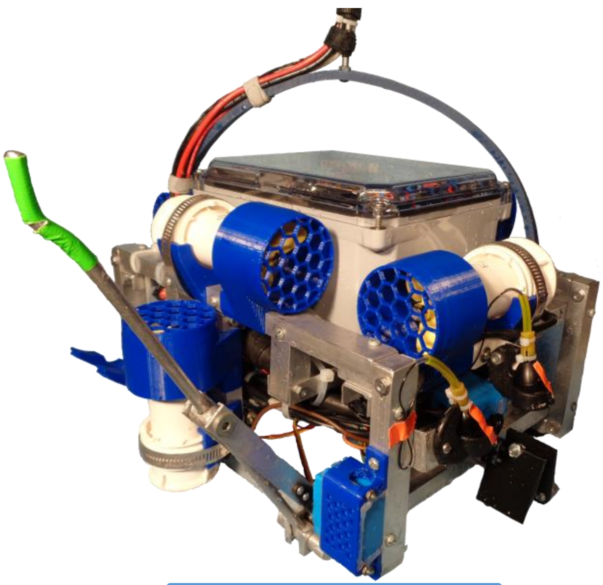
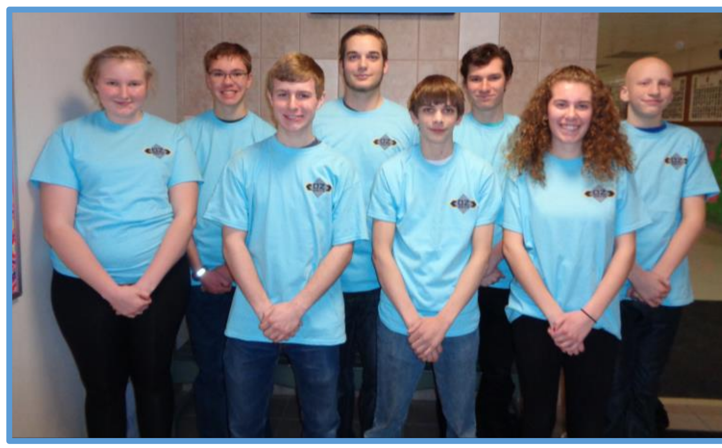
Ozaukee Robotics

Ozaukee High School, Fredonia, WI



Squirtlebot



Ozaukee Robotics Team

Member Name	Position	Member Name	Position
Josh Vogt	CEO/Software Engineer	Zachary Wagner	Mechanical Engineer
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Connor Freiburger	Mechanical/Electrical Engineer	Hannah Bell	Technical Writer
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Randy Vogt	Mentor		

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Abstract

As our seventh consecutive year returning, Ozaukee Robotics has assembled a remotely operated vehicle for the MATE ROV Competition. This robot, known as Squirtlebot, has been built and operated to handle a variety of different obstacles within waters on earth or another planet.

Squirtlebot can measure water depth and thicknesses of ice, take temperatures of venting liquid, and retrieve oil to analyze a gas chromatograph. Furthermore, the robot specializes in installing then securing a flange, reading serial numbers from CubeSats, and analyzing different coral colonies.

To accomplish these tasks, Ozaukee Robotics has custom built an aluminum C-channel frame designed specifically for the tooling necessary to be successful. Essential tools include a temperature sensor, an oil mat tool, cameras, a depth sensor, and a prong. We have programmed this vehicle entirely with student-written coding. Squirtlebot is managed through its onboard microcontroller, receiving commands from the pilot who utilizes a PlayStation 2 controller and a computer keyboard.

To make transportation efficient, Ozaukee Robotics has created a vehicle with a diameter of 48 cm, allowing for easy shipping. Not only the size, but the weight is economical. By utilizing minimal material, our ROV weighs less than 11 Kg and can be carried by one person.

Ozaukee Robotics has found repeated success due in large part to its strong business orientation and adapting a corporate structure that is perfectly suited to our needs. Created for efficiency, safety, and love of exploration, our robot is the capstone of the team's enthusiasm and hard work.

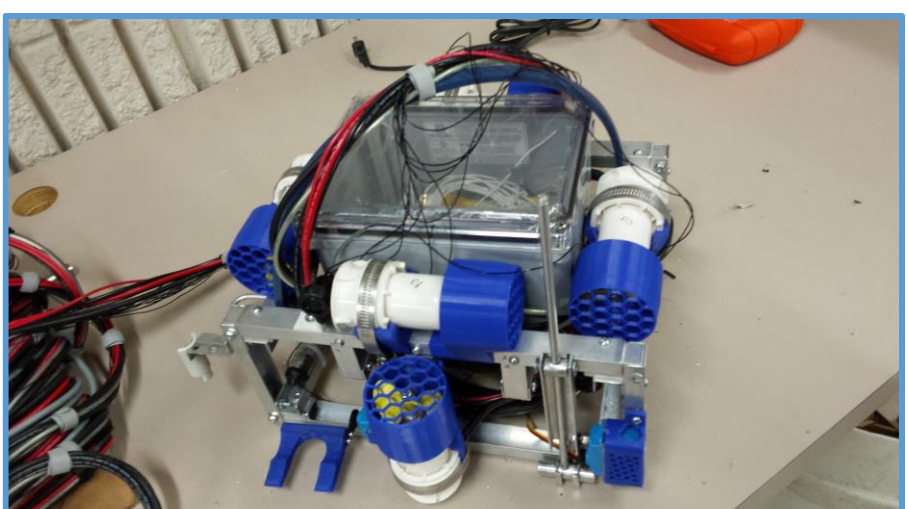


Figure 1: Squirtlebot Under Construction

Corporate Profile

Striving for efficiency, Ozaukee Robotics has developed a structured and individualized approach to business management. The company is divided into two primary branches: Business and Engineering. Splitting power between the two areas has streamlined decision-making while also encouraging communication between the different branches. This approach allows each department to primarily focus on the area that best suits its expertise while maintaining communication between members.

The business department oversees all financing and public relations. Fundraising is responsible for seeking donations and performing profit making ventures. Those active in public relations operate the company website and are chiefly responsible for making the marketing display.

The engineering department is split into three sub-departments: electrical, software, and mechanical. The electrical department controls all electronic hardware; software does all of the software programing; the mechanical department creates the physical structure and working components of the ROV, including frame and tool designs.

Although organized into two divisions, the team works conjunctively to produce a distinct department: technical writing. The responsibilities of the team's technical writers include composing the technical document, supplying information for the marketing display and website, writing press releases, and offering support for the business department when penning official documents. Our team's architecture has led to many creative additions to our marketing, including a few puns inserted into this document.

Ozaukee Robotics firmly believes the best ideas surface when many talented individuals are involved in the creation process. By creating a specific business structure, the team has been able to achieve high quality results for many years. Through this system, each individual is able to achieve great things, and in turn, the team flourishes.

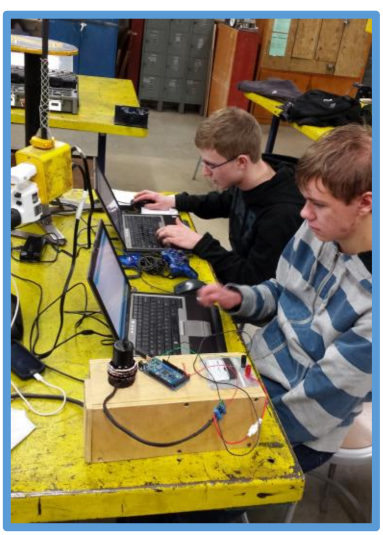
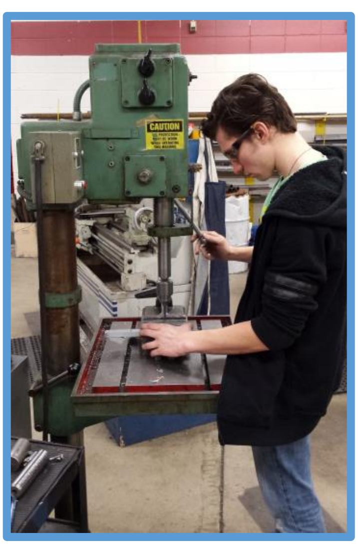


Figure 2: Software Department Working (Left)

Figure 3: Engineering Department Working (Right)



Design Rationale

Frame

This year, due to the new weight restrictions, we brainstormed to find a lighter frame. After finding pros and cons between aluminum C-channel and the HDPE used in previous years, it was determined that the aluminum was the best choice.

Not only is it lighter, but it requires less hardware to effectively secure items to it. This became increasingly important to staying within the weight limits. Our team had to be as conservative as possible to avoid exceeding restrictions. At 2.039 grams per centimeter Squirtlebot uses 333.6 centimeters of product. This totals out to .680 kilograms of frame used in the entire robot. In comparison, last year the dry weight of the frame was approximately 5.23 kilograms, this year the frame of Squirtlebot is a fraction of that weight. To attach the separate pieces of aluminum together, we used 8-32 screws in comparison to the ¼ -20 screws we used last year, thus shaving off excess material.

Dry Housing

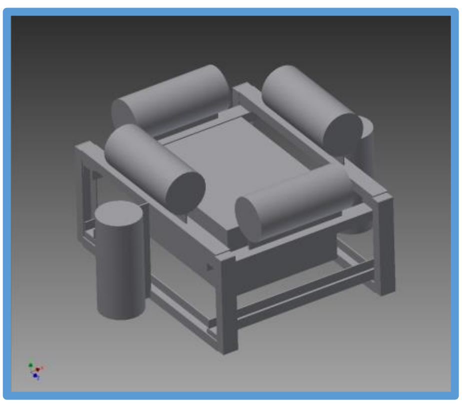


Figure 4: Frame and dry housing plans

The dry housing of our robot is an IP68 rated Integra Enclosure, chosen for its reliability in protecting the vital electrical components. This keeps our microcontroller and driver boards safe from water intrusion. The connectors on the enclosure are SubConn bulkhead connectors, which are completely sealed with gasket sealer. The lid of the dry housing is fastened with screws and a reinforced waterproof gasket.

Ozaukee Robotics takes extra care to ensure a completely waterproof seal prior to every pool run. We begin every run by first placing the ROV in the water before turning anything on. This way we can test the non-operational features - namely buoyancy and the waterproof seals - before we consider motors, tools, and propellers. Only if everything looks satisfactory do we begin test runs.

Not only does the dry housing assure the safety of the ROV's electrical components, but its calculated buoyancy assists in keeping the ROV neutral while underwater. The enclosure measures 20.3 x 15.24 x 10.16 cm for a total volume of 3143 cm^3. This volume helps to offset the weight of the tools which allows our ROV to remain neutrally buoyant. By focusing the buoyancy of the dry housing at the top while placing the heavier elements near the bottom, the robot's center of gravity is low while in the water. This keeps Squirtlebot stable during all movements. Additionally, in order to allow easy access to the tether and create a more stable ROV, the dry housing is located at the top of the craft.

Bulkhead Connectors

Squirtlebot's dry housing features three SubConn bulkhead connectors. The bulkhead connectors provide a secure, waterproof connection from the tether to the dry housing, allowing information and power to be relayed without damaging the electrical components of the craft. Each connector is secured with silicone gasket sealer to provide a flexible, yet reliable seal.

The craft's onboard microcontroller communicates with the surface through a CAT5 Ethernet cable fastened to an eight-pin connector. Additional data, primarily signals that are sent to the motors and from the outside sensors, are sent through two 16-pin, 18 AWG connectors. This structure creates a waterproof, not merely water resistant connection, quite like the skin of a sea animal. Because of this, our connection is more secure than other options. The bulkheads also provide the ability to quickly and easily disconnect the dry housing and its components. This proves useful every year as the craft is torn down and reconstructed to suit new missions.

Figure 5:
Bulkhead Connectors

Figure 6:
Tether

Tether

In previous years, Ozaukee Robotics used mesh to hold the wires together within the tether. This year we found a more efficient way to hold together the exceedingly important cords. The mesh used previously was hard to manipulate, mainly when putting wires through it and taking them out. This became especially true for the ever so small camera wires that tangle exceptionally well. Not only did stringing wires consume valuable time, it was also extremely inefficient.

As of this year, we have begun holding the wires together by attaching Velcro straps every 15 cm. It is very efficient for our team to use this over our previous method. With 16 separate wires completing the tether, it contains all of the cables transmitting power and information between Squirtlebot and the computer operating it.

In contrast to what has been done previously, we now have four separate power cables rather than two. Having different groups of wires for the controls and the thrusters allows for better noise reduction. As the thrusters are turned on and off, they tend to cause power usage to fluctuate. By separating the thrusters from the controls we can improve on the connection between the Arduino and the computer.

Propulsion

Maneuverability was a key concept addressed when determining the design of the ROV. To maximize movement, six Tsunami 1200 bilge pumps have been converted into thrusters using propeller shaft adapters and Octura 1255 propellers. This combination of adaptations provides the most efficient operation in terms of the power produced compared to cost. Each set of motors efficiently produces 7 newtons of force while consuming only 4.2 amps of current.

Each motor uses approximately 25 watts of power with 2.1 amps of current at 12 volts. When all thrust and lift motors are fired, they use approximately 8.4 amps of current. As 25 amps are allotted, the thrusters fall well short of the required limit, even when including the current used by the electronic components of the craft. With this limited power, the motors can generate up to 14 newtons of force. According to Newton's 2nd Law, the ROV can accelerate at 1.273 m/sec^2 in all directions.

Additionally, much thought has been put into creating the shrouds for the motors. Using a 3D design program, Ozaukee Robotics drafted a few different designs of shrouds, aiming for maximum efficiency. When designing the new shrouds, the team focused on a variety of areas: we experimented with induction port size; the size of the honeycomb grate; the diameter of the shroud; the shroud's length and moving the mounting holes, so they would not interfere with spinning propellers.

Figure 7: Shroud Design Evolution

Once the team chose an effective design, we printed a test model. When there were no obvious problems with the design, the team printed the final production pieces. We then examined how the motors worked within the shroud and noted any necessary changes. We finalized the shroud with a larger port size and two separate mounts, one to attach the motor to the C-channel frame and another which provides the main shroud surrounding the propeller. By separating the design into two pieces, we were able to use the frame to cover the distance between them rather than printing a connecting leg. This reduces the overall water resistance and material used. With these final adjustments, the shrouds currently fit better than a Squirtle in his shell. Furthermore, we assured that the shrouds were easily removable for greater accessibility.

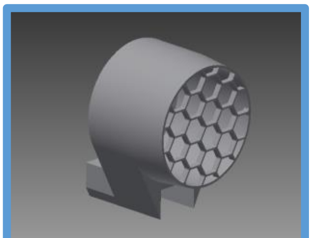


Figure 8: 3D Shroud

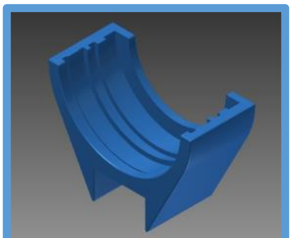


Figure 9: 3D Motor Mount

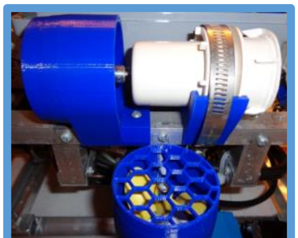


Figure 10: Motor and Shroud

Control System

Hardware

Figure 11: DualShock 2

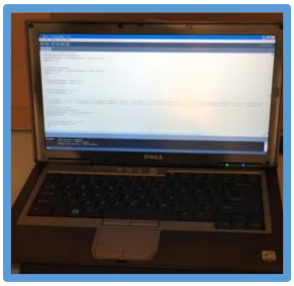


Figure 12: Keyboard

Focusing on precision and accuracy is essential for any capable ROV. For this mission, Ozaukee Robotics chose to use the Arduino microcontroller and Pololu motor controllers. The six Pololu 18V15 motor controllers are responsible for moderating power to all the thrusters. These controllers allow the pilot to manually adjust the settings of each element. Manual adjustment allows the power and polarity of each motor to be adjusted independently.

The motor controllers fall under the control of the robot's Arduino MEGA Microcontroller. The microcontroller manipulates the motor controllers by releasing Pulse-Width Modulated (PWM) signals. The Arduino adjusts the duty cycle of these signals to change the power sent to the motor boards, allowing for precise control of each element.

Featuring 54 input/output pins, 16 analog pins, 128KB of flash memory, and a 16MHz Atmel processor, the controller boasts massive yet efficient power. In compliance with MATE specifications, the microcontroller is powered through an onboard 12V DC to 7V DC converter.

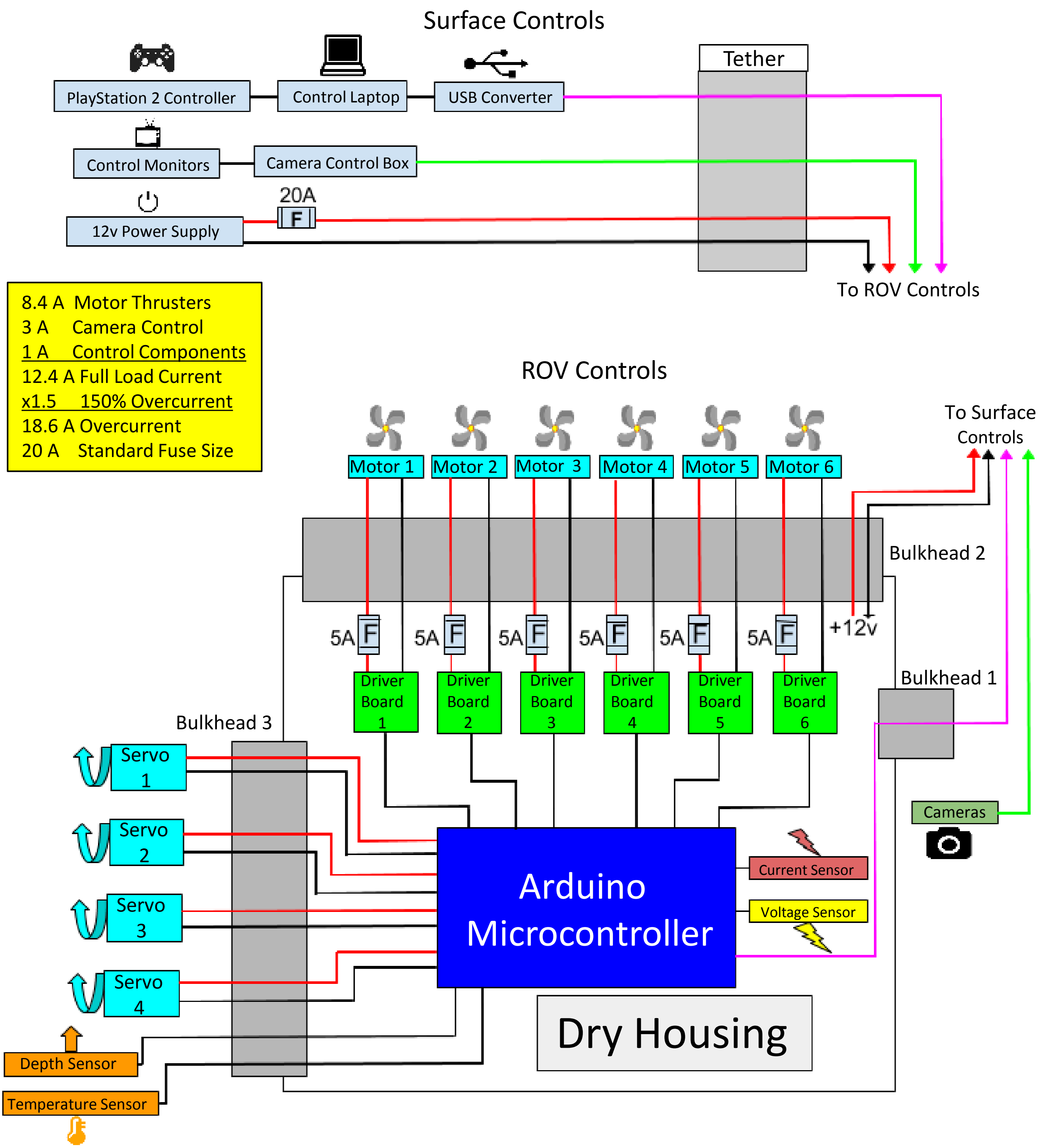
The ROV is manipulated with a laptop keyboard and a DualShock 2 controller (Figures 10 and 11). The joysticks of the controller are used to drive the primary motion of the craft while the keyboard toggles the modes of the ROV. Their use allows for easy direction and programing, permitting more attention to be given to completing the mission, rather than focusing on the controls.

Controls

Right Joystick	Right thrust speed
Left Joystick	Left thrust speed
L1 Button	Lift up
L2 Button	Lift down
L3 Button (Left Joystick press)	Strafe left
R3 Button (Right Joystick press)	Strafe Right
Up Dpad	Select prong tool
Down Dpad	Select oil mat tool
Left Dpad	Select bolt tool
Right Dpad	Select connector tool
Triangle Button	Close selected tool
X Button	Open selected tool

"G" Key	Ground mode
"H" Key	Hover mode
"P" Key	Precision mode
Up Arrow Key	Up directional mode
Down Arrow Key	Down directional mode
Left Arrow Key	Left directional mode
Right Arrow Key	Right directional mode
"T" Key	Turns on mode to read temperature sensor
"S" Key	Selects which depth to be taken
"D" Key	Sets selected depth equal to current depth
"Z" Key	Starts on-screen timer
"Q" Key	Resets on-screen timer

System Interconnection Diagram



Software

Ozaukee Robotics' custom software serves two crucial functions: to control the microcontroller and to translate data from the tools. The microcontroller software, written in C code, is stored within the robot's 128 KB of onboard flash memory. The code allows the microcontroller to communicate with the motor controllers, which are responsible for the craft's propellers. The software collects analog signals from the depth sensor, current sensor, and voltage sensor. The signals are then converted to a digital signal on the topside laptop's graphical user interface (GUI). These readings from the laptop's software communicate with the microcontroller and aid the pilot in determining position, orientation, and stability.

Multiple aspects of data are displayed simultaneously by overlaying them on the laptop. This enables the pilot to monitor both position and data. Prominent components of data displayed include the following: thrust generated by each motor, current consumption, status of the instruments, craft depth, and forward orientation. The laptop then interprets, commands, and toggles accordingly when it receives input from the DualShock 2 controller or keyboard.

Video System

Through seven years of experience, Ozaukee Robotics has discovered that maximizing vision during missions is a top priority. To accomplish this, Squirtlebot is fitted with eight full-color cameras which can view all sides of the craft as well as every essential tool used during the mission tasks. Squirtlebot's cameras were manufactured for ice fishing. Each camera broadcasts in an analog signal that transmits a 150 degree field of vision and displays in 480p. They were chosen specifically for their IP68 rating, functioning depth of up to twenty meters, and minimal and lightweight design.

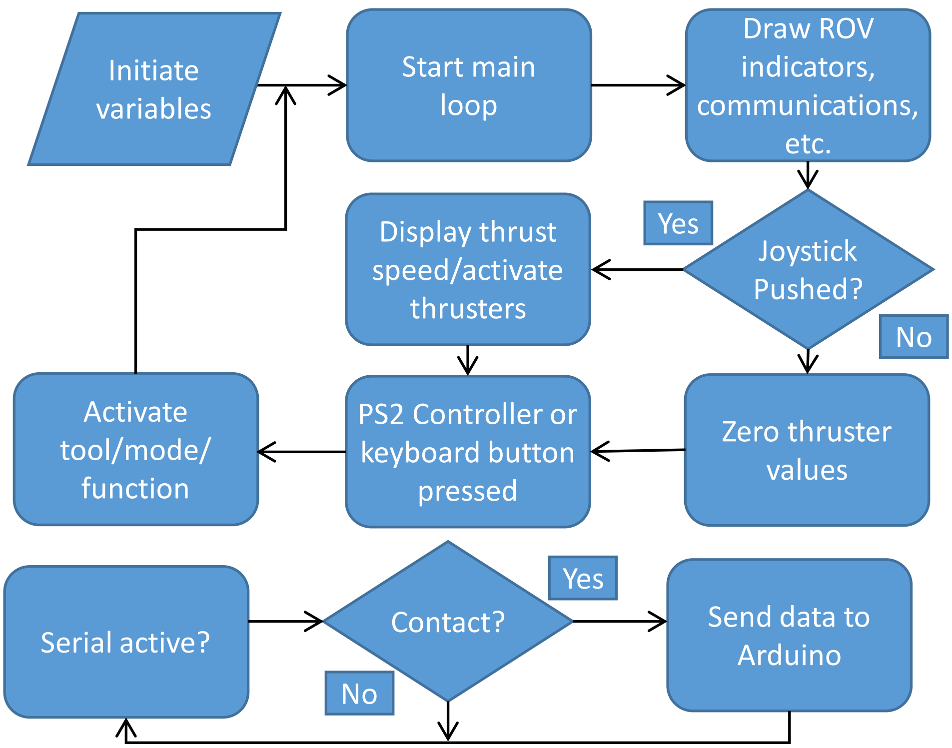
The images gathered by the cameras travel through the tether to the topside, linking directly to the video-processing center. The center, a customized system, condenses the signals from the eight camera boards into two multiplexers, which are responsible for segregating video feeds for display purposes. The footage travels via AV cables to two 81 cm video monitors. Arranged to surround the pilot, the rightmost monitor features four cameras focused on specific tools which aid in specific mission tasks. The leftmost monitor shows the displays from the cameras mounted on the cardinal sides of the craft.

Figure 13: DualShock 2 Controller (Left)

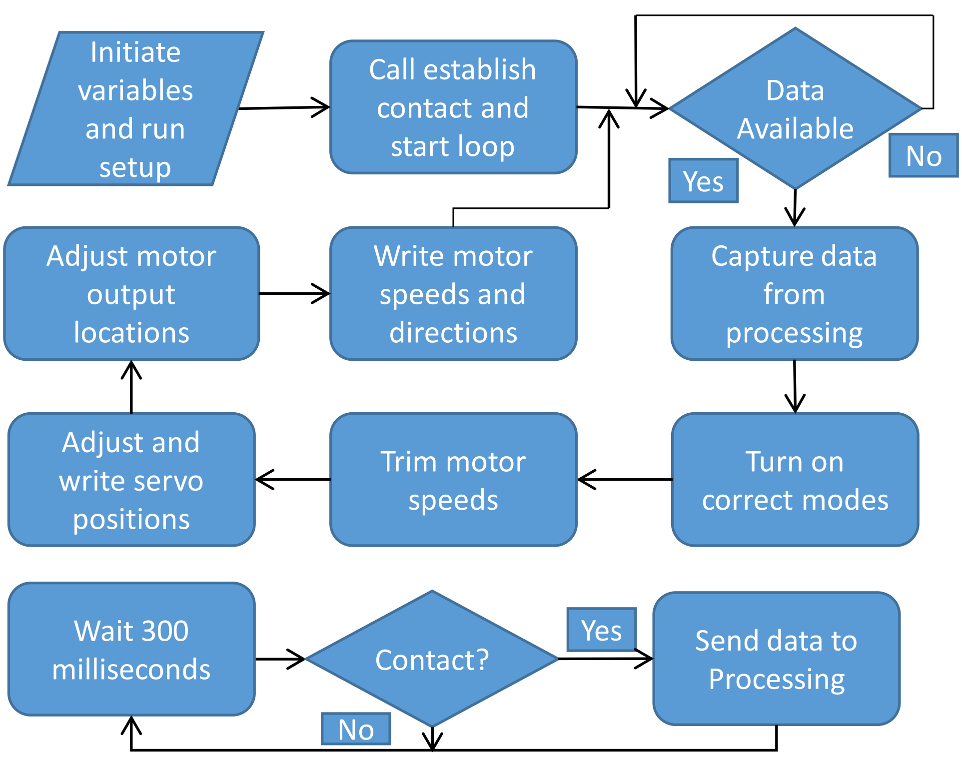
Figure 14: Cameras (Right)

Software Flowcharts

Laptop GUI Flowchart



Arduino Microcontroller Flowchart



Modes

To be properly equipped in all mission situations, Ozaukee Robotics has given the robot multiple modes of operation that alter the basic functions of the craft to enhance specific maneuvers.

For example, hover mode suspends the robot in the water, as still as a diving Squirtle. Hover mode is executed primarily through the use of the depth sensor. Once activated by the "H" key on the keyboard, the craft is suspended at its current depth. This constant positioning is produced by the vertical thrusters, which exert force in amounts parallel to the amount of change in depth to prevent movement and stabilize the ROV.

Activated by the "G" key, ground mode fires all thrust motors downward at 50% to settle the ROV at the bottom of the pool so movement can be restricted to lateral directions.

Precision mode, activated by pressing the "P" key, reduces all thruster values to half of their original voltage. This allows the pilot to make fine movements while using the full range of the joysticks on the controller.

Our programming has allowed the creation of a unique orientation selection feature, named direction mode. Activating an arrow key allows the pilot to designate any side of the craft as "front." The variables within Squirtlebot's code instantly adapt so that the microcontroller reassigns input to a different side of the craft as "front." Though dominance often falls to the short sides of the craft as they allow the robot to flow through the water with less resistance, all sides are equipped with this function. Specific sides are easily determined by the color and direction of the arrow as it appears in the top right corner, which changes based upon the current direction mode. This feature increases task efficiency and completion time because the pilot does not need to concern himself with turning the craft around or navigating sideways or backwards.

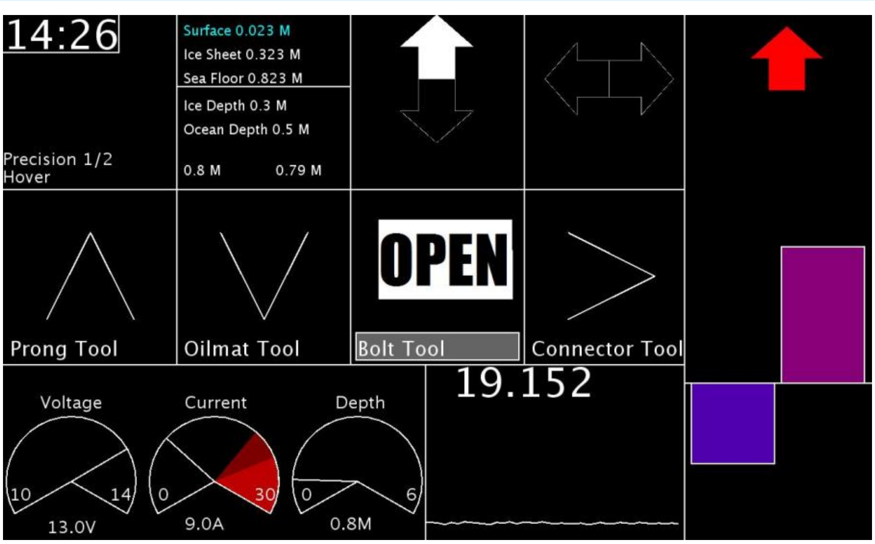


Figure 15:
GUI

Prong

The team brainstormed the prong to complete the mission task of identifying and placing CubeSats. The team initially considered the alternative of using a gripper but evaluated that a prong would be faster and easier to use. The servo motor moves the prong up and down. With a camera attached behind it, the team on deck can see what they are retrieving and also locate the CubeSats' serial numbers necessary to complete the mission. The tip of the tool is slightly bent to ensure that the objects received do not fall off.

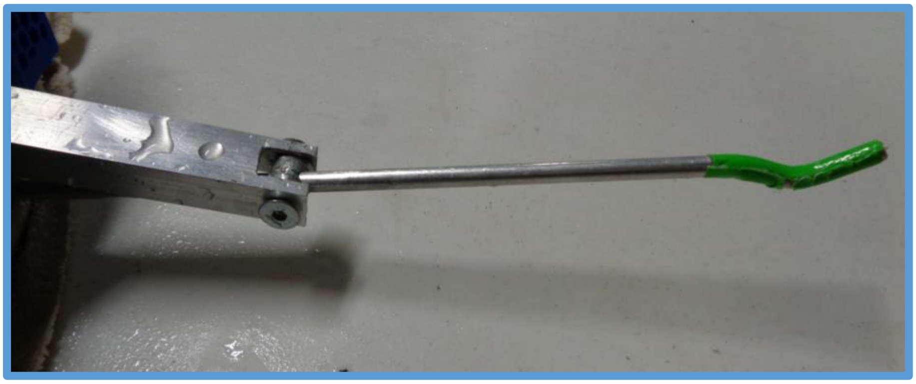


Figure 16:
Prong

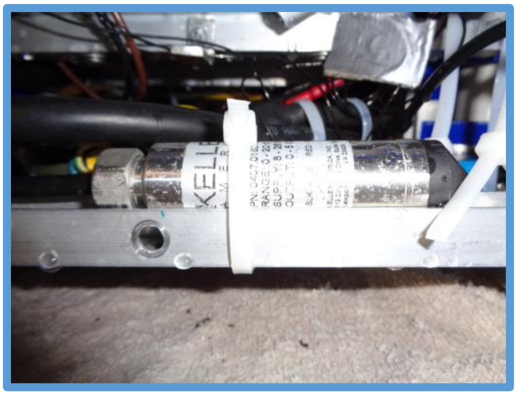


Figure 17:
Depth Sensor

Depth Sensor

In previous missions, completing the designated tasks has been difficult; our ROV would move up and down with the flow of the water, making precision tools almost useless. To combat this problem, we designed hover mode to keep Squirtlebot static in the water. The depth sensor is also a crucial part of task completion as it is used to measure vertical distances, specifically the depth of the ice sheet.

In order to accomplish the calculations responsible for this, we employ a Keller submersible level hydrostatic depth sensor. The sensor emits data in an analog signal; a Wheatstone Bridge within the sensor gauges water pressure, relaying data to the dry housing. Within the housing, the onboard Arduino microcontroller calculates the data and sends it to be displayed in real time topside on the GUI. The microcontroller and sensor retain accuracy within two centimeters, which is more than sufficient for maintaining stability. The accuracy and reliability of this system has reaffirmed its value to the ROV.

Oil Mat Tool

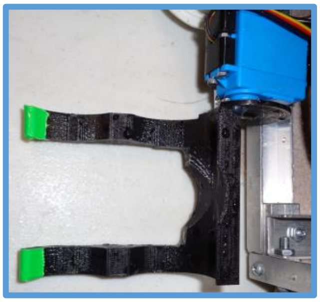


Figure 18: Oil Mat Tool

In order to find the origin of the oil given to us, the company created what we call an oil mat tool. In the mission, the team will collect two different oil mats from the seafloor and return them to the surface. We then have to evaluate a chromatograph to figure out the oil's origin. This tool can carry both of the oil samples at the same time for efficiency.

Bolt Dispenser

Figure 19: Bolt Dispenser

The bolt dispenser helps accomplish multiple mission tasks. The dispenser assists securing the flange and bolting down the cap for the wellhead. The team initially designed the bolt dispenser to be capable of retrieving two bolts at the same time, however after brainstorming we realized the design was too long and would interfere with other parts of the ROV. We solved this problem by having the bolt dispenser carry one bolt at a time, allowing us to shorten its design. Made from 3D printed material, the tool opens and closes using a servo motor. By closing the tool while the bolt is being held, the team can clearly see where they are inserting the bolt. The bolt can simply be released by opening the tool with the servo motor.

Connector

The connecter is essential in completing multiple tasks within the competition. The tool retrieves the ESP, picks up the flange, and installs the wellhead. This tool also collects the coral samples from the bottom of the pool. Viewable by a camera from the pool deck, the tool simply opens and closes like a book to retrieve the objects needed.

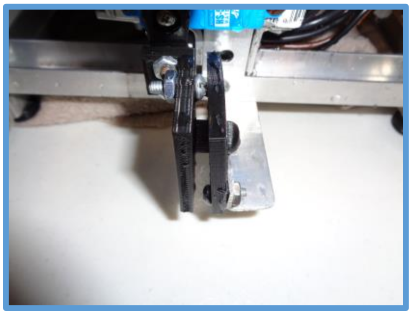


Figure 20: Connector

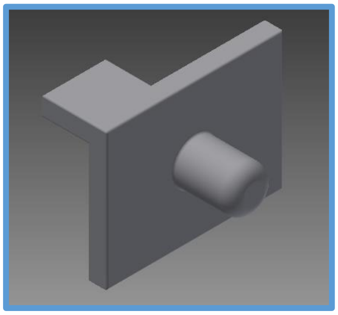


Figure 21: 3D Connector

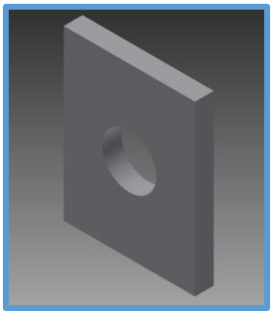


Figure 22: 3D Connector2

Safety

Ozaukee Robotics takes extra precautions to assure that our ROV is as safe as possible. In order to guarantee the safety of the craft and its personnel, Ozaukee Robotics has taken a number of safeguards to prevent both electrical and mechanical damage.

The most important safety feature lies topside, at the very beginning of the ROV's tether. Thirty cm from its point of attachment, the tether ends in a 20 amp, single inline fuse. When securely attached to the power supply, the fuse monitors a steady, constant flow of current to the dry housing. In the event the fuse blows, damage to our ROV will be minimal, as all the positive leads on the craft's components have been fused to prevent energy backlash. To manage the heat generated by the dry housing's electronic components, devices that draw high amounts of power were wired in parallel through the bulkhead connectors, dividing the current load through multiple cables. All possible leaking areas were thoroughly sealed.

Safety features exist for those working around the craft as well. All sharp frame edges have been rounded or marked as sharp and padded. The propellers are enclosed with custom 3-D printed shrouds to prevent entanglement and skin contact, and are marked as moving parts. All team members are required to wear safety glasses and closed-toed shoes when operating or modifying the robot. Before each run, all safety components, from the 20 amp fuse to our goggles, are checked to ensure universal safety.

Safety Checklist/Protocol

	Safety Checklist
	All Items attached to ROV are secure.
	Sharp edges that have not been smoothed are marked.
	Single inline 20 amp fuse is in place.
	No exposed copper or bare wire.
	No exposed propellers.
	All wiring is securely fastened.
	Tether is properly secured at surface point and at ROV.
	All wiring and devices for surface controls are secured.
	All control elements are mounted inside an enclosure.
	On-deck team is wearing safety glasses and close toe shoes.

	Safety Protocol
	Uncoil tether
	Check tether and all other tripping hazards are organized neatly on deck
	Check for safety goggles
	Power On
	Check all cameras are positioned properly
	Test thrust motors
	Test lift motors
	Test strafe motors
	Test servos
	Check depth sensor is functioning
	Check voltage meter is functioning

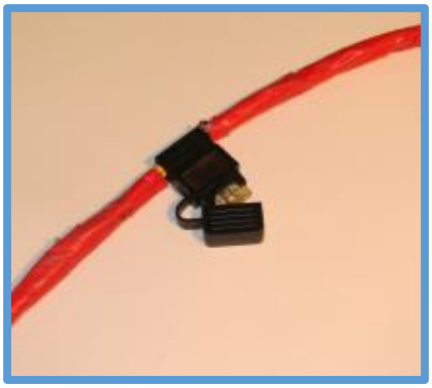


Figure 23: Single Inline Fuse

DESIGN THEME

Because of this year's emphasis on marketability, the team decided that a cohesive theme for the ROV and the team as a whole would be highly beneficial. The team had a brainstorming session and eventually voted on Squirtlebot as the name for our ROV due to their love of Pokémon and the robots water like nature.

We then tried to include the concept of Squirtlebot into the different parts of the competition. The poster features a water background and a theme-focused tagline and mission statement. The technical document includes many shades of blue (reminiscent of the water themed Pokémon) and various references to the game.

This integrated design allowed our team to be further united along all aspects of the mission. It also encouraged the team to put new energy towards the marketing portions; the theme promotes endless creativity in unique marketing solutions. Additionally, it brings a certain level of creativity into the competition and makes this process even more enjoyable for the team.

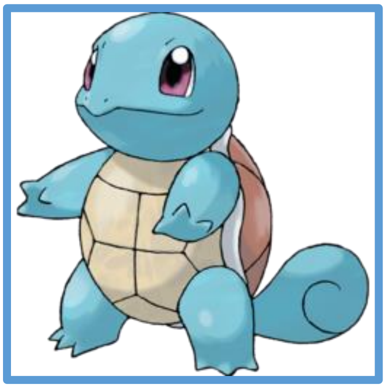


Figure 24: Squirtle

Figure 25: Team Shirt Design

Troubleshooting

One of our problems we encountered while building our robot was that our prong was not strong enough to lift up the CubeSats. Our original design was meant to pick up two CubeSats at once. When we realized we were unable to achieve this, changes had to be made. As a team, we discussed ideas. In the end, we decided to make the prong shorter and pick up each CubeSat one at a time. Another problem we faced was when Squirtlebot's motors were not working properly due to software glitches. Luckily our software engineers figured out that we did not set the pins on the microcontroller to the right mode. These are just a few examples of how the entire vehicle along with each component were extensively tested.

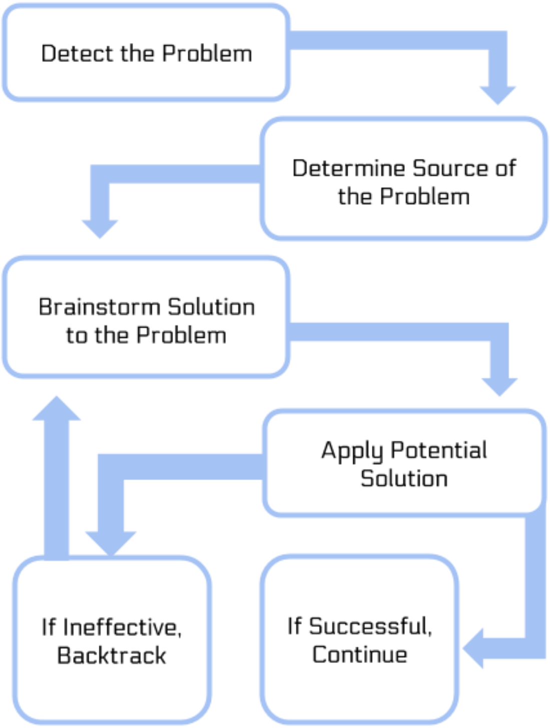


Figure 26: Troubleshooting Process

Challenges Faced

Technical

This year, it was a challenge to construct our ROV to earn the points for the size and weight parameters. Our robot has been very large in the past, making it difficult to reuse parts from our old robot without exceeding the criteria. We had to completely redesign our robot and build it out of a new material to stay within the size and weight conditions.

One step we took to decrease overall size was to get a new dry housing. We initially considered 3D printing a dry housing to allow us to inexpensively create a smaller container. However, we ultimately decided against this as we were not certain that the 3D printed housing would be capable of withstanding the pressure of the water. We instead chose to purchase a new 20.3 cm by 15.24 cm by 10.16 cm Integra dry housing. This dry housing is significantly smaller than our old dry housing and has allowed the size of our robot's frame to be greatly diminished.

Deciding what material to build the frame from was another challenge we faced when redesigning our robot. Last year's frame was made up of high-density polyethylene and T-slot 80/20 aluminum. While these materials were sturdy, they were very heavy and would not be usable in this year's design. PVC pipe was considered as a possible alternative that would decrease Squirtlebot's weight. However, PVC would be difficult to mount tools due to it's shape. Instead, we decided to use C-channel aluminum. This greatly decreased the weight of our robot and provided a shape that was easy to mount tools to.

Non-Technical

Ozaukee Robotics members struggled with intercommunication. Because of the structure of our team, it was difficult to accommodate the needs of both the Engineering and Business departments. Both areas had personal timelines for their respective goals, but these two calendars did not always align. The two areas are completely reliant upon each other so this posed a huge problem for the team.

A month into practices we recognized that this format would not continue to work long-term. The entire team met and consolidated the conflicting schedules, putting them on one shared calendar. The calendar included dates and times, but it also included various goals we set for each meeting. This allowed us to better collaborate with each other, as well as achieve the goals we set in a timely manner. Our structure is now a major asset to the team.

One intrapersonal challenge we faced was communicating who would be able to make it to meetings. Often times team members would arrive at meetings and find that other members were not present or that they would be arriving late. This was a problem as it made it difficult to plan on what would be accomplished during a specific meeting. We solved this problem by establishing a group text between all team members. This allowed meeting times to be easily communicated and made it easy for members to let everyone know if they would be present or not.

Another intrapersonal problem faced, was having everyone work efficiently at meetings. Team members would often have specific tasks they were trying to accomplish on the robot. However, they could not accomplish them if others were working on the robot as it was difficult to have too many people working at one time. This often left people waiting for access to the robot while other team members finished working on it. To circumvent this problem, we began giving team members multiple jobs at one time so that they could always be working on something. If a mechanical engineer was waiting for access to the robot, for example, they could review parts of the technical document that related to them. Additionally, if a team member had nothing to work on at the moment, they were encouraged to ask others if they needed help with anything. This allowed efficiency to be maximized at team meetings.

Lessons Learned

Technical

Now that a weight and size limit has been introduced to the rules and regulations, we have learned that every piece counts. We have weighed all components down to evert last nut and bolt on our ROV. In order to keep track of the weights, we created a spreadsheet and updated it frequently. Through this we have learned the importance of following restrictions, and making sure we know how much everything weighs before the competition.

Interpersonal

In previous years, our team had trouble coordinating a sufficient amount of practices. All of the members of our ROV team are very involved in other activities, which makes it nearly impossible to find practice time that accommodates all of our members. This year we learned the value of small groups.

Although this is a seemingly simple concept, it has transformed the efficiency of our team. Instead of limiting ourselves to dates that oblige everyone, we have learned to split into smaller units according to what is on the agenda for that week. For example, if the week's goal is to finish designing the frame, the mechanical engineers would have to find a time that they can all meet, but they do not have to consider the rest of the team's schedules. Obviously, the team continues to meet as a group for all of the dates that work for everyone but that requirement no longer limits us.

Future Improvements

One future improvement our team would like to make is to use thrusters designed specifically for underwater use. We have previously used bilge pump motors as they were easily available and cheap. However, these bilge pump motors carry a number of downsides. These motors are not neutrally buoyant, they are unshrouded, and they require some modification to be used on an ROV. Underwater thrusters are built for ROV use. They are neutrally buoyant, shrouded, come ready to use, and would provide a greater amount of thrust than our current motors. These thrusters would allow our team to more easily assemble our ROV as we would no longer have to go through the process of designing shrouds for our motors. Additionally, these thrusters would be easier to wire into our dry housing and mount on our frame. Our ROV would be capable of moving significantly faster with these thrusters and could complete tasks swiftly. Underwater thrusters are unfortunately very expensive compared to our current bilge pump motors. However, by reaching out to companies that manufacture these thrusters, we may be able to have these thrusters donated or discounted, allowing us to make this improvement to our ROV.

Reflections

Being in ROV has taught me that everyone has something to offer to the world. I didn't always go in sports or the usual after school activities, then I found out about robotics and joined. I now feel I grasp a greater understanding of machines, electronics, and science in general. I used to hate typing up essays and other electronic school assignments but ROV sparked my interest in computers and technology related work. I feel that what I learned here I will use for the rest of my life.

-Jarrod Bares, Public Relations/Electrical Engineer

Before I was a part of ROV, many of the things I learned felt like they had no real relevance outside of school. However, once I joined ROV I found that I was able to apply these skills to make contributions to the creation of our robot and completing the mission. For example, I was able to use knowledge I had in algebra and trigonometry to program our robot's microcontroller and graphical user interface. In addition, ROV has showed me what it is like to work as part of a team developing a product. This has greatly enhanced my skills in communication and organization. ROV has improved my abilities to apply my knowledge and work in a team and these experiences will help me throughout my life.

-Josh Vogt, CEO/Software Engineer

ROV has given me the opportunity to participate in something much bigger than anything I could do on my own. It has given me great insight into the experience of working on a team, meeting deadlines, and overcoming challenges that actual engineers face and deal with everyday. It has enabled me to learn new skills and utilize previously learned ones such as 3D modeling in a practical real world situation. Being a part of the Ozaukee ROV team has reaffirmed my desire to spend my life as a computer engineer.

-Nick Marz, Software Engineer

Being in ROV, has truly been a great experience. I increased my insight on teamwork and my knowledge in science. I learned so much about what skills and equipment it takes to build a robot. Most of my work was done through the technical report, which helped me understand all the aspects of building the ROV. All of the skills I have acquired are essential and I believe are something I will take with me throughout my life.

-Hannah Bell, Technical Writer

Becoming a member of ROV has helped me understand the value of teamwork as well as how everybody can succeed in their specific categories. It amazes me how all the different groups of people can come together and make something so interesting and intricate. Being a member of this group helped me learn more about what it all takes to get a robot to succeed in these missions. Being a technical writer broadened my ability to analyze situations or products and efficiently write about them. This will help me later in life and I appreciate the opportunity to learn.

-Hannah Nordby, Technical Writer

Since becoming a member of our ROV team, I have learned many new things, and have been able to help teach others what I have learned. When I first joined the ROV team, I was assigned to do the less critical jobs, such as building the props for the practice course, sometimes designing a small component of the ROV. I am now designing and creating key parts to our ROV, as well as helping to build it as quickly and efficiently as possible. Through all of this, I have learned important life skills such as teamwork and good communication. Being a member of this ROV team has helped me to prepare for my later life and has helped me to become a better member of society.

-Zach Wagner, Mechanical Engineer

Being a member of our ROV team has taught me many things. When I first joined, I worked on programming the robot and the graphical user interface. Coding a robot is a very difficult thing to do, and I was honored to be part of that. I am now working with mechanical and electrical duties, which I find more desirable due to my abilities. Working on the frame of the robot and with the wire connections has made me enjoy ROV more than when I was working with code. ROV has also taught me skills that I may need for the future, such as working as a team and working with restrictions. Utilizing all of these new skills has been beneficial as I can now apply my knowledge and be a better team member. These skills will be helpful throughout my life.

-Joseph Ceranski, Mechanical/Electrical Engineer

Joining the ROV team at our school has introduced me to many new things and experiences. I learned how to make detailed diagrams that people could understand and read as well as simple ones. Besides creating schematics and diagrams I also practiced soldering large wires as well as organizing them and directing them into the designated areas that my schematics had shown. Learning how to plan out and execute is a very useful skill that I will definitely use later in life along with my other sets of skills. Being on the ROV team has taught me how to work with a team to work on different parts of a project at the same time as well as practicing and perfecting my different sets of skills. This experience will have made me a better person through skill and through practice.

-Connor Freiburger, Mechanical/Electrical Engineer

Company Effort

Designing our ROV was a company effort achieved by the members of the team. Once the mission was released, the team's engineers began drafting ideas for our ROV's design. Team members came up with concepts for tools to help us compete tasks and ways to create a frame that was small enough to meet the new size requirements. As time went on, concepts for the design of the ROV were tested by the team to see which methods were most effective. The team then assembled the ROV and continued to test and redesign specific components to maximize functionality. Additionally, the company's employees worked together to write the technical document and design the marketing display.

Project Management

To manage the development and building of Squirtlebot, Ozaukee Robotics established weekly goals that aligned with the long-term plans established on the build schedule. Each department would then have tasks to accomplish over the course of the week. This allowed the departments plenty of time to accomplish each week's tasks as well as communicate with each other when necessary. During meetings, each department would check in and report where they were with their current tasks. This communication allowed the whole team to be informed of what had been accomplished thus far. Additionally, if a department ran into a problem, the team was easily able to come together to solve it.

Build Schedule

Date	Build Task
1/8/2016	Put holes in and mounted bulkhead connectors on dry housing
1/15/2016	Built and tested CubeSat lifts and collection for oil mat and servo bolts
1/18/2016	Tested ROV's cameras and designed and printed servo motor mount
1/22/2016	Designed temperature probe assembly and printed motor mounts
1/29/2016	Built tether, re-did black box for cameras and worked on website
2/1/2016	Took team picture, wired thrust motors and designed dry housing shelf
2/5/2016	Tested communication, 3D printed electronic shelf, and assembled driver boards.
2/8/2016	Assembled micro controller and voltage regulator boards and wired dry housing
2/12/2016	Tested Servos, 3D modeled the dry housing, and 3D printed temperature probe
2/22/2016	Built the frame, designed the connector assembly, and mounted hook
2/24/2016	Tested and wired temperature probe and depth sensor and mounted servo motors
3/1/2016	Wrote GUI and micro controller code
3/7/2016	Mounted 2 servos, last camera and temperature probe
3/14 - 4/10	Worked on tech report and pool runs until Regional Competition

Vehicle Systems

Components

Many aspects of the robot were custom designed and 3D printed. Additionally we reused functional items from past years, including the propellers, the servo motors and components within the dry housing. The team purchased items that were too complex to create in house. Purchased items include the aluminum c-channel frame and six new cameras. The numerous tools and propeller shrouds were 3D printed. If a part could be made in house, the team decided to custom make the part, instead of buying it.

Team Memory and Evolution

Past members had an influence on the planning process. They had more experience and were able to offer suggestions from previous years. These members also helped the new members by giving them an overview of the competition set-up, layout, and what was expected of the teams. The team researched the mission through the MATE and NASA websites and custom designed the ROV for the mission requirements.

Cost Analysis/Projection

At the beginning of the year, the team planned how we were going to design the robot. Research was done to learn about different materials to find the best design to complete the mission tasks. Ozaukee Robotics had money and materials saved from previous years. The team additionally did a number of fundraisers. These included selling T-Shirts to friends and family and organizing a brat fry. Creating a budget was an important part of the cost analysis process. When looking at what materials to use, the team estimated how much each would cost and then totaled this amount. If any specific items were rather expensive, the team looked for alternatives to reduce the cost, such as purchasing different materials or finding a way to manufacture that item in house.

Budget / Expense Report

Value of Reused Items		
Item Description	Est. Cost	Original Year
Arduino MEGA	$15.00	2010
Multiplexor	$26.00	2011
Depth Sensor	$50.00	2011
Motor Drivers	$60.00	2011
Bulkheads	$200.00	2011
Cameras	$50.00	2013
TV Monitors	$200.00	2013
Tsunami Motors	$141.00	2015
Propeller	$89.75	2015
Prop Adapters	$32.00	2015
Total	$863.75	

Material Donations		
Donated Material	Est. Cost	Company
Dry Housing Enclosure	$108.00	Integra
Tether Wire	$55.00	Ancor
ROV Tote	$64.00	Bares Family
Total	$227.00	

Monetary Donations	
Company	Cost
Fredonia Mobil	$250.00
Wagner Family	$100.00
First Southwestern Title Co.	$200.00
Thrivent Financial	$250.00
Total	$800.00

Services Donated	
Item Description	Est. Cost
Ozaukee High Woodshop	$900.00
Vogt's Tools & Workspace	$250.00
Total	$1,150.00

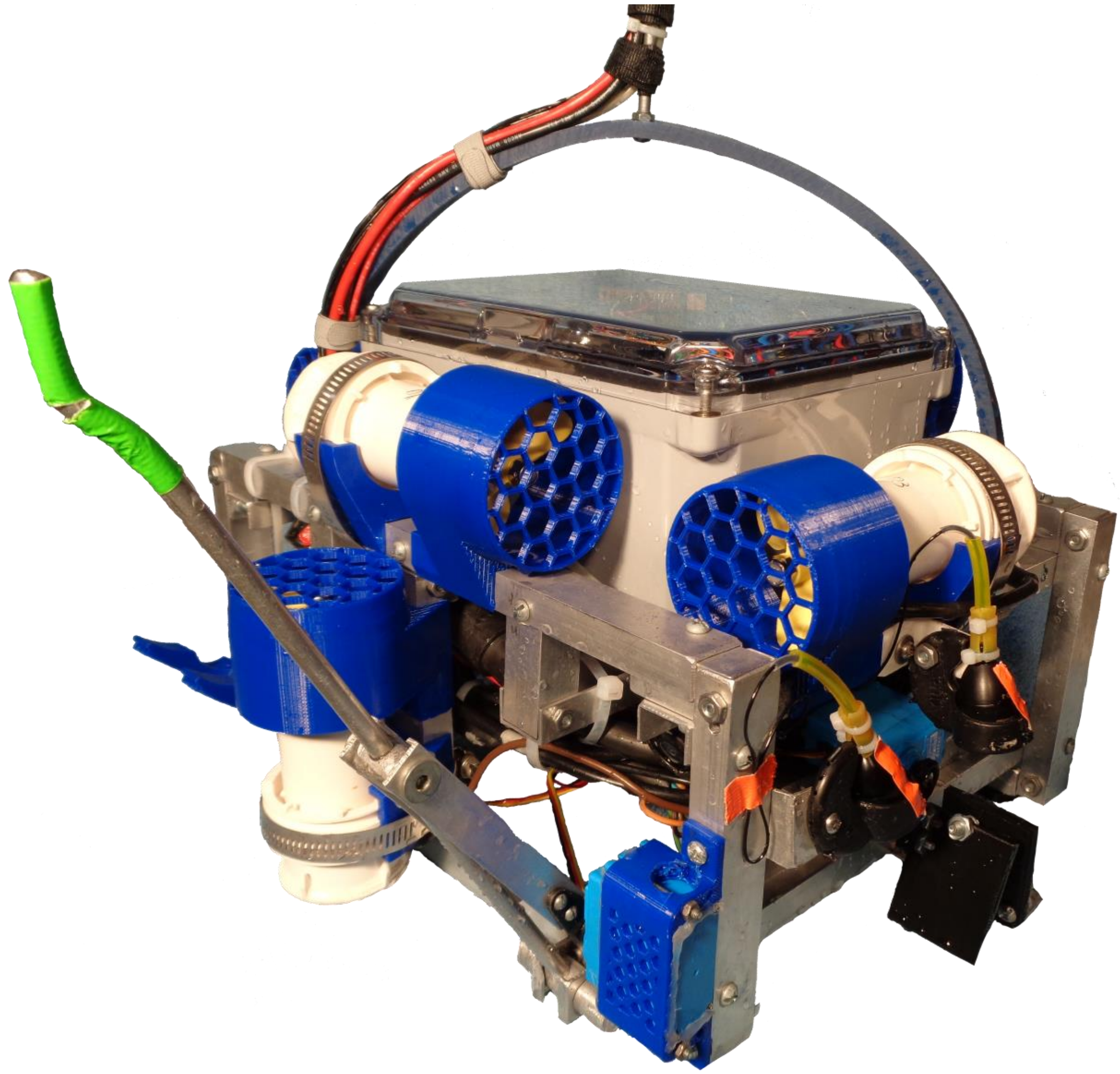
General Expenditures	
Item Description	Cost
Ink Cartridge and Clips	$21.82
T-Shirts	$256.05
MATE Registration	$25.00
PVC Pipe	$57.67
Total	$360.54

Travel Estimate	Cost
Travel	$4,050.00
Hotel	$1,995.00
Total	$6,045.00

ROV Build Expenditures	
Item Description	Cost
Misc. Hardware	$13.47
Aluminum Pieces	$42.86
Temperature Sensor	$18.80
Tools	$14.00
Fuse Holder	$3.45
Servo Motors	$119.98
Velcro	$17.57
Powerwerx Connectors	$11.95
Cat 5 Cable	$7.41
Hardware	$15.00
Fasteners	$16.41
Buoyant Foam	$4.17
Cameras	$180.00
Laptop Batteries	$37.76
Compass Board	$38.47
Duck Tape	$23.59
Total	$564.89

Total ROV Cost	**$1,655.64**

Summary Sheet



Dimensions: 46 cm x 39.5 cm x 38 cm

Dry Weight: 9.88 Kg

Approximate Total Cost: $1,655.64

Acknowledgements

Ozaukee Robotics would like to thank:

- MATE: for hosting this amazing competition
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- SubConn: material donation
- Bares Family: material donation
- Ozaukee High School: for their facilities
- Fredonia Mobil: monetary donation
- First Southwestern Title Co.: monetary donation
- Thrivent Financial: monetary donation
- Wagner Family: monetary donation
- Randy Vogt: for his technical expertise

Photo Accreditation

Cover Photo 1: Hannah Bell
Cover Photo 2: Monica Vogt
Figure 1: Randy Vogt
Figure 2: Randy Vogt
Figure 3: Randy Vogt
Figure 4: Nick Marz
Figure 5: Hannah Nordby
Figure 6: Hannah Nordby
Figure 7: Josh Vogt
Figure 8: Zach Wagner
Figure 9: Zach Wagner
Figure 10: Randy Vogt
Figure 11: Hannah Nordby
Figure 12: Hannah Nordby
SID: Connor Freiburger
Figure 13: Hannah Nordby
Figure 14: Randy Vogt
GUI Flowchart: Nick Marz
Arduino Flowchart: Josh Vogt
Figure 15: Josh Vogt
Figure 16: Randy Vogt
Figure 17: Randy Vogt
Figure 18: Randy Vogt
Figure 19: Randy Vogt
Figure 20: Randy Vogt
Figure 21: Zach Wagner
Figure 22: Zach Wagner
Figure 23: Hannah Nordby
Figure 24: Google Images
Figure 25: Mountain Promotions
Figure 26: Hannah Nordby
Summary Sheet: Hannah Bell

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