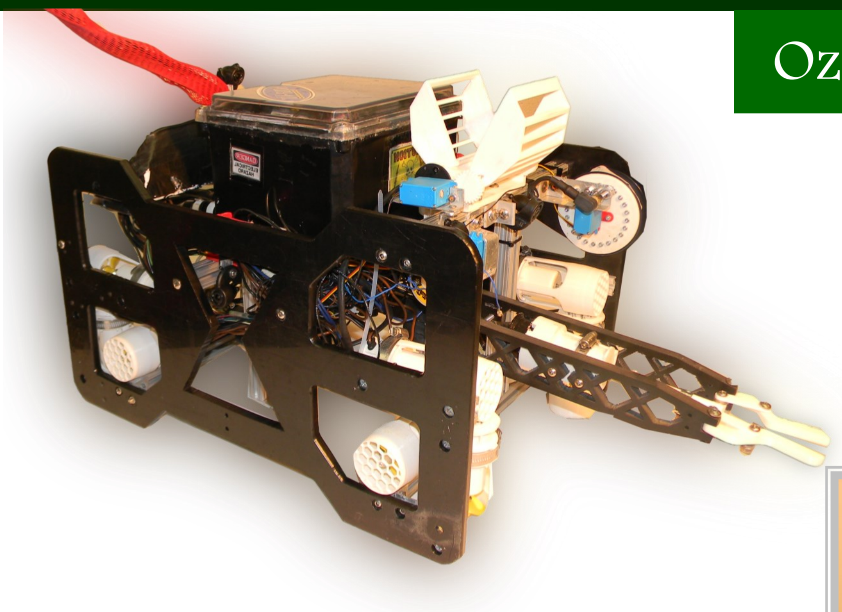
Wizard Automation

Ozaukee High School, Fredonia, WI



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WIZARD AUTOMATION

MATE 2015 Technical Document

Abstract

Returning for a sixth year, the Ozaukee robotics team has again set out to construct a specialized remotely operated vehicle (ROV) for the MATE Robotics Competition. This craft, affectionately known as Ozcar, has been built specifically to assist both oil and gas operations as well as researchers' work in the Arctic.

Ozcar is able to count species and sample organisms, determine the threat level of an iceberg to offshore installations, and complete pipeline inspection. Furthermore, the ROV can test the grounding of anodes on an oil platform, determine the angle at which a wellhead emerges from the ocean surface, and regulate the flow of oil through a pipeline.

To accomplish these tasks, Wizard Automation has custom built a hydrodynamic High-Density Polyethylene frame designed specifically for the tooling needed to be successful in the mission. Essential tools include the grippers, the conductivity sensor, the valve turner, the measuring tool, and the algae sampler. Wizard Automation has programmed Ozcar entirely with student-written coding; the ROV is managed through its onboard microcontroller, receiving commands from the topside pilot who utilizes both a PlayStation 2 DualShock 2 controller and a computer keyboard.

Wizard Automation has found repeated success due in large part to its strong business orientation; adapting a corporate structure that is perfectly suited to our needs has helped us immensely. Created for speed, safety, and love of exploration, Ozcar is the pinnacle of the team's enthusiasm and hard work.

Figure 1: Memorial University

Figure 2: OCRE Facility

Figure 3: Example Pipeline Section

Competition Mission

Located in close proximity to coastlines, historical sites, and a vast range of wildlife, St. Johns, Newfoundland and Labrador, Canada, is the home of the Memorial University of Newfoundland's Marine Institute (MI) and the National Research Council's Ocean, Coastal, and River Engineering (OCRE) facility (Figures 1 and 2). These facilities are in use by aspiring Arctic scientists as the MI is home to the world's largest flume tank, and the OCRE includes an ice tank and an offshore engineering basin. The facilities are also inhabited by the offshore oil and gas industry.

Polar science enthusiasts and offshore energy industries are in need of an ROV that can complete operations such as counting species and sampling organisms, deploying a sensor, and determining the threat level of an iceberg to offshore installations beneath the ice surface. Furthermore, the ROV needs to inspect and repair a pipeline by replacing a corroded section of an oil pipeline and preparing a wellhead for a Christmas tree delivery (Figure 3). Finally, the MI and the OCRE need a vehicle that can conduct offshore oilfield maintenance, which will include testing the grounding of anodes on an oil platform, determining the angle that a wellhead emerges from the ocean surface, and regulating the flow of oil through a pipeline.

This year's mission is very important as there are data gaps in regards to arctic sea environments. Scientists are in need of quality ROVs to fill in these informational holes, not only to influence the advancement of science but also to prepare in case a crisis were to present itself.

The oil related tasks are extremely prevalent as the National Research Council (NRC) recently released a report saying how detrimental an arctic oil spill could be. Currently oil companies—including ExxonMobil, Shell, and ConocoPhillips - are looking into arctic oil mining. A spill could cause oil prices to rise substantially in order to pay reparations to reconstruct destroyed habitats in addition to the detriment in profit.

Corporate Profile

Striving for efficiency, Wizard Automation has developed a structured and individualized approach to business management. The company is divided into two primary branches: Business and Engineering (Figures 4 and 5). Splitting power between the two areas has streamlined decision-making while also encouraging communication between the different branches. This approach allows each department to primarily focus on the area that best suits its expertise while maintaining communication between members.

The business department oversees all financing and public relations. Sub-departments include fundraising, public relations, and accounting. Fundraising is responsible for seeking donations and performing profit-making ventures. Those active in public relations operate the company website and are chiefly responsible for making the marketing display. Accounting tracks all business expenditures accrued by the other departments.

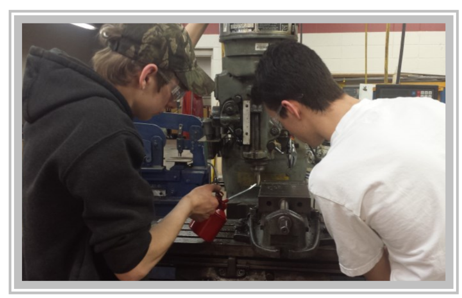
The engineering department is split into three sub-departments: electrical, software, and mechanical. The electrical department controls all electronic hardware; software does all of the software programing; the mechanical department creates the physical structure and working components of the ROV, including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

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

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

Figure 4: Business Department Working (Left)

Figure 5: Engineering Department Working (Right)



Design Rationale and Vehicle Systems

Frame

An integral element of the construction of Ozcar was the frame. Because of the size restrictions posed in the mission, special consideration had to be given to the frame design.

The team chose to construct the frame from High-Density Polyethylene (HDPE) and 80/20 aluminum due to their reliability in the past. The HDPE creates a strong and versatile frame due to its strength and almost neutral buoyancy, allowing for a sturdy frame with little impact on the craft's buoyancy. The sheets are then joined by the 80/20 aluminum. The inclusion of 80/20 cross members helps to stabilize the sides of the frame while providing versatile tool mounts.

The HDPE that composes the sides of the frame is 1.25 cm thick. Both sides of the frame are identical sheets cut to a length of 60 cm and a height of 35 cm. Additionally, Wizard Automation counterbored the exterior hardware into the frame for all of the attachments, creating a smooth finish for less resistance.

Dry Housing

The dry housing of Ozcar is an IP68 rated Integra Enclosure, chosen for its reliability in protecting the vital electrical components, specifically the microcontrollers and motorboards, from water intrusion (Figure 6). The connectors in and out of the enclosure are SubConn bulkhead connectors, which are completely sealed with gasket sealer and epoxy. The lid of the dry housing is fastened with screws and then reinforced with silicone, a sealant which is primarily used to waterproof boat engine components.

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

Not only does the dry housing assure the safety of Ozcar's electrical components, but its calculated buoyancy assists in keeping the ROV neutral while underwater. The enclosure measures 25.4 x 20.3 x 15.4 cm for a total volume of 7.866 l^3; this large volume helps to offset the weight of the tools which allows our ROV to remain neutrally buoyant. By focusing the buoyancy of the dry housing at the top while placing the heavier elements near the bottom, Ozcar's center of gravity is low while in the water, keeping Ozcar stable during all movements. In order to allow easy access to the tether and create a more stable ROV, the dry housing is located at the top of the craft.

Figure 6: Dry Housing (Left)

Figure 7: Bulkhead Connectors (Right)

Bulkhead Connectors

Ozcar's dry housing features six SubConn bulkhead connectors (Figure 7). The bulkheads provide a secure, waterproof connection from the tether to the dry housing, allowing information and power to be relayed without damaging the electrical components of the craft. Each connector is secured with silicone gasket sealer and epoxy to provide a flexible, yet reliable seal.

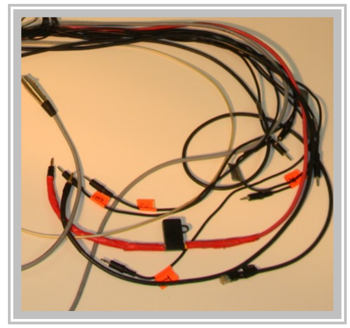
Ozcar receives its electricity from the largest of the connectors, a two-pin bulkhead rated for 25 amps of continuous current. The craft's onboard microcontroller communicates with the surface through a CAT5 Ethernet cable fastened to an eight-pin connector. Additional data, primarily signals that are sent to the motors and from the outside sensors, are sent through Ozcar's four 16-pin, 18 AWG connectors. This structure creates a waterproof, not merely water resistant, connection. Because of this, our connection is more secure than other options.

The bulkheads also provide the ability to quickly and easily disconnect the dry housing and its components, which proves useful every year as the craft is torn down and reconstructed to suit new missions, preventing possible damage to the components within the dry housing.

Tether

The lifeline of Ozcar is the 18 m tether (Figures 8 and 9). Located at the top of the ROV to allow for greater maneuverability and prevent entanglement, the tether binds cables from Ozcar to the on deck system. To ensure positive buoyancy and prevent the tangling of the line, the tether is wrapped in a protective plastic shroud and equipped with buoyant foam every 40 cm.

The main power for the dry housing flows through an 8 AWG marine grade cable, which reaches from the topside power supply to the bulkheads, after which busbars within the dry housing distribute power accordingly. The video signals from the cameras are sent to the surface through the tether along their stock 28 AWG and 100 Newton sheer-tested cables. The shielding of the camera wires prevents excess energy generated by auxiliary forces from interfering with the analog video signals. Primary communication with Ozcar is facilitated through the CAT5 Ethernet cable that runs through the tether. The tether features only two non-electrical components. These components, matching 2.5 mm diameter plastic tubes, are responsible for sending air below the water's suface. One is attached to the depth sensor, giving it the ability to compare underwater pressure with surface air pressure. The other exists in case of emergency and acts as a spare.



Figures 8 and 9: Tether

Propulsion

Maneuverability was a key concept addressed when determining the design of the ROV. To maximize movement, twelve Tsunami 1200 bilge pumps have been converted into thrusters using propeller shaft adapters and Octura 1255 propellers. This combination of adaptations provides the most efficient operation in terms of the power produced compared to cost. Each motor efficiently produces 7 Newtons of force while consuming only 4.2 amps of current. All motors are mounted inside the frame to prevent entanglement during the mission and transportation and to reduce drag.

To maximize stability and speed, four motors are assigned to each type of directional movement: up/down, left/right, forward/backward (Figure 10). All are mounted symmetrically, with the exception of "left/right" motors. These two motors, near the front of the ROV, are placed higher to accommodate additional tools, simultaneously focusing weight in the rear-bottom of Ozcar for increased buoyancy. All motors counter-rotate with their symmetrical partners and are mounted in-series, with the exception of the left/right motors, which are mounted in parallel to aid with strafing.

Each motor uses approximately 50 watts of power with 4.2 amps of current at 12 volts. When all forward/backward motors are fired, they use approximately 16.8 amps of current. As 25 amps are allotted, the thrusters fall well short of the required limit, even considering the current used by the electronic components of the craft. With this limited power, the motors can generate up to 28 Newtons of force. According to Newton's 2nd Law, the ROV can accelerate at 1.544 m/sec^2 in all directions.

Additionally, much thought has been put into creating the shrouds for the motors. We initially designed them purely for safety purposes but quickly realized that the shrouds could be beneficial in many ways.

Using a 3D design program, Wizard Automation drafted a few different designs of shrouds, aiming for maximum efficiency. When designing the new shrouds, the team focused on a variety of areas: we experimented with induction port size; curving the inside of the shroud, to compress the water pressure and increase the force; the size of the honeycomb grate, trying to reduce resistance; the diameter of the shroud, to accommodate the new size of our propellers; the shroud's length, to adjust for the propeller adapters; moving the mounting holes, so they would not interfere with spinning propellers; and custom printing the propellers to fit bilge pumps.

Once the team chose a design thought to be most effective, we printed a miniature model of the shroud (Figure 11). When there were no obvious problems with the design, the team printed a correctly scaled shroud and placed it over the motor. We then examined how the motors themselves worked within the shroud and noted any changes that needed to be made. We finalized a shroud with larger port size, increased honeycomb grate, and more shroud length (Figure 12). This design decreases the overall water resistance, as well as the amount of material used (therefore decreasing cost and build-time). With these final adjustments, the shrouds currently fit better than the Munchkins in their hiding-holes. Furthermore, we assured that the shrouds were easily removable for greater accessibility.

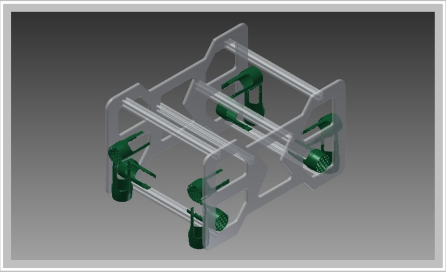


Figure 10: Thruster Placement

Figure 11: 3D Shroud Model

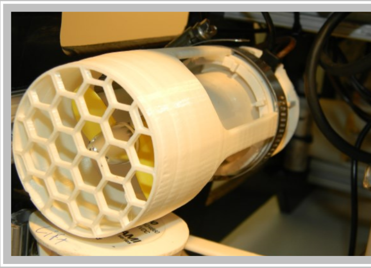


Figure 12: The Finalized Shroud

Control System

Hardware

Focusing on precision and accuracy is essential for any capable ROV. For this mission, Wizard Automation chose to use Arduino microcontrollers and Pololu motor controllers.

Ozcar's ten Pololu 18V15 motor controllers are responsible for moderating power to all thrusters. These controllers allow the pilot to manually adjust the settings of each element. Manual adjustment allows the power and polarity of each motor to be adjusted independently.

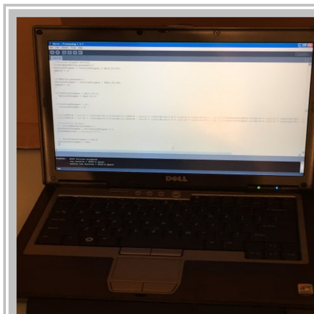
The motor controllers fall under the control of Ozcar's Arduino MEGA Microcontroller. The microcontroller manipulates the motor controllers by releasing Pulse-Width Modulated (PWM) signals. The Arduino adjusts the duty cycle of these signals to change the power sent to the motor boards, allowing for 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. The Atmel processor and 128KB of flash memory enable Ozcar to process software commands without hesitation. In compliance with MATE specifications, the microcontroller is powered through an onboard 12V DC to 7V DC converter.

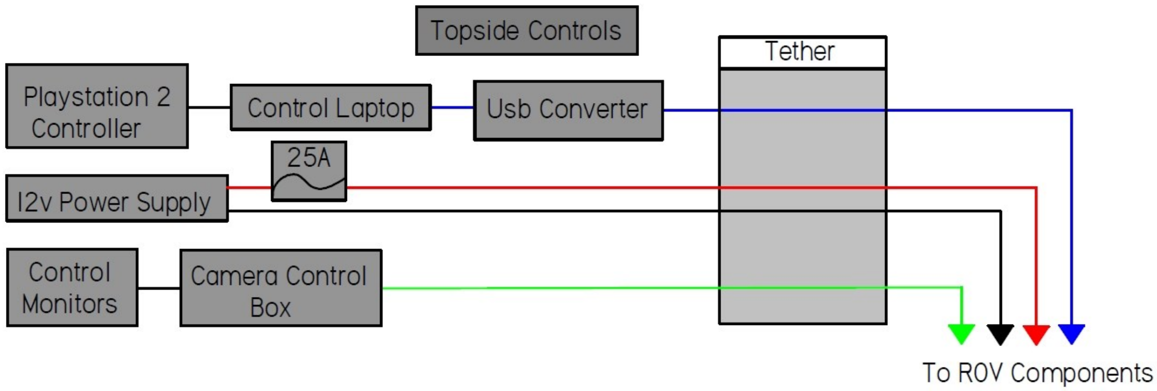
The ROV is manipulated with a laptop keyboard and a DualShock 2 controller (Figures 13 and 14). The joysticks of the controller are used to drive the primary motion of the craft while the keyboard toggles Ozcar's modes. Their use allows for easy direction and programing, permitting more focus to be spent on completing the mission, rather than focusing on the controls.

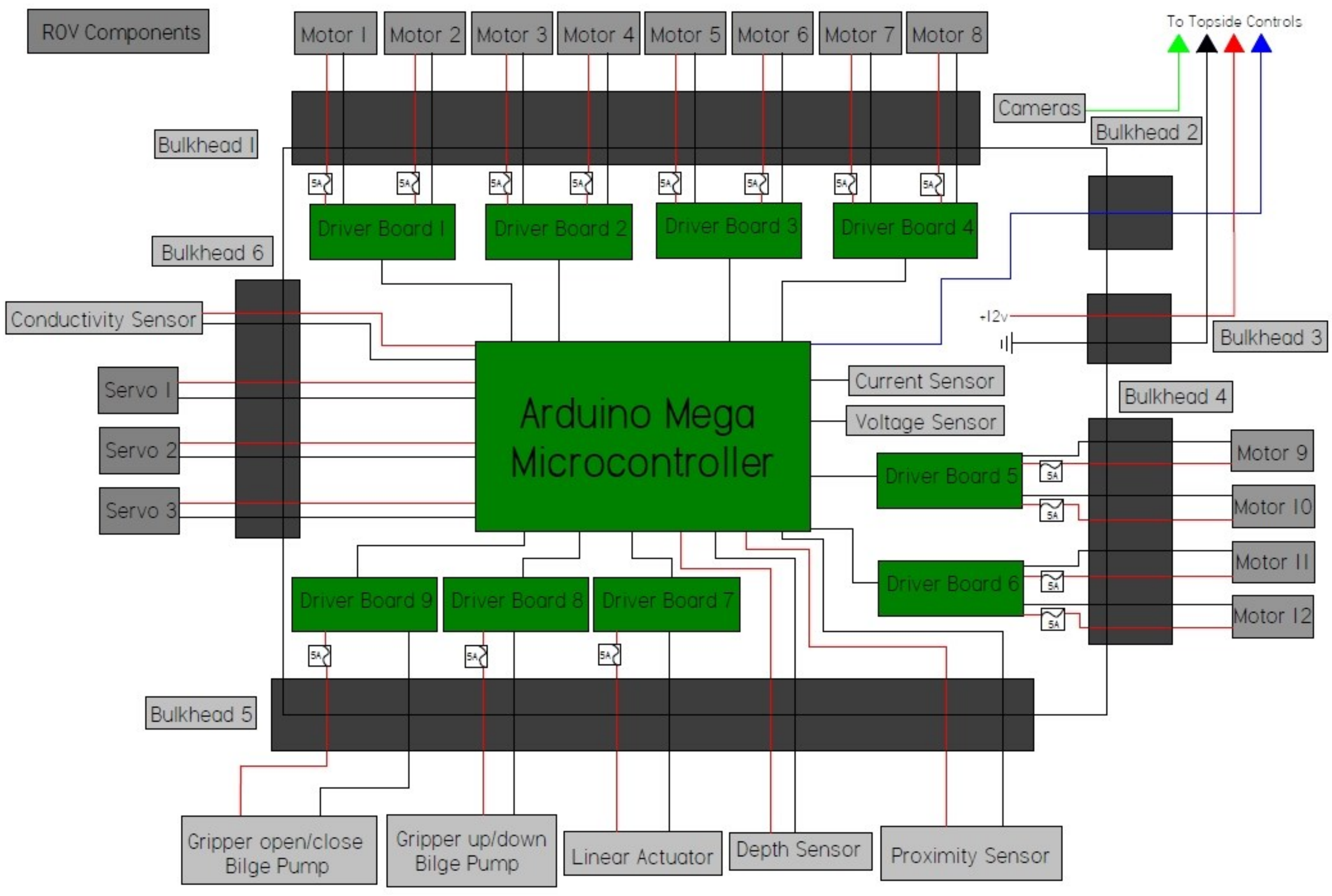
Figure 13: DualShock 2 Controller

Figure 14: Keyboard



Electrical Schematic





Controls

Ozcar's Ps2 DualShock2 Controls

Right Joystick	Right Thrust
Left Joystick	Left Thrust
Triangle Button	Actuating Gripper Open
X Button	Actuating Gripper Close
Circle Button	Reciprocating Gripper Open
Square Button	Reciprocating Gripper Close
D Pad Up	Reciprocating Gripper Up
D Pad Down	Reciprocating Gripper Down
L1	Lift Upwards
L2	Lift Downwards

Ozcar's Keyboard Controls

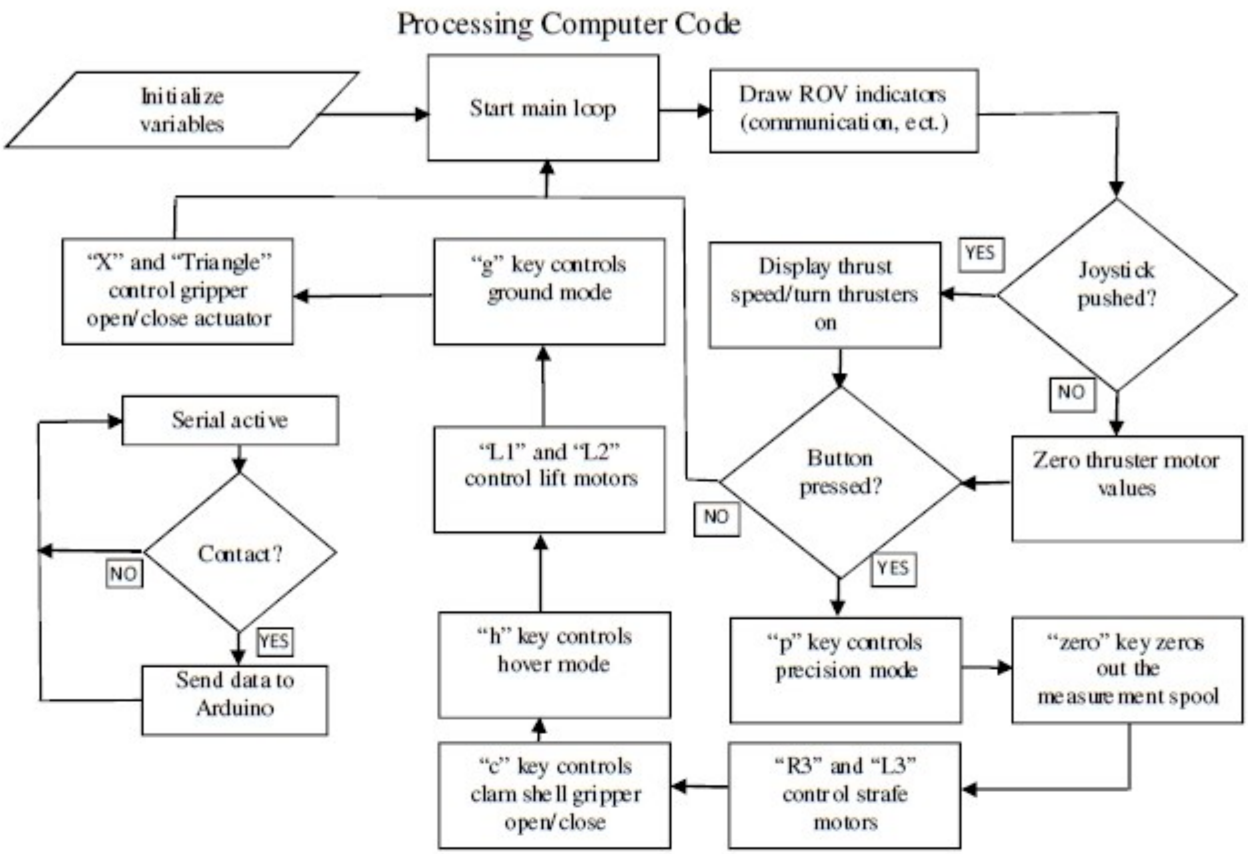
P Key	Precision Mode
H Key	Hover Mode
G Key	Ground Mode
(Four) Directional Arrows	(Four) Directional Modes
C Key	Open/Close Clam Shell Gripper
N Key	Measuring Spool Dispenses
M Key	Measuring Spool Retracts
A Key	Conductivity Spool Dispenses
S Key	Conductivity Spool Retracts
Zero Key	Zeros out Measurement Spool
D Key	Record Depth Measurement

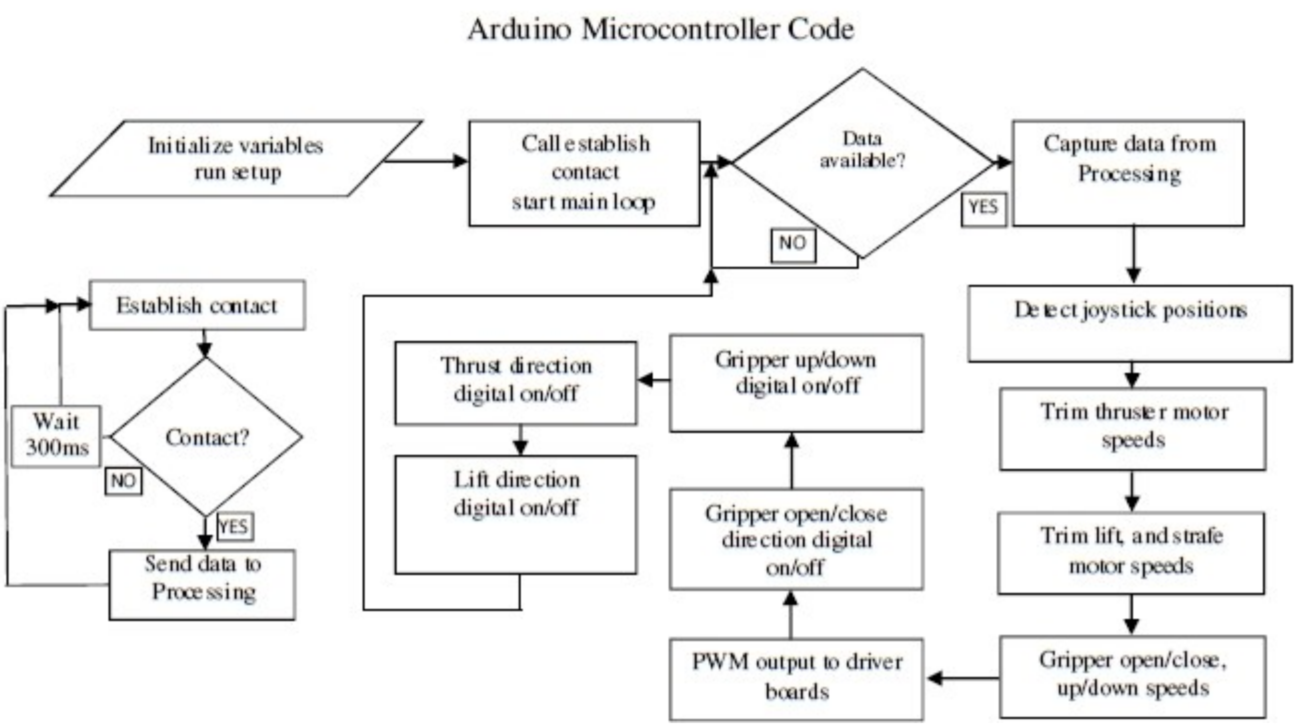
Software

Wizard Automation's custom software serves two crucial functions: to control the microcontroller and to translate data from the tools. The microcontroller software, written in C code, is stored within Ozcar's 128 KB of onboard flash memory. The code allows the microcontroller to communicate with the motor controllers, which are responsible for the craft's propellers and grippers. 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 top-side laptop's graphical user interface (GUI). These readings from the laptop's software communicate with the microcontroller and aid the pilot in determining position, orientation, and stability.

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

Software Flowcharts





Modes

To be properly equipped in all mission situations, Wizard Automation has given Ozcar multiple modes of operation that alter the basic functions of the craft to enhance certain maneuvers (Figures 15 and 16).

For example, hover mode suspends Ozcar in the water, as still as the Tinman without oil. Hover mode is enabled primarily by the depth sensor. Once activated by the “H” key on the keyboard, the craft is suspended at its current depth. This constant positioning is produced by the vertical thrusters, which exert force in amounts parallel to the amount of change in depth to prevent movement and stabilize the ROV.

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

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

A new background mode, referred to as the current limiter, detects when current is approaching overloading levels, at which point the current to certain functions is reduced. This creates an additional safety barrier for Ozcar by providing another method to prevent current overload and therefore system failure due to overheating.

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

For turning the flow valve, many different options were discussed. The most obvious solution would be to attach a gripper that could turn the valve, however, the gripper would then extend out from under Ozcar. This would be a problem, as a new bilge pump motor and another motor driver board would need to be installed along with a planetary gearbox. These conditions would lead to an unnecessarily complex system. Furthermore, the gripper would most likely spin Ozcar instead of the valve, possibly risking damage. Instead of utilizing a gripper to turn the flow valve, a new mode was created. Named rotate, the mode uses eight of the twelve motors to spin Ozcar. We attached a hook to the bottom of the ROV’s frame, placed the hooks around the valve, and then activated rotate mode, which in turn spun the valve. While we ultimately decided to change our valve system, rotate mode remains useful.

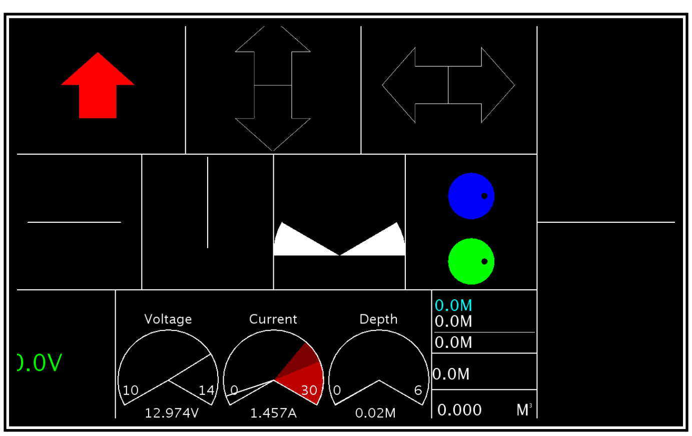


Figure 15: Blank GUI

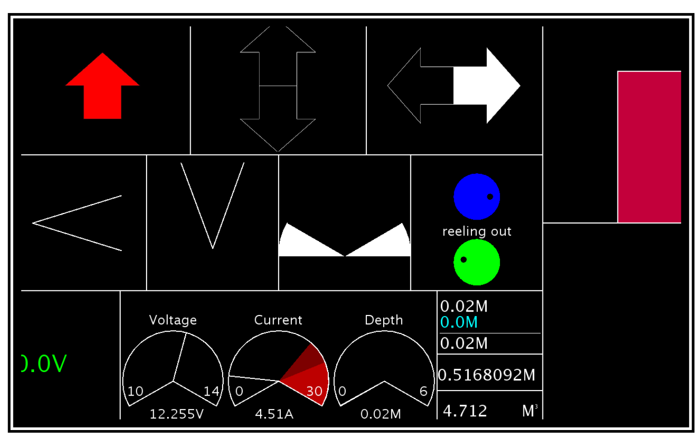
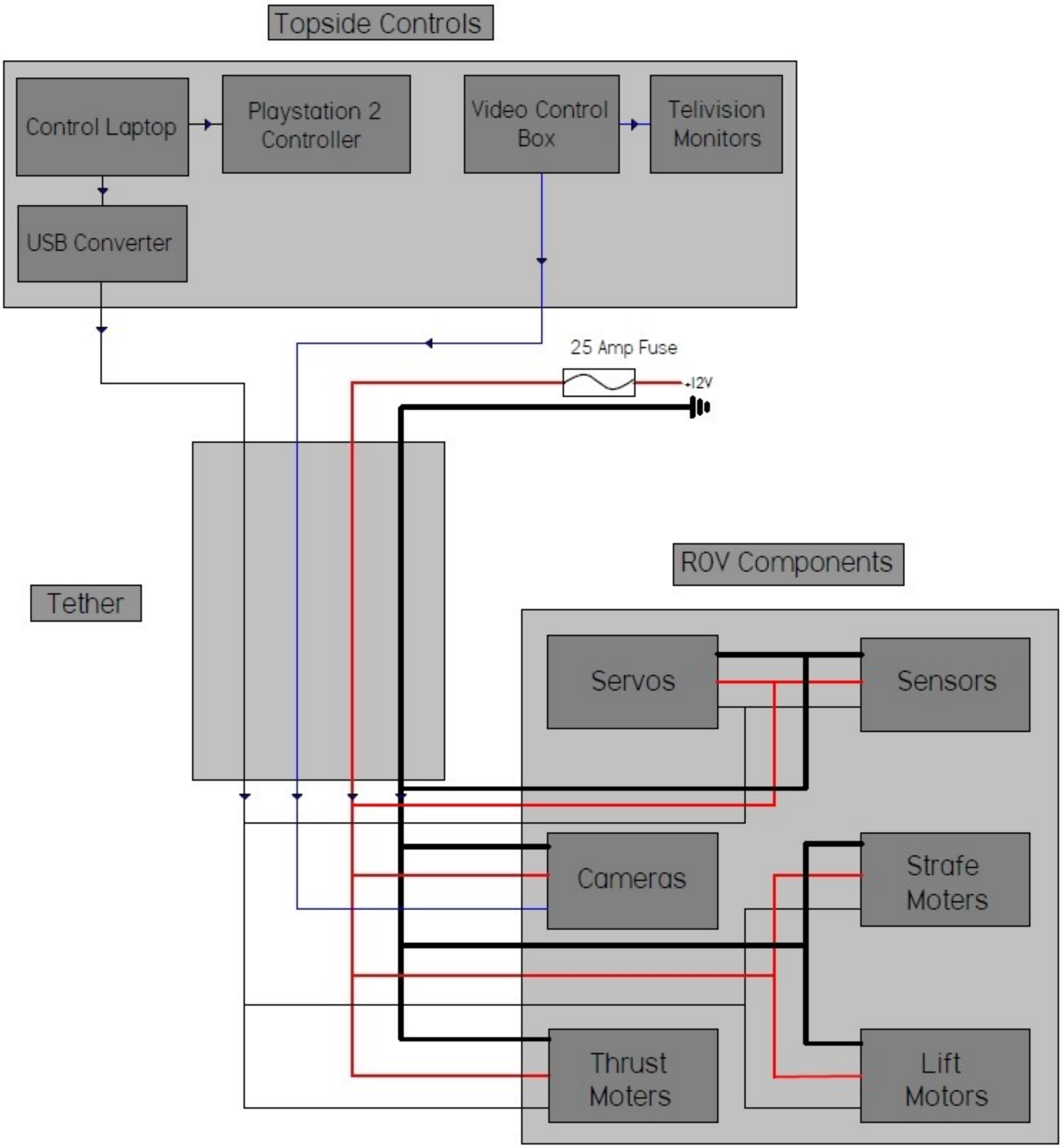


Figure 16: Running GUI

System Integration Diagram



Video System

Through six years of experience, Wizard Automation has discovered that maximizing vision during missions is a top priority. To accomplish this, Ozcar 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 (Figures 17 and 18). Ozcar'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, their functioning depth of up to twenty meters, and their minimal and lightweight design.

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

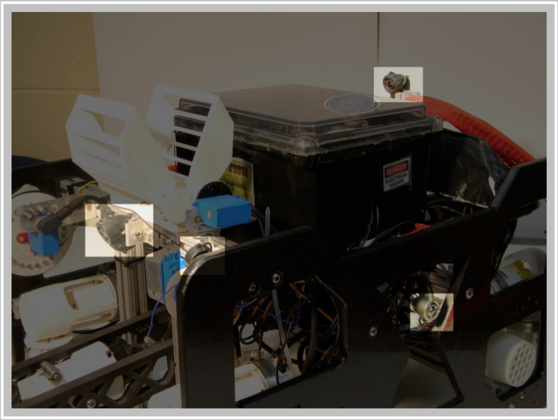
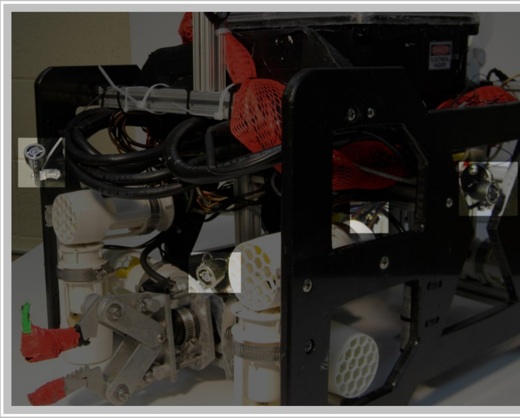


Figure 17: Camera Placement

Figure 18: Camera Placement



Valve Turner

Figure 19: Valve Turner

For the regional competition, Wizard Automation employed a simplistic design to turn the valves. We machined an aluminum spin plate and attached four flanges under Ozcar's frame that hooked on the valve. We then spun the ROV itself, thus causing the valves to spin. Upon further consideration, the team recognized that this design was not very efficient. At first glance, simplistic designs are best; however, this design had too many flaws to remain for the international competition. It caused our tether to tangle, and it took an excessive amount of time to complete the task.

For internationals, the team redesigned the valve turner to be a motorized system (Figure 19). The team began by mating a bilge pump motor to a planetary gearbox. We then cut out a spin plate from aluminium sheeting and attached four 7 cm bolts. The four bolts catch on the valve; when the motor turns the valve turns. This design is more complex than our previous one but is more straightforward as applied to the mission.

Measuring Device

Because of the high number of tasks the ROV must complete, most of our tools serve multiple purposes. The measuring device is utilized to measure both the iceberg and the wellhead.

The primary component of the measuring tool consists of a modified servo and a fishing spool (Figure 20). A flexible measuring tape is wrapped around the fishing spool. The co-pilot may then activate a key on the computer to extend or retract the tape measure. A camera is strategically mounted, so the pilot may easily read the measurement.

In order to hook the measuring tape onto the objects we need to measure, Wizard Automation employs two different tools.

To measure the iceberg, a spring clamp, which is attached to the end of the tape, is placed in the primary gripper (Figure 21). The clamp surrounds the iceberg, and then the gripper releases the clamp. Once the measurement is taken, the clamp is removed from the iceberg.

To measure the wellhead, the team has constructed a measuring sleeve. The measuring device consists of a larger PVC sleeve and prong designed to slide to the bottom of the wellhead, providing a measurement which is both accurate and precise.

Figure 20: Measuring Tape on Spool (Left)

Figure 21: Spring Clamp (Right)

Bolt Dispenser

In order to insert the bolts into the flange, the team utilized a simple three-pronged claw. The first two prongs are fixed onto a custom 3D printed plate. The third prong is centered above the other two and is opened using a servo. The bolt is clamped between the prongs and is inserted into the flange by maneuvering the ROV. The claws simply release the bolt once it is in place.

Grippers

Wizard Automation carefully considered many options when deciding which payload tools would provide the highest efficiency in completing this year's mission. Wizard Automation then designed and created a highly effective system consisting of an actuating gripper and reciprocating gripper combination (Figures 22 and 23 respectively). The use of both grippers adds to Ozcar's versatility as it allows the pilot to choose between a horizontal or a vertical gripper.

The strongest of the grippers is mounted vertically at the back of the ROV (Figure 22). Powered by a linear actuator, the gripper weighs 1290 g, helping to focus the weight on the bottom rear of the craft. The strength and versatility exhibited by this gripper allow for the pilot to remove the pipeline and attach the lift line.

Ozcar's reciprocating gripper employs a Tsunami bilge pump motor; the motor's shaft was milled to fit a planetary gear box, and the team machined a hex to threaded-rod adapter (Figure 23). This combination acts as a multi-step transmission, increasing the torque output. This torque is then converted to a linear motion by means of a nut-sled. The system was then sandwiched between two Nylon 6,6 plates, which were water-jetted using CAD files to create a slim, low-resistance design. This reciprocating-style gripper becomes particularly useful when attaching the measuring device to the iceberg.

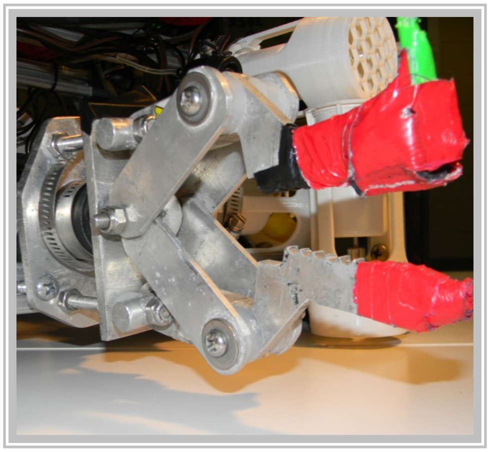


Figure 22: Actuating Gripper

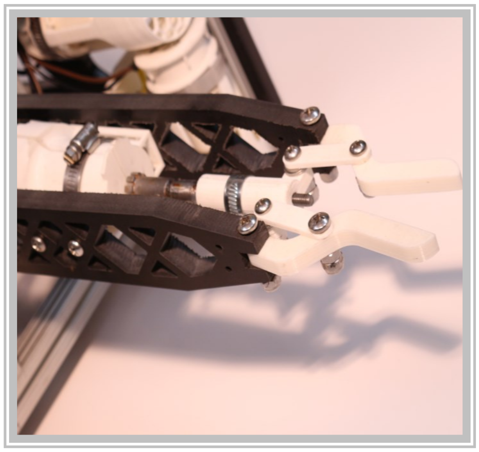


Figure 23: Reciprocating Gripper

Figure 24: Depth Sensor

Sensors

Depth Sensor

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

In order to accomplish the calculations responsible for this, we employ a Keller submersible level hydrostatic depth sensor (Figure 24). 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, displaying it in real time on the topside GUI. The microcontroller and sensor retain accuracy to 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.

Conductivity Sensor

The conductivity sensor was built completely in house by Wizard Automation engineers specifically to test oil pipelines (Figure 25). Consisting of a neodymium magnet and conductive pad, the basis of this design was developed from a dream that CEO Evan Lallensack had. One neodymium magnet is connected to a grounded 50 cm copper wire and wound onto a fishing line spool that is connected to a servo modified to spin 360 degrees. The other end of the wire attaches to an analog input on the Arduino, which is capable of measuring changes in voltage. The conductive pad is located on the reciprocating gripper jaw; we will simply have to touch the gripper to the testing point and any electric current that may be present will be sent to the Arduino. The detected values are then processed by the GUI. If an electric current is detected, the voltage will be displayed in bright red to indicate a failing test point. Conversely, a functioning test point is signified with green text on the GUI.

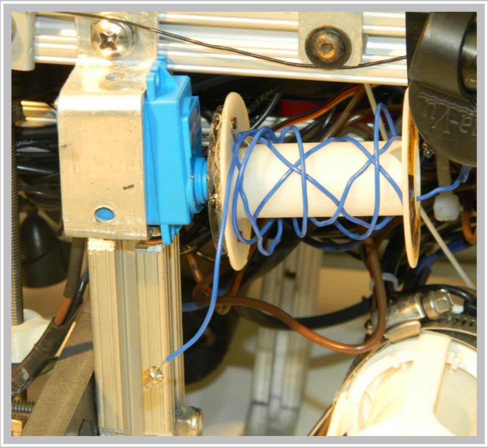


Figure 25: Conductivity Sensor

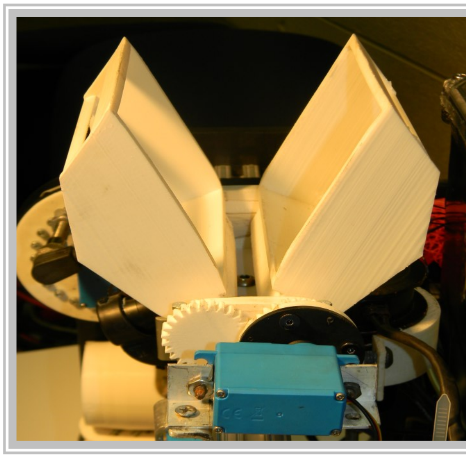


Figure 26: Algae Sampler

Algae Sampler

When designing a tool for sampling algae from the bottom of the iceberg, the team decided on the most straightforward route. We went with the first concept we conceived, purely because it was so direct; this simple nature minimized possibilities for error.

Our design features a clamshell gripper that the engineers designed and 3D printed (Figure 26). The shell is driven by gears in the two halves, that are powered by a servo. The clamshell can simply open, surround the algae, and close, all with minimal risk of the machinery having problems or the algae being crushed.

Flange Installer

Wizard Automation focused on creating a streamlined design for inserting the flange into the pipeline. We used a similar motor and gearbox setup as employed for the valve turner: we attached a bilge pump motor to a planetary gearbox. This spins a 5/16 in. threaded rod that in turn moves a nut sled back and forth. At the end of the nut sled is a 3D printed nose cone, inserted in a 1.25 in. PVC shroud. The nut sled moves forward along the rod and pushes the flange off the apparatus. This entire process is quick and precise.

Safety

Wizard Automation takes extra precautions to assure that our ROV is as safe as possible; our machine is so safe that even the cowardly Lion wouldn't be scared to operate it. In order to guarantee the safety of the craft and its personnel, Wizard Automation has taken a number of precautions to prevent both electrical and mechanical damage.

The most important safety feature lies topside, at the very beginning of the ROV's tether. Thirty cm from its point of attachment, the tether ends in a 25 amp, single inline fuse (Figure 28). When securely attached to the power supply, the fuse monitors a steady, constant flow of current to the dry housing. In the event the fuse blows, damage to Ozcar will be minimal, as all the positive leads on the craft's components have been fused to prevent energy backlash. To manage the heat generated by the dry housing's electronic components, devices that draw high amounts of power were wired in parallel through the bulkhead connectors, dividing the current load through multiple cables. All possible leaking areas were thoroughly sealed.

Safety features exist for those working around the craft as well. All sharp frame edges have been rounded or marked as sharp and padded (Figure 27). The propellers are enclosed with custom 3-D printed shrouds to prevent entanglement and skin contact, and are marked as moving parts. All team members are required to wear safety glasses and closed-toed shoes when operating or modifying Ozcar. Before each run, all safety components, from the 25 amp fuse to our goggles, are checked to ensure universal safety.

Safety Checklist

	Pre-mission Safety Checklist
	All items attached to ROV are secure
	Hazardous items are identified and protection is provided
	Sharp edges that have not been smoothed 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 control 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

Figure 27: Rounded Corners (Left)

Figure 28: Single Inline Fuse (Right)

Figure 29: Team Logo (Left)

Figure 30: Team Shirt (Right)

Design Theme

Because of this year's emphasis on marketability, the team decided that a cohesive theme for the ROV and the team as a whole would be beneficial. The team had a brainstorming session and eventually voted on Ozcar (a play on the Wizard of Oz's full name) as the name for our ROV.

As the season progressed, the team found ways to incorporate the theme into our projects. We adjusted the team name to match the new theme; previously known as ZO_3, we now go by Wizard Automation. The team then designed our own logo, capitalizing on the "wizard" portion of Wizard of Oz (Figure 29). Our logo can now be found on all of our documents, official correspondence, social media websites, and the team shirts (Figure 30).

We then tried to include these concepts into the different parts of the mission. The poster features a Wizard of Oz font, a yellow brick road background, and a theme-focused tagline and mission statement. The technical document includes many shades of green (reminiscent of the Emerald City) and various references to the movie. In an attempt to coordinate our ROV with the theme, we attached a decal of our logo on the inside of our dry housing and the two monitors used on pool deck

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

Troubleshooting

Wizard Automation's troubleshooting method is one that is persistent and explores all avenues of resolution. When a problem arises, the company quickly assembles team members and works to collectively identify the problem. After identifying the issue, the team discusses possible solutions or alternative routes to achieve the goal. The solution that is most effective is then applied. If a measure fails, the process restarts (Figure 31).

Perhaps the clearest example of troubleshooting this season was the process of creating the shrouds. After digitally designing multiple shrouds, the team printed a prototype that we thought would best suit our needs. It was only after the prototype was printed that we realized that our design did not live up to its full potential; the shroud did not completely accommodate the shape of the props, and it did not improve the thrust as we were hoping.

The engineers quickly got together and, using brains that the Scarecrow was not gifted with, identified the various shortcomings of the original design. The mounting holes did not line up properly, the newly sized props did not fit within the shroud, and the honeycomb grates were smaller than maximum efficiency.

Going back to the drawing board, the engineers drew additional models of the shrouds. All of the engineers reviewed the designs, made adjustments, and chose the model that best exemplified their wishes. They then printed a prototype, and tested it with the new props.

The new version perfectly accommodated the motors and increased our efficiency by a great deal. Using our troubleshooting technique, we were rapidly able to move forward on our design, feeling completely confident in our solution.

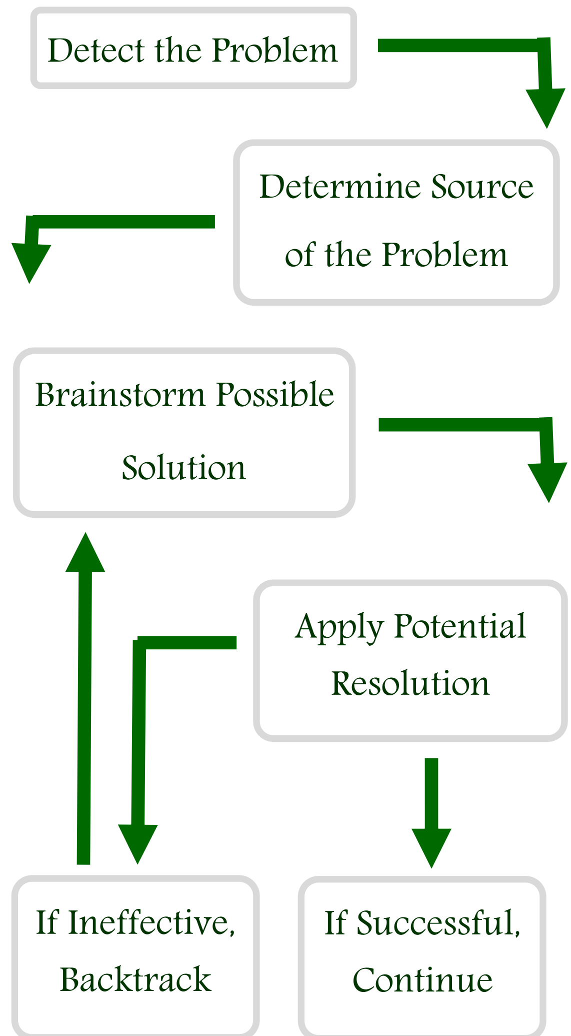


Figure 31: Troubleshooting Process

Challenges Faced

Technical

Wizard Automation experienced a number of failures involving 3D printing this year. A large portion of our tools were designed and printed by the team, and while we eventually mastered the technique, we ran into a number of problems before that.

We use a single extruder 3D printer, which means that we do not have the ability to print dissolvable supports. This makes small complex builds very difficult; we are forced to remove the supports ourselves, which can easily damage the printed parts.

Furthermore, the machine itself is very sensitive. If the build platform is not perfectly level, the part may print incorrectly. The same could happen if the temperature or infill percentage is set incorrectly. We also learned that we needed to print in standard resolution (rather than high resolution) because it uses more plastic to provide a better filament strength. As a whole, the team rapidly learned to triple check the details on any part we were printing before we began or else risk damaging the part we were trying to print.

Interpersonal

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

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

Lessons Learned

Technical

This year Wizard Automation has learned that simplicity is best. The team learned this lesson initially when designing a tool for turning the valve. Originally, the team was going to create an additional tool that used a motor to gear down and rotate the valve. This would have involved complex mechanics within a planetary gear box and would have required a lot of time to build. We ultimately decided to go the opposite route, and instead, build a stationary hook on our frame and have the ROV itself rotate.

Our first plan was to make a PVC handle; this concept was quickly modified as it required the ROV to push down while it was spinning as to not lose traction with the valve. We eventually modified our handle to have hooks at the edges, so it easily grasps the valve. This allows us to put all of our movement towards rotating.

Throughout this process, the team learned that sometimes the best route is the most straightforward. When working with complex machinery, intricate designs just hinder the process in both time and material usage.

Interpersonal

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

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

Future Improvement

In the future, Wizard Automation would like to improve our actuating gripper. There is currently an excess of "play" in the gripper's jaws. The connections between the mechanical pieces of the gripper are worn, which cause the jaws to move freely about 12 mm.

Although the team is aware of this issue, we are not currently able to conceive an efficient solution to this problem. In the future, when Wizard Automation has more time to devote towards this issue, we are positive that we can design a resolution but are currently resigned to continue on as is.

Reflections

“As our time until the ROV competition winds down, I find the entire concept of the MATE ROV competition to be incredible. MATE has truly developed a phenomenal program for high school students, including myself, to dive deeper into the technological, engineering, and fiscal responsibilities involved in a robotics company. As a four year participant, I am in my last year of the competition in the Ranger level and have been able to experience this program to my fullest potential. I am the CEO of our team, Wizard Automation, and have been privileged to witness not only personal growth, but also the growth of our team as individuals and as a whole. I have gained new leadership skills from this position, specifically skills in communication, problem-solving, and responsibility. This experience has both reaffirmed my passion for engineering as well as my interest in the realm of entrepreneurship. I owe thanks to the MATE ROV competition for the opportunity to participate in this program; however, I also owe many thanks to our mentors who guided us, and lastly, I owe thanks to my teammates who have allowed me to learn from them.”

—Evan Lallensack, CEO (Figure 32)

“My involvement with the ROV team has truly been an eye-opening and extremely beneficial experience. Throughout the two years that I have been involved with this team I have learned a lot about myself and my capability to work as a team. Being a technical writer has taught me a lot about science and sparked my interest in physics, a subject that I could not stand to sit through prior to joining the team. Furthermore, my involvement in the Business department has given me experience that I can apply to my career in the future.”

—Jacqueline Janik, Technical Writer (Figure 33)

“As a senior in high school, this is my first year on the Wizard Automation team and I am happy to have joined. I have an interest in chemistry and physics, but was never interested in engineering. Joining the ROV team has initiated an interest in engineering as I am able to see what goes into making a robot and how accessible it can be. Being a member of the team has also taught me the importance of teamwork; a lot of the work done on Ozcar, the Technical Document, and the Marketing Display was accomplished through teamwork and could not have been completed without collaboration of multiple members on the team. Additionally, being a member of Wizard Automation has affirmed my choice of physics as a major in college.”

—Chris Peterson, Accountant (Figure 34)

Figure 32: Evan Lallensack

Figure 33: Jacqueline Janik

Figure 34: Chris Peterson

Budget/Expense Report

Available Funds

Starting Balance	
2014	2,025.14
Monetary Donations	
Watry's Maintenance	100.00
Kohl's Cares Grant	500.00
Fundraisers	
STEM Camp	1,020.00
T-Shirts	248.00
Brat Fry	1,494.00
Bake Sale	121.00
Total Available Funds	5,508.14

Expenditures

Item Description	Cost
Dielectric Spark Plug Boot Protector	1.49
1.5v Watch Battery	4.19
Tsunami Motor	571.48
Octura 1255 Plastic and Grauper K Series 51 mm Propellor	15.11
Grauper Carbon Filled Nylon Propeller 57 and 54 mm Propellor	89.57
Miscellaneous Home Depot Supplies	75.29
1/2" Cross Slip T PVC Connector	27.00
Octura 1255 Plastic Propellor	23.61
Prop Adapters for 3.17mm Shaft	32.00
Plastic Propellers 55mm	21.34
1-1/2" to 2-1/2" Clamps, Nuts/Bolts/ Miscellaneous Hardware	9.39
3D Printer Filament	75.00
Miscellaneous Menards Supplies	69.18
Total Expenditures	1,014.65

Total Final Vehicle Value

Material Donations	244.00
Expenditures	1,014.65
Reused Items	1,779.39
Total	3,038.04

Services Donated

Item Description	Estimated Cost
Ozaukee High School's Woodshop	900.00
Wiedmeyer's Pool	125.00
Vogt's Tools and Workspace	250.00
Total Estimated Value	1,275.00

Material Donations

Donating Company	Donated Material	Estimated Cost
Englewood Electric	3M Adhesive Heat Shrink	200.00
Integra	Dry Housing Enclosure	44.00
Total Estimated Value		244.00

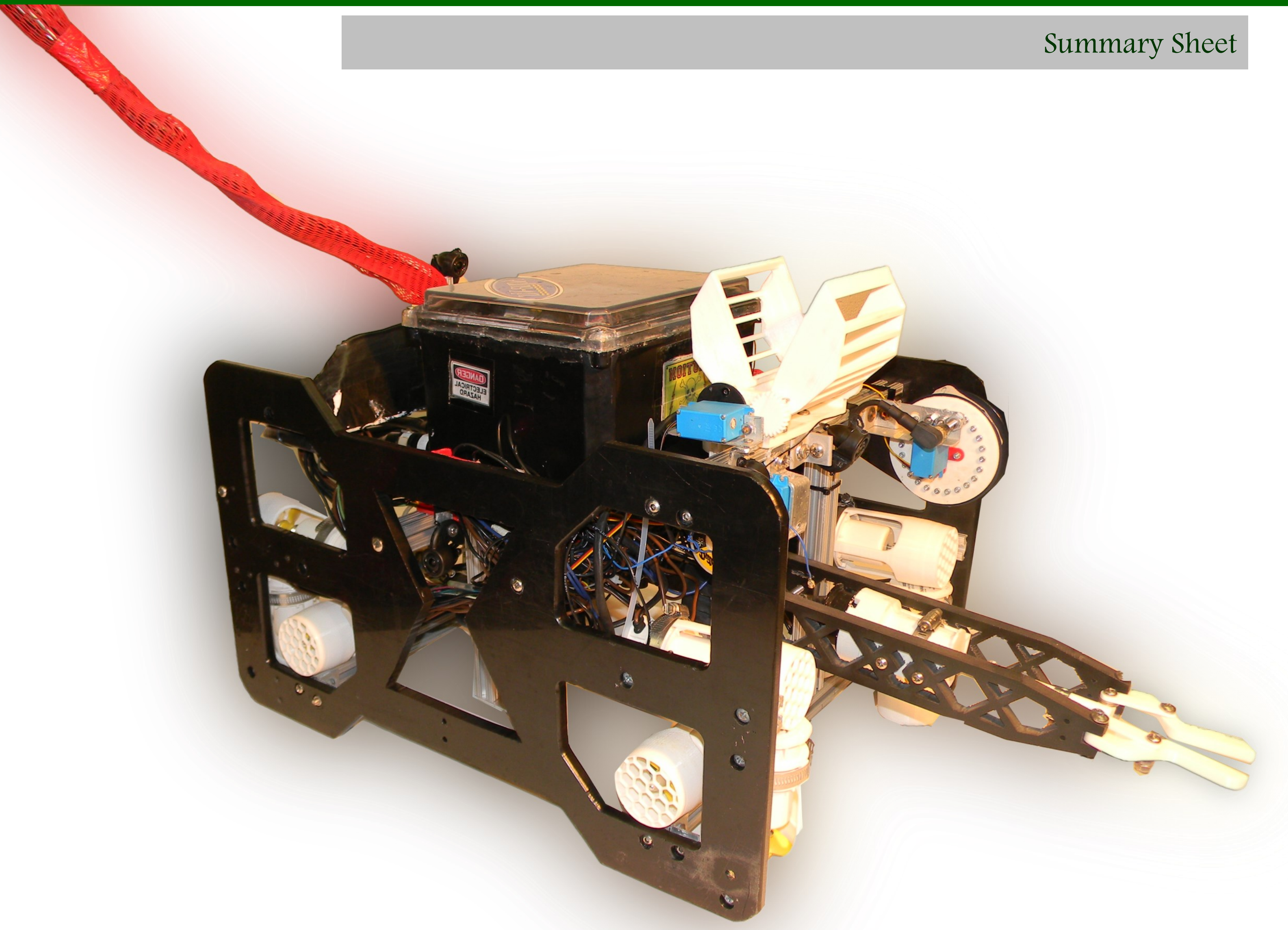
Value of Reused Items

Original Year	Item Description	Current Cost
2009	Arduino MEGA	37.90
2010	USB Hub	5.00
2010	USB 2.0 Extender	152.72
2010	Linear Actuators	78.00
2011	Multiplexor	26.00
2011	Depth Sensor	131.50
2011	Motor Drivers	85.00
2011	Bulkheads	255.00
2012	Dry Housing	22.00
2013	Cameras	500.00
2013	TV Monitors	300.00
2013	Bilge Pumps	41.57
2013	HDPE Sheet	89.70
2014	80/20 Aluminum	55.00
Total		1,779.39

Travel Costs

Item Description	Estimated Cost
Team Lodgings	6,149.14
Team Travel	10,500.00
Shipping	1,200.00
Total Estimated Value	17,849.14

Summary Sheet



Dimensions: 99 cm x 46 cm x 42.5 cm

Dry Weight: 20.9 kg

Approximate Total Cost: $3,050

Acknowledgements

Wizard Automation would like to extend thanks to:

- MATE: for hosting this amazing competition
- UW-M: for hosting our regional competition
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- Integra: for their material donation
- Ancor: for their material donation
- Englewood Electric: for their material donation
- Ozaukee High School: for their facilities
- Peter Wiedmeyer: for his facilities
- Chris Hartzell: for his technical expertise
- Randy Vogt: for his technical expertise
- Leah VanMinsel: for her technical expertise

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Figure 19: Jacqueline Janik
Figure 20: Leah VanMinsel
Figure 21: Jacqueline Janik
Figure 22: Leah VanMinsel
Figure 23: Jacqueline Janik
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Figure 29: Zenyse Miller
Figure 30: Jacqueline Janik
Figure 31: Jacqueline Janik
Figure 32: Zenyse Miller
Figure 33: Jacqueline Janik
Figure 34: Jacqueline Janik
Summary Sheet: Jacqueline Janik

References

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Rovs In Extreme Environments: Science And Industry In The Arctic. *RANGER CLASS2015 MATE ROV COMPETITION: (n.d.): n. pag. MarineTech. Marine Advanced Technology Education. Web.*