Technical Documentation May 24, 2023

Underwater Research Robot Company

Alpena High School Underwater Robotics Club

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The UR^2 Team:

CEO	Lydia Thomson (9th Grade)
Safety Officer and Project Manager	Sarah Rabbideau (10th Grade)
Pilot and Team Engineer	Clayton Thomson (12th Grade)
Pilot and Lead Engineer	Nik Jones (12th Grade)
Project Specialist and Mechanical Engineer	Gus Wirgau (9th Grade)
Project Specialist	Lucas Thomson (9th Grade)
Engineer and On-deck Operations	Gunner Moe (9th Grade)
Special Projects/Technician	Elizabeth Rabbideau (8th Grade)
Business Management	Abbey Glover (8th Grade)
Mentor	Paul Coleman
Mentor	Bob 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 comprises twelve skilled students from eighth to twelfth grade, dedicated to helping the environment and waterways.

Our remotely operated vehicle (ROV) is the culmination of years of experience in innovation and troubleshooting, resulting in many professional-grade features. These features include a Pixhawk Flight Controller, a 3D printed biconvex frame design, and a mechanical grabber. Our control system, a Raspberry Pi processor networked to a Linux-based topside computer that uses an Xbox 360 controller to activate our thrusters, is a new design in an acrylic enclosure that is both a housing unit and a buoyancy tube. A water-tight Pelican Case houses all the system controls and connects our ROV through a fifteen-meter braided nylon mesh tether.

Our Acrylonitrile Butadiene Styrene (ABS) frame features four T-100 thrusters, with two positioned vertically and two positioned horizontally. The biconvex frame design has less chance for entanglement while performing maintenance on ocean-based renewable energy stations. Our engineering team invented a marine debris vacuum that effectively captures biocontamination. We created an APU (Alternative Power Unit) system that provides lateral movement to aid in the capture of marine debris. The ROV uses a high-resolution camera that can view 180 degrees to ensure the safety of any marine life we may encounter. The UR^2 created an ROV focused on protection, innovation, and conservation - our ROV is built to solve any problem it faces.

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Project Management

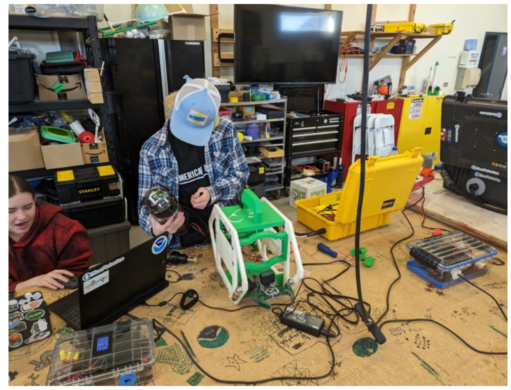
This year, our team came together to build an ROV superior to our previous models, allowing us to advance in the rankings. To accomplish all the tasks of making an ROV and preparing for the competition, our team held meetings weekly on Tuesdays, Thursdays, and Saturday starting at the beginning of November 2022. We have our team schedule attached on page four of this document.

Even with a team as small as ours, there are often a few meetings that 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. The task board allows members who have missed a meeting to save 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 lets everyone stay updated and informed on what happened at meetings.

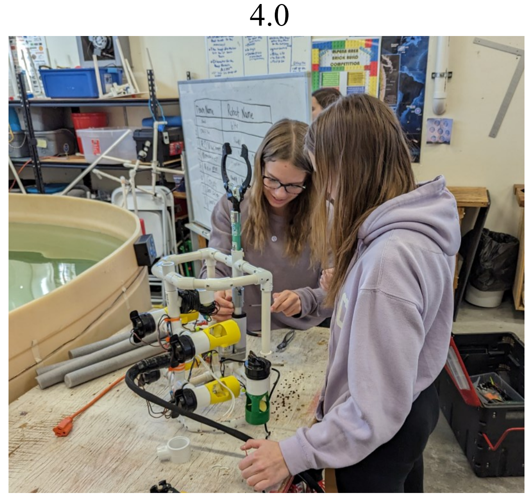
Our whole team is involved in the design and engineering of the ROV, but to complete the tasks at hand, each member specializes in a specific department. For example, the software department has a lead member who could answer questions from other members on the particular topic of software. The different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

The mentors encouraged us to problem-solve as a team when a problem arose. Still, when we needed the extra help, we utilized community members such as Paul Coleman, a local coding expert. We also used internet resources like 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 many new members, and we need help when we get stuck or need extra help troubleshooting.



(Above) Gunner checks the enclosure pressure while Lydia records the measurements.

(Above) Clayton, removes parts from the Wildcat 4.0 to repurpose on the Wildcat 4.0



(Above) Sarah collaborates with Elizabeth on prototype. In the back of the picture you can see the task board.

Project Management: Team Schedule

The UR2 Team Schedule 2023	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
Phase One: September - December						
September Schedule:						
Meeting once a week:						
Week: 1		3:00 - 5:00 PM				
Week: 2		3:00 - 5:00 PM				
Week: 3		3:00 - 5:00 PM				
Week: 4		3:00 - 5:00 PM				
October Schedule:						
Meeting once a week:						
Week: 1		3:00 - 5:00 PM				
Week: 2		3:00 - 5:00 PM				
Week: 3		3:00 - 5:00 PM				
Week: 4		3:00 - 5:00 PM				
November Schedule:						
Meeting once a week:						
Week: 1		3:00 - 5:00 PM				
Week: 2		3:00 - 5:00 PM				
Week: 3		3:00 - 5:00 PM				
Week: 4		3:00 - 5:00 PM				
December Schedule:						
Meeting once a week:						
Week: 1		3:00 - 5:00 PM				
Week: 2		3:00 - 5:00 PM				
Week: 3		Winter Break				
Week: 4		Winter Break				
Phase Two: January- Feburary						
January Schedule:						
Meeting two times a week:						
Week: 1		3:00 - 5:00 PM		3:00 - 5:00 PM		
Week: 2		3:00 - 5:00 PM		3:00 - 5:00 PM		
Week: 3		3:00 - 5:00 PM		3:00 - 5:00 PM		
Week: 4		3:00 - 5:00 PM		3:00 - 5:00 PM		
Phase Three: March-May						
March Schedule:						
Meeting three times a week:						
Week: 1		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 11:00 AM
Week: 2		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 11:00 AM
Week: 3		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 11:00 AM
Week: 4		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 11:00 AM
April Schedule						
Meeting three-four times a week:						
Week: 1		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 11:00 AM
Week: 2		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 11:00 AM
Week: 3		3:00 - 5:00 PM	3:00 - 5:00 PM	3:00 - 5:00 PM		9:00 - 12:00 AM
Week: 4		3:00 - 5:00 PM	3:00 - 5:00 PM	3:00 - 5:00 PM		9:00 - 12:00 AM
May Schedule						
Meeting three- four times a week:						
Week: 1		3:00 - 5:00 PM	3:00 - 5:00 PM	3:00 - 5:00 PM		9:00 - 12:00 AM
Week: 2		3:00 - 5:00 PM	3:00 - 5:00 PM	3:00 - 5:00 PM		9:00 - 12:00 AM
Week: 3		3:00 - 5:00 PM	3:00 - 5:00 PM	3:00 - 5:00 PM		Reginal Comp
Week: 4		3:00 - 5:00 PM	3:00 - 5:00 PM	3:00 - 5:00 PM		
		3:00 - 5:00 PM		3:00 - 5:00 PM		9:00 - 12:00 AM
Phase 4: June						
June						
Meeting Once a week:						
Week: 1		3:00 - 5:00 PM (Last practice)				
No more meetings						

Developing Team Participation:

Developing and maintaining an active team schedule required adjustment at the start and end of each athletic season. With our team not having competed in three years and only two remaining team members that actively competed at the Ranger Level, was a challenge. What helped the team was competed in the Square One Network Underwater Innovative Vehicle Design Challenge. This is an ROV competition that takes place within the State of Michigan but it is not as challenging as MATE. This competition was a good experience for those team members that had not been to an ROV competition before. With our success at the UIVD competition, it kind of energized the team to push to be ready for the Great Lakes Regional.

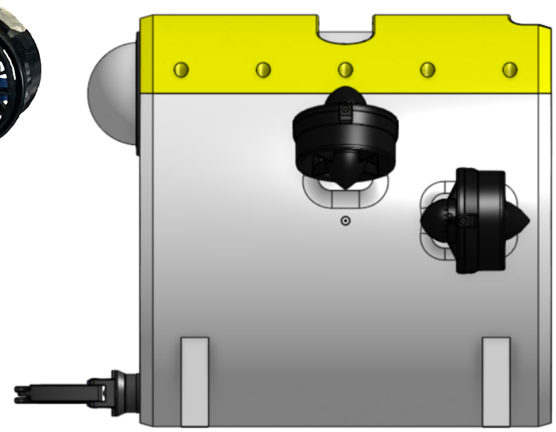
ROV

Dragster

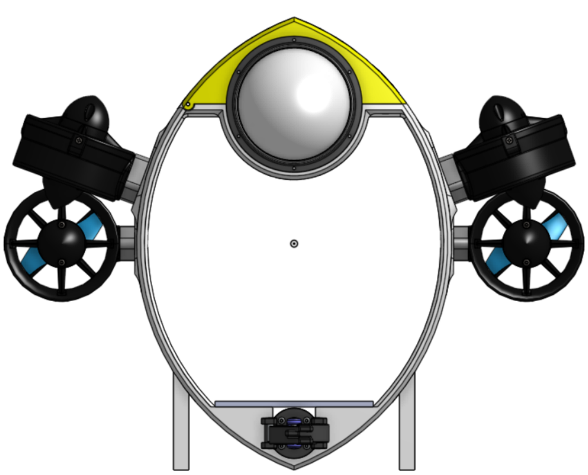
The UIVD competition has a dragster division where you create an ROV to go forward as fast as possible. It has to be above the pool bottom, but it has to be below the water surface.

Wildcat 4.0

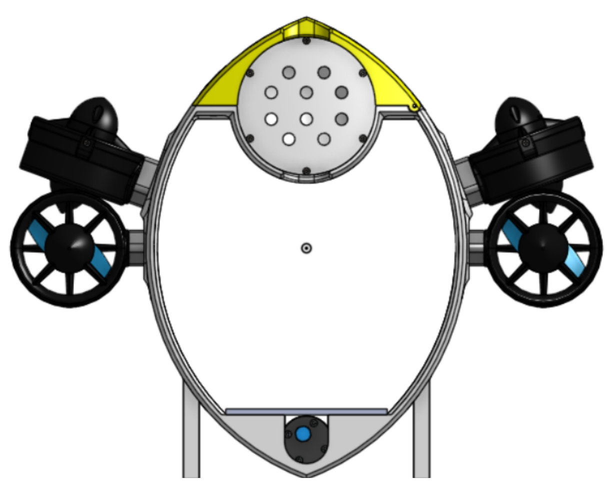
Side View



Front View



Rear View



Underwater Research Robot Company

Understanding the ROV

The Underwater Research Robot Company (UR²) is committed to fulfilling all research needs. Operating in the ocean, small lakes, or rivers, the UR² team has embraced the demanding tasks that accompany working on this job site. Our team is uniquely qualified to develop a remotely operated vehicle in the sometimes confined and often precarious conditions created while working in the ocean and the delicate ecosystems of rivers and lakes. Our engineering team has developed an ROV that can assist in clearing marine contamination and complete maintenance tasks on any marine renewable power station. From identifying and removing invasive species to safely transporting and planting native fish to secure a high survival rate, we engineered an ROV to meet the challenge. Our team innovated a marine vacuum system that safely removes biofouling from the mooring lines holding the floating wind turbines. Additionally, our team can quickly refit the vacuum system to accommodate the safe release of fry, providing correct data of organism count and finally collecting water quality samples for analysis using our uniquely designed DNA sampler.

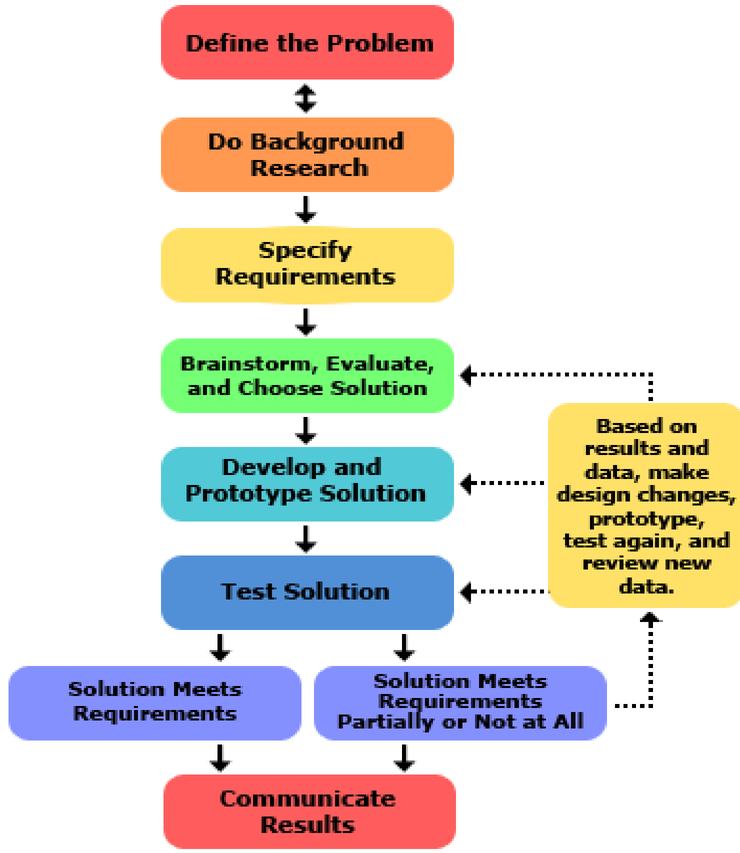
Our frame, composed of ABS, provides durability for high and low-temperature ranges. We have worked with many different framing materials, but our research has shown that ABS's versatility and proven to be best. The ROV's biconvex design houses an onboard watertight enclosure to confine all electronics 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. By encasing all of the electronics in our enclosure, we could reduce the weight and width of our tether. Overall, our design focused on developing a hydrodynamic, compact, and lightweight ROV to easily transport it in any work environment while working swiftly. UR² is committed to providing reliable and valuable research platforms capable of ensuring our clients with accurate and trustworthy data. The Wildcat 4.0 is the robot that will answer your needs.

THUNDER BAY
NATIONAL MARINE SANCTUARY

One way our team gains experience and knowledge is by working with local experts on environmental conservation projects. One recent is helping the Hubbard Lake Sportsman Club monitor their artificial reef project. We use our research ROV to inspect the square reefs that are placed in the water at a depth of three meters. The artificial reefs are used as safe habitats for young fish to grow. Hubbard Lake has experience a lot of changes in ecology due to invasive species. Below the Sportsman Club is building a set of reef to be placing in the lake.

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

1. Define the Problem
2. Do Background Research
3. Specify Requirements
4. Brainstorm Solutions
5. Choose the Best Solution
6. Do Development Work
7. Build a Prototype
8. Test and Redesign



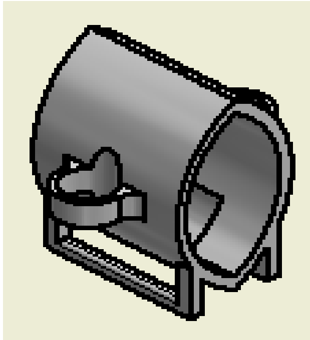
The UR² Company has experienced many successful research projects and competitive achievements, but we challenge ourselves with new ideas and technologies to be more successful. Our senior team members developed a new design during the COVID-19 shutdown but did not get to test it at a competition. Our team will be competing for the first time in three years.

The last ROV design we completed featured a new hydrodynamic design that was entirely 3D printed. The plan had many problems, but we wanted to see it become successful. We learned more about the 3D printing process, structure, and design strength. The solution to fix the design required, creating a hydrodynamic and compact frame, a reliable control system, and developing unique job site tools. We printed our frame designed out of ABS plastic. In past years we had chosen to use High-Density Polyethylene (HDP) at the cost of being a bulkier and square frame. However, this year we decided to use ABS plastic again, but we expanded our knowledge about design to create a strong and aesthetically pleasing frame. This new and improved frame is more hydrodynamic than ever due to its biconvex shape, allowing water to flow through more efficiently. This frame design also includes an onboard watertight enclosure, where all electronics and electrical connections are enclosed on the ROV. This allows for the tether width to be reduced and the total weight of the tether to be significantly decreased. Our overall design focused on developing a hydrodynamic, compact, and light ROV. This design provides for more efficient transportation in any work environment.

Our engineering team has developed the following job-site specific tools to complement our highly diverse robot. These include an accurate linear measuring device with autonomous capability, de-biofouling tools, and fish transfer attachments.

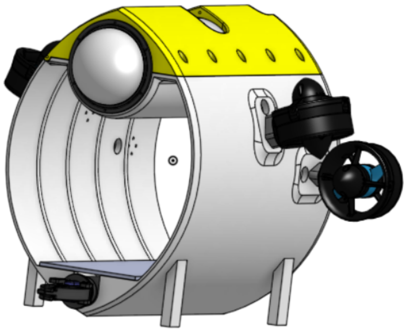
Frame Design:

Our first attempt at the biconvex design succeeded, but a list of issues needed to be addressed before we could use the format again. The first issue was buoyancy. We learned the hard way that 3D printed frames require a little design thought because of the air that gets capture on the inside of the print. For the ROV to reach neutral buoyancy, we had to drill the frame full of holes so the structure could fill with water. The electronics enclosure had to be removed entirely from the ROV for maintenance. Making any change or adding any auxiliary equipment to the frame was nearly impossible.



Our first biconvex frame design did not account for the addition buoyancy added from 3D printing and thought for attaching the enclosure.

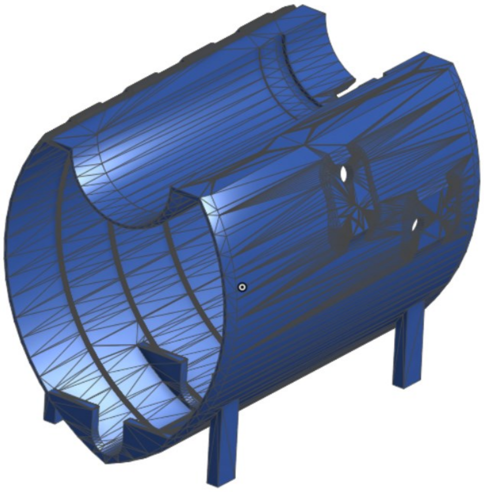
To reduce the additional buoyancy that occurs from 3D printing, we eliminated the fill space between the shell of the frame. By making the frame thinner, we had to add strength, but we needed to avoid creating air pockets in the frame. We increased the shell thickness and eliminated the fill space. Every three inches, we added a vertical rib that ran the height of the frame. The rib provided ridged strength to the frame but avoided adding any additional air pockets in the frame.



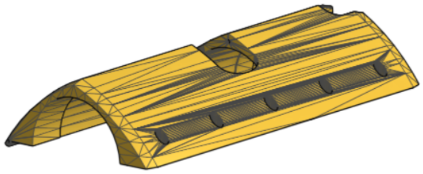
Our new biconvex frame design has thinner walls but utilizes ribs to provide strength, and the frame is a solid print. The enclosure has a hinged cover for easy access for maintenance and repair.

The enclosure problem was solved by adding a hinged cover that could be opened, exposing the whole enclosure. Another area for improvement with the first biconvex was no solid tether attachment point. The tether attachment was an afterthought on our first attempt. The tether attachment point was built into the enclosure cover in our new design.

Navigating the ROV around all the different attachment points requires deploying and securing a floating solar panel array to make the frame smoother, with less opportunity for the frame to become entangled. To address this issue, we decreased the support legs on the bottom of the ROV and created an attachable thruster guard that allows the mooring line to slide past the ROV without getting entangled in the thrusters.

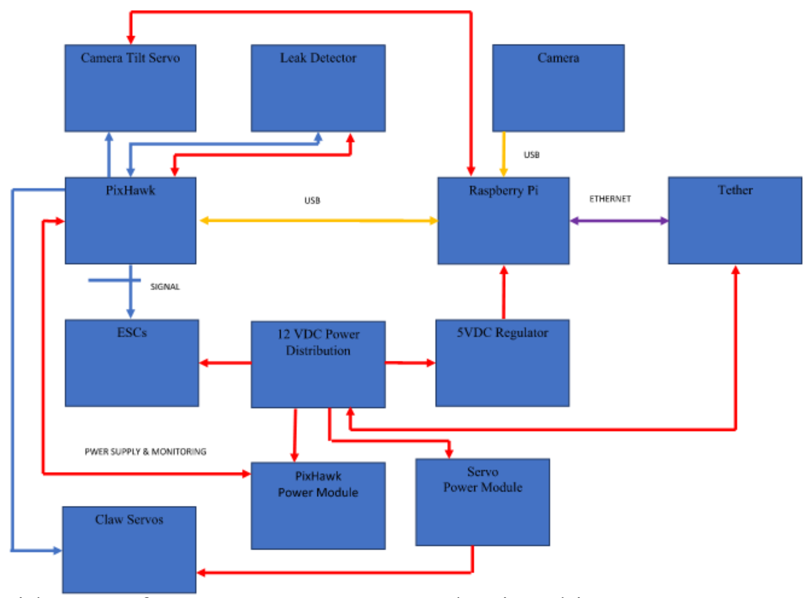


The bottom section of the frame was designed to attach our gripper to the bottom, allowing us to place a cover plate over it. This gave us additional space to add other payload tools to accommodate the work that needed to be completed. The top section provides easy access to the enclosure without separating the whole ROV.



Control System

System Block Diagram



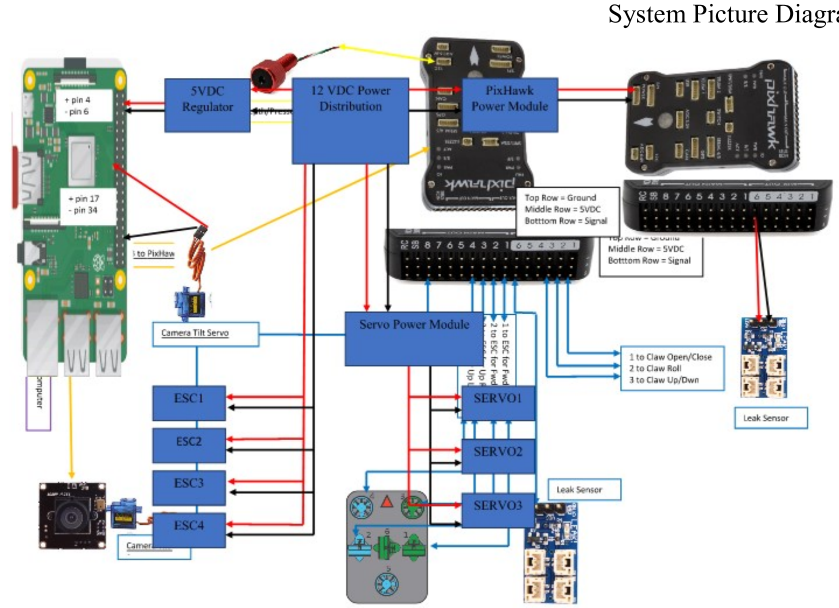
The Raspberry Pi system provides us with reliable processor control within our budget. The code and the PixHawk convert the analog input from the joystick to the electronic speed controllers needed to input power to the T100 thrusters. Working with QGround Control, a drone flight software on a laptop, we can use an XBox Controller to control the thrusters, camera, and manipulator. This compact and reliable system allows 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 mission requirements.

With 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.

Using the XBox game controller provides the pilots with operation familiarity. The controller is economical and far cheaper to buy than to build. Also, it is durable and field tested to sustain high 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 adapt to future missions. When closed, the case is easy to transport, making our ROV highly mobile for shipboard missions or land-based operations. We have even used it in the winter on a sheet of ice in the middle of a lake.

System Picture Diagram



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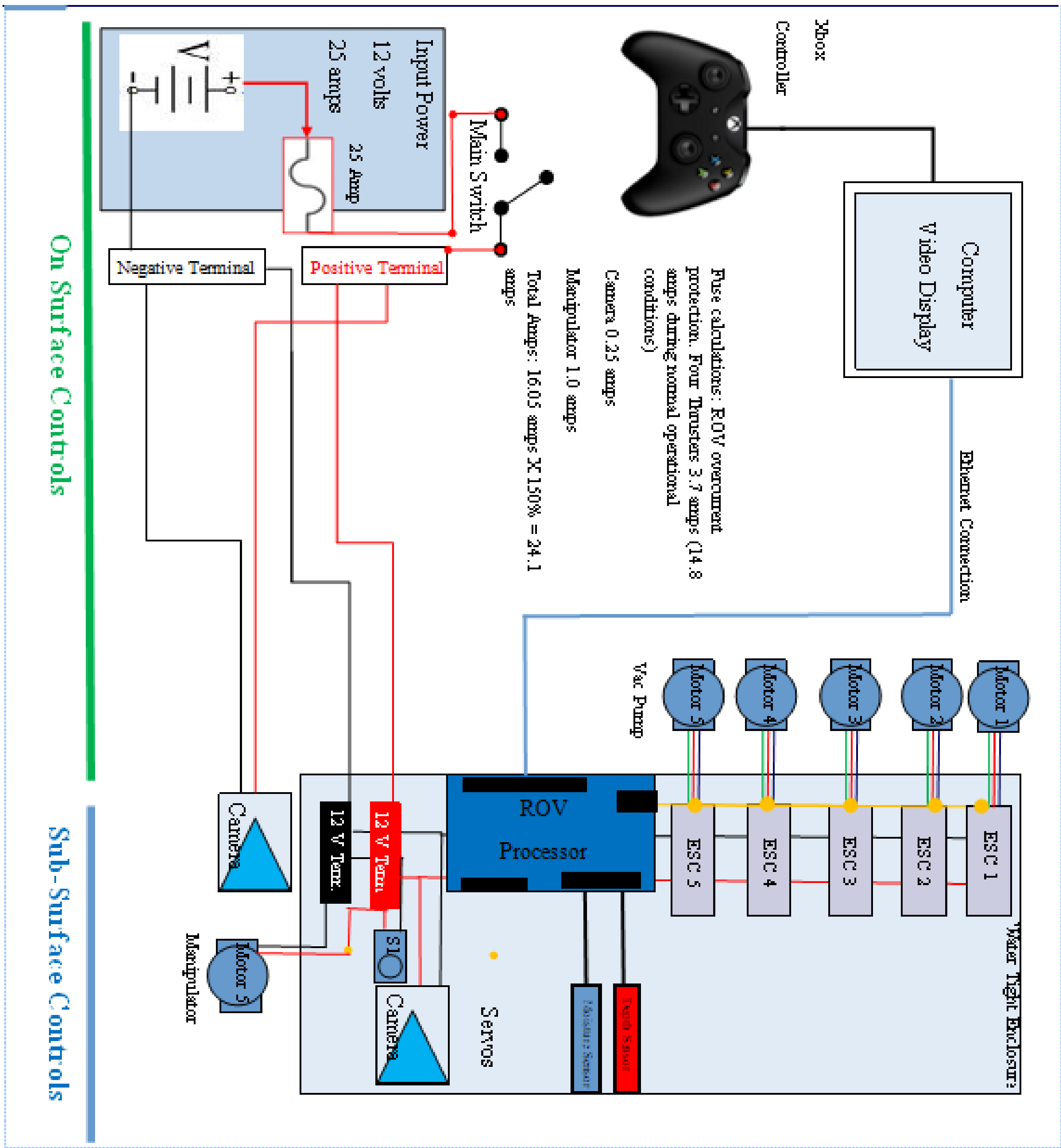
System Integrated Diagram (SID)



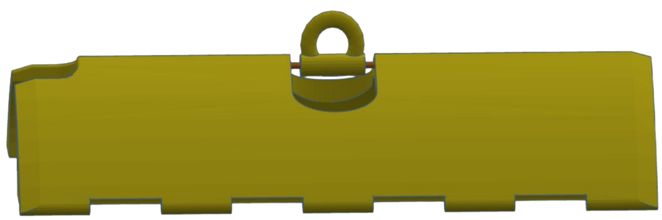
Developing our own Command and Control

Our ROV has always been networked to a surface laptop to run our control programming. We placed the controls in a large Pelican Case and then attached a laptop next to the control case. We wanted to simplify the controls by removing the laptop. We needed to build a computer into the pelican case to do this. This required us to understand how to build a computer and use an operating system. We acquired several older desktop computers from the school's tech department and got to work!

Our mentor Paul Coleman coached us on how parts of the computer function. We had to load a new operating system, and Nik Jones, our software developer, has built some of his own computers and has used UDOOBunto. The O/S is Linux based and developed for people wanting to create a lower-priced computer.

We had to develop some parts, such as the ventilation ducts for the computer, brackets for the hard drive, and electrical bus connections.

The hardware for the computer fit well into the Pelican Case. We created a plexy glass cover so that the components could be seen . The monitor is mounted into the lid of the case.



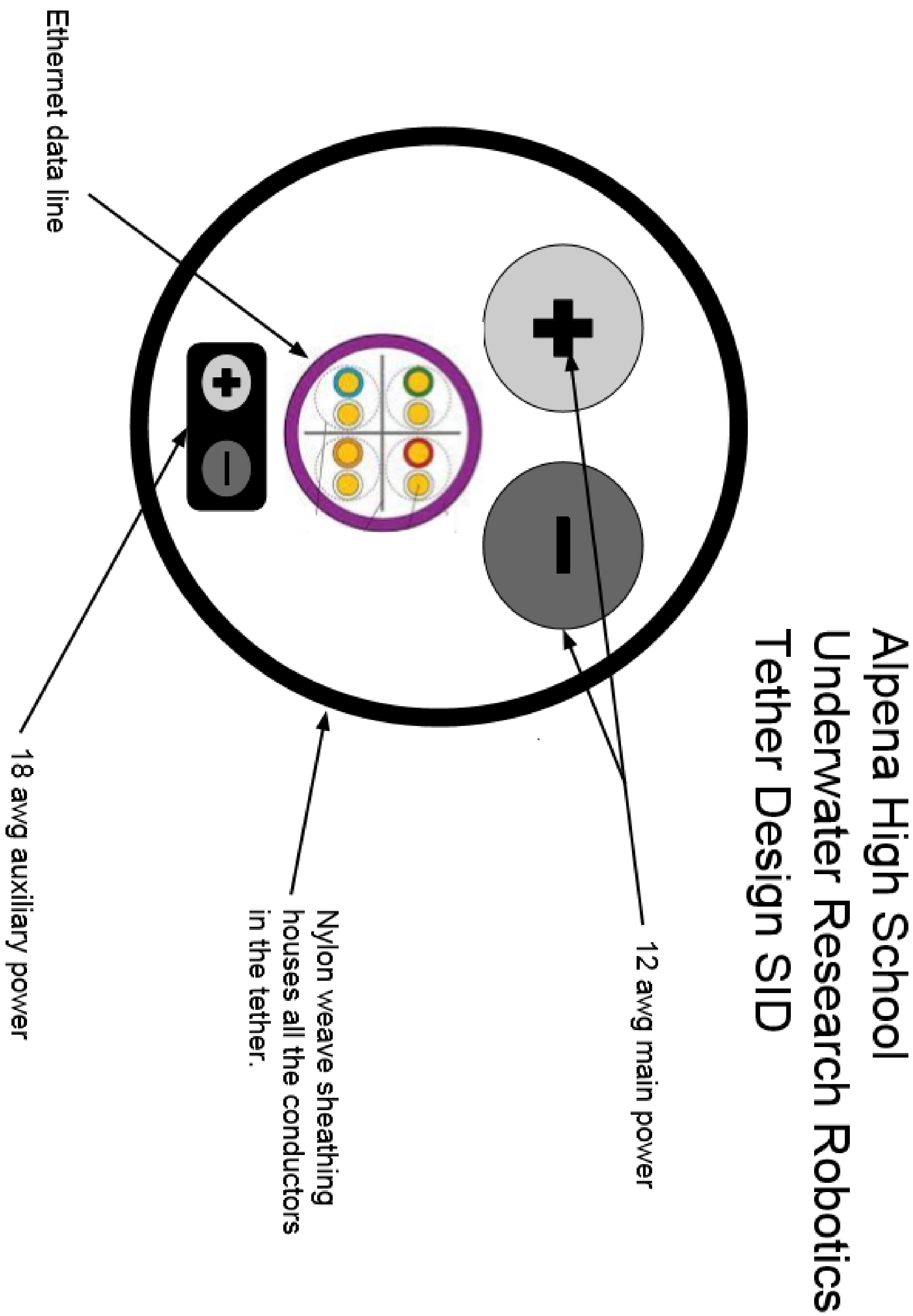
To prevent the tether from influencing the positioning of the ROV, we created a strain relief positioned in the center of the ROV. The custom strain relief allows the ROV to be lifted without pressure on any exterior wiring and provides a safe, even lift.

Tether

This year's mission criteria made us rethink and consider ways to make the ROV, and we reduced the number of conductors used in the tether to reduce its weight. We also researched different conductor materials for the tether 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 outlines the conductors. Our tether management protocol for our payload specialist to start each operation by flaking a line and making sure it is not a tripping hazard. We double-check the ROV's tether to ensure it has the right amount of slack.

Thrusters

We picked four T-100 Thrusters because of their safety and efficiency. We placed two vertically to move up and down quickly and adjust our height. Both vertical thrusters provide twelve newtons of force, allowing us to efficiently remove debris from the subsurface to the surface. We also added two thrusters horizontally for going forward and backward. The thrusters are positioned on the aft portion of the ROV to maximize forward thrust and turning capability. By placing our thruster here, we can twist from side to side. This helps us move when stuck in tight places.


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

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 finding space for the camera, and it wasn't easy to mount.

This year, we made our 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 when 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 and at a perfect viewing angle of the ROV.

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.

Using one camera instead of multiple cameras eliminated the costs of purchasing other cameras and 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, which can produce the ROV's position on the screen and what cardinal direction the vehicle is moving.

Once we started working with some of the props, we soon learned that we would need to add another camera to get a better view of the props from below. The anchors for the solar array are blocking the view of the gripper and makes it difficult to see the correct placement. The team decided to make the change and add the camera.

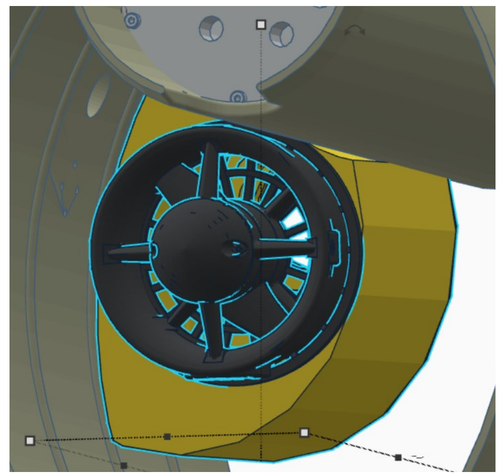
The created a 3D model of the camera placement and a mount that would hold the camera so we could adjust its position for the best possible angle.

HV1 System

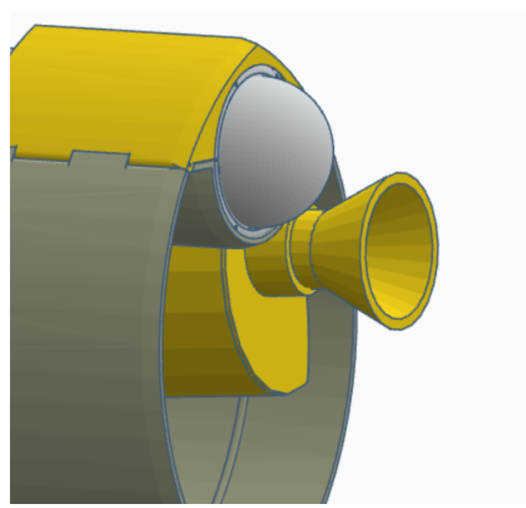
One of our newest innovation is the self contained HV1 (Hydro vacuum-cleaned 1) developed for debris pick up and fish delivery system. This new system collects biofouling from the turbines quickly and efficiently by vacuuming them up. The idea came from an early team that created a vacuum using a thruster to retrieve zebra mussel samples from shipwrecks. The team used a bilge pump thruster that didn't have a lot of power. We looked at the archived documents that the team left behind and liked the idea, but we wanted to make it smaller, lighter, and more powerful.

This ROV was built in 2011. You can see the large PVC vac container mounted onto the bottom side of the ROV. It was large and heavy, causing the ROV to move very slow.

The Main Vac Body



Using OnShape, we could import the T100 part and create a custom fit for the thruster eliminating any wasted space.

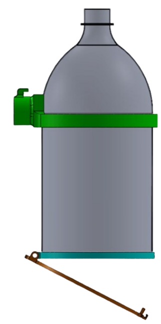


Biofouling Remover

The biofouling device comprises the vac cover and the attached vac cone. The cone extends out from the ROV to the point of the gripper. This allows us to briefly secure the ROV while engaging the vac system. Even though we have limited the thrust power to fifty percent, it still has enough force to push the ROV back. To make access into the vac body quickly, we have added two quick disconnect latches that provide easy access to the vac main body so that we can remove its contents. We have placed debris guards over the thrusters to prevent anything from getting into the propellers of the thrusters.

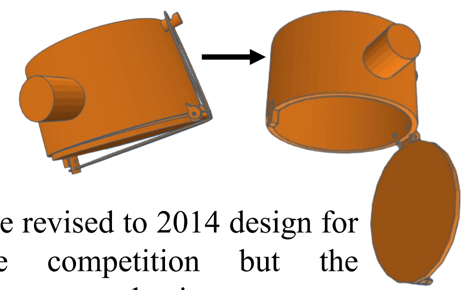
Fish Delivery System

Our development team created multiple fish delivery systems. Our team has developed many versions of this system starting with our first delivery system created to plant lake trout. Our team working with the State of Michigan in a lake trout recovery project to develop a way to deliver fish directly to a reef and potentially improve survival rates. This link is a video of the first run proved the concept, but ended in the total destruction of the ROV, Lake Trout Delivery System.

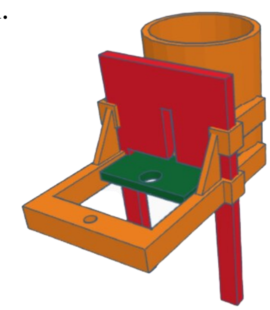


In 2014 we developed a delivery system using a 2 liter bottle with a trapdoor system to transport live lake trout using an ROV.

This year our team reviewed the 2014 design and started to develop some ideas. We also looked at a design the team used a few years ago to deliver fish fry from a previous mission task. The device required to use of the gripper to hold on to it for the whole time you were releasing the fish. This year's mission task require the pilot to complete lots of small tasks. Keeping the gripper committed to the fish deployer the whole time seemed to be too much time wasted. We came up with a better solution that did not require the use of the gripper. When our design team created the HV-1 system for the removal of biofouling, we discussed how could we us it to possibly plant the fish fry.

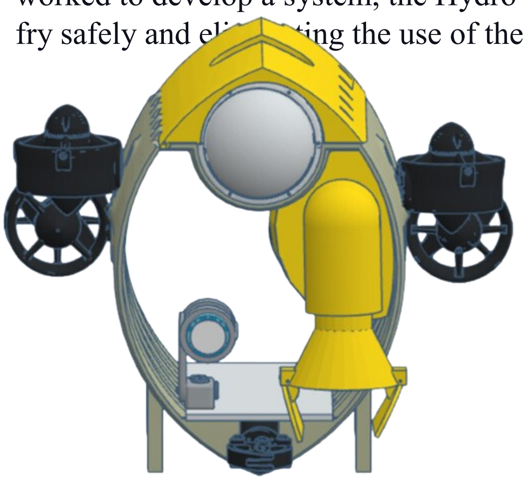


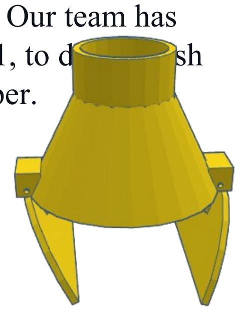
We revised to 2014 design for the competition but the release mechanism was not able to adapt to the ROV design.



Pictured above is a fish release used during a previous competition that uses a trap door that is activated when the legs are pushed up from below

The innovative team at UR² has created a new fry transfer device that will safely transfer the Redbelly Dace. These Fish have a protective coating over their scales to keep bacteria and viruses from penetrating the scales. The danger in over-handling fish is that you remove this coating. Our team has worked to develop a system, the Hydro-Vac 1, to deliver fish fry safely and eliminating the use of the gripper.

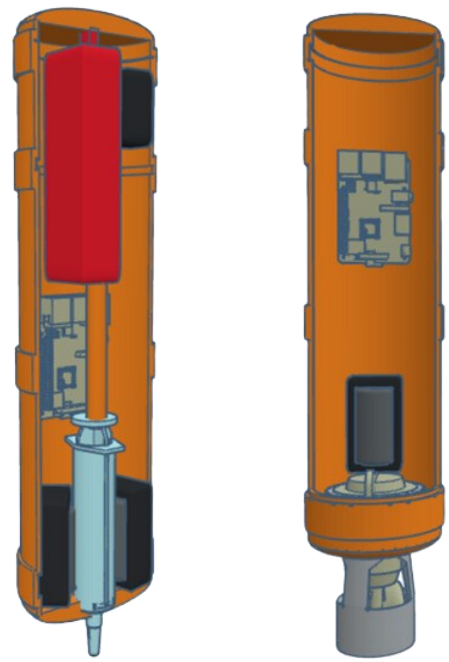




Our fish delivery system uses a trap door system that is released with a change of water flow. The fry can be placed in the vac main body or at the funnel end. The trap doors are locked, and when the pilot reaches the release sight, the pilot briefly activates the vac motor, which triggers the doors to release.

Vertical Profiling Float

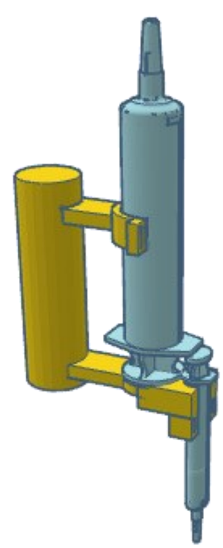
UR² created two vertical profiling float devices. Both can take a vertical profile of the body of water they are placed in. We made a thruster-controlled float first, then the buoyance-controlled float. Both work autonomously to collect data and transfer the collected data wirelessly to an assigned shore station.
The design team started developing the hardware and software to drive the float. While the team was developing the components, we started drawing the float and how it would all fit together. The float needed to be designed to be neutrally buoyant to work. We calculated the tube size and how much water it would display. The float needed to weigh about 13 kg to match its displacement volume. Once we had the number we created the thruster float that works, but we want to see if we could get the total point value for the mission by creating the buoyance engine.
To make the buoyance float work, we had to find a syringe volume that would hold enough water to overcome the resting inertial of the float to get it to sink. We went with a 150.0 cc syringe based on the volume and weight change from empty to full. It gave the float just enough to get it down and up consistently.



Thruster propelled and buoyance engine vertical sampling float.

Coral Head Sampling Device

Based on our work with the float syringe and the fact that the team had used a linear actuator during a summer workshop using a syringe, UR² innovation team focused on creating a sampler that was driven by a syringe actuator powered by a hand pump. The mission requires that the sample be taken with a 10ml syringe. The syringe would be supplied on the pool deck. This meant that we would have to be able to attach and detach the sample syringe. We employed a second syringe and designed a harness to hold the syringes. The larger one is pumped with air, creating an actuator-style piston to pull the sample syringe. We 3D printed the holder so that it can be attached to the ROV's gripper to take the sample.

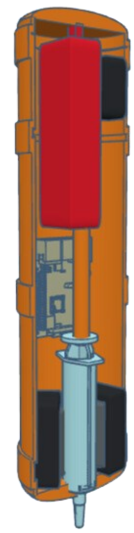


Coral Head DNA Sampler

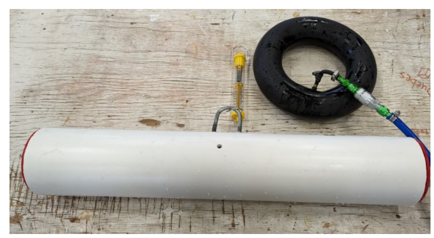
Build vs. Buy

This year we built or 3D printed everything that we could on this robot. Taking what we learned form the team's first attempt to print an ROV frame, we designed it to be a solid print that only cost the price of a role of filament. Additionally, all of our auxiliary equipment attached to the frame has been 3D printed. The one item that we did originally brainstorm as a ridge 3D print was the additional buoyance attachment for removing large debris. For this task we purchased a small inflatable innertube. The innertube is positioned in the center of the ROV and once the pilot has securely attached the ROV's gripper to the item being lifted to the surface, the tube is inflated, and the ROV becomes positively buoyant, easily lifting large items to the surface.

Lift Capacity of the ROV	12N
Lift Capacity of the Lift Float	20N
Total Combined Lift	32N



The frame of the vertical sampling float is completely 3D printed. Costing only a few dollars for filament.



To calculate the lift capacity of the added buoyancy to the ROV we first created a very large and heavy pipe and added a lot of re-rod to it. In the water, the tube required 24N to lift it. We then added the additional buoyance and that reduce the needed force to lift the tube to 4N. The resulting difference is 20N. When we add the 12N of the ROV and the lift float our total lift capacity is 32N.

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 in 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 proven to be reliable and efficient. We reviewed and found that reusing the Ethernet cable, Xbox controller, Laptop, Tether, T100 Thrusters, Enclosure, Dome, Camera, Pelican box, manipulator skeleton and temperature probe would save our company a substantial amount. The only time our team invests 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 robot's safety features. These were simple purchases because they were safety items and we wanted to eliminate any malfunction risks.

Safety Officer: Sarah Rabbideau

As the Safety Officer, it is my job to oversee all of our safety practices. I must ensure my crew works safely on the pool deck and the job site. My role is to ensure we do not lose any team members or equipment because of an accident that could have been prevented. Each member of our research team is responsible for safety. Our belief is a check-twice policy. Please inquire about our safety checklist.

The Underwater Research Robot Company aims to provide a safe, positive working and learning environment. Each company member must practice the three safety rules we developed as a team. First, proper clothes must be worn while working on and with the ROV. Safety items include 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 to avoid any mishap resulting in injury. Our last safety rule is to clean up after yourself. The rare injuries in the past involved someone slipping or tripping on something left on the floor and not put away. It can be as simple as pieces of PVC tubing left on the floor for someone to slip, fall, and injure themselves.

Our motto is that a safe company is a happy company, and a content 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. Staying productive is why we need to have consistent safety practices. Our Safety Check Sheet (Page 17) exemplifies our dedication to maintaining a safe working environment. Also, we have appointed our CEO as our safety officer. She has our company's permission to stop work if an unsafe condition arises.

As a company, we wanted to ensure that safety was extended to our working environment and the actual ROV. The vehicle incorporates two strain reliefs that prevent the rope from being ripped out. The first strain relief is located on the back of the ROV and is a simple carabineer clip that clips onto a cable thimble. This setup attaches to all the wires from 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 top thrusters are surrounded with yellow and black warning tape as a visual warning to anyone around the ROV. In addition, all 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.

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

Our goal is to make every member of our company aware of situations that may lead to an injury or damage to equipment. All team members are assigned safety goggles.

UR^2 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

Our team first competed nearly fifteen years ago and we have accumulated a large network of support. Our team has been using 3D printing for about seven years and it has growing affect on our team each year. 3D printing has allowed us to quickly build and test a part without the need to order anything. We can brainstorm a solution and have a part to test in a few hours.

During our prep work for this year's mission, one thing we did not anticipate is the thruster position when attempting to moor the floating solar array. All of the rope that are hanging down create a difficult situation for navigating the ROV. The Thrusters on our ROV are mounted on the outside and make a perfect location for the thruster to change one of the mooring lines without the pilot noticing. After just a few minutes of attempting to secure the first mooring line the ROV was tangled.

The problem was how do we maintain all the design elements we created in the frame and eliminate the the tangle points the ROV. The solution was to create plastic bumpers that are flexible to clip on and off the ROV based on the need of the mission. The material we used was some small strips of plastic left over from a previous team. We 3D printed some clip on hasps to attach it to the frame so we didn't have to screw anything new to the frame. The ROV can now pass through the mooring ropes without getting entangled.

(Above) Gunner works on a solution to keep the thruster from tangling in the mooring ropes for this year's mission shoots.

Learning the Hard Way

When we built the computer into the control case, we screwed the mother board down to the bottom of the control box. This saved us time at the moment, but cost us in the long run. We should have put stand-offs under it to provide some clearance.

We were just about to have the whole control box completed when we decided to test everything one more time before closing it up. A small screw had slipped under the board and shorted part of the board cause the board to crash completely. We had to replace the whole things and start from the beginning. It was a good learning experience, but one design decision cost us a lot of time.

Challenges

Three of our greatest challenges were working to on the control box, working around everyone's schedules, and trying to get the team and our facility back in order and all of working together.

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. Finding the balance of doing all the other things that high school is about and creating an ROV team that can compete at Worlds. In addition our team is young and three years of experience has left the team.

Blue Robotics has been a great thing for the ROV community and the competition, but it also made many of the teams using the same resources. By creating our own control box from a computer, the goal was to learn, but we want to make us look different and not so dependent on Blue Robotics. The challenge is how do we build something that none of us knew much about, but we knew this is something we had to do to be competitive. This is where we learned the importance of asking for help from our community.

Our two seniors on the team had attempted the vertical sampling float last year when it was offered up as a satellite challenge and started experiment with the buoyancy engine. Going into the planning stage of the float design, we thought we had a small head start on the project. That head start went away quickly once we started calculating all the amount of weight the tube would need to be able to reach neutral buoyance. This is where 3D printing has become valuable in the prototyping process. We created short sections for the housing tube that we could add or subtract based on what we needed to adjust to the size of the syringe that we would use to counteract the buoyance to allow the float to sink. This gave us another variable we could adjust to control the displacement of the float.

(Above) Clayton, one of our two seniors on the team is testing our 3D printed float prototype. We worked on several prototypes using both TinkerCAD and OnShape to develop our ideas and to 3d print them.

Lessons Learned

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.

One project that taught us a lot about the power of community. Our mentor, Mr. Thomson, asked us if we would help create a LEGO build competition. He had students watch the FOX show LEGO Masters and wanted to know if there was anything like that in our state. After researching it we didn't find anything and so he reached out to us to see if we would like to try and create it. We reached out to four community partners with our plan and we made it happen. We had over seventy K-12 students/teams register and we raised $1,500 in prizes. It was a great experience developing a scoring rubric and setting competition guide lines. The competition was not perfect, but we will grow because all are partners want to do it again.

Helping create the Brick Build Competition and judging it was a great experience and helped us understand the logistics of working with community partners to develop a program that we hope continues on with the team.

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 more accessible access to all of its parts. The ribbed design of this year's frame was excellent for housing the acrylic enclosure. Still, it also meant that the whole frame had to be dismantled whenever we wanted to adjust other parts, such as the mechanical grabber or thrusters. We could design a frame that did not need to be disassembled to modify its parts, saving 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. During this competition season, our team spent a lot of time experimenting with different parts and tools we could potentially use on our robot. Because we spent extra time experimenting, that set us back in finalizing the tools we would 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 entirely prepared to take on the product demonstration during the competition.

Underwater Research Robot Company

Budget

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 and equipment was through a State grant called MiSTEM. Our total award equaled $4,000.00. There were also other private donations including the laptop and pool time. We only spent a total amount of $975 on new parts. Because our team is now going on fifteen competition seasons, we have accumulated a multitude of parts available for reuse. The total value of reused parts on this years ROV is $1,878. The total value of our complete ROV unit is $2,853.

Category	Description	Cost or Value	New or Reused
ROV Structures	ABS Filament	$125	New
	Enclosure and Electronics tray	$252	Reused
Propulsion	5 T100 Thrusters	$685	1 New and 4 Reused
Electronics	5 Electronic Speed Controllers	$150	1 New and 4 Reused
	Raspberry Pi	$40	New
	Pixhawk	$85	New
	Xbox controller	$65	New
	3 Servos	$150	New
	180 Wide view Camera	$65	Reused
	Wiring	$50	Reused
	4 Penetrators	$16	New
Tether	Mesh Casing	$53	Reused
	Fantom ROV tether cable	$20	Reused
Mission Tools	Vertical Float	$350	New/Reused
	Fish Deployer	$10	New
	Measuring Device	$10	Reused
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	$165	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	$975
Value of Reused Items	$1,878
Total ROV Value	$2,853
Total Competition Expenses	$3,753

The table below displays a donation and funding report

MiSTEM Grant	$4000.00
NOAA (In-kind: Faculties and Utilities) Donation	$10,000.00
2022-2023 In-kind and Grant Total	$11,500.00

Thank you very much to:

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· Paul Coleman

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· Alpena Public Schools
· Marine Advanced Technology Education Center
· MISTEM
· All the volunteer divers and NOAA staff members that make everything possible.

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All pictures of team members used in this technical documentation were taken by Lydia Thomson and Sarah Rabbideau.