INNOVOCEANX

Innovation in Marine Technology

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Vehicle: SAM-V

Carrollton High School

Carrollton, Georgia

2012 - 2013

Abstract

In response to the University of Washington's recent release of Requests for Proposals, InnovOceanX has created an innovative vehicle to extend the network of cables, nodes, and instruments on the Axial Seamount. InnovOceanX is an oceaneering company created in 2007 that designs, constructs and operates Remotely Operated Vehicles (ROVs) to service Ocean Observing systems. Our newest vessel, the Servicing and Monitoring Vehicle, more commonly referred to as SAM-V, is equipped with the necessary elements to complete a full servicing of the Regional Scale Nodes (RSN) cabled observatory off the coast of Seattle, Washington. SAM-V's services include completing a primary node and installing a scientific instrument on the seafloor, taking a temperature measurement of a hydrothermal vent over a time interval, removing and replacing the ADCP on the Mooring Platform, and the safe removal of any biofouling on the ocean floor. To perform these services, SAM-V features an advanced digital control system, powerful thrusters, panning cameras, and a partially passive, partially active ballast system. Our company has also developed four tools specifically for the servicing of Ocean Observatories. These include a rotating manipulator, a temperature probe, a hook, and a gate latch. InnovOceanX guarantees professional and safe servicing of the RSN Cabled Observatory.

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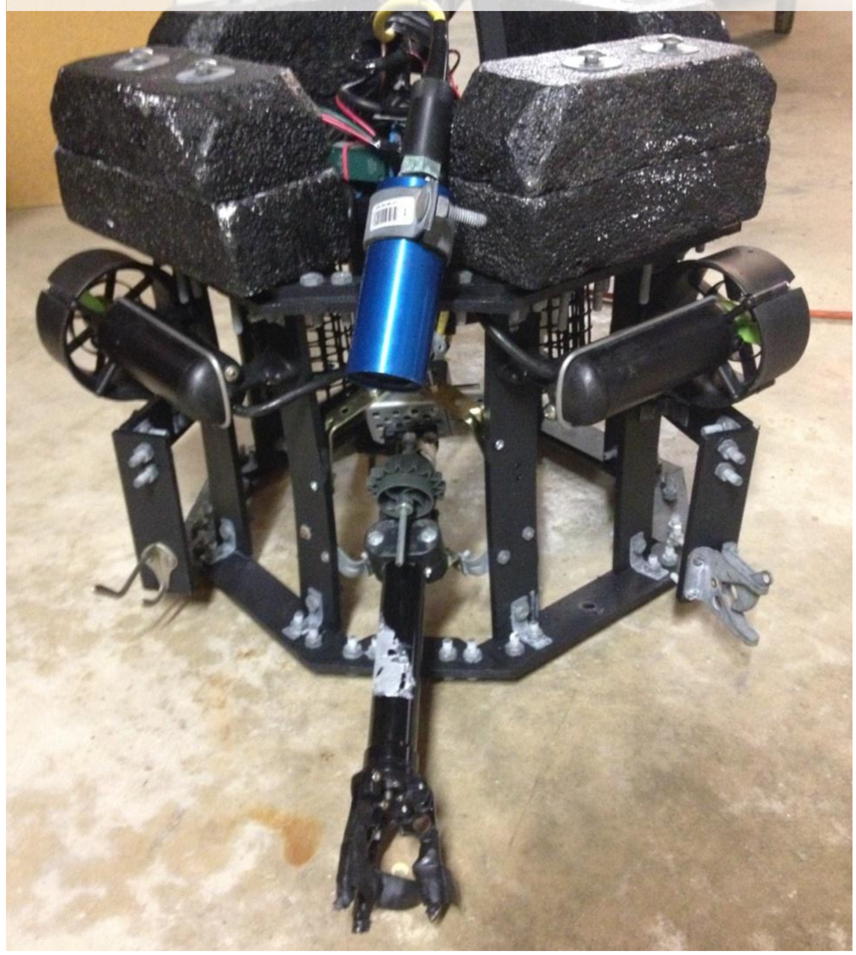
Company Profile

At InnovOceanX, we are dedicated to creating not only efficient vehicles, but also to building strong customer relations. We ensure that each member of our company is qualified to provide the services required by our customers. At the onset of this year, each staffer was required to submit a detailed application summarizing his/her strengths, weaknesses, interests, and availability. These applications allowed our CEO, Kelcy Newton, and COO, Abbey Greene, to create the most dedicated and skilled company possible and to eliminate candidates whom they did not think would be wholly dedicated to the company. In previous years, InnovOceanX has created a company board to better manage communications between groups. This year, however, our company is much smaller and we soon realized there was no need for such a grouping. There are four to five weekly meetings of the full company, as well as several smaller specialty group meetings. A smaller company allowed for much more communication and cooperation among the employees. In the past, one team of employees worked solely on the manufacturing of the vehicle and its subsystems, and another team focused on research, development and marketing. With a twelve person company, employees are able to do both, creating a much more diverse and interconnected group who are extremely knowledgeable about all aspects of the company.

Figure 1: SAM-V



When InnovOceanX employees began brainstorming the line of vehicles to service Ocean Observatories, we created a set list of focal points that would allow the vehicles to operate at optimal efficiency. These focal points included:

- Decreasing mass while increasing speed and maneuverability
- Using simple, yet effective payloads to complete all services
- Employing recycled materials and resources whenever possible

Safety

InnovOceanX's top priority is safety. While constructing SAM-V, all employees practiced safe habits such as wearing eye protection and closed toed shoes and tying back long hair. Additionally, InnovOceanX operates in a safe environment. We clean our workshop after every construction meeting in order to ensure a consistently orderly workspace. By keeping our workshop organized, we decrease the number of potential safety hazards. Our workshop includes a tool wall for keeping equipment neat and contained, as well as various stations for different tasks. Our build station is set-up with power tools, safety gear, clamps, vices, etc., while the electrical station houses all wiring tools and provides an out-of-the-way area for soldering. InnovOceanX's dedication to safety is also evident in the numerous safety features on SAM-V. SAM-V incorporates an array of safety precautions, including a 25 amp fuse to protect the onboard electronic components. Additionally, all thruster and camera cords are pulled taut around the frame to minimize slack and prevent entanglement with any external or internal moving parts. All thrusters are equipped with safety partitions, and the tether is covered in an abrasion resistant wrap. SAM-V's frame design also allows for all moving parts to be confined within the frame. Our control box also features safety stickers labeling all hazards, warning employees to proceed with caution. The company follows a strict checklist before and during mission runs. The protocols we take are enforced in order to protect all members from moving parts and "hot" wires (See Appendix A).

Apparatus Protection

- Are you experienced with the machine operations?
- Has it been previously inspected for damage?

Personal Protection

- Gloves (If Necessary)
- Ear Plugs (If Necessary)
- Safety Glasses
- Closed Toed Shoes
- Long Hair Tied Back
- No Baggy Clothes!
- No jewelry (watches, rings, bracelets, etc.)

Figure 2: The InnovOceanX workshop—all work stations

Design Rationale

InnovOceanX's top vehicle, SAM-V, performs its most basic functions using six main systems: Frame, Thrusters, Manipulator, Ballasts, Cameras, and Software.

Frame

In brainstorming the fundamentals of SAM-V, we divided frame construction into two phases: Materials Analysis and Shape Design. Concentrating on these two aspects individually ensured that the frame was sturdy enough to hold all components of the vehicle and nimble enough to work efficiently.

Materials Analysis

Our first step was identifying a lightweight yet sturdy material, to use for the frame. Before researching any new materials, we first evaluated the effectiveness of previous frame designs.

Figure 3: Finished Frame Design

Previous InnovOceanX vehicles utilized a wide range of building materials including PVC, Aluminum, and Polycarbonate. However, we have found structural issues with each of these materials. PVC, although lightweight, cost efficient, and easy to manipulate lacks the sturdiness of harder plastics. Aluminum, though structurally sound, is heavy, dense, and not exactly versatile when it comes to attaching payloads and other components. Polycarbonate, accompanied by foam, was sturdier than PVC, but we had to incorporate several sheets in order to make the frame structurally sound, which increased the frame's overall weight. After considering all of our previous frame materials, we decided to look into harder plastics. After much research, we chose High Density Polyethylene (HDPE). This plastic is made specifically for underwater environments, so, unlike aluminum, there is no risk of corrosion. The plastic itself is also thicker than the polycarbonate we previously used. Thus, we eliminated the need for multiple layers or excess materials, decreasing overall weight. The frame was custom cut by our employees on a router at Carrollton High School.

Shape Design

A major modification that makes SAM-V unique from most other ROVs is the shape of its frame. The past three InnovOceanX vehicles have been based on a rectangular prism. Though this shape has worked well, we experienced some technical issues with it during a shipwreck survey last year. During a mission run, our pilot, Brendan Whitaker, noticed that the ROV was tilting significantly to one side. Because the ROV was unstable, we were unable to complete some aspects of the mission. We also had difficulty strafing side to side, which made minute adjustment extremely difficult, if not impossible. When discussing ideas for SAM-V's structure,

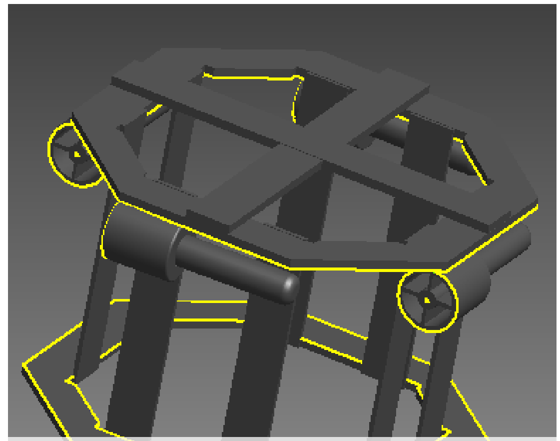


Figure 4: Frame Design and Thruster Orientation Model

we narrowed our ideas down to either the fairly common rectangular prism or a more innovative solution: an octagonal prism. After further discussion and planning, we recognized the benefits of an octagonal frame over that of a rectangular prism. An octagon would provide radial symmetry for four lateral thrusters, which would it make the vehicle much easier to rotate during mission runs. With our thruster orientation, the vehicle would be able to spin 360 degrees. There would also be no need for a specific front and back of the vehicle which would allow it to be more versatile in terms of mounting payload tools. In addition to thrust, our past frame shapes were cramped and had limited space for all ROV systems. With eight sides, we could ideally mount each payload on a different side. An octagonal frame is also much more open than a rectangular frame which would provide easy access to all components in case of troubleshooting.

Propulsion

A major focus in this year's vehicle design was maneuverability. This was given consideration when deciding thruster orientation. SAM-V features a total of seven thrusters, four for lateral motion and three for vertical motion. The radial symmetry of the frame lends to a superior turning radius. The four lateral thrusters are Seabotix thrusters which provide much more power than our previous modified bilge pumps. They are mounted on four opposite sides of the frame. Each thruster draws 4 amps of power and provides approximately 28.4 N of thrust. To make sure we weren't compromising speed or power in the diagonal force of our thrusters, we created a vector diagram to calculate how much forward thrust we would have.

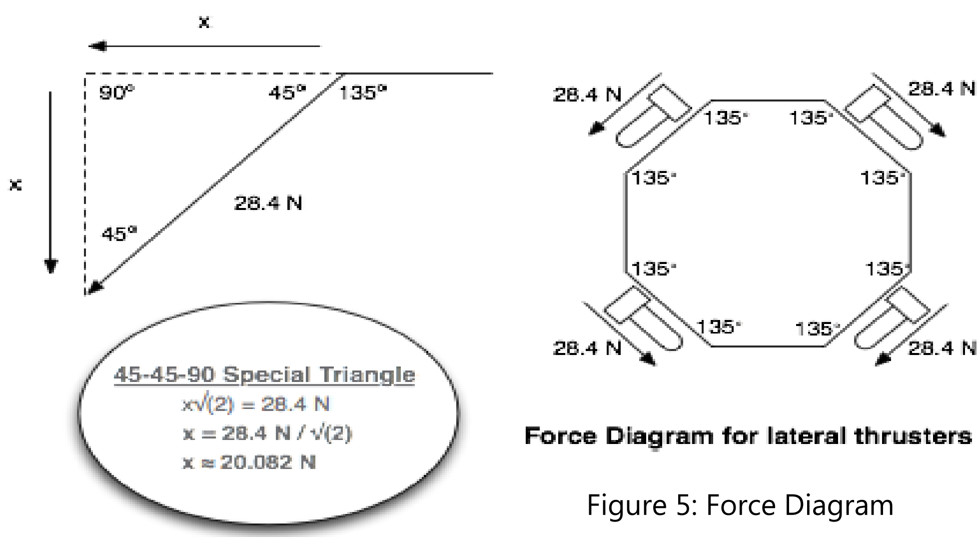
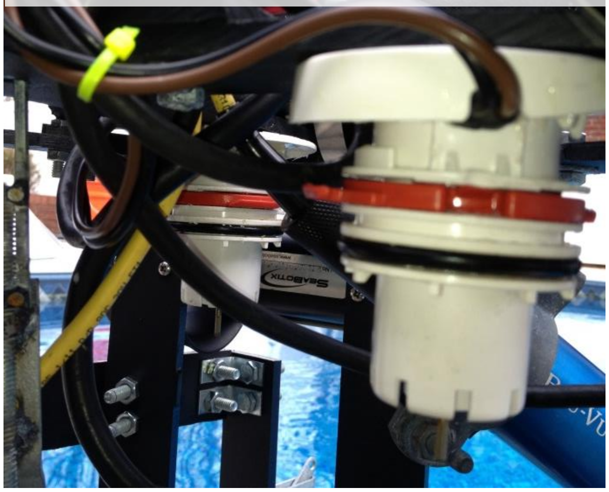


Figure 5: Force Diagram

Figure 6: Vertical Bilge Pumps (Pre-safety partitions)



Through the calculations, we found that the combined force of all four diagonal thrusters was greater than that of our two straight thrusters from last year. All Seabotix thrusters are positively buoyant and feature safety partitions around the propellers to protect both InnovOceanX employees and marine life. Our fifth Seabotix thruster is mounted for vertical motion along with two modified bilge pumps to provide additional power. All thrusters are paired to motor controllers which allow them to have variable speed. Each lateral thruster is paired to an individual motor controller and the three vertical thrusters are paired to the last motor controller

Manipulator

Figure 7: Manipulator and Gearbox

Arguably the most important aspect of any ROV used in marine exploration is its ability to manipulate its environment--remove damaged materials from the workspace, make system repairs, and make additional installations. At InnovOceanX, we realize the importance of this tool and have invested in a powerful manipulator capable of performing a wide variety of jobs and ensuring maximum quality performance. The device has 200 kg of gripping force, a lifting capacity of 100 kg, and weighs 235 g in water. The manipulator draws a maximum current of four amps and runs off twelve volts of power. It is extremely durable and has been used on previous InnovOceanX vehicles. It is mounted on a side of the frame at an angle which allows maximum extension while not protruding from the base of frame. A large portion of ocean observation requires disconnecting and reconnecting power to several scientific nodes and instruments. Because many of the connectors must be installed in a specific orientation, the ability to rotate the connector easily is vitally important. Consequently, we began to design a system to rotate our manipulator. We chose to use a gearbox, high strength gear, and servo motor, similar to our rotating camera. We found it necessary to use a custom gearbox with a worm gear in order to have an adequate amount of power to rotate the high strength gear mounted to the rod of the gearbox. The high strength gear meshes with tank treads wrapped tightly around the manipulator.

Ballast

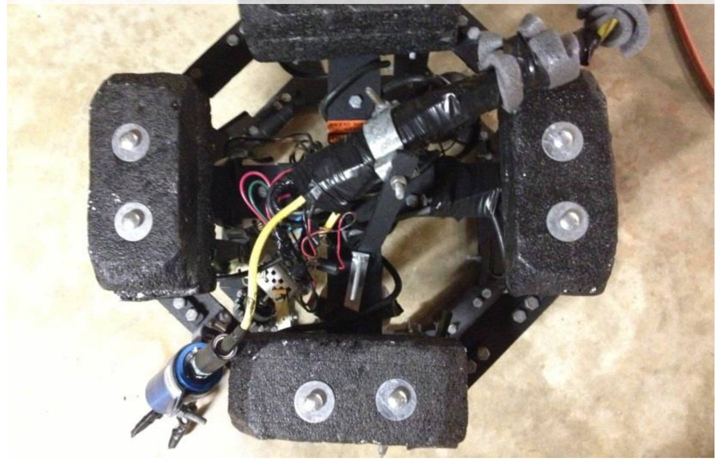


Figure 8: Completed Ballast Tanks

SAM-V features a partially active and partially passive ballast system. During our design process, we realized that by manufacturing the passive ballast system in four separate parts we would be able to make size adjustments more easily. To form each tank, we cut a large Styrofoam block into smaller squares and rounded off the edges. The expanded polystyrene foam is closed cell, meaning that all air pockets inside the foam are separate. Should water fill one air pocket, it will not spread to any others, allowing the ROV to remain neutrally buoyant. Each tank was then fully coated in latex paint to prevent any parts of the foam from breaking off and polluting the marine environment. The tanks were placed on the top of SAM-V to ensure stability and minimal drag. Although our thruster orientation allowed for maximum lateral rotation, we needed a successful way of moving vertically in the water column. To maximize vertical speed, SAM-V features an active system as well, which is placed in the middle of the vehicle. It consists of two PVC end caps glued together with an opening on one cap for an air tube. The air tube runs through the tether and attaches to a bike pump on the surface where an employee will fill the tank with air in order to rise more quickly. The active tank also features several smaller holes on the caps for water to flow through to regain neutral buoyancy.

Camera

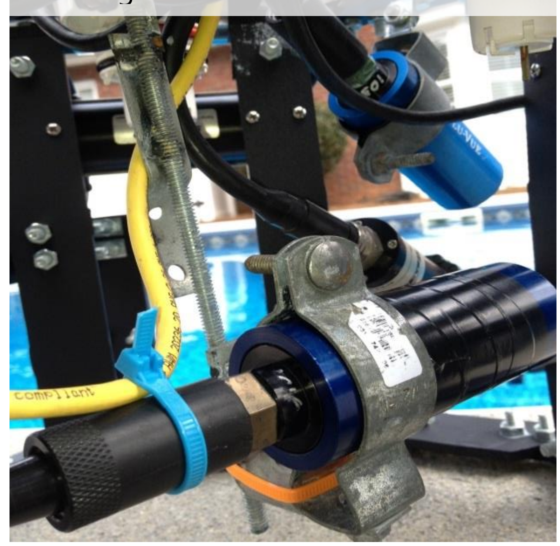


Figure 9: Double Camera System: Panning Camera and Mounted Camera

Our design team realized that in order to take advantage of SAM-V's radial symmetry, we were going to need to implement a more versatile camera system. The ability to mount components on all sides of the vehicle would be rendered useless without the ability to view them. However, having a separate camera for each viewing space would be highly impractical in terms of both space and money. We approached the idea of a rotating camera warily because of failed development in the past, but we decided that it would be imperative for the success of our vehicle and therefore put priority on its development. We began brainstorming and drew detailed sketches of each idea. We designed several unique systems--one consisting of a camera on a track around the circumference of the frame, another with multiple cameras each with their own individual movement. After considering these designs, we chose to pursue prototyping a system consisting of a single axle mounted in the center of the frame. The single rotating camera provides the viewpoints of multiple stationary cameras and requires less mounting space than would several cameras. The entire system is comprised of a camera, axle, gearbox, and servo. Several team members created a set of gearboxes from spare Vex Parts that would allow the servo to turn the camera more slowly. It also offsets the weight of the camera because the servo doesn't have to provide as much torque. With the prototype we created, we discovered that if we did not limit the rotation of the camera to just 360°, the camera's power cords would twist possibly compromising power to the camera.

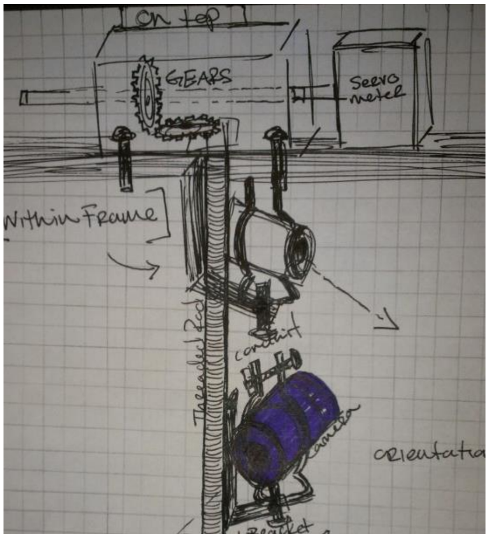


Figure 10: Mechanical Sketch of Panning Camera System

We placed pieces of tape on two of the frame's support bars that indicate to the pilot not to rotate the cameras any farther. The panning Blu-Vue camera is held by a conduit and welded to an axle mounted in the center of SAM-V for a 360 degree view. The gearbox is mounted to the top of the frame and connects to the axle via locking collar. Additionally, there is a second Blu-Vue camera mounted for viewing the manipulator as it is our most useful payload tool. Both cameras feature 6 white Light Emitting Diode (LED) lights for vision on the ocean floor.

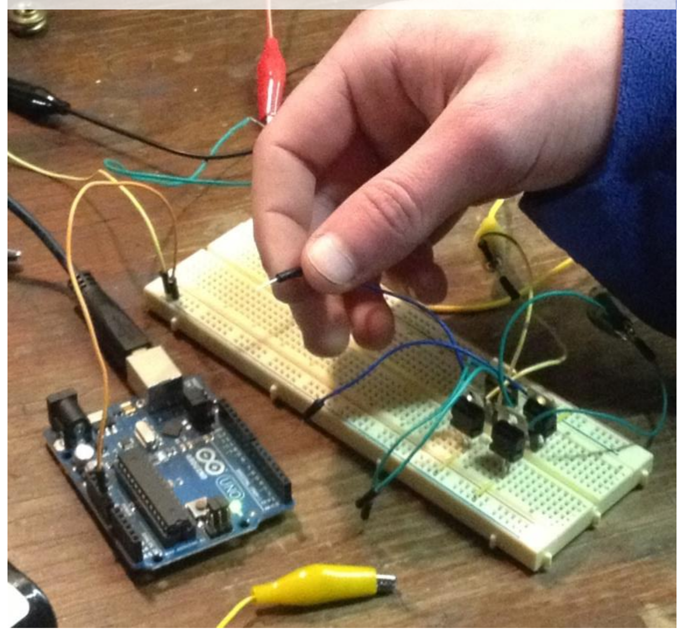
Control System

Our current model of SAM-V houses InnovOceanX's most advanced control system to date. In the past, we have employed various hardware-based systems that involved no software in their design. Such systems were comprised primarily of toggle switches that only allowed for on/off control of our thrusters. As our ROV technology developed, we recognized the need to develop our controls as well. This year, we have once again used an Arduino microcontroller as the "brain" of our system. Like last year, each thruster has been paired with its own VEX Victor Speed Controller, and each of these motor controllers receives power from our 12 volt battery and redistributes it to the thrusters based on pulse width modulation (PWM) signals from the analog pins on the Arduino. The fluctuating PWM values allow for our thrusters to run with variable speed. This is an essential ability for the ROV to have because it provides more intuitive control over the vehicle and allows for fine adjustments in the water. With our new frame, we decided to use four of our

Figure 11: Completed Control System: Arduino, Motor Controllers, Camera feed, Switches

Seabotix thrusters for lateral propulsion and one for vertical, as opposed to last year when we used three for lateral and two for vertical. Traditionally, we have wired our vertical thrusters to the same motor controller; therefore, only four of them were needed for the thrusters on the vehicle and the last could be used to control our claw. However, this year, with four lateral thrusters all requiring their own motor controllers and our remaining vertical thruster and modified bilge pumps on the fifth, we would not be able to interface our claw with the Arduino, at least not like we did last year. In addition, we wanted to add a panning camera system, as well as the rotating manipulator which would require controlling two more motors. Instead of making two very large investments into more Victor speed controllers, we sought out our own solution to interfacing our extra components with the Arduino. We wanted to use transistors to create H-bridges which essentially act as mechanical switches with digital input. On their own separate circuit board, these components “bridged” the mechanical motors to the digital control of the Arduino, allowing us to avoid using switches or investing in expensive motor controllers. Two of our company members built 4 H-bridges to control the extra components, but due to technical problems discussed later (page 14: challenges) the H-bridges did not work. We knew we only needed to control two extra components: the panning camera and the opening and closing of the manipulator. It was decided that these devices could be efficiently controlled using dipolar momentary switches with a basic on/off system because the manipulator only has an open and closed position and the rotation of the camera and manipulator at full speed is just slow enough that the pilot is able to stop the camera at any position.

Figure 12: Experimenting with H-bridges



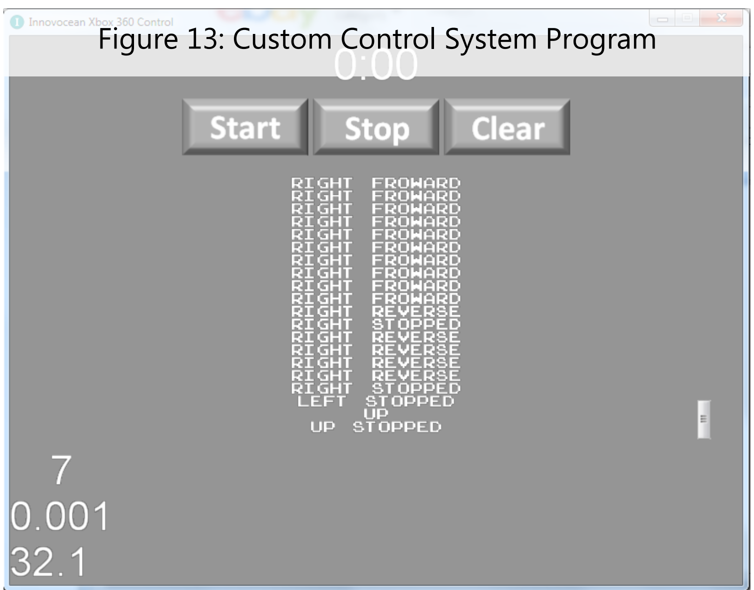
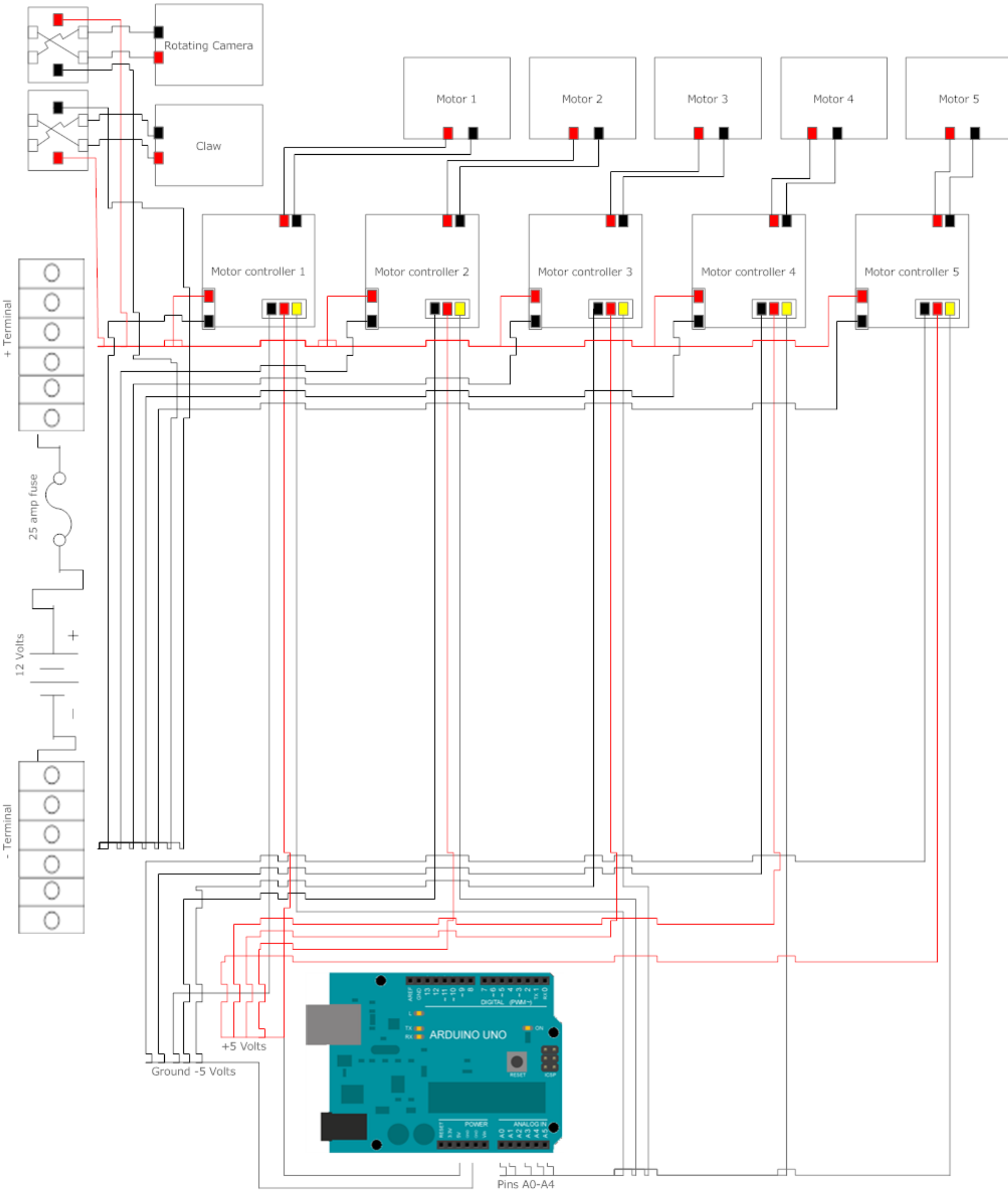


Figure 13: Custom Control System Program

Electrical Schematic



Mission Overview

The majority of the services InnovOceanX offers for ocean observatories involves moving machinery or transplanting old components with new ones. To accomplish these tasks, SAM-V features four main payloads, all designed with simplicity and efficiency.

TASK 1 OVERVIEW

The first service SAM-V provides is the completion of a primary node and the installation of a scientific instrument on the seafloor. The primary node is completed by installing the Science Interface Assembly (SIA) into the Backbone Interface Assembly (BIA) and inserting the Cable Termination Assembly (CIA) into the BIA. Installing the scientific instrument includes deploying the Ocean Bottom Seismometer (OBA) into the ASHES study site (or other designated location) and connecting it to power and communications via the BIA.

Figure 14: SIA Hook

Hook

To transport the Science Interface Assembly to the ocean floor and then to the Backbone Interface Assembly, SAM-V features a hook mounted to one side of the frame. At the onset of the mission, an employee will attach the U-Bolt on top of the SIA to the hook, and SAM-V will take the SIA down on its initial descent. SAM-V will utilize the manipulator to disconnect and reconnect the system to power.

TASK 2 OVERVIEW

In addition to machine servicing, SAM-V is also capable of gathering real time data about its underwater surroundings. SAM-V will install a temperature probe over a hydrothermal vent at the ASHES site and collect measurements over a designated time period.

Figure 15: Temperature Probe

Temperature Probe

In order to measure the water current's temperature that flows from the hydrothermal vent, we have engineered a sensor that can interpret the temperature at the vent and send a digital reading to TI-Nspire CX CAS calculator on the surface. We obtained a Vernier Temperature Probe from our school's chemistry department and modified it to fit our needs. The wire was spliced and lengthened so that it may act as an individually tethered component of the ROV. The temperature probe plugs into a port on the calculator and

Figure 16: Vernier Data Quest Program

launches the Vernier DataQuest program. In this program we can easily view the temperature reading as well as create graphs comparing the temperature and time. We constructed a carrier that allows the probe to be inserted into the vent opening and gather the data while we proceed to other tasks. This carrier was made by attaching a 2 inch PVC end cap and a ½ inch PVC "T"'. The end cap fits securely over the lip on the hydrothermal vent. On its initial descent, SAM-V carries the probe, which secures to a split U-bolt on the side of the vehicle, to the ocean floor.

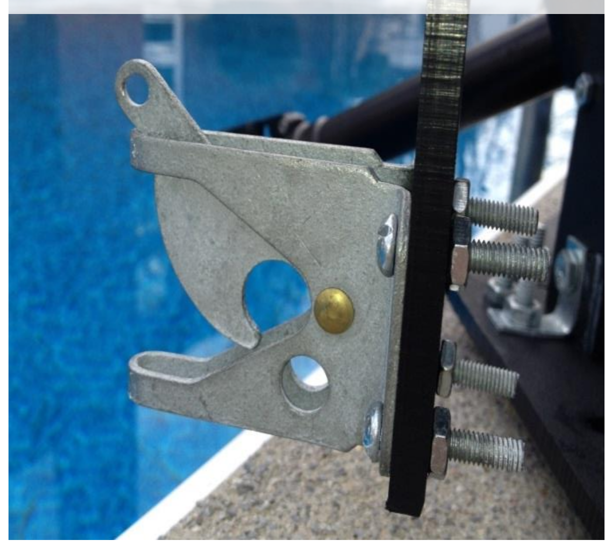
TASK 3 OVERVIEW

SAM-V's capabilities also include repairing an Acoustic Doppler Current Profiler (ADCP) on a mooring platform suspended in the water column at the Axial Seamount site. This process includes disconnecting power from the platform, unlocking and opening a hatch to expose the ADCP, removing the old ADCP and installing the new ADCP in its place, then locking the hatch and reconnecting power to the mooring platform.

Gate Latch

To transplant the ADCP, SAM-V uses a gate latch. Early on in the design process, we contemplated using the normal hook for both the transportation of the SIA and the replacement of the ADCP. But repairing the ADCP requires traveling from the Axial Seamount, up to the surface and back down again. This amount of movement in the water column necessitated a more secure way of transporting the ADCP. The gate latch contains a locking mechanism which securely grips the handle of the ADCP during vehicular movement. To unlock and lock the hatch, SAM-V will employ its manipulator which can efficiently grip the hatch handle

Figure 17: Gate Latch



TASK 4 OVERVIEW

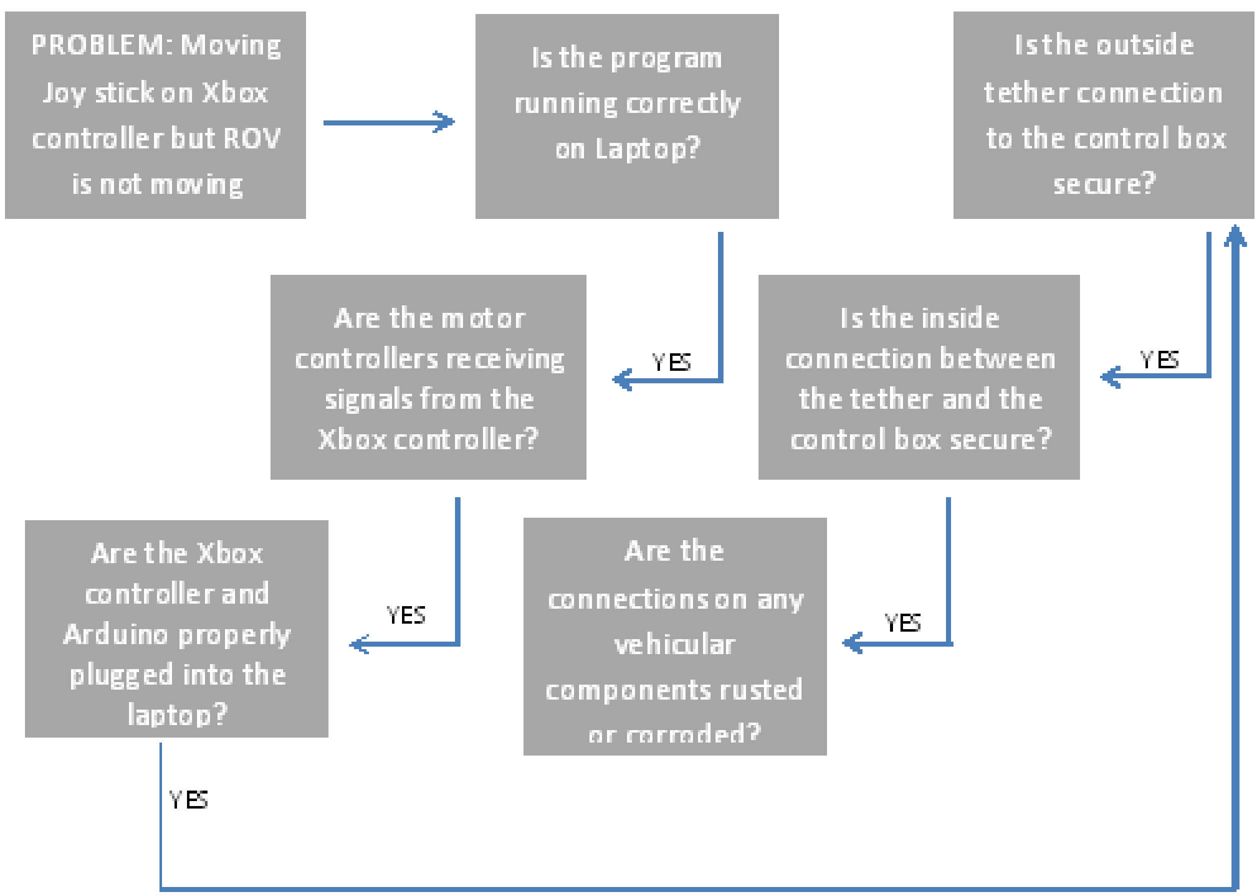
In addition to repairing all components of the Ocean Observatory, InnovOceanX is fully prepared to safely remove any biofouling covering the various structures and instruments of the regional cabled observatory.

Manipulator

To pick up the biofouling, the pilot uses the manipulator. Rather than removing all five samples of biofouling at once, we remove the samples from the various instruments and nodes throughout the mission.

Troubleshooting

InnovOceanX's success as a business is dependent on our ability as a company to solve the problems we encounter. This is accomplished through a versatile troubleshooting process. This process was used in almost all designs of SAM-V and streamlines the process of developing new technologies and solving system malfunctions, as opposed to the infamous "guess and check" method which is far from expedient. InnovOceanX has created various troubleshooting diagrams for specific system issues, but our general process is outlined by the following steps: **Identify the problem, brainstorm solutions, implement the best solution, test its effectiveness, and repeat**. Each diagram explains the steps necessary to solving complex problems. Essentially, the process begins with identifying whether the problem is electrical or mechanical. This allows us to decide whether we should check the control system or one of the mechanical systems. From there the charts diverge and outline the parts of the system that should be checked for any sort of damage. The following diagram is a flow chart the company



created which shows the steps we took when we discovered that the ROV was not communicating with the control system. If the answer to any of the questions in the process is no, then that is the likely problem and appropriate steps should be taken to resolve it.

Our 4 step process was used once we realized we needed a way to control both the panning camera and the manipulator (**PROBLEM)**. We could either order two more motor controllers or create our own using circuit boards. We opted for the latter because we wanted to challenge ourselves (**BRAINSTORM SOLUTIONS).** After creating the H-bridges, we tested the vehicle and the rotating components in the water and found that the H-bridges were only transmitting 5 volts of power to the components when 12 volts were needed. This was clearly an ineffective solution (**TEST ITS EFFECTIVENESS).** Once again, we faced the same problem. We chose to go for a more simplistic solution: dipolar momentary switches (**BRAINSTORM SOLUTIONS)**. Once we soldered two switches to the camera and manipulator, they worked perfectly (**CELEBRATE).**

Challenges

Throughout the duration of this project, InnovOceanX experienced various challenges that we had to overcome. We encountered both technical and company based obstacles, and sometimes these tasks became overwhelming. However, company members worked together to transcend these challenges and find innovative solutions to solve all technical and company based problems.

Interpersonal Challenges

For the past two years, all vehicle construction has taken place at the workshop of one of our company employees. However, when construction began for this year, we learned that we would no longer have access to this space. This caused several complications. The majority of our tools were at the shop, along with most of the parts from previous vehicles. This required us to be more conservative with the materials we purchased because we did not have as many materials at our disposal. Additionally, company members had to collaborate to find a new workshop that was easily accessible and centrally located. With the generosity of one of our company members, a new workspace was located.

Technical Challenges

Furthermore, we faced two major technical obstacles: rotating one of our cameras, and creating variable speed controllers for additional mechanical components. Company members brainstormed several ideas for creating a panning camera system. After considering many ideas, the company decided to use VEX parts, as we had used in previous projects. VEX parts were used to create a gearbox that would attach to a bilge pump. Bilge pumps were optimal because they are made to run in water. However, once the gear system was tested, we found the bilge pump was not strong enough to rotate the camera. We decided to use a servo instead. The servo presented several advantages. Not only was it strong enough to rotate the camera, but it was already waterproofed, eliminating the possibility of the motor shorting out due to electrical failure. A similar gearbox and motor system was implemented to rotate the manipulator as well.

In the past we have only needed five motor controllers, one for each of our four lateral and vertical thrusters and for our manipulator. However, due to our new thruster orientation and the addition of a rotating camera and manipulator, we discovered we would need to control three extra components with variable speed. Software Engineer Wesley Ivester did some research and found a method which uses transistors to create H-bridges that would allow us to interface the extra components with the Arduino. After building the H-Bridges, we observed that they were not functioning correctly and, when plugged in, were heating up to extremely high temperatures. With competition so close, we decided it would be more beneficial to use simple dipolar momentary switches, a system with which we were extremely comfortable, to control the rotating camera and manipulator. We debated whether to use motor controllers for the manipulator and rotating camera, but we decided that it would be more important for the four lateral thrusters to have variable speed, as that would allow our pilots to make minute adjustments in the water. The manipulator just opens and closes so variable speed is not necessary, and the speed of the rotation of the camera at full power is slow enough that the pilot can place the camera view wherever desired.

Lessons Learned

As InnovOceanX is a fairly new marine machining company, we recognize that there are many lessons to be learned in terms of being a successful business. Fortunately, we are learning these lessons with each ROV we build. There are, of course, lessons we have learned which are specific to SAM-V and the 2012-2013 staff of InnovOceanX.

Interpersonal Lessons Learned

The past two years have been building years for InnovOceanX. Several top company members graduated in 2011, leaving behind a very skilled group to continue to program. However, this team only consisted of juniors and sophomores, with no newer, freshmen members. Fortunately, this year we recruited several new members, including two freshmen, who have been a definite asset to our team. Each has been extremely eager to build an efficient vehicle for our customers. Eagerness without skill, however, is unproductive and wasteful. Since there will be more seniors graduating in the next two years, we found it imperative to ensure that the younger members of the team are fully prepared to run the team when that time comes. In this preparation, one of our chief pilots decided to step down and let the newer members, Dorothy Szymkiewicz and Connor Dempsey, drive the vehicle. Not only will the team be able to continue for many years, but now each and every member of our team is fully qualified to drive SAM-V and explain our product to potential customers.

Technical Lessons Learned

The most important lesson our team learned this year was the idea that we can build most of our vehicle entirely ourselves and limit the amount of commercialized, "off the shelf" components we purchase. We discovered this through the creation of the gearbox which rotates the camera and the H-bridges. Although one device worked while another failed, we gained significant experience in building our own electronics, specifically circuit boards. Team members who had never soldered before were able to construct functioning circuits within a few weeks. That is what InnovOceanX is about. It's about creating remarkable machinery for our customers and giving our employees the chance to know that they built something amazing.

Future Improvements

InnovOceanX is constantly looking for ways to advance; there is always room for improvement whether it is in the design, function, and controls of the vehicle or even in the structure of the research branch of our company.

Onboard Control System

In past iterations of our vehicle, we focused primarily on having a working control system and sacrificed maneuverability for the sake of simplicity. We have found that while a simple system can get the job done it can also limit maneuverability and other key features. With the development of our knowledge we decided it was best to further develop the electrical aspects of our design. Last year was the first year we were able to upgrade from toggle switches to an Xbox 360 controller by incorporating an Arduino microcontroller as the central component. The next step would be progressing to an onboard control system. In the past, the maneuverability of our vehicle has been compromised due to a thick, cumbersome tether. The benefits of having all our electronics housed within the ROV would be reducing the size of our tether, and the addition of a positively buoyant control box.

Time Management

With several new team members this year, we realized how lazy we had become with communication. We were so used to everyone just “playin’ it by ear” that we didn’t accommodate for our new, younger comrades who depended on a parent to take them to and from meetings. After a few weeks, we began to notice their frustration and tried to be more thoughtful in structuring our schedule. Next year, we will try to be more structured from the very beginning to prevent these inconveniences from happening.

Reflections

This year our team has been challenged in new ways and we have had to explore new ideas in order to overcome many obstacles as they arise. This experience has taught us responsibility, leadership, and diligence. We have all learned how to cooperate together and have grown as a team and as friends.

“Throughout my entire high school career, one thing, in particular, has been a constant beneficial influence: ROV. ROV has taught me core principles that prepare me for a career and a successful life. I have learned not only, how to manage my time with a group but also how to be a productive, innovative, patient, and communicative individual.”

-Brendan Whitaker- Junior, Pilot

“Being a new student is a challenge right away because it is a new environment with new people. ROV has helped open me up to a new group of friends and introduce me to the engineering field. It is a way to apply the knowledge you learn in science and math classes to real-life, hands-on situations. Before I joined the team my insight on marine engineering and concepts was narrow but I now have a better understanding of all the possible branches of work that are available. ROV has been a great experience for me so far, and I plan to continue with it throughout high school."

-Dorothy Szymkiewicz- Freshman, Pilot

With all of these attributes, the team has been able to build an ROV that can fulfill all requirements necessary to succeed and we continue to improve the sophistication of our design and its level of performance.

Acknowledgements

InnovOceanX would like to recognize several sponsors and individuals for their support and assistance throughout this year. The team would like to acknowledge **Carrollton High School** for allowing us to use the STEM equipment to help construct our frame and add special features, like rotation to our cameras. We would like to thank **Mr. Matt Greene**, who willingly devoted some of his time to aid us in making the switch to a printed poster by introducing us to new design software. Additionally, we would like to give a special thanks to our **parents and families** for their advice, inspiration, and encouragement as we take on new challenging endeavors. Two individuals, in particular, have gone out of their way to make this year possible; **Papa Sam and Mrs. Ann** have offered the team a meeting space where we can collaborate and use their workshop for construction. Without the support of **Jeremy Huff and Kristi Bradford-Hunt**, our mentors, none of our accomplishments would have been possible. They have ensured that we stay organized, have guided us along the way, and have never stopped believing in us. We appreciate all that these individuals have done! Finally, InnovOceanX would like to acknowledge **Gray's Reef National Marine Sanctuary** for providing the facilities for the Regional Competition, and **MATE** for giving us the opportunity to participate in this amazing experience.

Servicing Warranty

To ensure customer satisfaction and reflect InnovOceanX's confidence in our product, SAM-V, a one year servicing warranty is included with each vehicle. If at any time a system fails due to a technical malfunction, an InnovOceanX engineer will fix and/or replace that part or system at no expense to the customer.

Budget

Deposit or Expense	Vendor	Description	Balance
$1000.00 (D)	ROV Team Members	Team Dues	$1000.00
$200.00 (D)	Georgia Greenhouses	Poinsettia Fundraiser	$1200.00
$150.00 (E)	ePlastics	Frame Plastic	$1050.00
$22.00 (E)	Hobby Lobby	Ballast	$1028.00
$29.99 (E)	Home Depot	Bolts for Frame	$1020.01
$9.58 (E)	Home Depot	Angle Brackets	$1010.43
$ 5.00 (E)	Home Depot	Conduit Clamps	$1005.43
$14.99 (E)	Home Depot	Wire	$990.44
$24.72 (E)	Home Depot	Zip ties	$965.72
$10.00 (E)	Home Depot	Foam for tether	$955.72
$8.50 (E)	Home Depot	Plywood/Dowels	$947.22
$15.50 (E)	Amazon.com	Bilge Pump Propellers	$931.72
$150.00(E)	Security Solutions	Tether Wire	$781.72
$4.00(E)	Home Depot	Threaded Rod	$777.72
$8.25 (E)	Home Depot	Hooks	$769.47
$10.00(E)	Home Depot	Liquid Tape	$759.47
$11.00(E)	Radio Shack	Solder	$748.47
$10.00(E)	Home Depot	Heat Shrink	$738.47
$9.58 (E)	Home Depot	Angle Brackets	$728.89
$15.96 (E)	Home Depot	PVC end caps	$712.93
		Total Cost to Build SAM-V	**$487.07**
2249.84	Seabotix	Thrusters	Reused
$850.16	Seabotix	Manipulator	Reused
$3750.00	Lights, Camera, Action	Blu-Vue Cameras	Reused
$130.00	Online	Tether Wrap	Reused
$449.95	VEX.com	Motor Controllers	Reused
$100.00	Pelican Company	Pelican Control Box	Reused

Appendix A

PRE-MISSION LIST

Physical

- All items attached to ROV are secure and will not fall off (Check connections)
- Hazardous items are identified and protection provided.
- Propellers are enclosed inside the frame of the ROV or shrouded such that they will not make contact with items outside of the ROV (Check Safety Partitions)
- No sharp edges or elements of ROV design that could cause injury to personnel or damage to pool surface

Electrical

- Standard male Banana plugs to connect to MATE power source.
- 25 amp Single Inline fuse or circuit breaker within 30cm of attachment point (Check Fuse)
- No exposed copper or bare wire (Check connections, use electrical tape or liquid tape if required)
- No exposed motors
- All wiring securely fastened and properly sealed (check connections, especially at control box and at conduit)
- Tether is properly secured at surface control point and at ROV
- Any splices in tether are properly sealed
- Surface controls: All wiring and devices properly secured
- Surface controls: All control elements are mounted with wiring inside an enclosure.

DECK COMMAND LIST

"Going Hot"- This is the pilot's signal to all deck members that the ROV is about to be powered on.

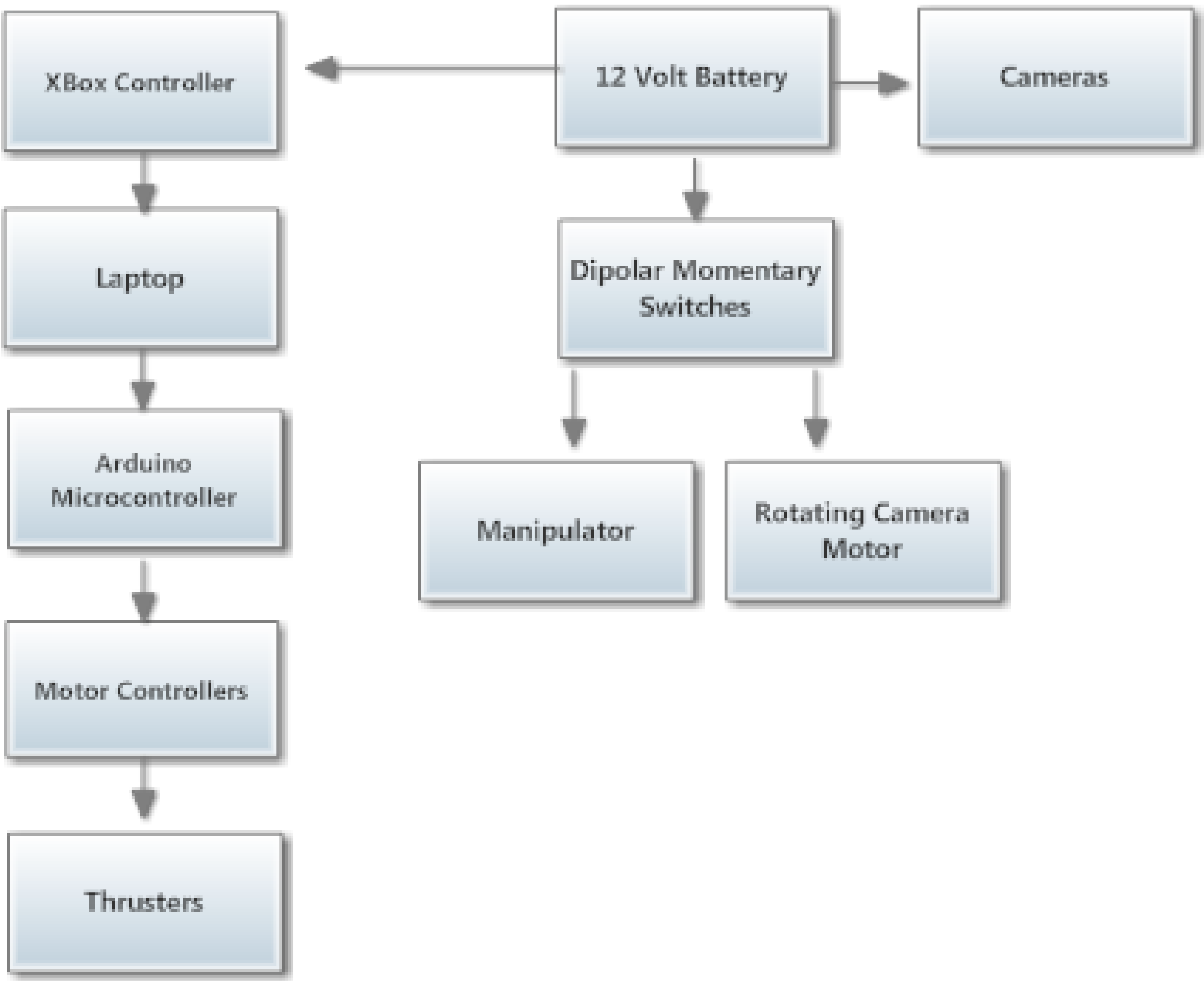
"All Hands Clear" - Everyone should remove hands and other extremities from the ROV and its moving components.

"We're Cold" – This is the pilot's signal to all deck members that the ROV has been disconnected from the battery and is okay to handle.

"**Tether"** – This tells the tether manager to feed more tether into the pool.

Appendix B

BLOCK DIAGRAM



Appendix C

Note: Using Google Calendar allowed us to keep track of the progress of vehicle construction. The calendar was shared among all team members.