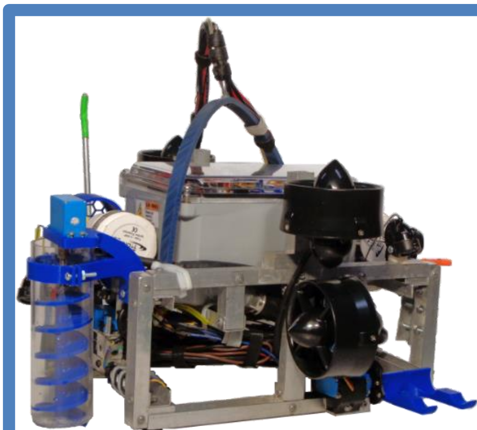
Ozaukee Robotics
Ozaukee High School, Fredonia, WI



Leviathan

Ozaukee Robotics Team

Member Name	Position	Grade	Member Name	Position	Grade
Josh Vogt	CEO/Software Engineer	12th	Hannah Bell	Technical Writer	11th
Nick Marz	Software Engineer	12th	Hannah Nordby	Technical Writer	11th
Connor Freiburger	Electrical Engineer	12th	Jarrod Bares	Electrical Engineer	10th
Joseph Ceranski	Pilot	12th	Eli Bayer	Mechanical Engineer	9th
Zach Wagner	Mechanical Engineer	11th			
Nick Janik	Mechanical Engineer	11th	Randy Vogt	Mentor	
Amy Wolff	Technical Writer	11th	Bob Wagner	Mentor	

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Abstract

This is Ozaukee Robotics eighth year participating in the MATE ROV Competition, and as a team we are proud to have built and controlled such a complex, yet usable, remotely operated vehicle. Ozaukee Robotics' most recent vehicle, Leviathan, has the ability to assist in underwater construction, reinstall fountains, as well as mark and remove contaminants to promote health. Not only is Leviathan a powerful name, but once a goal is set, this sea creature refuses to give up before success is reached. These characteristics are parallel to the ones our team possesses.

As the year proceeded, many obstacles were overcome. This includes, but is not limited to, new technology, inner-club communication, teamwork, and teaching new members.

Although size and weight restrictions are not new to this year's competition, the robot's qualities still revolved around this idea. This year, as well as focusing on various restrictions, the move from brushed to brushless motors caused a large change from previous years.

We accomplished the tasks in this years competition through excellent teamwork, student coding, and specialized tools. This includes reused items, such as the prong, but also many new tools, including the auger. A light frame from aluminum c-channel and 3-D printed tools allow for Leviathan to remain under 11 kg in weight, enabling a single person to easily transport the vehicle.

Continual success of Ozaukee Robotics is due to hard work, dedication, and perseverance to maintain the necessary communication between various departments of our team.

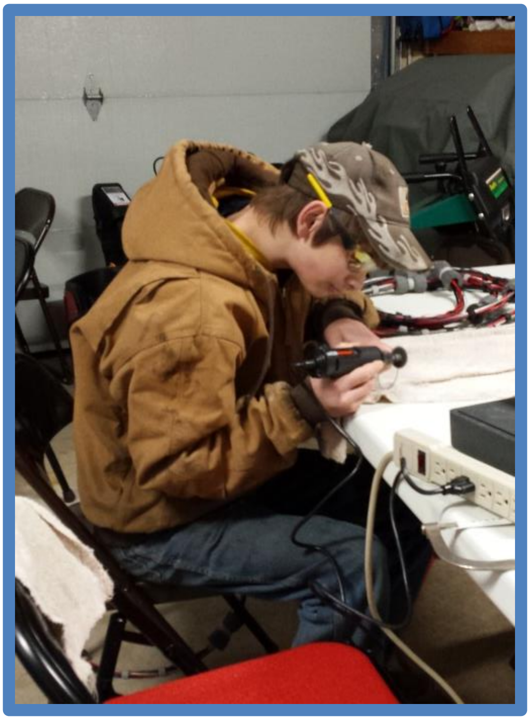
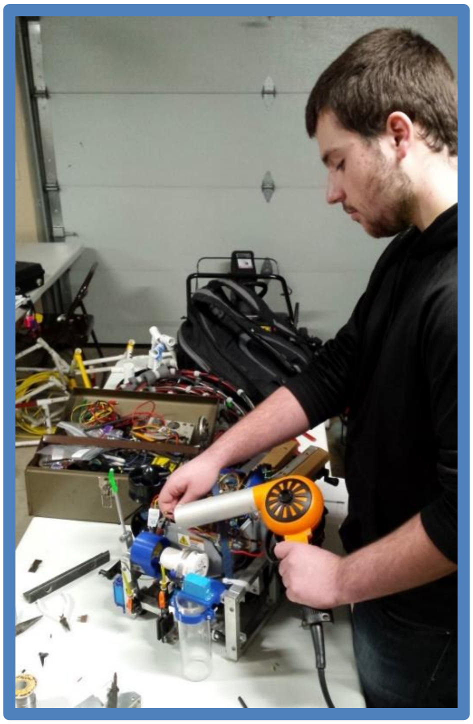


Figure 1: Mechanical Assembly (Left)

Figure 2: Electrical Assembly (Right)



Corporate Profile

Over the years, a complex approach to operations has emerged within Ozaukee Robotics. The two divisions of our team work on the business and engineering aspects of this elaborate process respectively. Between the subsections of our company, the two groups work together equally and communicate effectively. These two facets have become key to our overall success. Although these are challenging aspects, they allow for success both in individual tasks and as a whole company.

The business department works with internal affairs and elements of fundraising, public relations, and literary components. In terms of those focusing on public relations, the individuals are primarily responsible for developing the marketing display.

As the engineering division of the team, three groups of engineers work to perfect varying aspects of Leviathan. The engineering groups work on different aspects of the ROV, including electrical, software, and mechanical implements, in order to enable operation of the ROV. Respectively, the electrical engineers control electrical hardware, software engineers create and program aspects of coding, and mechanical engineers create the fundamental architecture and tools. All of these positions are codependent upon one another, and only through success in all regions is overall productivity possible.

Of all the various aspects involved in participating in this competition, our team is brought together by the technical writing. The responsibilities of the team’s technical writers include composing the technical document, supplying information for the website and marketing display, offering support to the business department, and composing press releases. Through the technical writing, the purpose and reasoning behind every component of Leviathan 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 as the company 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

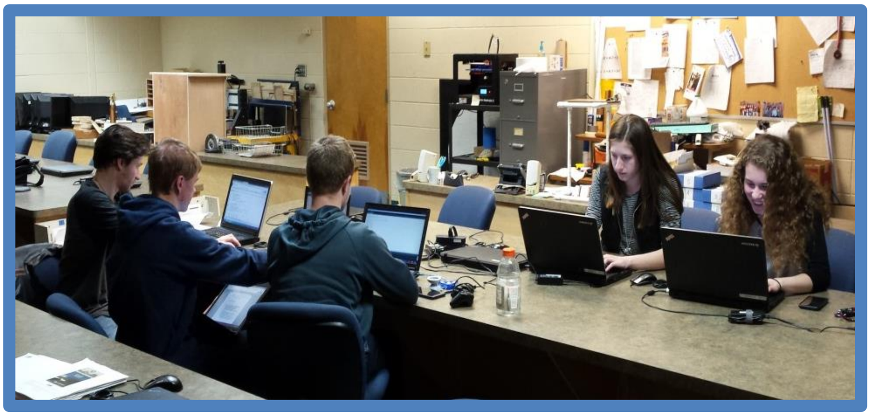


Figure 4:
Software Engineers and Business Department

Design Rationale

Frame

Ozaukee Robotics decided to continue our use of an aluminum c-channel frame this year, as it proved to be both light and durable last year. After using HDPE in previous years, we determined that aluminum c-channel would be more effective. This frame is light enough to stay within the given weight restrictions, and allows for easy attachment of accessories. In consideration of the size and weight restrictions, Leviathan utilizes 366 centimeters of product. The weight of this product per centimeter is 2.039 grams. This totals out to be 0.746 kilograms of frame used in the entire robot.

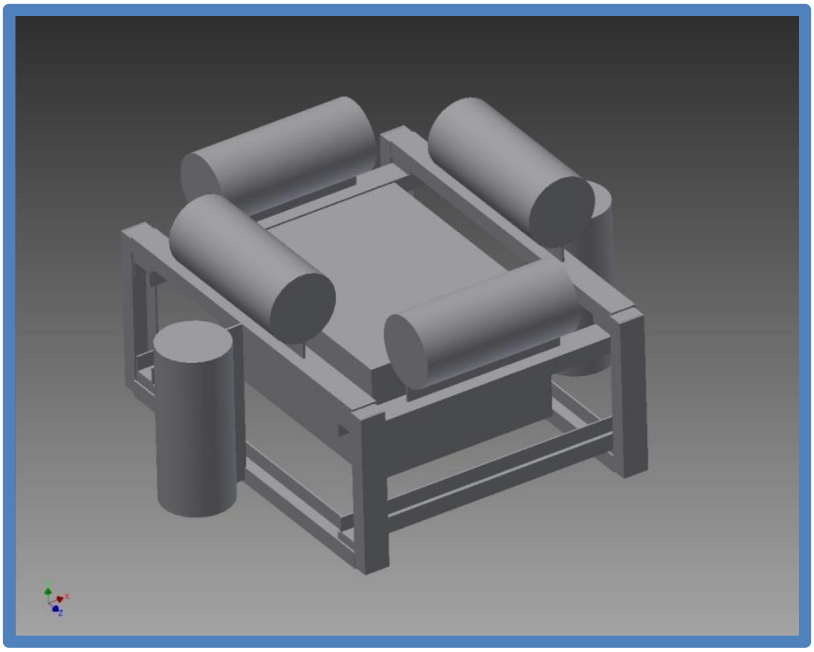


Figure 5:
CAD Drawing of Frame

Dry Housing

Our ROV's dry housing is an IP68 rated Integra enclosure, being completely water-sealed and keeping the precious internal electronics safe from the outside environment. Since the dry housing is located near the top center of the ROV, the connected tether is easily accessible. Attached SubConn bulkhead connectors are completely sealed using gasket sealer. The clear lid securing the dry housing has screws to fasten it shut as well as a waterproof gasket.

Before each run, one of the tether managers will consistently ensure the waterproof seal is properly secure. This is done by placing the robot in the water before starting anything up. As a result, buoyancy and waterproof seals are tested. Only under the circumstance that everything goes smoothly are the motors, tools, and propellers turned on and test runs begun.

With measurements of 20.3 x 15.24 x 10.16 cm, the total volume of our dry housing is 3143 cm^3. This volume of air counteracts the weight of the frame and accessories, keeping the ROV neutrally buoyant. Heavier products are placed near the bottom of the dry housing, keeping the center of gravity low. This allows our robot to be balanced underwater, making maneuverability and use of tools effortless.

Bulkhead Connectors

Leviathan's dry housing contains three SubConn bulkhead connectors. These connectors allow the tether to have a secure, waterproof connection into the dry housing, enabling the transfer of information and power to the robot without risk of damage to the electronics. The connector is secured with silicone gasket sealer, which allows a flexible yet trustworthy seal.

The microcontroller onboard the ROV communicates to the laptop through a CAT5 Ethernet cable. This particular cable is connected to an eight-pin bulkhead connector while the rest of the sensors and motors are connected through two separate 16-pin, 18 AWG connectors. This structure has proved to be immensely reliable, as it has been through many hours of testing but has shown little devaluation. Despite the numerous reconstructions of the ROV, the bulkhead connectors have shown their reliability.

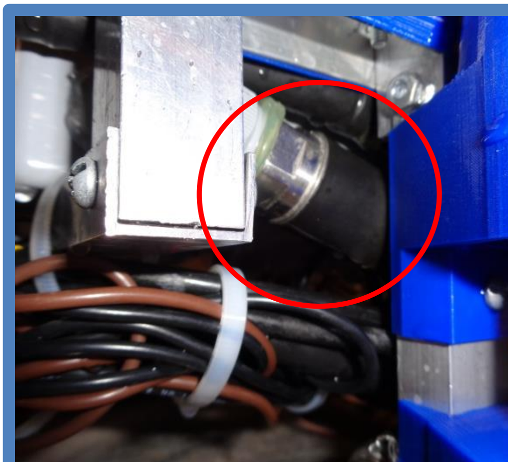


Figure 6:
Bulkhead Connector
(Left)

Figure 7:
Tether
(Right)

Tether

Similar to last year, the team attached Velcro straps to the tether every 15 centimeters to hold the important wires together. Ozaukee Robotics found this method very effective over our previous method which involved stringing wires through a hollow mesh tubing. Even though this method worked, it was not easy to manipulate. It was found very difficult to rethread the wires without wasting valuable time. In total, there are 16 components that make up the tether, 4 wires for power, 10 wires for video, 1 communication cable, and 1 hose to provide an atmospheric reference for the depth sensor.

The craft has four power wires this year in contrast to the two separate power wires we had previously. Due to the fact that there are two different groups of wires there is a decrease in voltage drop over the length of the tether. By separating the power for thrusters from the controls, the connection between the Arduino and computer improved because the power usage no longer fluctuated when the thrusters were turned on and off.

Propulsion

When determining propulsion for this year's ROV, maneuverability was a key component. In past years, our team has used six Tsunami 1200 bilge pump motors for propulsion, placing two for the ROV's lift, thrust, and strafe respectively. This year, our team decided to replace our lift and thrust bilge pumps with four T100 Blue Robotics Brushless Motors.

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. Each motor can produce a total of 23.1 Newtons of power. According to Newton's 2nd Law, the ROV would be able to accelerate at 2.143m/sec^2 when lifting or thrusting.

Each Tsunami motor uses approximately 25 watts of power with 2.1 amps of current at 12 volts. When both motors are fired, they use approximately 4.2 amps of current and produce 7 newtons of force. The ROV can accelerate at 1.273 m/sec^2 when strafing.

Regularly, only two motors are being run at full power, drawing at most 9 amps of current. Additionally, the lift motors tend to be consistently running at partial power due to our ROV's "Hover" mode, described later in this document. The two lift motors typically run at 25% of their full power while in this mode, thus drawing an additional approximate 2.25 amps. This means that at any given time, our propulsion system will likely draw no more than 11.25 amps.

Identical two-piece shrouds were used on both Tsunami 1200 bilge pumps, while the new motors came with built-in shrouds. Last years Tsunami motor shrouds were specifically designed to prevent interference with spinning propellers, and the two piece design reduces water resistance and overall material used. Overall, the partial switch to brushless motors allowed for several benefits, including increased efficiency and speed, and longevity of products.

Figure 8: 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 Blue Robotics Electronic Speed Control (ESC) driver boards to work with our new Blue Robotics motors. These new 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 value between 1100 and 1900 microseconds. 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. Additionally, because the motors are brushless they produce less electrical noise.

The bilge pump motor driver boards fall under the control of the robot's Arduino MEGA Microcontroller. The microcontroller manipulates the motor driver boards by outputting 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.

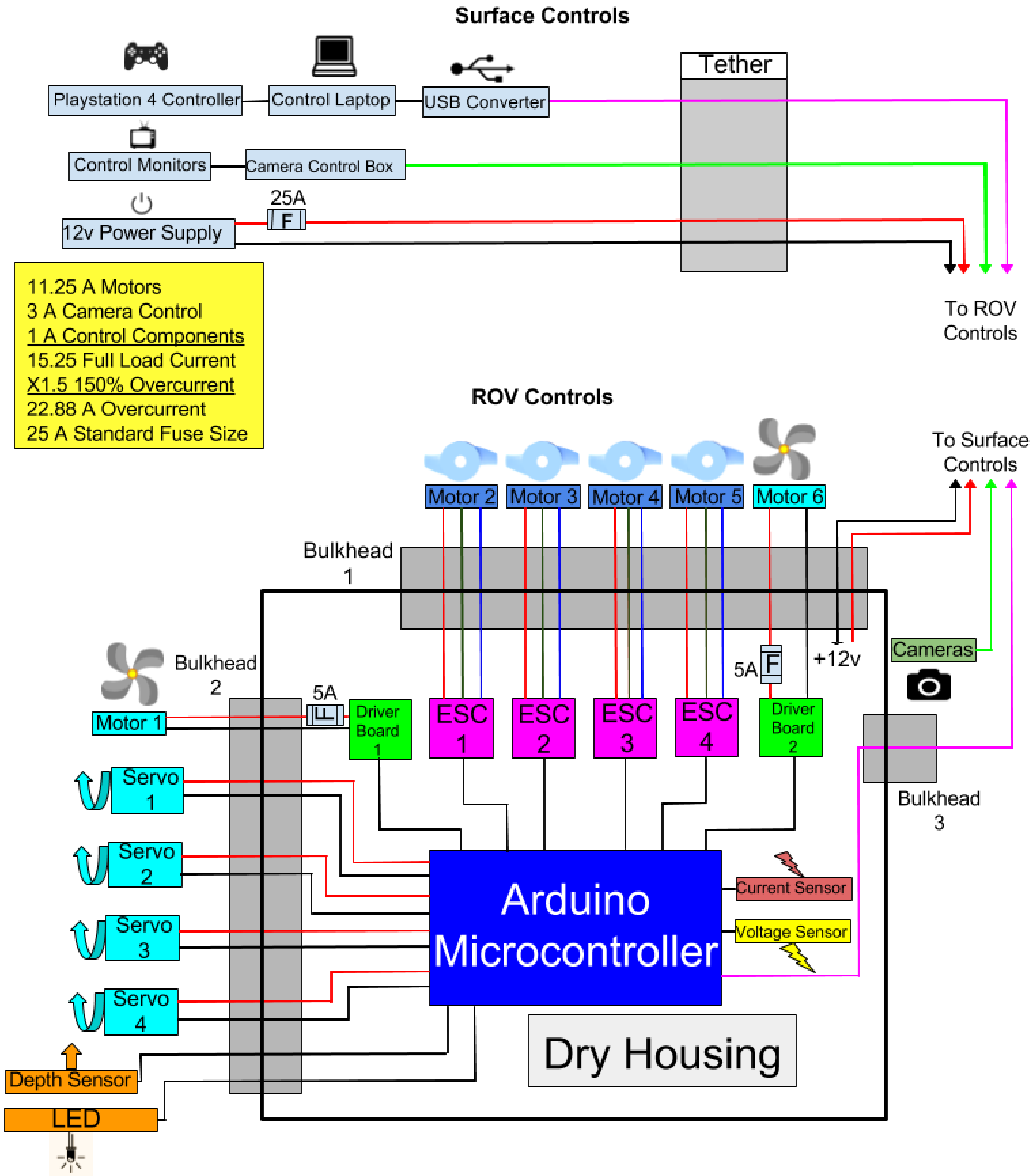
Featuring 54 input/output pins, 16 analog pins, 128KB of flash memory, and a 16MHz ATmega1280 processor, the microcontroller boasts massive yet efficient power. In compliance with MATE specifications, the microcontroller is powered through an onboard 12V DC to 7V DC converter.

The ROV is manipulated with a laptop keyboard and a DualShock 4 controller (Figures 9 and 10). The joysticks of the controller are used to drive the primary motion of the craft while face buttons control the tools. Lift is controlled by the left shoulder buttons and the right shoulder buttons control the precision mode of the craft. The keys on the laptop toggle the various modes of the ROV, such as the H key for hover mode and the G key for ground mode. Their use allows for easy control and programming, permitting more attention to be given to completing the tasks of the mission, rather than focusing on the controls.

Figure 9: Laptop (Left)

Figure 10: Controller (Right)

System Interconnection Diagram



Software

Ozaukee Robotics' custom software serves two crucial functions: to command 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 output signals to the motor controllers, which are responsible for the craft's propulsion. 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 using a 19.2K baud communication rate 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 4 controller or keyboard.

New code had to be written this year for the microcontroller to work with the new Blue Robotics motors. Additionally new code had to be written for the operation of our auger and clam collector. The GUI was also modified this year as there were several elements from the past that could be removed, making the GUI cleaner and easier to understand at a glance.

Video System

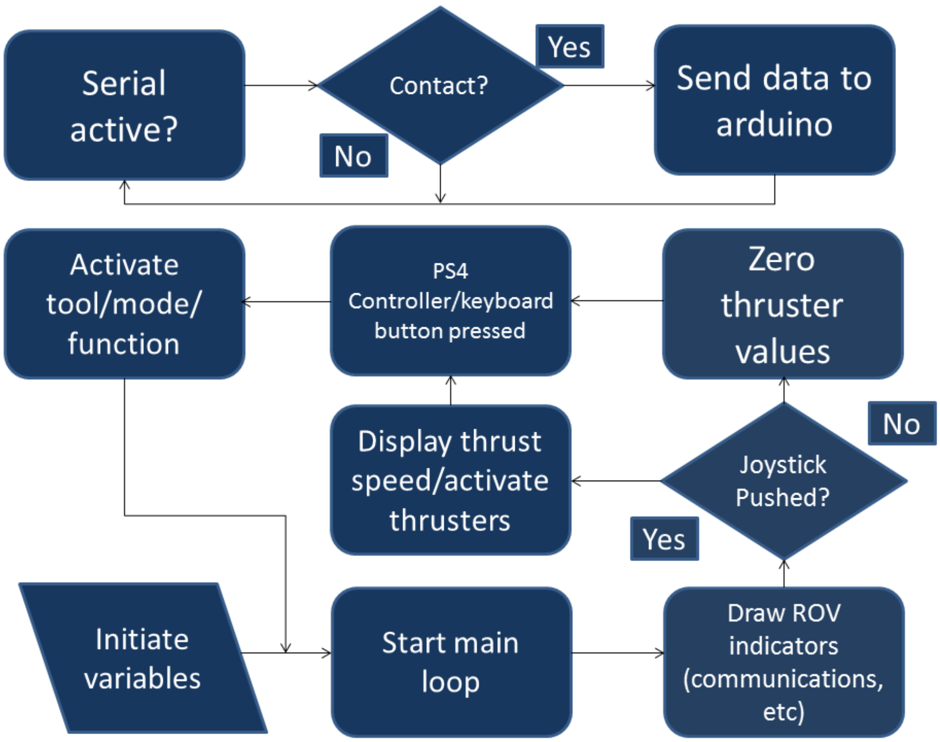
Through eight years of experience, Ozaukee Robotics has discovered that maximizing vision is a top priority. To accomplish this, Leviathan is fitted with eight full-color cameras which can view all sides of the craft as well as every essential tool used during the mission tasks. Leviathan's cameras were 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. The monitors contain the images from all the cameras organized in a manner that allows the pilot to keep track of all tools and directions.

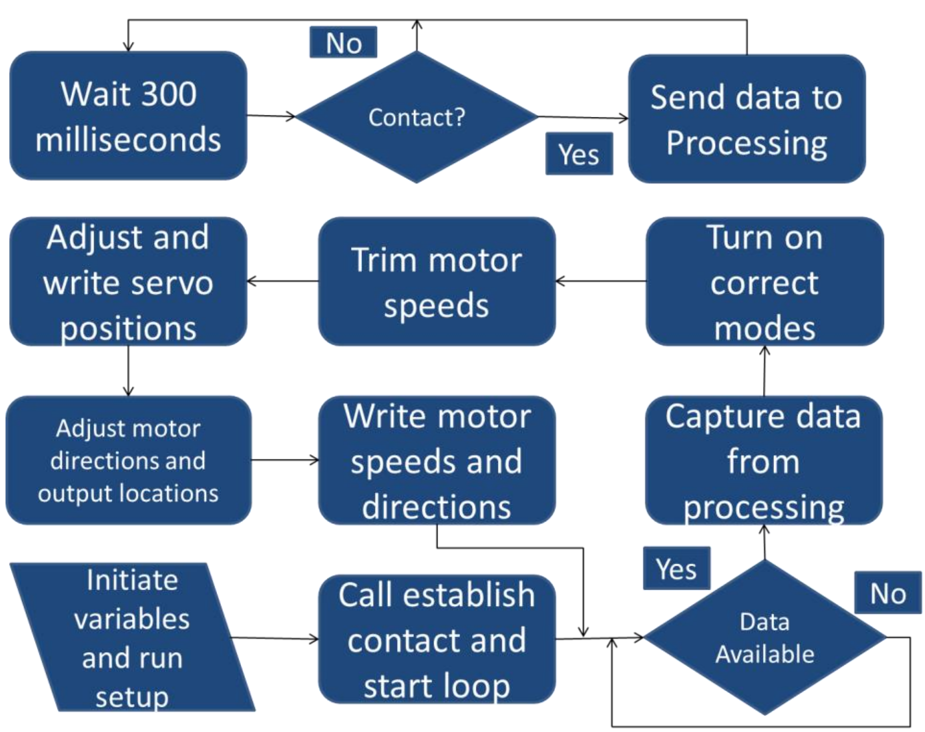
Figure 11: Cameras Mounted on Frame

Software Flowcharts

GUI Laptop Flowchart



Arduino Microcontroller Flowchart



Modes

In order to complete each mission with ease, Ozaukee Robotics has programed Leviathan with multiple operation modes that enhance specific maneuvers by modifying certain basic functions.

For instance, 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.

Activated by the “H” key, hover mode suspends the ROV at the height it is currently at 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 at a speed proportional to the change in depth to offset any vertical movement of the ROV. This allows the ROV to quickly return to a precise depth when affected by external forces.

Precision mode, which reduces the speed of all motors to 50 or 25 percent of the original speed, 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.

Through the combination of our custom programming and simple box-like design of our ROV, we have implemented a unique orientation selection feature, named direction mode. Activated by pressing one of the four arrow keys, each key designates its respective side of the ROV as the “front”. The variables within Leviathan’s code instantaneously adapt as the inputs from the PS4 controller are reassigned to a different side, effectively changing the side of the ROV considered the “front”. 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 lower right corner of the GUI. The color and direction of the arrow corresponds with its respective side, allowing for immediate recognition and movement.

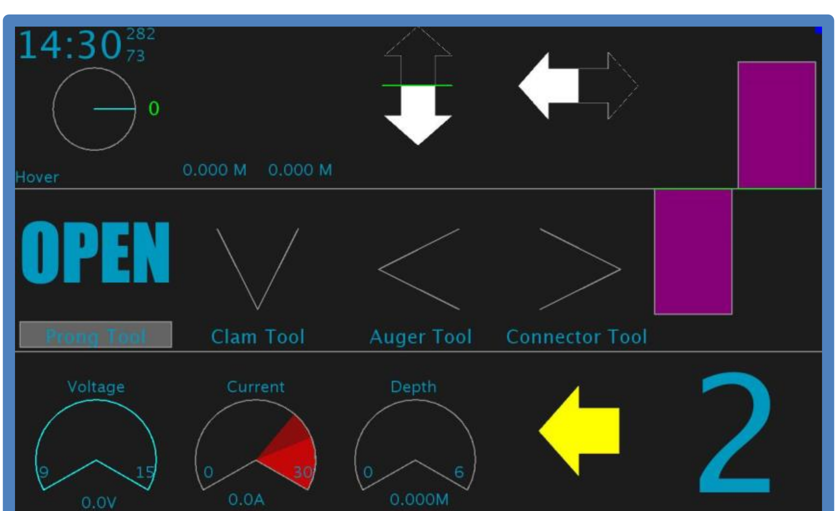


Figure 12:
GUI

Prong

Due to great achievements with the use of our prong previously, we continued with its use for this years competition. The prong is a versatile tool used for manipulating various parts of each task, such as turning the valve to stop water flow to the fountain and collecting the beacons distributed around the Hyperloop. The prong is fast and simple to use, with a camera mounted behind the tool for easy and precise control. At the end of the prong, there is a slight hook that keeps objects from sliding off the tool. This tool is able to move up and down by means of a servo motor attached at its base.

Figure 13:
Prong

Depth Sensor

In previous years, it has been difficult to complete precise tasks due to the inability to hold the ROV vertically steady. The robot would move up and down with the flow of the water making precision tools virtually useless. To combat this, we developed a mode for the ROV to keep Leviathan static in the water. Using a Keller submersible 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 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.

Figure 14:
Depth Sensor

Agar Extractor

Ozaukee Robotics decided early on that in its approach to agar extraction, simplicity was key. From the beginning, it was decided to use an auger type device, much like one that burrows through the ice on a lake while ice-fishing. Using our school's 3D printer, we were able to design and manufacture our own auger completely in house. After a few failed attempts, a long robust design was settled upon to ensure efficiency and durability. Made from polylactic acid (PLA), the auger itself measures approximately 12 cm in length and 5 cm in width. The helix is encased by a plexiglass tube, allowing space to store agar that is collected from the sediment. The auger is spun by a Hitec servo that is mounted atop the pipe using a specially designed and printed mount made by our mechanical engineers. When Leviathan is above the sample, the entire craft lowers, inserting the auger tool into the sediment sample. After it has returned to the surface, the servo runs in reverse to empty the contents of its casing, which is around 120 mL.

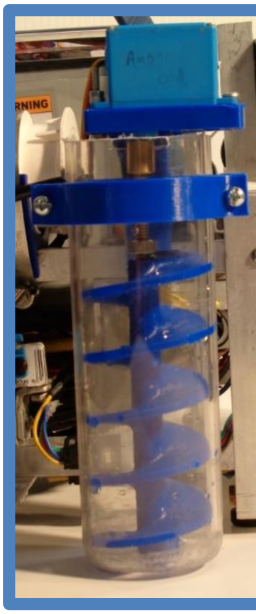


Figure 15: Agar Extractor

Clam Collector

The clam collector tool is used to retrieve the two necessary clams from the contaminated area, as well as transporting the two pieces of rebar in the Hyperloop construction. This tool was 3D printed with two rounded slots capable of holding both pieces of rebar at once. The team modeled this tool after one that we used last year to collect oil samples. This year's model is smaller and is able to be used more efficiently for the given missions.

Figure 16: Clam Collector

Connector

The connector is a versatile tool on our robot which is used to complete a multitude of tasks. Constructed of two 3D printed plates, this tool has a knob on one side that corresponds with a hole on the other, acting as a sort of gripper. We use the connector for various tasks throughout the mission. One of these tasks is the replacement of the old fountain with a new one, while another task is the disconnection and reconnection of the power cable in the light and water show maintenance task. Another example of the importance of the connector is that it is additionally used to move the hose in the Hyperloop construction task. This tool was not modified after we used it in last year's competition, as it still functions effectively and effortlessly.

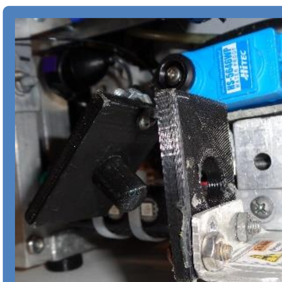


Figure 17: Connector

Components

Some operative items from last year's ROV have been reused this year in addition to various aspects that were custom designed or 3D printed. The guide pin and the clam collector are two components that were 3D printed, while the motor shroud, motor mount, and frame were reused from last year. This conservative action allowed for our team to cut costs and time. In addition to these elements, the new brushless motors needed to be purchased as we could not design them in house. 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.

Design Theme

In order to promote collaboration and cohesiveness within our team, a theme was designed surrounding our robot's name. Following a brainstorming session, it was decided that our robot should be called Leviathan due to the sea creature's determined nature. This theme was then included in the poster, as well as this technical document.

The poster incorporates Leviathan through its background of waves, as Leviathan often creates waves when navigating through water. Additionally, a theme-focused tagline and mission statement have been designed in order to reflect the theme. The technical document includes navy and other shades of blue as predominant colors in order to display the water-based theme involving Leviathan.

Ultimately 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 also to focus more on the marketing aspects of the competition.

Figure 18:
Leviathan Illustration (Left)

Figure 19:
T-Shirt Design (Right)

Safety

Within Ozaukee Robotics, safety has established itself as one of our team's top priorities. In order to ensure the security of all personnel as well as the ROV, various precautions are taken.

The tether, located on the top of the ROV, has established itself as one of the most essential safety features. A 25 amp, single inline fuse is located within 30 centimeters of the tether's point of attachment. This fuse will monitor a steady, constant flow of current to the dry housing. If the fuse were to blow, the damage to the ROV would be quite minimal. Furthermore, devices that can draw high amounts of power were wired in parallel through the bulkhead connectors. The reason for this is to manage the heat produced by the dry housing's electronic elements. Additionally, any possible leakage area was thoroughly sealed.

For personnel working around the craft, safety features exist as well. One of these safety features includes rounding all sharp frame edges. These edges are then padded or marked as being sharp if they cannot be rounded. Another safety feature includes enclosing the propellers with custom 3-D printed shrouds. These prevent entanglement and skin contact. In addition, all team members are required to wear safety goggles as well as closed-toed shoes when working around the ROV. Prior to each run, all precaution measures are checked, ensuring the safety of all personnel.

Safety Checklist/Protocol

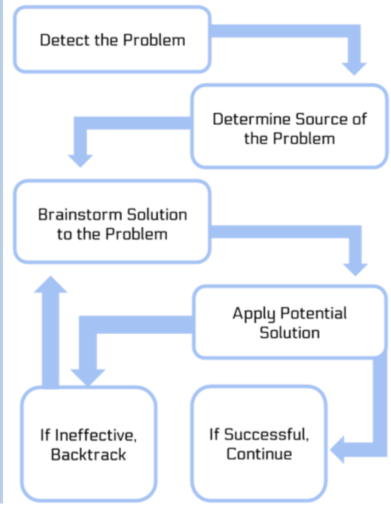
	Safety Checklist
	All items attached to ROV are secure
	Sharp edges are marked
	Single inline 25 amp fuse is in place
	No exposed copper or bare wire
	No exposed propellers
	All wiring is securely fastened
	Tether is properly secured at surface point and at ROV
	All wiring and devices for surface controls are secured
	All control elements are mounted inside an enclosure
	On-deck team is wearing safety glasses and 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

Troubleshooting

At the beginning of the year, our 3D printer continually failed in creating the final product. A major issue was that printing material began to accumulate at the base of the printer. Our solution was to widen the base of our product. By changing the model rather than trying to correct errors in mechanics of our printer, time was preserved. This example shows the importance of working with issues and time management for our team.

At the regional competition during the initial pool run, our robot's cameras lost visual functionality. Following this run, our team's engineers collaborated in order to troubleshoot what exactly had gone wrong. In the end, it was concluded that our buoy overloaded a servo motor causing our cameras to lose power. The team decided to skip this part of the task and were able to achieve a higher score on their second run.



Challenges Faced

Technical

One technical challenge we faced in creating our ROV was installing the new brushless motors. It took three weeks to complete the rewiring of the motors and modification of the program. In addition, it took thorough communication and perseverance to ensure proper installation and greatest functionality of the motors. While it took many weeks, overcoming these challenges lead to success at our regional competition.

During our first pool run at regionals, our system for deploying our buoy failed. This is because our tool for the risk mitigation task consisted of a magnet that was designed to attach to the U-bolt. Unfortunately, the U-bolt at the regional competition was stainless steel, rather than zinc-plated, and therefore was not magnetic. To overcome this challenge, our team decided to utilize a carabiner for this task in the future, which will allow the buoy to attach to the U-bolt.

Non-Technical

Ozaukee Robotics members often struggled with intercommunication. Early on in the year, members showed up late or simply not at all to our meetings. This made it difficult to plan what would get done at each meeting. As a solution, we changed meeting times so that we could maximize the amount of people at each meeting. If somebody still could not make it, they could notify the rest of the team using the group text which included all team members.

Another issue we struggled with was using our time efficiently. At certain times, some people were forced to sit and wait for an opportunity to complete their assigned tasks. This was due to the fact that many different people needed to work on the different parts of the ROV at the same time. There simply was not enough room for everybody to work on it at once. The solution to this problem was to give everybody multiple jobs at a time so when they could not work on the ROV itself, they would always have something else to keep them busy, which, in turn, boosted team efficiency.

Lessons Learned

Technical

Many lessons were learned from the technical challenges faced involving the motors. Our team was required to use patience as well as dedication. Patience was needed as it took three weeks to complete the rewiring of the motors and the modifying of the program. In addition, it took a large amount of thorough communication and perseverance to ensure the most effective motors possible resulted. Despite taking more time than anticipated, our team found that the motors were worth the effort because they drastically improved the functionality of the ROV.

Interpersonal

Communication is a key factor to success for any team. Ozaukee Robotics has found various methods to promote effective communication amongst its members. One method that has proved successful is the use of a calendar of important due dates and meeting times. Each member has access to this calendar and has the ability to add or change any details within it, thereby ensuring every individual is receiving the same information. Every member of the team is also included in a group conversation through which reminders are sent from our team's CEO or mentor. This mode of communication transmits information directly to every member's phone, guaranteeing prompt conveyance of any message. Additionally, at each meeting our team holds, our mentor has created an effective way to gather everyone's attention. When our mentor says, "Hey team!" every member is supposed to respond with "What's up?" and then direct their attention towards our advisor. With this simple way to grasp each individual's attention, no time is wasted waiting for members to finish talking.

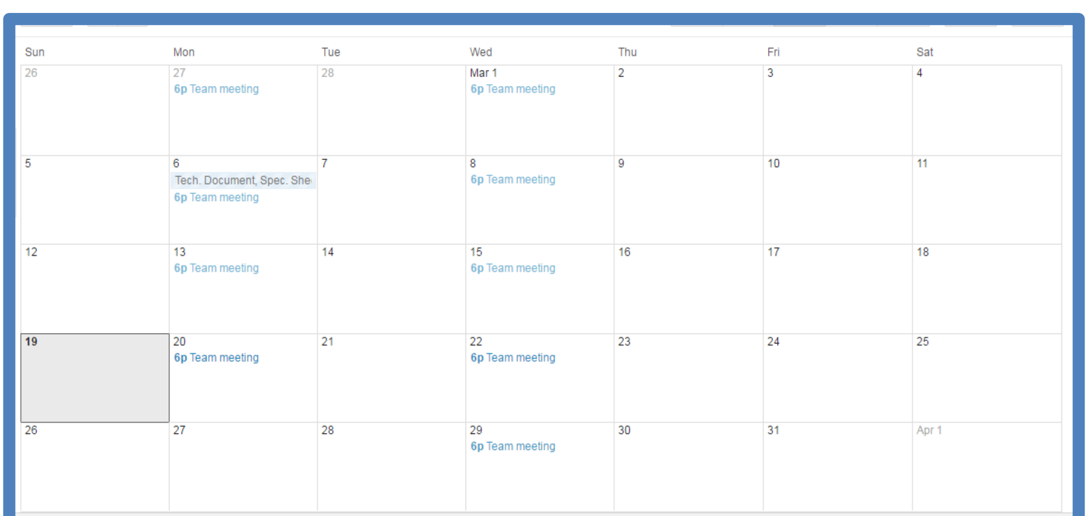


Figure 20:
Team Calendar

Senior Reflections

One of my favorite parts of ROV is the opportunity it provides students to apply the things they learn. Lots of the material we learn in school doesn't actually get put to use until students reach their majors in college or begin their first job in their field. ROV lets students practice the skills they have learned and see all the things they can do with these skills. Programming the microcontroller and GUI for my team's robot has given me invaluable experience in what I want to study that can't be replicated by just learning in a classroom. In addition to practicing skills, ROV has also allowed me to build my teamwork skills by working with a wide group of different individuals on a team. Having experience working on a team is another valuable asset that cannot simply be learned in a classroom. The experiences ROV has given me are key events that will shape the way I move forward in my education and career.

-Josh Vogt, CEO/Software Engineer

ROV has allowed me to participate in something much larger than anything I could accomplish by myself. It has given me great insight into the experience of participating on a team, meeting deadlines, and overcoming challenges that engineers face in their daily workloads. It has taught me valuable skills and allows me to utilize previously learned ones such as 3D modeling in a practical real world situation. My desire to become a computer engineer has been reaffirmed by my experiences on the Ozaukee ROV team.

-Nick Marz, Software Engineer

ROV has been a very useful and informative club for me such as helping me learn skills and practice good teamwork. I've continued to learn how to create schematics and wire up new equipment. By going back to my old schematics and seeing how they aligned with the robot as I rewired the new equipment, I realized how I could improve my schematics and what were bad practices on my part with my wiring. I'd say ROV is overall a great club as it helps one develop good teamwork skills, learn new strengths, and hone the abilities one already knows.

-Connor Freiburger, Electrical 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. I am now the pilot of the ROV, which has proven to be one of my most effective positions. 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, Pilot

Team Reflection

As a team, the members of Ozaukee Robotics commonly believe that participation within robotics requires strong teamwork, communication, as well as adaptive learning skills. The techniques that each team member has acquired may be applied within the real world, and the values that come along with such knowledge are immense. Overall, the various departments of our company each find their own benefits to their participation. Our engineers feel attention to detail is a crucial skill that is developed through involvement within this club. The technical writers have found that their participation has allowed them the ability to write with a purpose. Each team member has discovered benefits that will extend to their own life and, in some cases, assist them in preparing for their future careers.

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

In order to design our ROV, a company effort with contributions from each member of the team was required. To begin drafting tools that complete the required tasks, our team's engineers collaborated with one another. The new tools were then constructed and attached to the ROV along with the reused ones. Each tool was precisely placed in order to meet the size restrictions involved. After completing various trial runs, the tools were then redesigned if needed, as well as tested. Throughout the process of designing and modifying the ROV, all team members additionally drafted the technical document and created the marketing display.

Team Memory and Evolution

Ozaukee Robotics' team is full of diversity and varying experience levels which presents various benefits. Members from previous years have been able to influence the planning process more, as they have prior knowledge of the competition. Not only did these individuals' experience assist with building the ROV, but it also was crucial in teaching new members. Furthermore, an overview of the competition was presented to new members in order to provide them with a proper understanding of the requirements of each team. Additional resources and research, such as the MATE and Port of Long Beach websites, were utilized to gain a clear understanding of what is expected within the competition. Our research has influenced our procedure and design, such as utilizing our hover and precision modes to avoid disturbing the environment when collecting our sediment sample.

Project Management

To ensure that Leviathan was completed on schedule, weekly goals were established to align with a long term plan. The development of the ROV was managed through the use of a schedule. Every week each department would be given a series of tasks to accomplish. It was crucial to meet the due dates for the specified tasks, as each team member's schedule was dependent on another's. If one person were to fall behind, the whole team would be impacted as a result. This emphasizes the significance of being a good teammate. During each meeting, all of the team members were able to communicate with one another, which offered an opportunity to discuss issues and ask needed questions.

Build Schedule

Date	Build Schedule
12/2/16	Read the Ranger Manual
12/14/16	Order 2 Blue Robotics thrusters + ESCs
1/4/17	Build props
1/11/17	Brainstorm tool ideas
1/28/17	Order additional Blue Robotics thrusters + ESCs
2/1/17	Look into Bluetooth laser distance measurement tool and Arduino use
2/8/17	Look into new voltage converter for ROV and black box
2/20/17	Determine name of robot
3/1/17	Complete the auger tube
3/2/17	3D print clam collector tool
3/4/17	Test brushless motors
3/8/17	Wire ESCs
3/9/17	Configure motors
3/9/17	First pool test
3/10/17	Complete programming the code
3/11/17	Mount auger
3/11/17	Mount clam collector tool
3/12/17	Mount LEDs
3/15/17	Configure cameras
3/17/17	Finish the tech document
3/18/17	Add tools such as tape measure
3/19/17	Finalize magnet position
3/20/17	First mission practice

Future Improvements

Although there were many effective changes made for this year's team, there is still more to be improved on for years to come. For example, even though we did begin earlier, it took longer than anticipated to effectively communicate with other members as well as train incoming members on the various tasks. Mainly for future competitions, our team looks forward to promoting time efficiency in the early practices. Additionally, the team has done 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 21:
Electrical Engineers

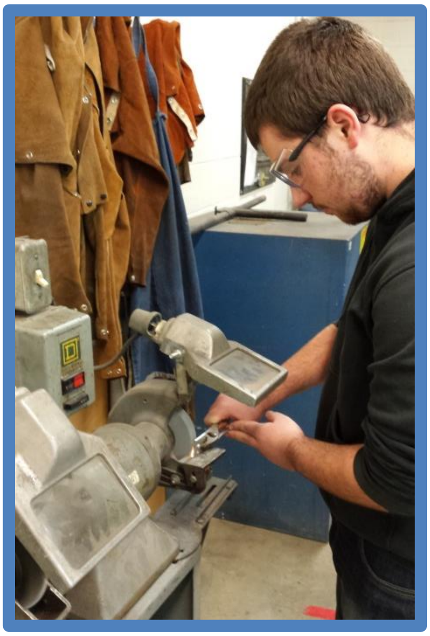


Figure 22:
Mechanical Engineer

Budget/Cost Analysis

Our ROV team made sure to complete extensive planning in order to ensure that the robot was built according to our budget. While designing the robot, research was conducted to become informed about different materials. This was completed in order to produce the optimal design to perform the mission tasks. The team is very fortunate to receive donations again this year from companies that have contributed in the past. As for materials, the team had some remaining from previous years that were able to be used for this year. However, when we had to purchase new materials, a budget was set and maintained. Furthermore, research was conducted to find the best quality of product at the most practical price. Additionally, our team was frugal. For example, instead of ordering team shirts, we designed our own using iron-on transfers. Strategies like this allowed our team to stay within our budget and have financial success.

Project Costing

Value of Reused Items		
Original Year	Item Desciption	Current Cost
2010	Arduino MEGA	$15.00
2011	Multiplexor	$20.00
2011	Depth Sensor	$50.00
2011	Bulkheads	$150.00
2013	TV Monitors	$150.00
2015	Tsunami Motors	$87.00
2016	Cameras	$170.00
2016	Integra Enclosure	$90.00
2016	Tether Wire	$40.00
2016	Compass Board	$30.00
2016	C-Channel	$10.00
2016	Servo Motors	$100.00
Total		**$912.00**

Material Donations		
Company	Donated Material	Est. Cost
TDK-Lambda Americas Inc.	2 DC-DC Converter I6A24014A033V-001-R	$68.58
Bares Enterprises	Polycarbonate tube	$8.50
Total		**$77.08**

Monetary Donations	
Thrivent Financial	$250.00
Fredonia Mobil	$250.00
Rosie and Herb Kuehne	$500.00
Exxon Mobil	$250.00
WillPemcoBielomatik	$500.00
Total	**$1,750.00**

Services Donated	
Item Description	
Ozaukee High School's Woodshop	$500.00
Vogt's Tools and Workspace	$250.00
Total	**$750.00**

General Expenditures	
Item Description	Cost
PVC parts Home Depot	$64.70
Props Home Depot	$14.33
Steel tent stakes	$6.20
Reed switches	$20.50
Buzzer	$4.54
10 10' 1/2 PVC pipe	$23.21
PVC pipe cutter	$10.53
3 way 1/2" PVC	$13.06
Agar	$8.99
Plastic sheeting	$22.66
T-shirts and transfers	$78.03
Chlorine	$3.64
Total	**$351.25**

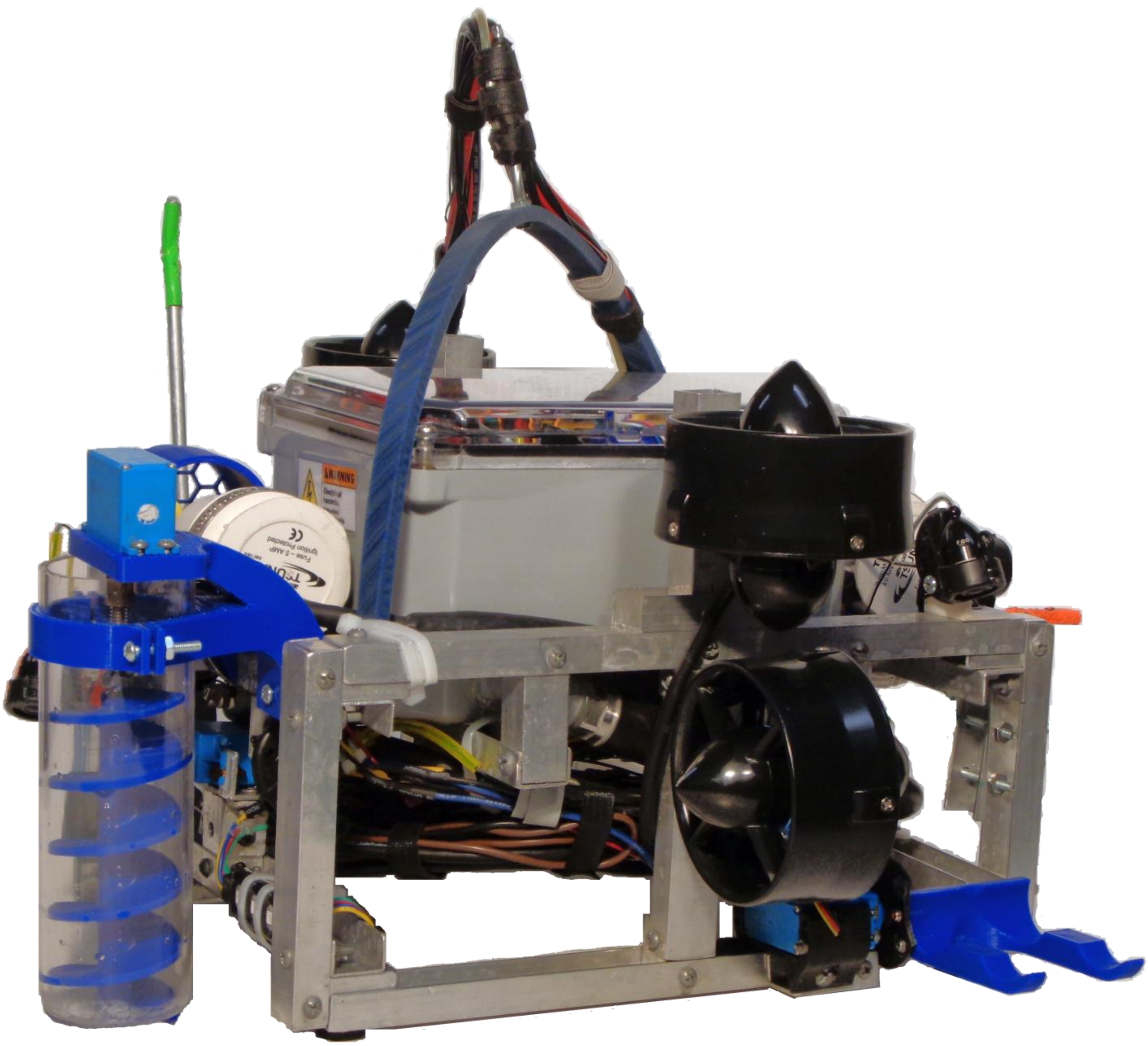
ROV Build Expenditures	
Item Description	Cost
T100 Thruster with ESC	$596.00
2-spools PPLA 3D Printer Filament	$57.98
Magnet with swing hook (CC)	$9.97
Tape measure	$7.03
Servo	$54.99
Total	**$725.97**

Travel Estimate	
Item Description	Cost
Travel	$3,471.00
Hotel	$3,895.00
Total	**$7,366.00**

Total ROV Cost

$1,715.05

Summary Sheet



Dimensions: 46 cm x 45 cm x 38 cm
Dry Weight: 10.97 Kg
Approximate Total Cost: $1,715.05

Acknowledgements

Ozaukee Robotics would like to thank:
MATE: for hosting this amazing competition
UWM: for hosting the regional competition
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Ancor: material donation
Pololu: material donation
Aqua-Vu: material donation
Keller America: material donation
SubConn: material donation
TDK-Lambda Americas: material donation
Bares Family: material donation
Ozaukee High School: for their facilities
Fredonia Mobil: monetary donation
Exxon Mobil: monetary donation
WillPemcoBielomatik: monetary donation
Thrivent Financial: monetary donation
Rosie and Herb Kuehne: monetary donation
Bob Wagner: for his technical expertise
Randy Vogt: for his technical expertise

Photo Accreditation

Cover Photo 1: Josh Vogt
Cover Photo 2: Randy Vogt
Figure 1: Randy Vogt
Figure 2: Randy Vogt
Figure 3: Randy Vogt
Figure 4: Randy Vogt
Figure 5: Nick Marz
Figure 6: Hannah Nordby
Figure 7: Hannah Nordby
Figure 8: Hannah Nordby
Figure 9: Josh Vogt
Figure 10: Josh Vogt
SID: Connor Freiburger
Figure 11: Josh Vogt
GUI Flowchart: Nick Marz
Arduino Flowchart: Josh Vogt
Figure 12: Nick Marz
Figure 13: Hannah Nordby
Figure 14: Hannah Nordby
Figure 15: Josh Vogt
Figure 16: Josh Vogt
Figure 17: Josh Vogt
Figure 18: Gonzalo Ordóñez Arias, Devianart
Figure 19: Hannah Nordby
Figure 20: Zach Wagner
Figure 21: Hannah Nordby
Figure 22: Randy Vogt
Summary Sheet: Hannah Bell

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