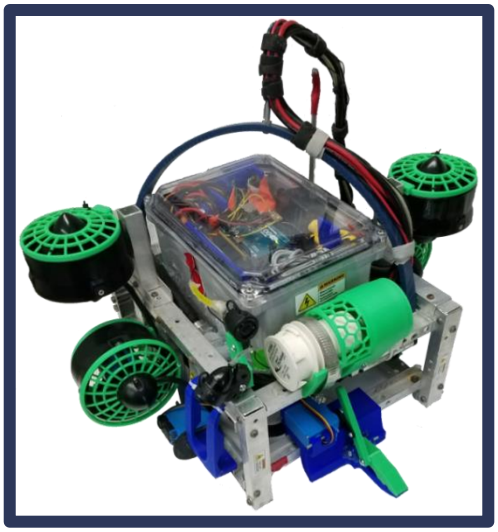
MATE 2018 Technical Document

Ozaukee Robotics
Ozaukee High School, Fredonia, WI



Warrior

Ozaukee Robotics Team

Team Members
(from left to right)

Max Frey, 9th: Mechanical Engineer/Electrical Engineer
Zach Wagner, 12th: CEO/Mechanical Engineer/Software Engineer/Electrical Engineer
Hannah Bell, 12th: Technical Writer/Public Relations/Accountant
Eli Bayer, 10th: Mechanical Engineer/Electrical Engineer
Nick Janik, 12th: Pilot/Software Engineer
Hannah Nordby, 12th: Technical Writer
Amy Wolff, 12th: Technical Writer

Mentors and Instructors
Bob Wagner
Chris Janik
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Abstract

As this is Ozaukee Robotics ninth year participating in the MATE ROV Competition, we are proud to build and control a usable, yet complex ROV. This year's vehicle, Warrior, has the ability to identify and remove debris, send acoustic signals, install various objects, and measure necessary distances.

Throughout the year, many challenges arose. These involve teaching new members, inner-club communication, new tools, and different technology.

While size and weight restrictions have been present previously, it still remained a top priority in the building process. New technology includes the acoustic release for the OBS and the lift bag used in the Aircraft task.

This year, the weight restriction increased by one kilogram, totaling 12 kilograms. With this additional weight, we were able to add components to our ROV.

We accomplished the tasks in this year's competition through the use of specialized tools. This includes reliable, reused items, such as the prong, but also many new tools, including the lift bag. A light frame made from aluminum c-channel and 3-D printed tools allow for Warrior to remain under 12 kg in size, enabling a single person to easily transport the vehicle. The specific tasks the team would like our ROV to accomplish are the acoustic release of the OBS and the use of a lift bag to move debris and an airplane engine.

Continual success of Ozaukee Robotics is due to hard work, dedication, and the overall refusal to abandon the necessary communication between various regions of business among our team.

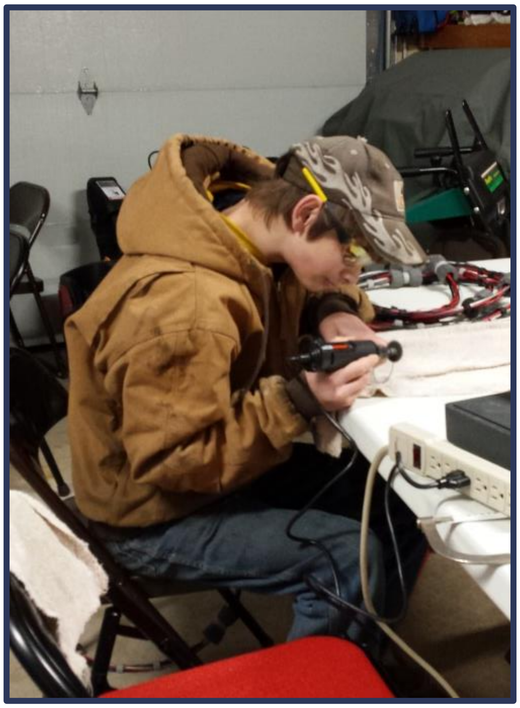
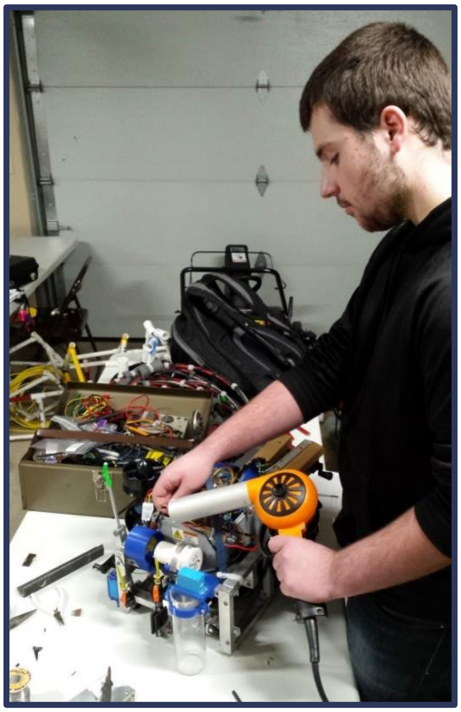


Figure 1:
Mechanical Assembly
(Left)

Figure 2:
Electrical Assembly
(Right)



Corporate Profile

Ozaukee Robotics acts as a functional business, comprised of two separate divisions. These two divisions work on either analytical or applicable aspects of the complex business approach that our team utilizes. In order for these two separate divisions to connect and effectively make up our business, communication is essential. Effective communication and equal participation are both fundamental to our business' success.

The analytical department operates to accomplish tasks involving fundraising, public relations, and various literary requirements. For example, this department is responsible for completing the marketing display and technical document.

Within the applicable division, three separate groups of engineers collaborate to perfect varying aspects of Warrior. Each group of engineers is dependent upon the others, as each is imperative to the achievements of Warrior. Respectively, the electrical engineers control electrical hardware, software engineers create and program aspects of coding, and mechanical engineers create the fundamental architecture and tools. The division of tasks among these separate engineer groups allows for better productivity within Ozaukee Robotics.

Functioning as the connection between every unit of Ozaukee Robotics, the ability of the technical writers to outline the various components of Warrior is imperative. The technical writers are in charge of drafting the technical document and composing press releases. Through the technical writing, the purpose and reasoning behind every component of Warrior is outlined.

Within Ozaukee Robotics, the division of the team into various sections enables each individual to maintain a clear understanding of the objectives and goals of both their division, as well the club as a whole. Understanding and using this effective method of division allows for overall success for our team and the individuals participating in it.

Figure 3:
Mechanical Engineers attaching tools

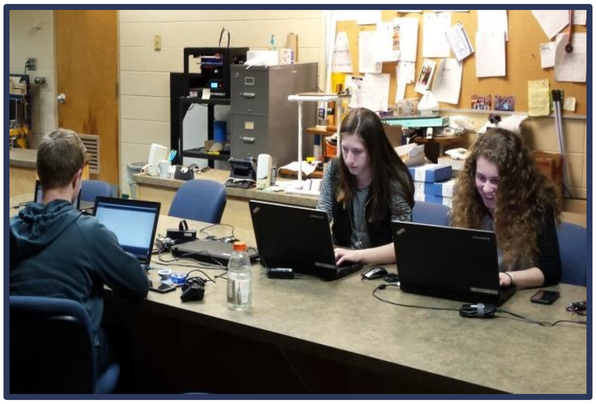


Figure 4:
Software Engineers altering the code and Business Department editing the technical document

Figure 5:
Electrical Engineer soldering

Design Rational

Frame

Aluminum c-channel has been utilized in order to construct the frame of our remotely operated vehicle this year. This material is the exact same as what has been used in the past two years for our ROV. The aluminum c-channel has proven to be more effective than other materials that have been used in the past, such as HDPE. Aluminum c-channel is more durable than HDPE, and is light enough to stay within the weight restrictions. Furthermore, this material allows for easy attachment of accessories. In total, 366 centimeters of aluminum c-channel has been utilized in order to construct our remotely operated vehicle. The weight of this product per centimeter is 2.039 grams, and so the complete weight of the frame is 0.746 kilograms. In previous years, the dry weight of our HDPE frame was 5.23 kilograms.

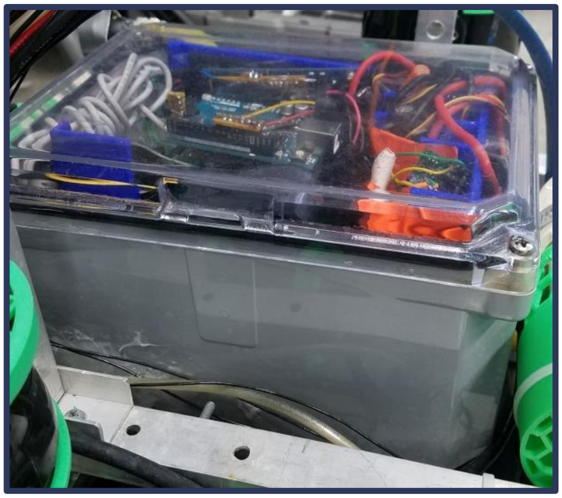
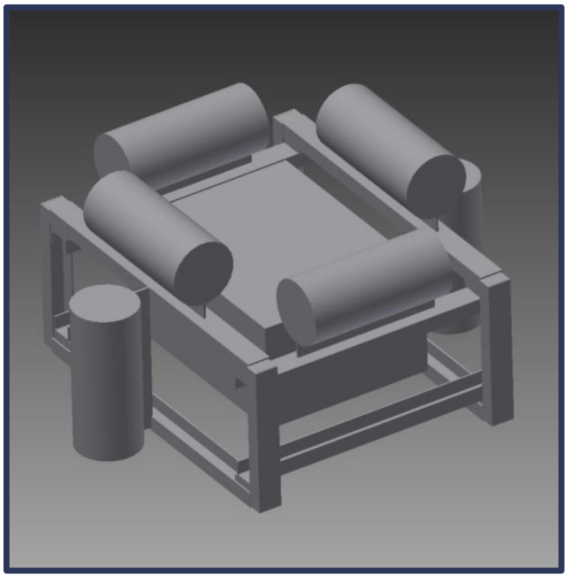


Figure 6:
Dry Housing
(Left)

Figure 7:
CAD Drawing of Frame
(Right)



Dry Housing

With an IP68 rated Integra enclosure, Warrior's dry housing is absolutely water-sealed. The clear lid at the top of the dry housing secures the internal electronics, keeping them safe from any outside forces. This lid is fastened shut by screws as well as a watertight gasket. Due to the dry housing being located at the top of our ROV, the tether is easily accessible. The SubConn bulkhead connectors are completely sealed using gasket sealer. Using the Integra enclosure ensured that our structure was waterproof.

Prior to each run, our tether manager will ensure that our waterproof seal is intact. By simply placing the ROV in the pool, both buoyancy and waterproof seals are tested. The motors, propellers, and tools are only turned on if the tether manager dictates that no issues have arisen through this preliminary pool test.

Warrior's dry housing has measurements of 20.3 x 15.24 x 10.16 cm, with a total volume of 3143 cm^3. The volume of the dry housing is able to counteract the weight of any attached accessories and the frame. In order to maintain a low center of gravity, the heavier products are placed nearer to the bottom of the ROV. This positioning allows for Warrior to remain balanced underwater, enabling maneuverability and the use of tools to be effortless.

Bulkhead Connecters

Warrior's dry housing has three SubConn bulkhead connectors, as seen in figure 8. Through these connectors, we are able to have a secure and waterproof connection into the dry housing. This enables the transfer of information and power to the ROV, while keeping the electronics safe. The bulkheads are sealed with silicone gasket sealer, making them trustworthy yet flexible.

The microcontroller onboard the ROV communicates to the laptop through a CAT5 Ethernet cable. This cable, in particular, is connected to an eight-pin bulkhead connector while the rest of the sensors and motors are connected through two separate eighteen AWG connectors. This particular structure has proved to be immensely reliable, as it has been through many hours of testing but has shown little wear and tear. Despite the numerous reconstructions of the ROV, the bulkhead connectors have exhibited their durability.

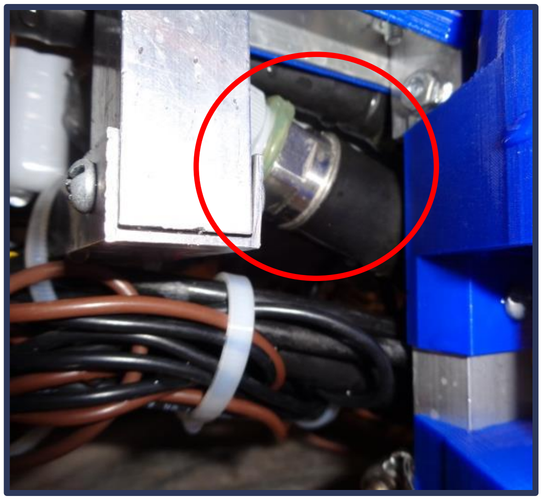


Figure 8:
Bulkhead Connecter
(Left)

Figure 9:
Tether
(Right)

Tether

Ozaukee Robotics utilized a similar design to last year in order to construct this year's tether. Warrior's tether is comprised of 16 wires; each wire transmits power or information between the ROV and the computer operating system. The tether's design involves the use of a Self-Wrapping Split Braided Sleeving to hold the necessary wires together, , as portrayed in figure 9. Every 38.1 centimeters, Styrofoam held on by Velcro strappings allows for the tether to float in water. Prior to using this method, our team routed the wires through a hollow mesh tubing. While this method worked, it was not as easy to replace wires as our new design.

Warrior makes use of only two power cables in contrast to the four separate power cables that have been used in previous years. By employing only two different power cables for the tether, the noise in the thrusters is decreased. Separating the thrusters from the controls has allowed for the connection between the Arduino and the computer to be improved. This is because the power usage no longer fluctuates when the thrusters are turned on and off.

Propulsion

In previous years, our ROV was comprised of solely Tsunami 1200 bilge pumps (Figure 10). However last year, with maneuverability in mind, we replaced four of our previous bilge pumps with T100 Blue Robotics Brushless Motors (Figure 11). These were purchased using a gift card from Blue Robotics that we received at a previous international competition. The motors are far more powerful, allowing us to complete tasks efficiency due to our increased speed and precision.

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. Each set of motors efficiently produces 7 newtons of force while consuming only 4.2 amps of current. As 25 amps are allotted, the thrusters do not exceed the maximum limit, even when including the current used by the electronic components of the craft. With this 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 any direction.

Each Blue Robotics motor uses 54 watts of power with 4.5 amps of current at 12 volts. Each pair of thrusters uses 9 amps of current. The motors can produce a total of 23.1 newtons of power. In total, the ROV would be able to accelerate at 2.143m/sec^2 in any direction. Identical two-piece shrouds were used on both Tsunami 1200 bilge pumps, while the new motors came with built-in shrouds. With new safety qualifications, there were changes made to previous shrouds, to develop thruster guards preventing injury of team members.

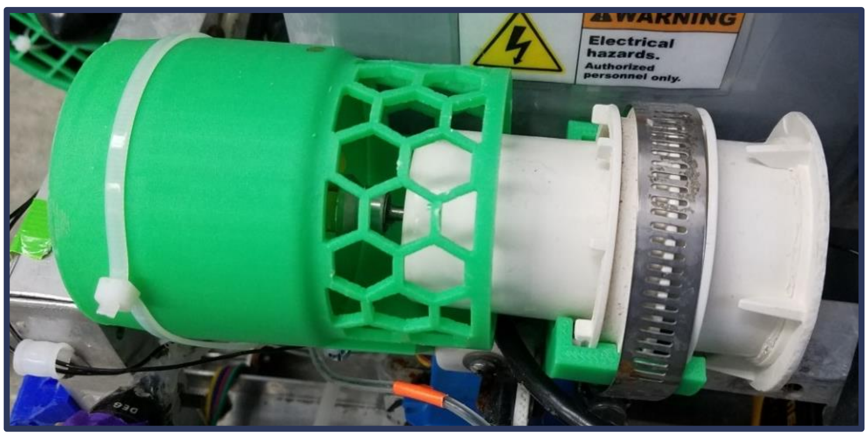


Figure 10:
Tsunami 1200 Bilge Pumps

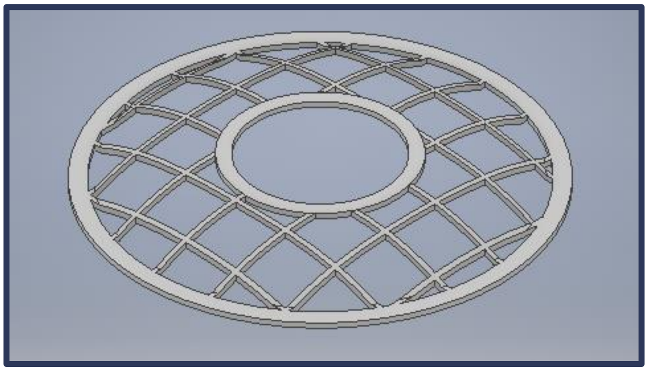


Figure 12:
CAD Shrouds

Figure 11:
T100 Blue Robotics Brushless Motors

Hardware and Controls

Precision and accuracy are essential for any capable ROV. For this mission, Ozaukee Robotics chose to use an Arduino Microcontroller and ESCs (electronic speed controls) to work with our Blue Robotics motors. These ESCs differ from our old motor controllers in that they receive only one value that determines both speed and direction of the motor rather than separate variables for each. The ESCs can receive a numeric value between 1100 and 1900. A speed value ranging from 0 to 400 can be added or subtracted from 1500 to make the motors spin clockwise or counterclockwise, respectively. Thus a value of 1100 is full reverse, 1900 is full forward, and 1500 is stopped. While this is slightly more complex than our old motor boards, the ESCs offer greater fidelity in the speed control of our motors, allowing us to make more precise movements.

Figure 13: ESC

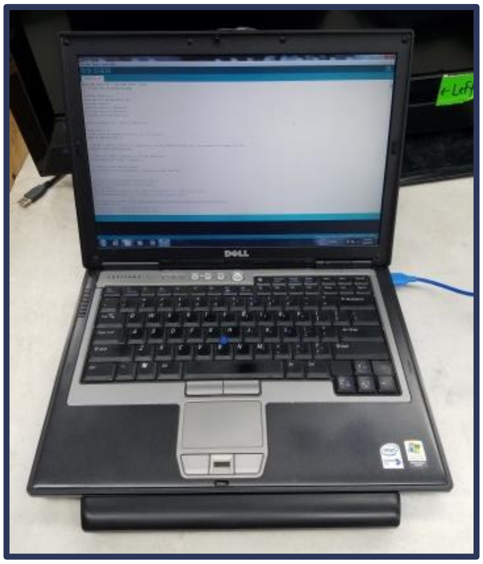
The motor controllers are under the control of the robot's Arduino MEGA Microcontroller. The microcontroller manipulates the motor controllers by releasing Pulse-Width Modulated (PWM) signals. The Arduino adjusts the duty cycle of these signals to change the power sent to the motor boards, allowing for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

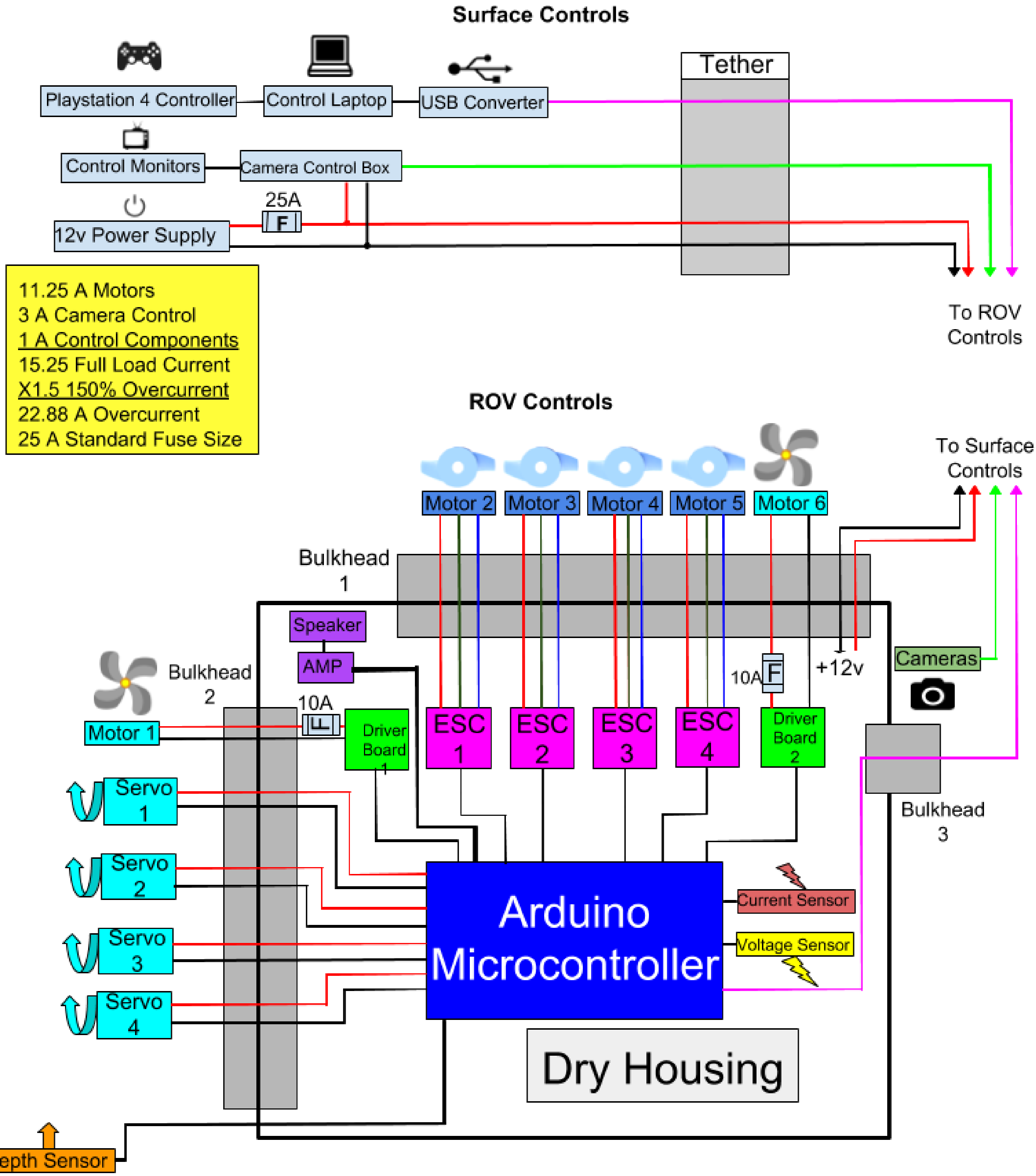
The ROV is manipulated with a laptop keyboard and a DualShock 2 controller (Figures 14 and 15). The joysticks of the controller are used to drive the primary motion of the craft while the keyboard toggles the modes of the ROV. Their use allows for easy direction and programming, permitting more attention to be given to completing the mission, rather than focusing on the controls.

Figure 14: Controller (Left)

Figure 15: Laptop (Right)



System Interconnection Diagram



Software and Video System

Ozaukee Robotics' custom software serves two critical functions: to control the microcontroller and to translate data from the tools. The microcontroller software is written in C code and is stored within the robot's 128 KB 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 to enable the pilot to determine position, orientation, and stability.

Multiple aspects of data are displayed simultaneously by overlaying them on the laptop display. This enables the pilot to monitor both position and data. Prominent components of the data displayed includes the following: thrust generated by each motor, current consumption, status of the instruments, craft depth, and forward orientation. The laptop receives input from the DualShock 2 controller or keyboard. It then interprets, commands, and makes automatic adjustments when the hover mode is enabled.

The microcontroller code was modified last year to work with the Blue Robotics motors. Our Tsunami 1200 Bilge Pumps have one value to determine spin direction and one value to determine speed. The Blue Robotics motors work with only a single value which determines both speed and direction by its difference from a center point. By altering the way the program interprets and outputs the values from the controller, the program was able to be changed to function properly with the new motors. The GUI was also modified this year as there were several elements that could be removed from the past, such as the temperature graph that took up a large portion of the screen. Because of this, the GUI was able to be made cleaner and easier to understand at a glance.

Through nine years of experience, Ozaukee Robotics has discovered that maximizing vision during missions is a top priority. To accomplish this, Warrior 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. The ROV's cameras were manufactured for ice fishing, and each camera broadcasts an analog signal that transmits a 150 degree field of vision and displays in 480p. The cameras were chosen specifically for their IP68 rating, functioning depth of up to twenty meters and lightweight design. This is optimal for the work we do with our robot here at Ozaukee Robotics.

The images gathered by the cameras travel through the tether to above water, 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. There are six cameras that display the tool interactions, while the other two are used for navigation. 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 17: Cameras Mounted on Frame

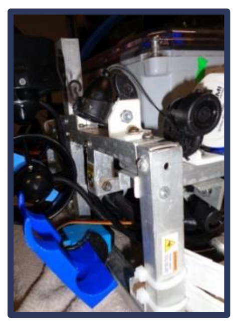
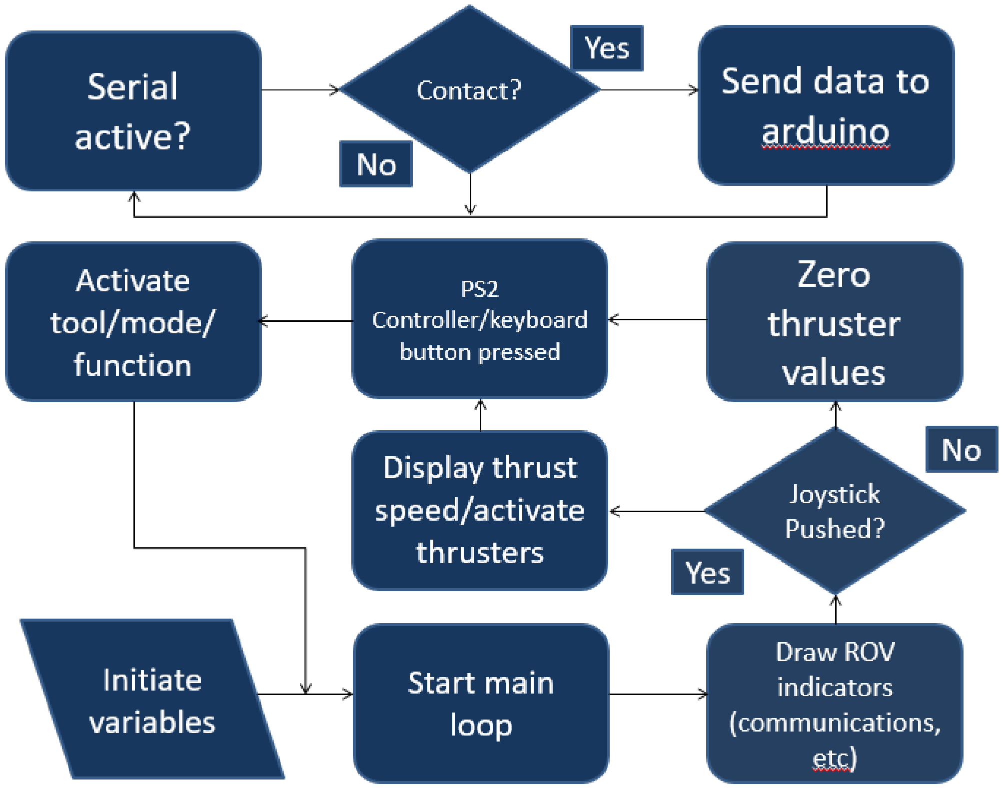


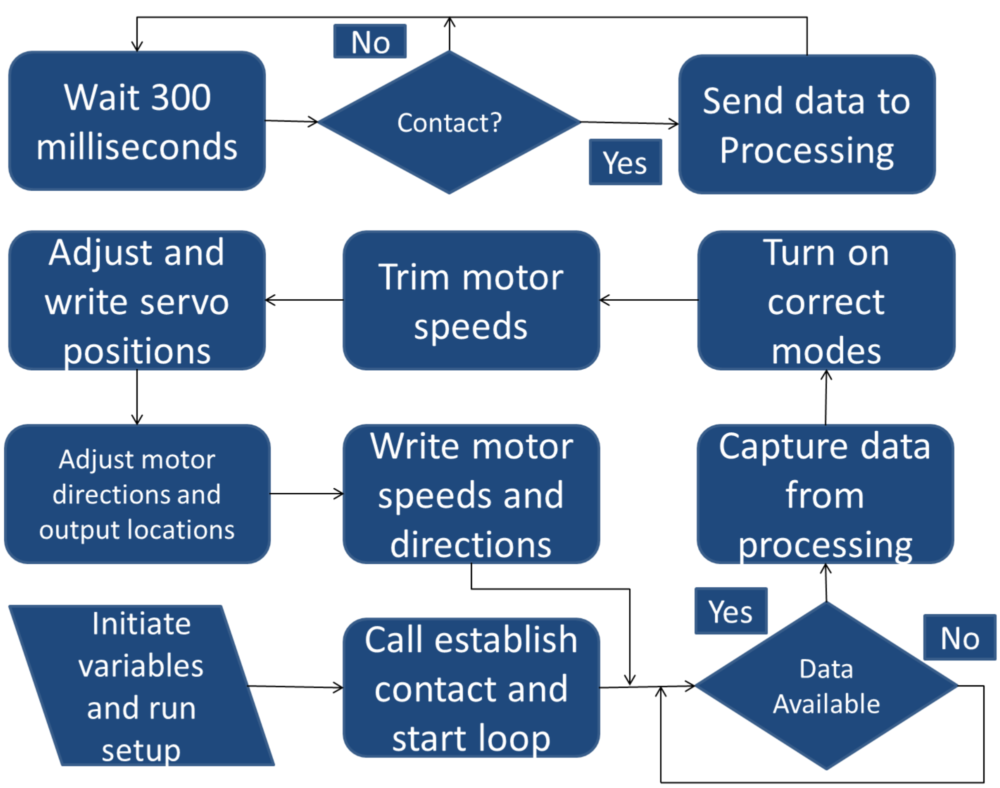
Figure 16: Navigation Set Up

Software Flowchart

GUI Laptop Flowchart



Arduino Microcontroller Flowchart



Modes

Warrior has been programmed with multiple modes that strengthen maneuvers by modifying basic functions. Through this, Ozaukee Robotics is able to complete missions with ease.

Ground mode, mapped to the “G” key on the keyboard, maintains the ROV’s position on the bottom of the pool by firing the lift motors downwards at 50%. This limits the ROV’s vertical movement in order to complete tasks on the floor of the pool. Ground mode will be used in our mission to collect eelgrass samples.

Activated by the “H” key, hover mode suspends the ROV at its current height and actively maintains this height. Hover mode is executed primarily through the use of the onboard depth sensor. By using the feedback from said sensor, the lift motors are automatically fired in a manner that offsets any vertical movement of the ROV.

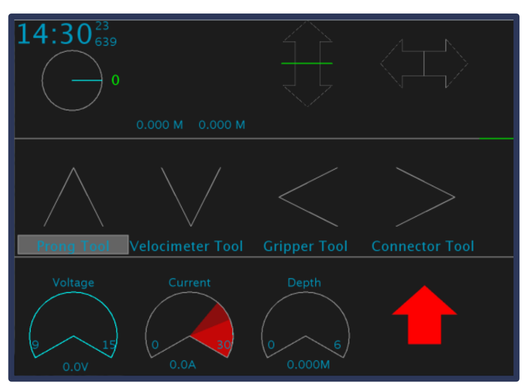
Precision mode, which reduces the voltage of all motors to 50 or 25 percent of the original voltage, is activated by pressing the “P” key. This enables the pilot to make use of the controller’s joysticks full range while making incredibly precise movements.

As a result of our unique programming and simple box-like design of our ROV, we have implemented an orientation selection feature, named direction mode. Activated by pressing one of the four arrow keys, each key designates the respective side of the ROV as the “front”. The variables within Warrior’s code instantaneously adapt as the inputs from the PS4 controller are reassigned to a different side. This drastically streamlines the task completion times and efficiency, as the pilot does not have to turn the ROV in order to move in the correct direction. Specific sides are determined with ease based on the colored arrow in the top-right corner of the GUI (Figure 18). The color and direction of the arrow corresponds with its respective side, allowing for immediate recognition and movement.

Button	Function
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 Velocimeter Tool
Left Dpad	Select Gripper Tool
Right Dpad	Select Connector Tool
Triangle Button	Close Selected Tool
X Button	Open Selected Tool

Button	Function
“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
“Z” Key	Starts on-screen Timer
“Q” Key	Resets on-screen Timer

Figure 18: GUI



Components

Some operative items from last year's ROV have been reused this year in addition to various new aspects that were custom designed or 3D printed. The gripper, the velocimeter installation tool, and the motor shrouds are three components that were 3D printed, while the motor mounts and frame were reused from last year. This conservative action allowed for our team to cut costs and time. Overall, our team acquired its components by recycling functional parts when appropriate and designing or purchasing new components when necessary, in order to produce an efficacious ROV. Repeated vehicle testing and the use of prototyping proved to be essential in our teams' quest to create an effective and functional ROV. Our team was able to rapidly manufacture prototypes of our tools through the use of a free CAD software and a 3D printer. This enabled our team to quickly determine the optimal design for our tooling. Each of the different tooling options equipped on our ROV enable for varying tasks to be accomplished. Warrior's immense versatility allows for the pilot to use specialized tools for specific tasks.

Prong

Ozaukee Robotics has used the prong tool for the previous two years and has had continued success as a result. The prong is an aluminum rod with a slight hook at the end, provided with colored tape at its tip for visibility (Figure 19). Able to move up and down by means of a servo motor attached to the base, the prong is easy to use. The prong has ample precision, and cameras mounted behind the tool allow for a clear view of movements. This tool is used throughout our runs to assist our pilot in missions such as to open and close the power connections hub.

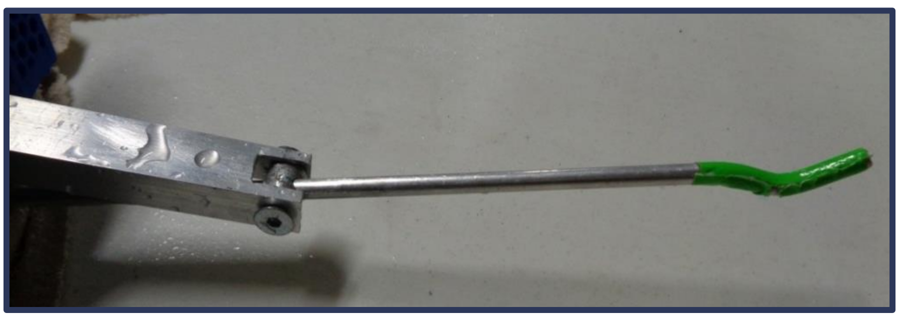


Figure 19:
Prong

Depth Sensor

Warrior's depth sensor, in conjunction with its hover mode, serves a crucial function—it keeps the ROV unmoving in water when necessary (Figure 20). Previously, Ozaukee Robotics has faced many challenges when performing precision tasks because the ROV has been unable to maintain itself vertically steady. Using a Keller submersible level hydrostatic depth sensor, we are able to hold the ROV's position vertically. 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 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.

Figure 20:
Depth Sensor

Velocimeter Installation Tool

The velocimeter installation tool is used solely to suspend the acoustic doppler velocimeter on the mooring line at a given height in the third mission task. This tool was 3-D printed with two rounded slots (Figure 21). With this particular design, the velocimeter is easily lifted and moved to the necessary location. This particular tool was used as the clam collector last year and has been recycled due to its ability to effectively complete this year’s mission tasks.

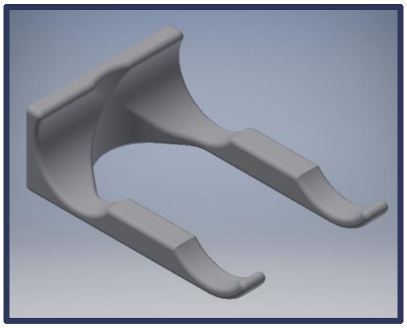


Figure 21: Velocimeter Installation Tool

Connector

The connector is one of the most versatile tools attached to Warrior, utilized to complete multiple mission tasks. This tool consists of two 3-D printed plates, one with a knob that corresponds to a hole on the other plate (Figure 22). One task includes disconnecting the OBS cable connector from the power and communications hub, while another is transporting the I-AMP to the stand. The first two tasks of the mission, involving the aircraft and earthquakes, are completed through the use of the connector on multiple occasions. This tool was not modified after we used it in last year’s competition, as it still functions effectively and effortlessly.

Figure 22: Connector

Gripper

The gripper is a 3-D printed mechanism, consisting of two separate projections that open and close together (Figure 23). Controlled by a servo, this particular tool is employed for numerous tasks. For example, the gripper is utilized in the first mission task to attach the lift bag to the debris. Additionally, the gripper functions to install the tidal turbine in the optimum location for the third mission task. The gripper is a completely new tool this year, designed specifically for the 2018 MATE competition.

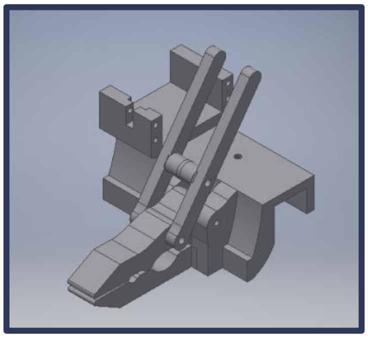


Figure 23: Gripper

Lift Bag

For the first mission task, which involves aircraft, our team manufactured a single, closed lift bag system (Figure 24). The on deck air compressor and controls supply air or create a vacuum. A system of valves direct air into the lift bag or through a vacuum generating venturi to remove air from the lift bag. This will allow us to inflate or deflate the lift bag depending on what the situation calls for. Through manipulation of three valves on the pool deck, our pilot is able to switch easily from air pressure to vacuum. Likewise, the lift bag release is servo controlled with a check value in the bag end of the connection, allowing the bag to release. The lifting mechanism associated with our lift bag has a simple hook at its base. The inflatable and deflatable balloon is held within a high strength enclosing mesh, which helps to carry the load. Lastly, our air supply is made of six millimeter tubing with a maximum pressure rating of 10 bars.

Figure 24: Lift Bag

Ocean Bottom Seismograph (OBS)

The OBS is constructed from a water tight enclosure fastened to a ballasted anchor, with its release mechanism attached to the underside. The enclosure houses the battery packs and electronics for the acoustic release system, and the data catching equipment required by the clients. A frequency release and manual release override have been incorporated into our OBS. The acoustic release we have constructed is based on the dual tone multi-frequency (DTMF) tone protocol developed by the Bell System for the over the line telephone switching system when touch tone phones replaced dial phones in the 1960’s. For the OBS that we have assembled, the tones will be generated by the Arduino uno linked to the mega controller located on the ROV. In addition, sequences of dual tones can be easily changed for security or to allow the ROV to communicate with multiple OBS receivers individually. Through the integration of two separate frequencies from our OBS, the resulting frequency is fed into a small mono amplifier. The output is then sent to the audio exhibitor—the Dayton Audio DAEX25—within the dry housing. This allows us to use the dry housing itself as an underwater speaker, providing acceptable tone reproduction with minimal added weight and complete enclosure. Attached to the water tight enclosure of the simulated OBS are five 27 millimeter piezoelectric transducers. The transducers are wired in parallel into a small 200x powered, preamplifier board. This raises the signal to line level. The line level signal is fed into the model AD22BO4 four channel DTMF controller which utilizes a Zarlink model MT8870D integrated decoding circuit. The controller can be reprogrammed with up to four different sequences per channel. We chose the DTMF controller, as it is a widely known standard with readily available and inexpensive programming. When our team wants to release the OBS, we are able to initiate tone generation from the ROV. After release, the enclosure is positively buoyant and will move to the surface. The signal will travel through the water and be received by the transducers, at which time the signal will be decoded. Once the signal is decoded, the DTMF controller will complete the relay circuit by allowing voltage from the on-board battery pack to energize the Tsunami bilge pump motor. This will allow for a screw to be driven and the latching mechanism to be opened. The OBS also has a backup manual release, which can be operated with a direct push or pull from the ROV.

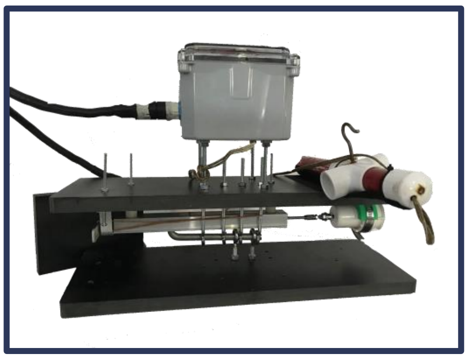


Figure 26:
OBS (Left)

Figure 25:
Warrior Illustration
(Right)

Design Theme

Ozaukee Robotics devised a theme surrounding our ROV’s name in order to promote collaboration and cohesiveness within our team. A warrior, the mascot of our high school, represents perseverance and determination. As a result of this, we decided to use Warrior as our ROV’s name. Ozaukee High School’s colors, blue and yellow, are incorporated within our logo, marketing display, and technical document. This allows for cohesion throughout our company. The poster includes a mixed blue background, the most dominant of our school colors. With a logo incorporating blue, yellow, and gray, the presence of our school and the mascot we hold is always present. The incorporation of the theme into each aspect of the mission enabled our team to become increasingly united. It inspired our team to not only become more creative, but to focus on the marketing aspects of the competition.

Safety

The safety of all personnel as well as the ROV has established itself as one of Ozaukee Robotics' top priorities. It is essential that various precautions are taken in order to ensure that no harm comes to either the ROV or any personnel.

Located at the top of Warrior, the tether has established itself as one of our team's most fundamental safety features. The 25 amp, single inline fuse located 30 centimeters from the tether's point of attachment monitors a steady, constant flow of current to the dry housing. The current is discharged only when the fuse is fixed firmly to the power supply. If the fuse were to blow, any damage to the ROV would be minimal. In order to manage the heat produced by the dry housing's electronic elements, any devices that can draw high amounts of power were wired in parallel through the bulkhead connectors. Moreover, any possible water leakage areas have been thoroughly sealed, preventing a shock hazard.

In regard to the safety of all personnel working around the craft, there are a multitude of protective features that exist. One essential safety feature is the rounding of all sharp edges on the ROV. Another safety feature includes enclosing the propellers with custom 3-D printed shrouds. These prevent both entanglement and skin contact. It is required that all team members wear safety goggles as well as closed-toed shoes when working around the ROV. Prior to each pool run, all of these precautionary measures are checked, ensuring the safety of all personnel.

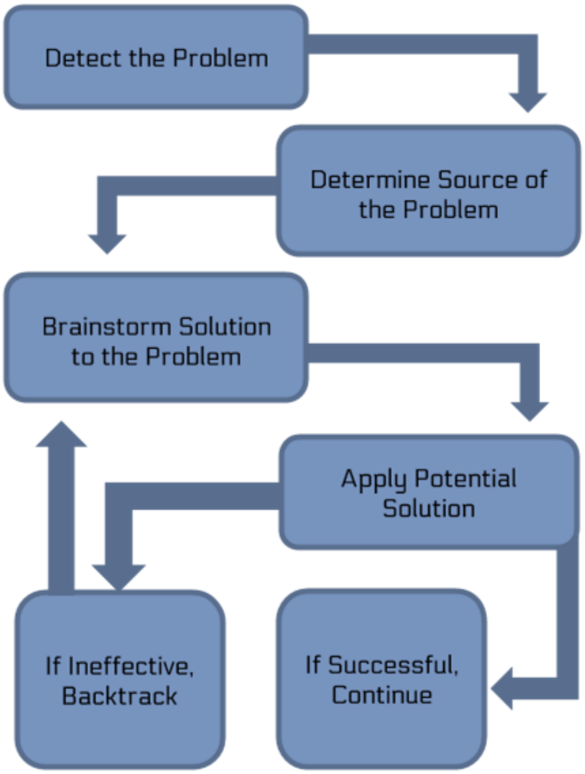
Safety Checklist/Protocol

	Safety Checklist
	All items attached to ROV are secure
	Sharp edges are rounded
	Single inline 25 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 closed 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

Troubleshooting

Early on in the year, our team discovered that our ROV's depth sensor was functioning inaccurately. Warrior's depth sensor's proper functioning is necessary for one of our modes, hover mode, to accurately operate. The team's pilot and copilot noticed hover mode would not lock the ROV at a set height. Instead, the ROV cycled from the bottom to the top of the pool repeatedly. To find the proper solution for this issue, our engineers first checked the ROV's software code. Our software department made one change after searching through the code. The software department pulled out a current limit for our hover mode which previously allowed the current (amp) value to reach up to ¾ of the maximum possible amp value. This current limit was altered so that the value of current could reach, but not exceed, the maximum limit available A second issue was that one of the wires was cracked and allowed water to enter. This inflow of water caused many of the wires to short out. The solution to this was to replace the depth sensor with a spare one that our team had on hand. The final and most significant issue was the sensor ground was incorrectly tied to the motor ground, and caused an incorrect reading when the motors fired. This was changed to tie it to the Arduino common, and with that final fix, the hover mode issues were corrected.



Problem Solving Process

Challenges Faced

Technical

Ozaukee Robotics faced two major technical challenges this year. The first issue was that the ROV would continually and randomly lose power while it was supposed to be functioning; the other issue was that the servos and tooling attached to the ROV would randomly twitch when not directed to. Both of these issues raised major concerns to our team and it was determined that a diagnosis must be made to correct these two issues. After examining the ROV's electronics, our engineers found the main power wire, which runs through a current sensor with a 25 amp max, had weakened and frayed. This wire has been reused for multiple years, and it was no surprise that this weakening had occurred. The wire was almost completely detached, which meant the ROV was not utilizing the full amount of power available and necessary. In order to correct this issue, a few inches of wire was cut off in order to expose a clean cut wire surface. This surface was then soldered back to the current sensor, resulting in a full and proper connection.

During our regional competition, our team ran into major complications involving communication. This lead to our robot sinking to the bottom of the pool for the entire 15 minute run. However, between runs, our team made an electrical diagnosis that our communication wires have faltered. Within this 30 minute time period, we then spliced and resoldered these wires. This allowed our team to complete our second pool run, as well as place first and qualify for the international competition.

Non-Technical

Throughout the year, one major challenge that Ozaukee Robotics faced was retaining everyone's undivided attention to the task being collaborated on. Due to our team being a tight knit group of individuals, maintaining focus was a primary concern early on. In order to manage our team's focus, Ozaukee Robotics formed specific goals and set deadlines for each one. Our goals were written on a large white board, mounted in our workplace. It was made clear to each of our members that every goal must be accomplished within the specified time restraints. This plan greatly increased our focus and productivity.

Furthermore, our team struggled to incorporate and encourage our younger members to participate at the beginning of the year. In order to make these younger members feel welcomed, our older members made sure to create a positive work environment. The more experienced members created this positive environment by constantly asking for the opinions of the less experienced members, as well as through continual encouragement.

Lessons Learned

Technical

A multitude of lessons were learned as a result of the discovery and diagnosis of Warrior's technical challenges, as discussed previously. Without a great deal of patience and dedication, a solution would not have been discovered as promptly and effectively as it was. Ozaukee Robotics spent a large amount of time searching through the ROV's electronics in order to find a solution. Had the team given up early on, the frayed and weakened wire may never have been discovered. Thorough communication as well as perseverance, as exhibited by all team members, allowed for Warrior to become the best possible functioning version of itself.

Interpersonal

For any team to be successful, exceptional communication is necessary. Ozaukee Robotics utilized a variety of methods in order to maintain intercommunication between the departments of the company. To begin each meeting, every employee gathered around our large, mounted whiteboard in order to review the meeting's to do list. Every department would discuss their goals for the day. Then, at the completion of the meeting, every member would once again gather around the whiteboard—this time to discuss what had been accomplished on the to do list (Figure 27). This way every employee was aware of the meeting's achievements of all other employees. Moreover, our team utilized the messaging system Remind 101 to notify all of the employees. Through this, our company was able to alert all members regarding important dates and information.

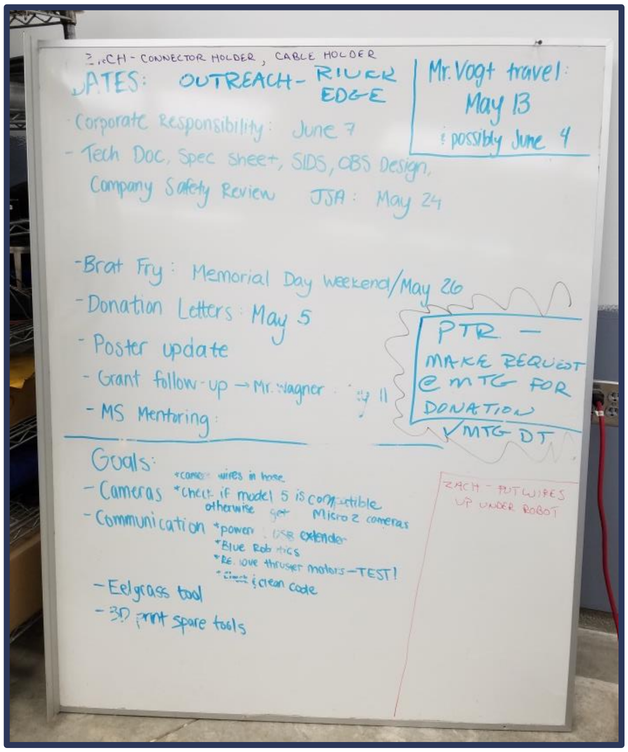


Figure 27: To Do List

Senior Reflections

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 four years ago, 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, CEO/Mechanical Engineer/Software Engineer

This is my second year on the ROV team, and I have learned many things. I worked on creating the props for the practice course, mounting various parts to the robot, and occasionally designing parts to be 3D-printed and used on the robot. This year I am also piloting the robot. Through this experience, I have learned how important attention to detail is as any small mistake could be the difference between something working or not working. I have also learned how to collaborate with other members of the team in order to do things I had not yet learned. Being a part of the team has helped me develop better teamwork and communication skills. These skills will help me later in life when I join the workforce, as I will be able to work well with my co-workers.

-Nick Janik, Pilot

Being in ROV, has truly been a great experience. It 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/Public Relations/Accountant

Becoming a member of the ROV team has certainly been a great experience. It has allowed me to gain knowledge on topics that are not always directly discussed in school, and in doing so, I am now able to see real world applications of my learning. Currently my position on the team involves writing the technical document, and this in itself has allowed me to learn a great deal pertaining to science and engineering. I have also learned various important life skills such as teamwork, reliability, and problem solving.

-Amy Wolff, 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

Team Reflections

This is the second year that I have done ROV, and it has been a great experience so far. I learned so much from it already, and did things I didn't think I would ever do outside of a metals class. This is going better for me than I thought that it would…and that really astonished me because I knew that I would love to be a part of the ROV team. Overall it's been an incredible experience, and I would recommend joining the team.

-Eli Bayer, Mechanical Engineer/Electrical Engineer

Before ROV I did play sports, but those quickly lost my focus. I became increasingly interested in technology, and ROV sparked my interest. My time in ROV is great and fun. I learned many skills that will be useful in the future. The team was fun to work with, and I am glad for the time I spent in ROV.

-Max Frey, Mechanical Engineer/Electrical Engineer

Mentor Reflection

As a mentor of this group of ROV enthusiasts, I have been amazed at the knowledge, skills, determination and grit displayed by each and every member of our team. No challenge is too difficult, no obstacle too great, for this group that relies on the strengths that can only come from an effective and cohesive team working towards a common goal. The individual commitment from each member is impressive – long hours, difficult tasks, new skills are learned or existing skills are honed throughout the build, practice, and competitions. I am honored to see the growth in each and every team member as the season progresses – and am sure that each will succeed in any future endeavor that they choose to pursue.

-Bob Wagner, Mentor

Company Effort

Throughout the year, Ozaukee Robotics functioned as a cohesive unit in order to create a fully functional ROV and meet all of the requirements for the competition. This required immense focus from all divisions of our company. The mechanical division designed the tools necessary for our robot to complete the mandatory tasks of each mission. Collaboration sessions for both brainstorming and designing tools took place between the members of the company on multiple occasions. The tools were then designed and redesigned, as needed. On the other hand, the technical writers drafted the technical document, marketing display, and poster.

Team Memory and Evolution

Ozaukee Robotics is a company composed of many members, each with differing experience levels. While this proved to be valuable, it also created challenges. The more experienced members of our company spent an extensive amount of time teaching and guiding less experienced members throughout the year. While the more experienced members initially had more influence on the planning process and construction of the ROV, the new members gradually grew in their participation through the year. Additionally, research was conducted by more experienced members to better inform other members of our company on the mission tasks and requirements. A multitude of additional resources, including the MATE website, were utilized to share necessary information to all team members.

Project Management

In order to ensure the completion of Warrior on time, a large schedule broken up into smaller segments was utilized. This schedule included a multitude of deadlines that aligned with our long-term plan. Each week, the large mounted whiteboard in our workplace, along with our monthly calendar, displayed the goals of that particular week and month. This informed every team member the knowledge of what needed to be completed at each meeting date, as each task was assigned to a team member or group of members. If one team member or group falls behind in the year, the entire team is at risk. So, with the implementation of such a detailed schedule, we minimized the risk of falling behind. This enabled our team to complete numerous pool runs prior to both the regional and international competitions. Testing our vehicle a multitude of times allowed for the members on the pool deck to master their roles. Ultimately, communication became fundamental to our team's success. Understanding and maintaining a schedule throughout the year allowed our team to function as a cohesive unit.

Figure 28: Monthly Calendar

Build Schedule

Date	Build Schedule
11/8/17	Read the Ranger Manual
11/13/17	Discussed positions on team, requirements, plans for year
11/29/17	Cleaned and organized materials
12/6/17	Built props and brainstormed tooling ideas; weighed the costs and benefits of each option
2/20/18	Determined name of robot
2/28/18	Began to construct OBS
3/1/18	3D printed gripper and velocimeter installation tool
3/4/18	Tested brushless motors
3/9/18	First pool test
3/10/18	Completed programming of the code
3/11/18	Mount gripper and velocimeter installation tool
3/12/18	Replaced depth sensor
3/15/18	Configured cameras
4/11/18	Finished composing the technical document
4/17/18	Finished editing the marketing display
4/19/18	First mission practice
4/29/18	Competed in regional competition
5/21/18	Finished rewiring the tether and cameras
5/23/18	Final review of technical document, spec sheet, JSA, and company safety review

Future Improvements

While Ozaukee Robotics has made a multitude of changes over the past few years, there is still more that can be improved upon in the future. One major change that would likely be very effective for our team is increased time efficiency. With improved time management, comes the opportunity to reach higher goals and accomplish more throughout the year. Mainly, Ozaukee Robotics wishes to teach new members more rapidly in the beginning of the year. This would allow for meetings later in the year to be less focused on teaching and more on collaborating. Additionally, the team plans to do a presentation for the middle school students to introduce them to this excellent STEM opportunity, and encourage these future high school students to join the team.

Figure 29:
Eli and Max building OBS

Figure 30:
Electrical engineers rewiring the robot

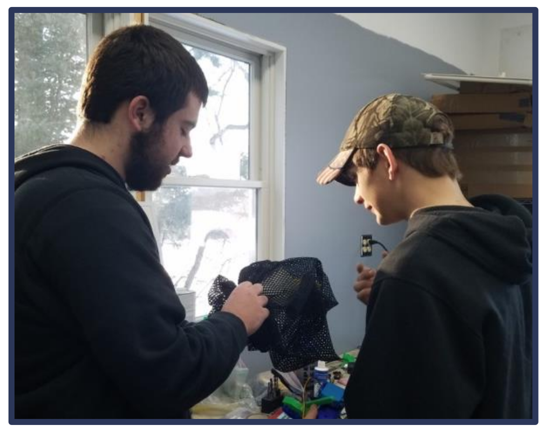


Figure 31:
Nick and Zach constructing the lift bag

Budget/Cost Analysis

Throughout the year, Ozaukee Robotics implemented and maintained a budget for the construction of Warrior. In order to design this budget, multiple team members conducted extensive research regarding materials. This inquiry allowed for our team to determine whether crafting tooling options in-house would be more cost-effective than purchasing them commercially.

Ozaukee Robotics has been very fortunate this year, as we have received donations from a multitude of contributors. These includes both monetary and material donations. Along with these donations, our team has funds remaining from previous years. The budget we designed was strictly followed throughout the duration of the year. Every material was researched to find the best quality of product at the most practical price. Each of our purchases were documented.

Budget

Value of Reused Items		
Original Year	Item Desciption	Current Cost
2010	Arduino MEGA	$13.00
2011	Multiplexor	$18.00
2011	Bulkheads	$135.00
2013	Cameras	$18.00
2013	TV Monitors	$135.00
2015	Tsunami Motors and adapters	$78.00
2016	Cameras	$135.00
2016	Integra enclosure	$81.00
2016	Tether wire	$36.00
2016	C-Channel	$9.00
2016	Servo motors	$90.00
2017	T100 Thrusters with Basic ESC	$588.00
Total		$1,336.00

Monetary Donations	
Company	Cost
Guy & O'Neill Inc.	$100.00
Petersen Resources LLC	$100.00
Great Lakes Eco System, Inc	$250.00
Moble Edu Alliance	$250.00
Ozaukee PTR	$500.00
AFS - American Foundary Society	$500.00
First Southwestern Title	$200.00
Thrivent Financial	$250.00
Total	**$2,150.00**

Services Donated	
Item Description	Estimated Cost
Ozaukee High School's Woodshop	$500.00
Wagner's Tools and Workspace	$300.00
Total	**$800.00**

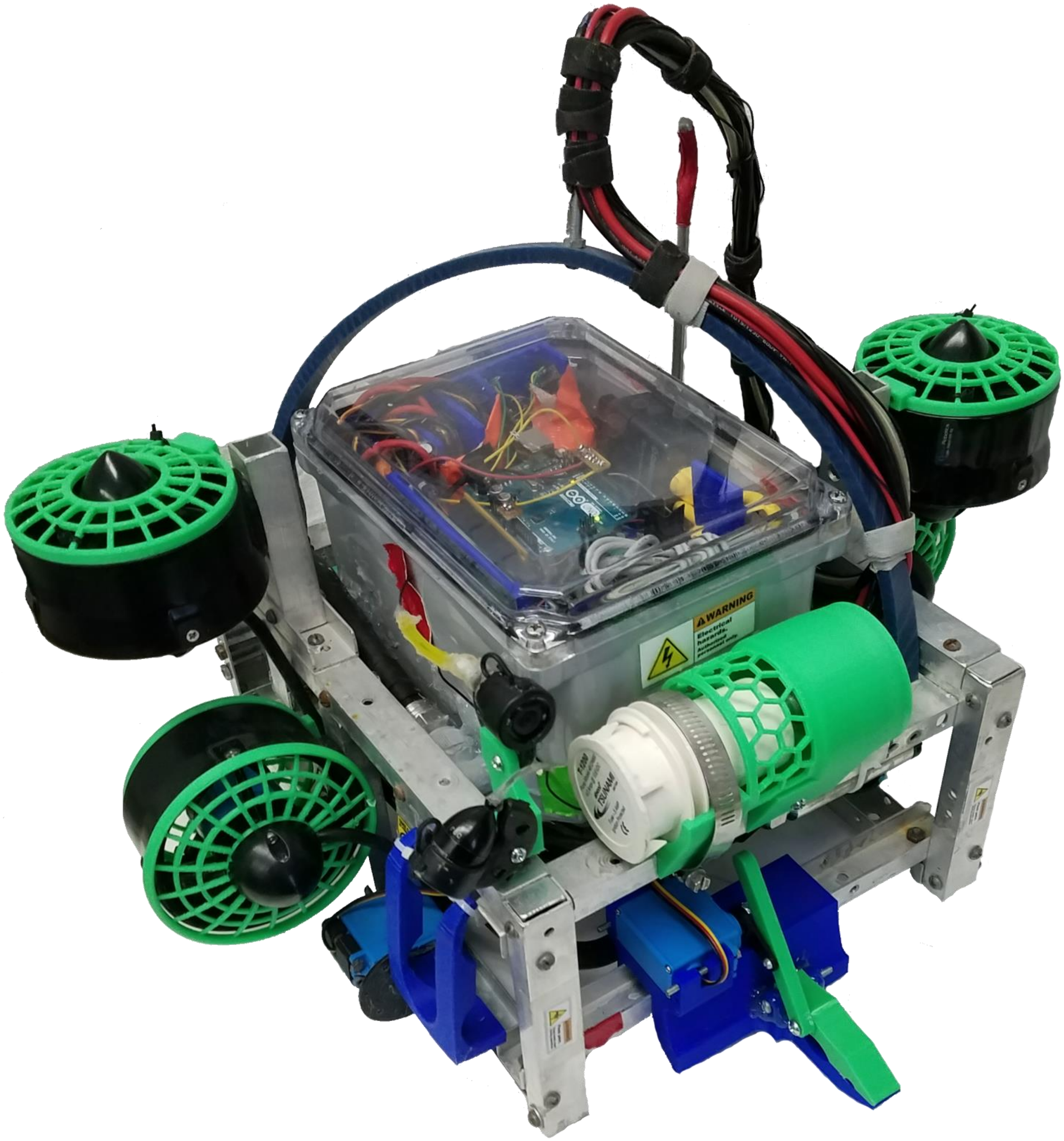
General Expenditures	
Item Description	Cost
OBS Supplies	$436.00
Team Shirts	$186.00
Pool Supplies	$55.38
18 ft Round Pool Winter Covers	$28.99
Prop Supplies	$44.22
Precision Wire Stripper	$5.08
Total	**$755.67**

ROV Build Expenditures	
Item Description	Cost
Lift Bag Supplies	$62.50
PS4 Controller	$50.69
Afinia 3D Plastic Filament & PLA	$184.07
Depth Sensor	$351.92
Hitec Servo	$56.49
Dayton Audio Exciter	$19.88
Arduino Uno Processor	$15.80
Smakin 12V Power Amp	$12.99
Komelon 12-Foot tape	$12.18
Flexbraid Teather Cover	$66.67
Cables, Connectors, etc	$110.15
Total	$943.34

Total ROV Cost

$3,035.01

Summary Sheet



Dimensions: 43 cm x 50 cm x 40 cm
Dry Weight: 11.97 Kg
Approximate Total Cost: $3,035.01

Acknowledgements

Ozaukee Robotics would like to thank:
MATE: for hosting this amazing competition
UW-M: for hosting the regional competition
Integra: material donation
Ancor: material donation
Pololu: material donation
Aqua-Vu: material donation
Keller America: material donation
SubConn: material donation
TDK-Lambda Americas: material donation
Ozaukee High School: for their facilities
Wagner Family: for their facilities
Guy & O'Neill Inc: monetary donation
Petersen Resources LLC: monetary donation
Great Lakes Eco System, Inc: monetary donation
Mobil Edu Alliance: monetary donation
American Foundry Society: monetary donation
Petersen : monetary donation
First Southwestern Title Company : monetary donation
Ozaukee PTR : monetary donation
Bob Wagner: for his technical expertise
Randy Vogt: for his technical expertise
Chris Janik: for his technical expertise

Photo Accreditation

Cover Photo 1: Hannah Bell
Cover Photo 2: Bob Wagner
Figure 1: Randy Vogt
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Figure 4: Randy Vogt
Figure 5: Hannah Nordby
Figure 6: Hannah Bell
Figure 7: Zach Wagner
Figure 8: Hannah Bell
Figure 9: Hannah Nordby
Figure 10: Hannah Bell
Figure 11: Hannah Bell
Figure 12: Zach Wagner
Figure 13: Hannah Bell
Figure 14: Hannah Bell
Figure 15: Hannah Bell
Figure 16: Hannah Bell
SID: Hannah Bell
Figure 17: Amy Wolff
GUI Flowchart: Nicky Janik
Arduino Flowchart: Zach Wagner
Figure 18: Zach Wagner
Figure 19: Amy Wolff
Figure 20: Hannah Nordby
Figure 21: Zach Wagner
Figure 22: Hannah Bell
Figure 23: Zach Wagner
Figure 24: Hannah Bell
Figure 25: NOSD Website
Figure 26: Max Frey
Figure 27: Hannah Bell
Figure 28: Hannah Bell
Figure 29: Hannah Bell
Figure 30: Amy Wolff
Figure 31: Hannah Nordby

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