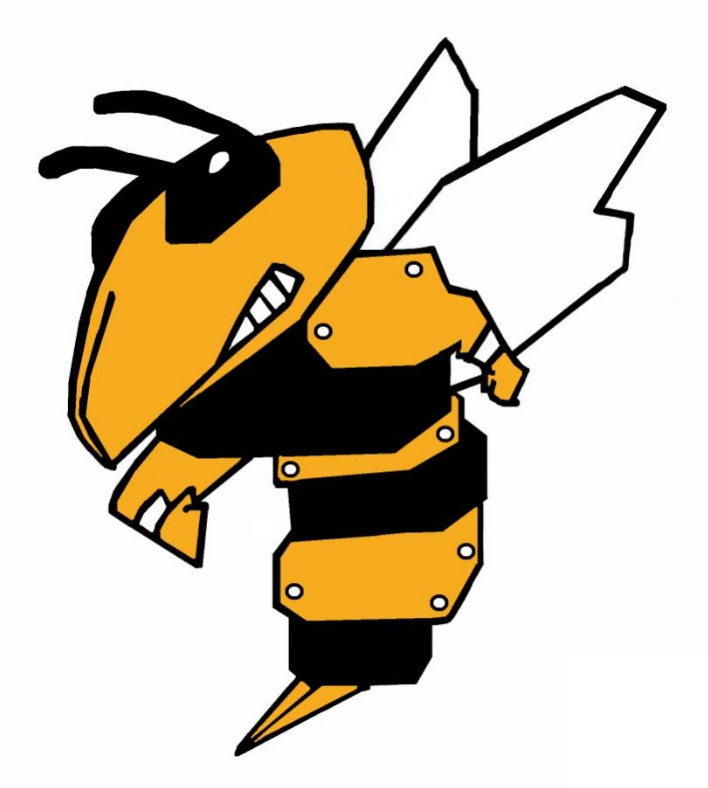
ROV Beta

Georgia Institute of Technology – Savannah



Georgia Tech Savannah Robotics (GTSR)

Advisor: Dr. Fumin Zhang

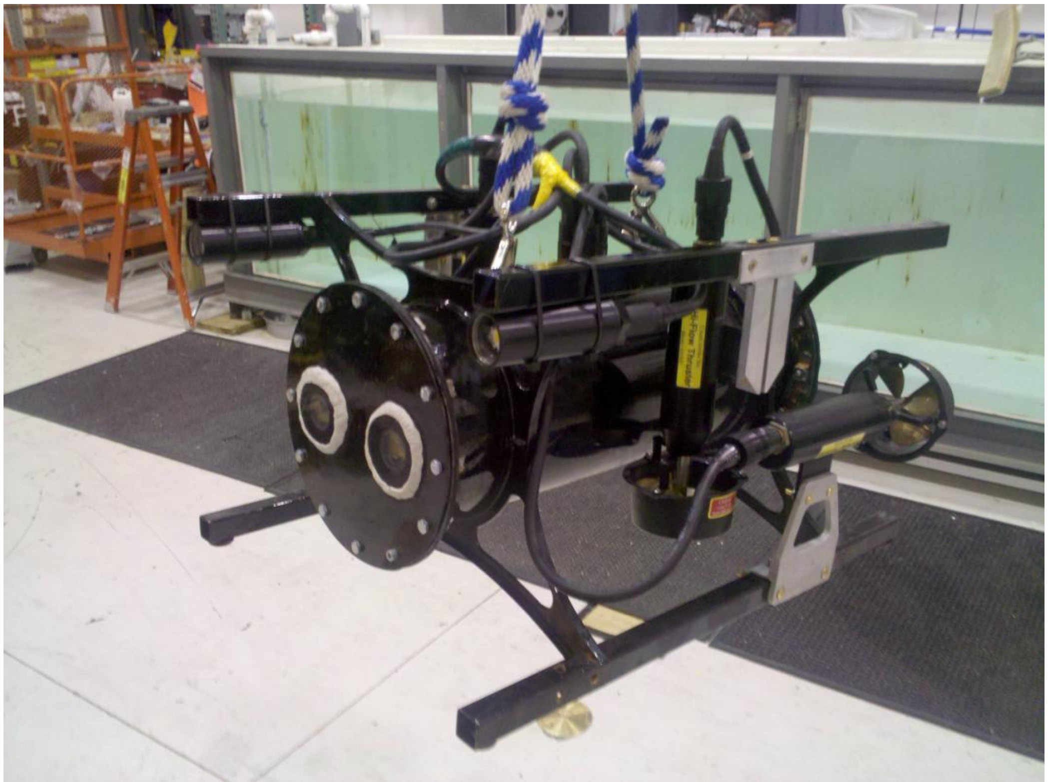
Members: Steven T. Bradshaw-Team Lead, Spencer Burch-Lead Design Engineer, Brandon Groff-Lead Software Engineer, Lisa Hicks-Lead Electrical, Patrick Lizana- Manipulator Design, Alfredo Santos-Manipulator Design, Evelyn Kim-ME Understudy, Angel Berrocal-Electrical Consultant, Chasen Born-Mechanical Consultant, Nicholas Parham-Software Understudy, Bridgette Reisinger-Electrical Understudy

Contents

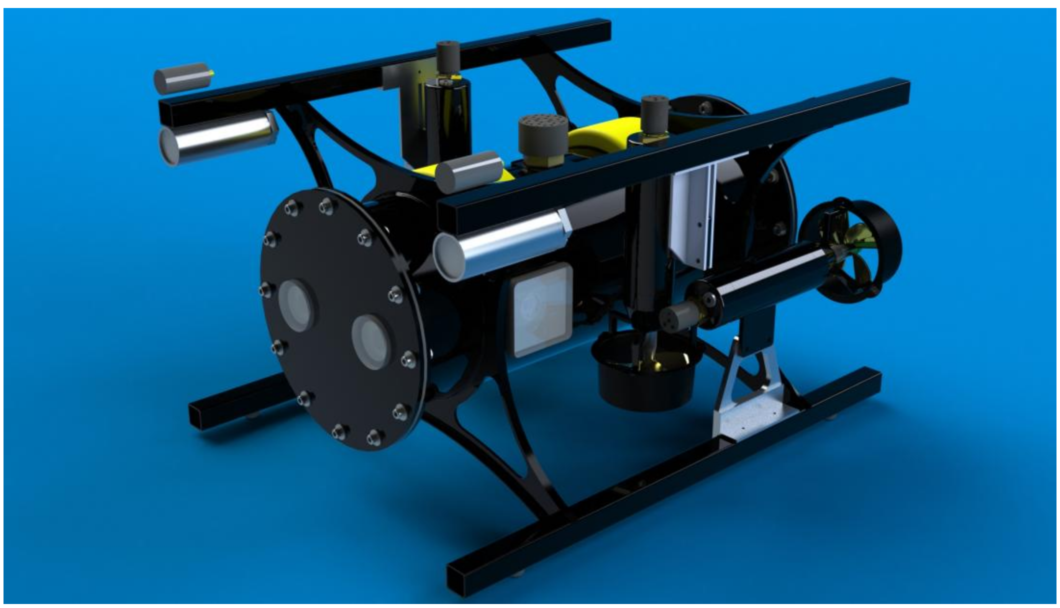
Abstract

In its second year of existence, the Georgia Tech Savannah Robotics (GTSR) team used lessons learned from the 2009 MATE International ROV Competition to design and manufacture its second generation ROV. With last year's Design Elegance Award in hand, the team took the positive attributes of the ROV and expanded on them. This included mounting four structures which surround the vehicle over last year's solo mounting plate to implement flexibility and versatility to the design. Along with this change, forward access to the cylindrical shaped hull was added to the previously aft only access. In addition to the hull improvements, there are two new subsystems: the manipulator and the Bilge-Pump Strafe Suction (BPSS) system. The manipulator, which is governed by waterproof electric servo-motors and inverse kinematic equations that govern motion control, was designed and manufactured by team members. The BPSS system consists of inline pumps that provide suction to collect crustaceans with the vectored discharge allowing for an extra degree of motion, strafe. With these additions, along with improvements in software knowledge and a more efficient electrical system, GTSR ROV-Beta promises to be a success in this year's competition, as well as a platform for future research at the Georgia Institute of Technology.

Photos of ROV



Completed vehicle



Completed SolidWorks model

Expense Reports

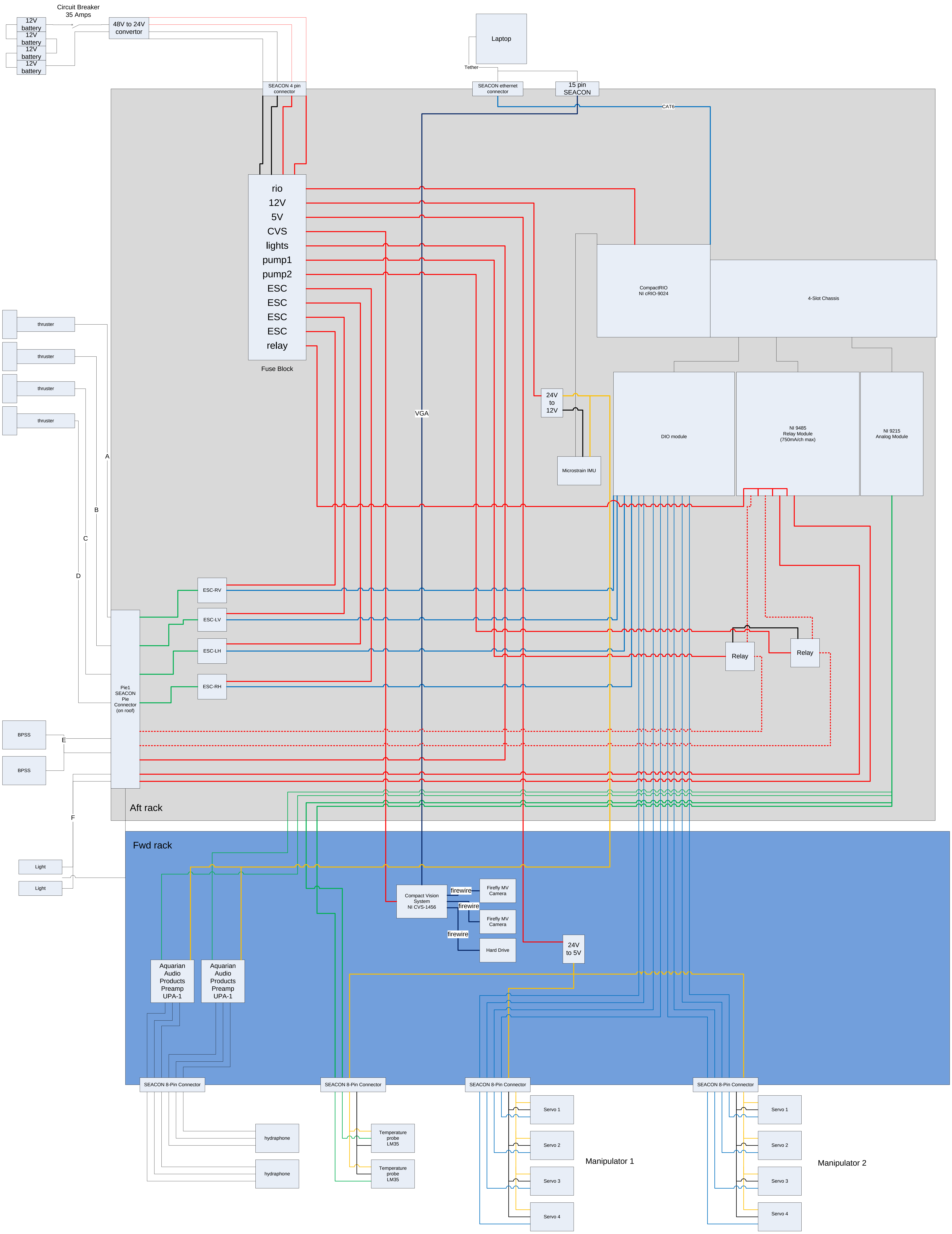
Component Expenses

Company	Product	Cost	Donation/Discount Amount
National Instruments	NI cRIO-9014	$2,429.00	$1,700.30
	NI CVS-1456	$3,779.10	$2,645.30
	NI 9403 DIO module	$332.10	$232.40
	Ni 9485 8-Channel Relay	$287.10	$200.90
	NI 9870 Serial Module	$521.10	$364.70
CrustCrawler	600HF Thruster (4)	$6,396.00	$800.00
	Hitec Servos (10)	$399.99	
SEA-CON	Waterproof Through-hull connectors	$2,500.00	$1,000.00
Outland Tech	UWL-401 LED Light	$2,600	$2,600.00
Castle Creations	Hydra 120 ESC (6)	$1,440.00	$420.00
VICOR	DC-DC Converters (4)	$378.00	$378.00
Metals Depot	Material (steel)	$400.00	
Cales to go	Tether (VGA)	$110.00	
Bulkwire	Tether (Power)	$390.00	
Point Grey	Firefly MV Cameras (5 each plus accessories)	$1,100.00	
Depco Pump Co.	In-Line Pumps (4)	$229.34	
	Total Expense	$23,291.73	
	Discounts/Donations		$10,341.60
	Net Expense	$12,950.13	(Covered by grants obtained by Dr. Fumin Zhang)

Travel Expenses

Expense	Cost	Each	Source	Total(Cost/Donation)
Airfare	$ 770.00	per person	Travel Inc.	$ 4,620.00
Dorm	$ 41.00	per room	Reservations from MATE website	$ 205.00
Hotel	$ 99.00	per room	Reservations from MATE website	$ 891.00
House	$ 171.00	per room	Dolphin Bay House	$ 1,197.00
Shipping	$ 800.00	each way 300 lbs	FedEx	$ 1,600.00
Per Diem	$ 47.00	per day	From DOD website	$ 1,974.00
Rental Car	$ 340.00	per vehicle per week	Avis	$ 680.00
			Total	$ 9,970.00
Dr Fumin Zhang				$ 3,000.00
Dr Frost/GTS Campus				$ 3,000.00
GTSR				$ 2,600.00
GT-S ASME				$ 990.00
			Total out-of-pocket expense per student	$ 63.33

Electrical Schematic



Design Rationale:

Mission Specific Features

One of the greatest strengths of our team is design. With a mix of artistic ability and technical knowledge, our lead design engineer put together an aesthetically pleasing vehicle. Among the new design are some very creative features that allow us to accomplish each mission.

The first mission relies heavily on the manipulator. This job was given to two Mechanical Engineering seniors: one designed the gripper, while the other designed the arm and mounting structure. The process of creating the manipulator consists of many designs which were modeled in SolidWorks before the two components were finalized and manufactured. The main pieces are machined out of thin, laser cut ABS plastic. This material was chosen due to its availability and for its high strength to weight ratio. Each manipulator was fabricated with ABS sections, spacers, and 4 servo-motors located at 1-degree of freedom joints. These motors were waterproofed using a combination of techniques found on YouTube and posted on the MATE website. They consist of filling the inside of the servo with a non-conductive paste and coating the outside with a flexible plastic material that allowed the servo horn to rotate while preventing water from damaging the electronics inside. Marine grease was placed inside the gear chamber, around the output shaft opening, and an o-ring was placed between the servo horn and the output shaft. The next step was to design an intuitive control for the manipulators. The primary means of controlling the vehicle and the manipulator are two Xbox 360 controllers. Controlling the motion of the arm via individual servo control was nearly impossible. So, with the use of LabVIEW, a graphical programming language from National Instruments, and kinematic relationships, we were able to write a control algorithm that enabled the user to control the servo angles by simply specifying the position of the end effector.

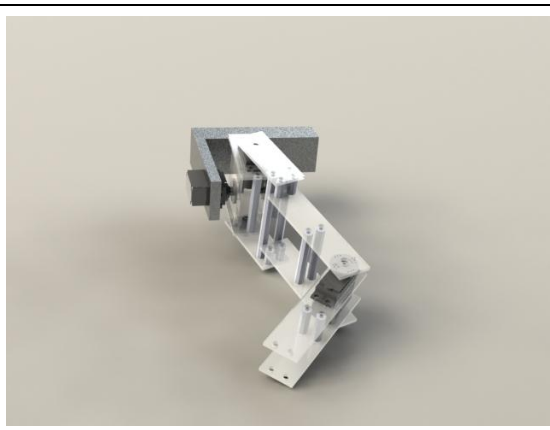


Figure 1 Initial manipulator concept

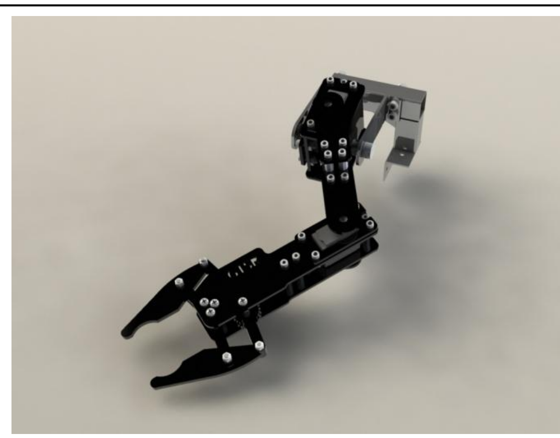
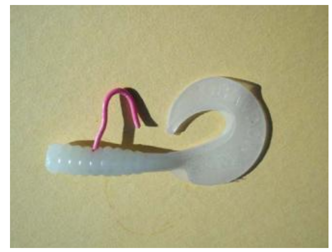


Figure 2 Final Manipulator Design

The main purpose of the first mission is to identify a "rumbling site", marked by a certain frequency buzzer, and then place the High Rate Hydraphone (HRH) in front of the proper rocky outcropping. This is done through the use of two H2b hydrophones from Aquarian Audio Products. The analog signal (voltage) generated by the sound picked up by these hydrophones, is then fed into a National Instruments' (NI) module (NI 9215). Through custom programming, the frequency is measured and displayed on the Graphical User Interface (GUI).

H2b Hydraphone Photo courtesy of www.aquad.com

The next mission requires us to navigate a 80cm x 80cm cave and collect crustacean samples from the back wall. Several ideas were brain stormed and a pool suction system was the agreed upon method. Our lead design engineer pointed out that using inline bilge pumps as a means to generate the suction would yield a discharge that we could then vector to the left and right of the vehicle. Only having four thrusters in our current configuration prevents us from using all six degrees of freedom (DOF). Using this idea, we were able to obtain another DOF, strafe.



Crustacean Photo courtesy of www.marinetech.org

Simulated Vent Site Photo courtesy of www.marinetech.org

The next mission was to read the temperature of different vent sites. This was simulated by having cooler/warmer water pumped and released into the pool through differing height PVC piping. In order to accomplish this mission, we used an LM35 sensor from National Semiconductor. This sensor was incorporated into our manipulator's gripper and waterproofed via methods found online. The custom control algorithm takes data from the probe through another analog input module from NI and plots a temperature vs. height graph on the GUI. The original plan was to use a depth sensor for height measurements but time constraints prevented the development of such. Given that the mission field props' dimensions were posted prior to the competition, we were able to approximate the heights for the three readings.

Agar Sample Photo courtesy of www.marinetech.org

The final mission is to collect a sample of bacteria simulated in the competition by agar. Since specific volume requirements are in place for maximum points, we were faced with the daunting task of scooping up a viscous fluid in a less viscous atmosphere. The original brainstorming ideas included a custom addition to the manipulator that would scissor the proper amount, using a syringe type system to pull a plunger to the desired volume, and by simply pushing a cup into the agar, allow the displaced agar to flow over and into the cup. The last option was actually implemented and a prototype was built for testing. We then discovered however, that the agar was too solid for this to work. Our new design consisted of a cylinder of diameter 8cm and height of 4cm. We capped the top and drilled a hole 0.5 cm down from the top (at a height of 3.5 cm) to allow the water to be pushed out of the cylinder when the open end is inserted into the agar. The suction force generated by the leaving water would then hold the agar in place until the vehicle returns to the surface.

Step-by-step Planning Process

The planning for this year's vehicle started immediately after last year's competition. We learned so much from the other teams and professionals involved, that we were eager to start improving our rookie effort. The first step was to examine the negative attributes of the vehicle and improve upon them. The next step was to examine the positive aspects, and replicate and improve where possible. Third was to streamline the overall vehicle design to allow for further functionality above and beyond the competition. The negative attributes were the hull material (aluminum end cap flange began to deform with repeated opening and re-tightening) and the limited mounting structure for mission specific systems and sensors (cylindrical hull made for no flat mounting surfaces, only a square tube along the keel allowed for external components to be mounted). The solution to the first issue was changing the hull material to steel. This allowed for deeper future applications and higher material strength that would resist deformation. Four frames surrounding the vehicle were added to allow manipulators, lights, and hydrophones to have stable, logistically sound locations. This also allowed for many other future sensors to be incorporated. The positive attributes were the cylindrical hull design (which we kept) and the central electronics shelf. Having only one access point to the vehicle caused us to have only one electronics shelf which proved hard to position certain specific components. The improvement this year was to incorporate a second access point and to allow the electronics to be divided into a dual shelf system. This also was made modular so that many shelves may be manufactured and swapped out based on the mission or task at hand. In an effort to minimize the tangled nest of wires carrying power to external components, through-hull connectors were added to the top and front plate to allow for a more streamlined vehicle.

Technical Rationale

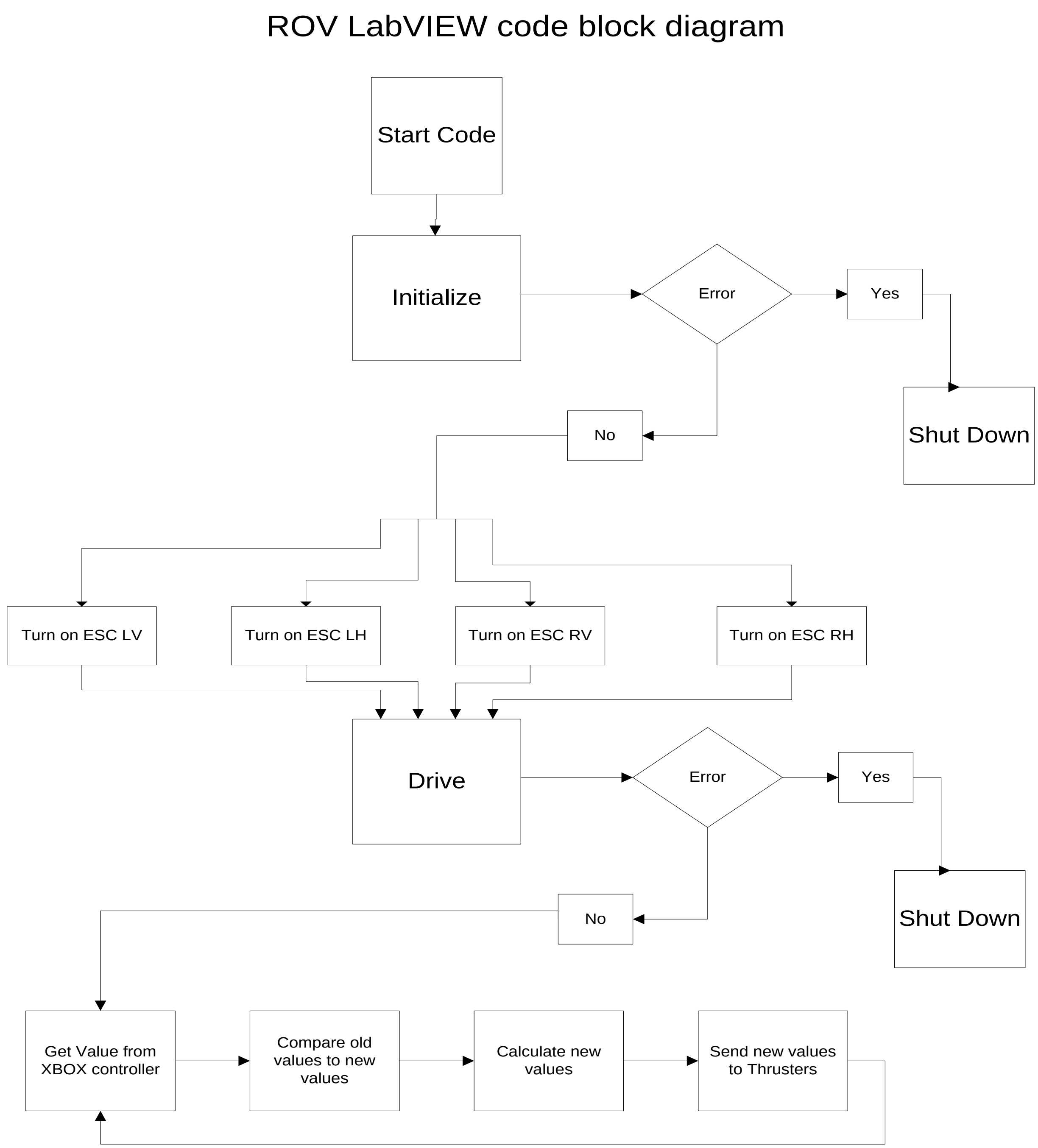
The tether consists of four 8 AWG wires, a VGA cable, and two CAT5 cables. The technical rationale for this design is the current rating of our thrusters and the desire to use them to near full capacity. The second CAT5 cable is there for redundancy. It not only serves as a back-up for the first communication CAT5, but it also serves as an alternate method of sending Pulse-Width-Modulated (PWM) signals to the servos used in the manipulators. This would also allow the use of an off-the-shelf board to do the intense kinematic calculations if our onboard processor was to become overwhelmed.

The technical rationale for using two hydrophones is to pinpoint the location of the rumbling site. This could be done with a single hydrophone by simply getting close to each location and comparing the loudness of the buzzers. Having to check each location and leaving the decision up to human interpretation as to which was louder takes more time and introduces human error. We decided to take a more autonomous approach. By comparing the phase of the signal received by each hydrophone and knowing the orientation of our hydrophones, we wrote an algorithm that aligns the vehicle to the source of the sound and therefore pointing it towards the rocky outcropping of interest.

Safety Precautions

The primary safety precaution this year was the circuit breaker located between the battery bank and the vehicle. Last year, during testing, we used four deep cycle marine batteries in series to simulate the 48-volt voltage requirement of the Explorer class competition. Our system ran on 24-volts, so a converter was necessary to step down the voltage. During one particular session, the convertor began to behave erratically and we began troubleshooting to determine the cause of the problem. While taking various voltage readings and performing continuity checks, the positive lead was disconnected from the convertor and the breaker was left in the on position. This meant that there was an energized 48-volt / +3000A (each battery was rated at 750 CCA) cable freely dangling in the immediate vicinity of many hands. Luckily, the only injury was a small burn to the hand of a person that was near the case of the convertor that the cable came in contact with. Ironically, the convertor worked fine after that!

Software Block Diagram



Challenges Faced

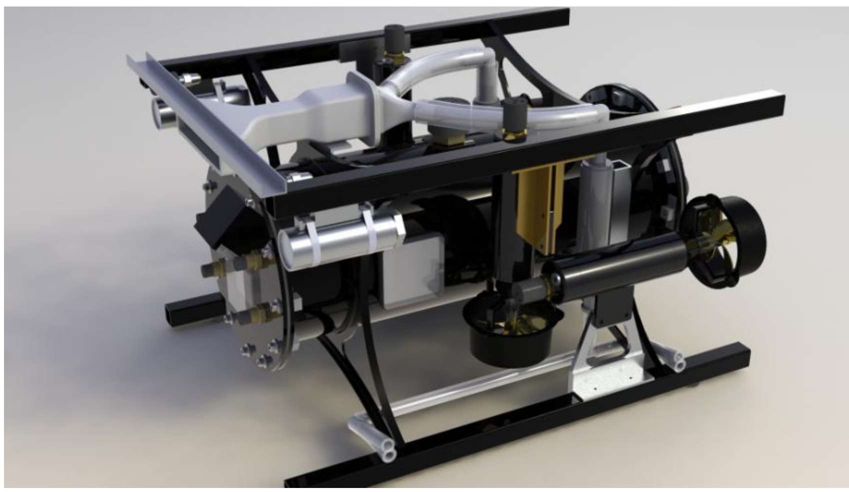
We faced many challenges during our sophomore effort. The most daunting challenge was trying to figure out how we were going to get to Hawaii. With last year's experience and a growing team, the normal challenges of time management and team productivity were solved relatively easy. We used a weekly schedule and had everyone's role clearly defined. This schedule was able to be accessed and viewed by everyone, allowing for the days' progress to be noted. This prevented too many people from working on the same task and also gave an idea of when each discipline (mechanical, electrical, software) was ready for the others' interaction. The total expense for all members to attend the competition was over $13,000. With a travel budget of just over $5000 (based on last year's travel budget), we knew it was going to be difficult to make to the international competition even though we qualified at the regional. The normal fund raising techniques (bake sale, car wash, etc.) seemed to barely put a dent in the deficit. The end solution was to hold a running race. Thus, the first annual Run and Ride for Robotics was born. Through many hours of planning and researching, one team member completely organized the event. We used our campus and incorporated an off-road section to set us apart from other similar types of races. It turned out to be a huge success. We not only raised a large amount of money, but also proved our dedication to our campus, which in turn donated the rest of our budget.

Troubleshooting Example

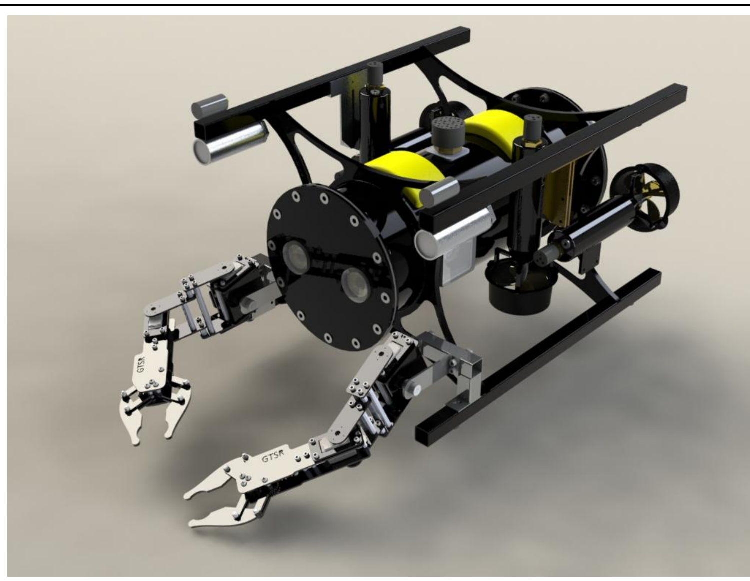
During one of the underwater practice runs, we noticed that our ROV could not ascend. Once the vehicle surfaced, we tested all four of the thrusters. Both of the horizontal thrusters (H thrusters) were operational, but the vertical thrusters (V Thrusters) were not responsive. We went and checked the LabVIEW code for the vertical thrusters and found that the code that we were using was actually one of our older versions. We then changed our code to the updated one, but only had one of the Vertical Thrusters functioning correctly. From there, we opened up the vehicle and checked the fuses of the non-working thruster. When we checked the fuses, we noticed that a fuse was blown. We replaced the fuse and kept the robot open to monitor and see if another fuse was blown. As soon as the vehicle was turned on and the thrusters were initialized, the fuse blew again. From there, we checked the wires to make sure that everything was connected and grounded properly. We found that a wire had become disconnected from the one of the connectors. We reconnected the wire into the right spot, replaced the blown fuse, and restarted the ROV to see if the fuse was going to blow again. When the thrusters were initialized, the fuse did not blow and the vertical thrusters worked properly.

Payload Description

There are two main systems that allow for the collection of all the required payloads. For the crustaceans, the BPSS system acts to collect them in a filtered storage area. This design allows for the suction path of the bilge pumps to pass through the entire system, be vented at the exhaust, and allow sideways translation (strafe). The manipulator is the second major payload system. The set of two manipulators will allow for the collection of the spire from the vent site, the transport of the HRH to the rumbling site, the removal of the cap, and the insertion of the plug into the junction box. The manipulator will also hold the bacteria mat collector. A simple vertical insertion of the PVC tube into the mat will allow for all the point-payload to be returned to the surface in one trip.



Bilge Pump Suction Strafe (BPSS) system



Twin manipulators

Lessons Learned

One valuable lesson learned from this year's experience is the need to design before you build. Our vehicle is intricately modeled in Solid Works, allowing us to know whether a component that needed to be added to the inside of the vehicle would fit or not. With this model, we were able to see the dimensions of the component with respect to the interior shelf. In the past, we would just fabricate the solution independently and waste valuable time and resources doing the same job over and over again because the compatibility was not considered beforehand.

Another lesson learned was the managing of the team dynamic. With first semester freshman to graduating seniors on the team, there was a large knowledge gap in some areas. The experienced people would get frustrated with the production of the newer students and the newer students could not relate to the project as they had never been part of such. At first, there was some friction, but that turned into a relationship where the newer team members wanted to learn and the senior team members wanted to help develop the younger minds.

Discussion of future improvements

With the development of the oil leak in the Gulf of Mexico, many members of the team began to think of how our vehicle could be adapted to this situation. Besides the obvious depth considerations (not a small task by any means), the control of the vehicle was the biggest area that we feel we can improve upon. Controlling a vehicle in such unfamiliar areas, like the bottom of the sea, is difficult for even the most experienced ROV pilot. The incorporation of a detailed sensor network and localization system would lead to a more efficient operation of the ROV. Autonomous manipulation would allow for the vehicle to be piloted to the proper location and positioned by the pilot. The vehicle itself would then assess the damage and relay it back to shore or begin the necessary operations to repair the damage. This would be like having a set of skilled hands in treacherous locations, such as the bottom of the sea. With most of the industry headed towards autonomy, this would be a huge improvement for the future.

The Lo'ihi Seamount

The Lo'ihi Seamount is an underwater shield volcano. A shield volcano is formed when lava flows great distances at small angles to the horizon. This is different from the mountain shaped volcano that is popularized in books and movies. The seamount is located approximately 30km south of Kilauea from the big island of Hawaii. It is located on a 5-degree slope with the north end beginning approximately 1900 m below the surface and the south end 4755 m below the surface. The volcano rises to about 969 m below the surface and is expected to break the surface within 10,000-100,000 years. Once thought to be a dead site, seismic activity in the late summer of 1996 has shown that the volcano is still very young and active. Its large area and newfound vent sites have had scientists in a frenzy to study the area.

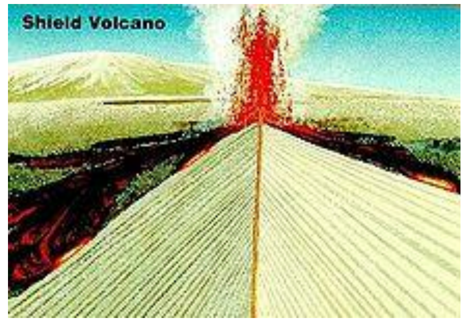


Photo courtsey of www.wikipedia.org

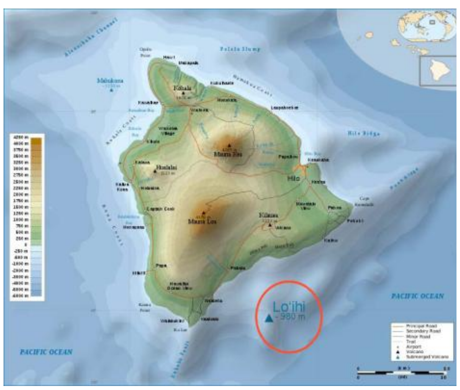


Photo courtesy of www.marinetech.org

From the bacteria forming, to the venting water and the continued seismic activity, Lo'ihi spans many fields of interest. Dr. Alexander Malahoff from the Hawai'i Undersea Research Laboratory (HURL) is the project coordinator of a research program that "focuses on submarine volcanology: the geology, geophysics, geochemistry, and biology of volcanic processes, their implications for island development and their contributions to the global carbon dioxide budget. It includes studies of their more remote effects (such as tsunamis) in order to better understand natural processes and enhance predictive models so as to improve short-term warning services. Lo'ihi Volcano is a prime site for this work, which includes monitoring submarine geophysical, geological and geochemical processes using an Ocean Bottom Observatory. These observing systems will provide a sound observational and monitoring capability."

The technology that we are developing for the MATE competition will act as a tool to aid Dr. Malahoff and others like him in the collecting of data and maintenance of underwater systems. This will lead to the understanding of these naturally occurring phenomena and prevention of such natural catastrophes, such as tsunamis.

Reflections

Using the skills built by the robotic team, I was offered and capable of accepting a summer internship at JCB Inc.

-Jasmine Magerkurth

Before I joined the team, I have to say my communication skills were sub-par (I really don't like to talk in a group that can express their own opinion). After joining the group and observing the reactions of the other members, I am starting to build up my communication skills better than ever.

-Nicholas Parham

As a direct result of our robotics team, I have gained much practical and experimental experience that I did not receive in class. Robotics has been a fortunate bridge of theory and experience. Also, presenting mechanisms that you designed and giving a justification for those designs is helpful when considering that is exactly what most of us (future engineers) will do after college.

-Chasen Born

While most engineering students' major focus in school is on their major alone, members of the robotics team have a unique opportunity to gain interdisciplinary skills. The single disciplinary focus creates a communication barrier to the other disciplines. In order to be proactive, team members had to take their own time to learn about other disciplines. Some even went as far as taking a class for credit completely outside of their discipline.

-Lisa Hicks

With the role of Design Lead, I took on a lot of responsibility with the team. This responsibility allowed me to enhance my leadership abilities and provide newer team members with someone who they can learn from. I will take these abilities into the industry where they will be a vital part of my success as a full-time engineer.

-Spencer Burch

Collaborating with the team has opened my eyes to the vast world of engineering. As a freshman joining the team, I had absolutely no inkling of what engineering was truly about. With my time on the team, I feel as though I have a better understanding of not only my passion, mechanical engineering, but also life skills and other engineering aspects.

-Evelyn Kim

Resources

Waterproofing Servos

http://www.youtube.com/watch?v=UZt7BuiNtc0

http://www.marinetech.org/rov_competition

Temperature Probe

http://www.instructables.com/id/Waterproof-a-LM35-Temperature-Sensor/

Lo'ihi Semount

http://en.wikipedia.org/wiki/Shield_volcanoes

http://www.soest.hawaii.edu/HURL/organization.html

http://marinetech.org/rov_competition/2010/2010_Competition_Missions_FINAL.pdf

http://hvo.wr.usgs.gov/volcanoes/loihi