

Lessons Learned

The first lesson we have 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 the 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 the 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.

Collective Reflection:

Overall the Wildcat 3.0 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 easy 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.

(Above) The UR^2 drive team gets ready to perform their product demonstration at the Great Lakes Region competition on May 12th. Photo taken by Lisa Beatty a team mom.

Individual Reflections:

"Looking back at the last eight years competing in MATE ROV competitions, I can only see how the MATE program has positively impacted my life. MATE has given me multiple opportunities over the last eight years from research opportunities to internships. Not only has MATE granted opportunities, but it has forced me to develop professional traits and acquire real world skills."

- Elizabeth Thomson
  CEO of Underwater Research Robot

"The staff and volunteers at NOAA have drastically impacted my life. Their dedication to my success, learning, and overall self has shown me that the MATE ROV program is more than a competition; it is a family. Without the guidance and support from the volunteers from MATE, I would not be where I am today."

- Katherine Nicholson
  Lead Software and Electrical Engineer

"ROV has taught me how to coordinate with others rather than just doing all the work individually. ROV has also taught me a great deal on engineering and problem solving. It has given me the skills I would have learned nowhere else."

- Josh Beatty
  Lead Pilot and Technician

(Above) The UR^2 stops to take a team photo at the Great Lakes Regional Competition on May 12th. Photo taken by Chuck Wiesen a volunteer at the Thunder Bay National Marine Sanctuary.

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.

For the international competition we calculated the cost per student of lodging and food for four days plus plane tickets for each member, which totaled approximately $1,200 per student. Our high school does not fund us in anyway, so raising the funds was up to us. We began fundraising efforts right away. As these fundraisers have just started, we cannot determine our final budget for the International Competition. In addition, days before the Regional Competition, we had a seal on our enclosure fail. After thirty hours of troubleshooting and repairs, we needed to spend an additional $300.00 to compete at the Great Lakes Regional. In order cover the budget loss and the materials to repair our ROV, it required us to over extend our budget. Our overall estimated budget for the preparation and travel expenses for the Great Lakes Regional and the International Competition is expected to be nearly $15,000 dollars.

Category	Description	Cost or Value	New or Reused
ROV Structures	High Density Polyethylene Frame	$125	Reused
	Enclosure and Electronics tray	$252	Reused
Propulsion	4 T100 Thrusters	$440	1 New and 3 Reused
Electronics	4 Electronic Speed Controllers	$100	New
	Raspberry Pi	$40	Reused
	Pixhawk	$85	Reused
	Xbox controller	$25	Reused
	3 Servos	$150	New
	180 Wide view Camera	$65	New
	Wiring	$50	Reused
	Arduino Uno	$30	Reused
	4 Penetrators	$16	New
Tether	Mesh Casing	$53	Reused
	Fantom ROV tether cable	$20	Reused
Mission Tools	OBS PVC Parts	$5	Reused
	Measuring Device	$10	Reused
	Lewansoul LeArm Robotic Arm	$130	New
Miscellaneous	Pelican Case	$160	Reused
	Subsea Buoyancy Foam	$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
Other Expenditures	Pool time	$900	n/a

The table below displays a financial summary report

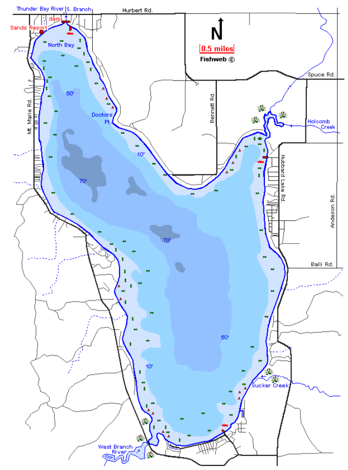
Purchased Items	$723
Value of Reused Items	$1,435
Total ROV Value	$2,006
Total Competition Expenses	$3,208

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

The Hubbard Lake Project

A continued goal of UR² is to use our ROV for more than just part of the competition. This year we were presented an opportunity to launch a historical investigation working closely with local Hubbard Lake historian, Mike Cornelius. The Hubbard Lake Project will involve taking our competition robot to Hubbard Lake this coming spring and launching it in the lake to search for a supposed sunken steam tractor. According to records and Mike Cornelius, the steam tractor sunk during a logging boom off of Doctor's Point, but it was never found. Our team, ROV, and a group of divers will go underwater and try to locate the steam tractor to resolve whether or not the stories about the sinking are correct.



Map of Hubbard Lake Michigan obtained from: http://www.fishweb.com/maps/alcona/hubbardlake/index.html

Tuskegee Plane Recovery Project

UR² is also working on an airplane identification and recovery project. The project involves working with Wayne Lusardi, an archaeologist from Thunder Bay National Marine Sanctuary, and sending our competition ROV and other commercial ROVs down to uncover aircraft lost in Lake Huron from various wars. Once the aircrafts are located the ROVs will take images and video footage to show surveillance in order to help the marine sanctuary with research as well as help family members locate the lost planes of relatives that perished during the war.

Photo of Tuskegee airplane obtained from: https://www.redtail.org/rise-red-tail/p-51c-mustang-tuskegee-airmen/

The Sturgeon Project

The final project this year is in partnership with MSU Fisheries and Wildlife. The team was tasked with designing an underwater trail cam to track the sturgeon population at the Black River Sturgeon Facility. Through communications with Douglas Larson, a research assistant at the Black River Sturgeon Facility, we were able to be presented with this idea and fulfill the task. From there, the designer Elizabeth Thomson, used a general shutter camera and designed a housing for the camera to sit on. The electronics and camera are housed in a clear watertight enclosure which keeps all electronic and the camera safe. The team travels to Black River Sturgeon Facility May 1st to present their project to Mr. Larson and his team to increase the accuracy of the sturgeon population count.

MSU EXTENSION

MSU Extension office Logo obtained from https://www.canr.msu.edu/od/communications_marketing/apparel