



PETSUCHOS II
FLOWER MOUND ROBOTICS

TECHNICAL REPORT
For
MATE 2009 International ROV Competition
Prepared by
Flower Mound Robotics – Team FloMo
Flower Mound, Texas

PETSUCHOS II



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Pictures of PETSUCHOS II



Isometric View of PETSUCHOS II



Isometric View of PETSUCHOS II



Side View of PETSUCHOS II



Top View of PETSUCHOS II

Note: Refer to page 7 for Isometric Mechanical drawing with labeled ROV elements.



Abstract

The Flower Mound robotics team will participate in the 2009 MATE Competition with their ROV “PETSUCHOS II”. This ROV is a new and improved version of “PETSUCHOS,” originally designed in 2008. This tethered ROV has been designed to complete all underwater missions associated with the competition theme of “Submarine Rescue.” These missions include diving to a distressed submarine, surveying and inspecting all visible damage, opening and closing an escape hatch for the transfer of ELSS pods, providing a life support airline link to the surface and docking on the submarine with a mating skirt. With these tasks in mind, PETSUCHOS II was specifically designed to be small, mobile, lightweight, swift and adaptable for various equipment configurations.

This ROV has a monolithic buoyant ABS frame, five thrusters for maneuverability, two polycarbonate acrylic buoyancy tubes which house the ROV electronics, two underwater color cameras, a PVC mating skirt and two pneumatic claws. The frame and all accessory components of PETSUCHOS II were generated using 3D CAD software for fabrication and fit-up. Command and control of the ROV are operated at the surface using a power management and signal processing box with double joystick control. All power and communication is sent to the ROV through a multi-conductor tether cable.

PETSUCHOS II has been tested and evaluated for all performance tasks required in the competition. The ROV has successfully completed all missions without complication. Furthermore, this ROV has proven to be an economical and reliable solution for the upcoming competition in 2009.

Petsuchos

Petsuchos was the name given to the living crocodile at Crocodilopolis in Ancient Egypt. This creature was worshiped as the manifestation of the Egyptian god “Sobek.” The name Petsuchos means “son of Sobek.” Crocodiles were deeply feared by the Egyptians who constantly navigated the Nile River. His worship began as an attempt to pacify the crocodile. Our ROV, PETSUCHOS II, cannot be pacified!

1. Team “FloMo”

Team “FloMo” is a hybrid team this year. Our team is made up of one junior, Luke Cragin, from Flower Mound High School in Flower Mound, Texas and two college freshmen, Collin Cragin, from the University of Texas at Austin and Nathan Georges, from Kansas State University. All of our team members are interested in science and math and want to pursue careers in engineering in the future. In fact, Collin and Nathan are both pursuing degrees in Mechanical Engineering.



PETSUCHOS II *FLOWER MOUND ROBOTICS*



Team “FloMo”: (left to right) Luke Cragin,
Collin Cragin, Nathan Georges

Because all three team members have been at different schools all year, coordinating ROV work schedules was a major challenge; the team met on weekends and relied on email communication to share ideas and CAD files. Despite this situation and no funding from any school, we were able to develop PETSUCHOS II and compete in this year’s competition.

Team Responsibilities:

- | | |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Luke Cragin (Team Captain) | - Project Organization
Electronic Assembly
2D/3D CAD/ and Stratasys Interface
ROV Construction and Final assembly
Programming
Technical Report/Poster |
| Collin Cragin | - Claw Design and Construction
Pneumatic Assembly
ROV Construction
Part Design with 2D/3D CAD
Technical Report/Poster |
| Nathan Georges | - Tether Management
Electronic Assembly
Frame Assembly
Technical Report/Poster |



2. Budget and Expense

Due to budget constraints and the unusual structure of our team, we did not receive any funding from our high school or college institutions this year. However, we managed to re-use many components from our 2008 ROV, made the appropriate modifications for MATE 2009 and created PETSUCHOS II. Without venter and parent donations, our eligibility would have not been possible. Our budget goal for this year was set at \$2,000.00 for the modifications, but we exceeded that amount slightly. For the final list of reused and new part expenses, donations, and travel cost, refer to Appendix A.

3. Design Rationale

Our original design goal for MATE 2008 was to design and build a versatile ROV that could easily be retrofitted for any competition. The 2008 PETSUCHOS performed extremely well and we thought that a total redesign was unnecessary for 2009. We began the task of transforming PETSUCHOS to become PETSUCHOS II. Our main design focus was to concentrate on the completion of mission objectives. Furthermore, we wanted to reuse existing ROV elements that were successful for us last year and enhance their capabilities where possible. With this concept in mind, we defined three areas of design for which we thought improvement or changes could be made:

- 1) Power and speed
- 2) Mission specific attachments
- 3) Tether design and quick disconnect ability to ROV

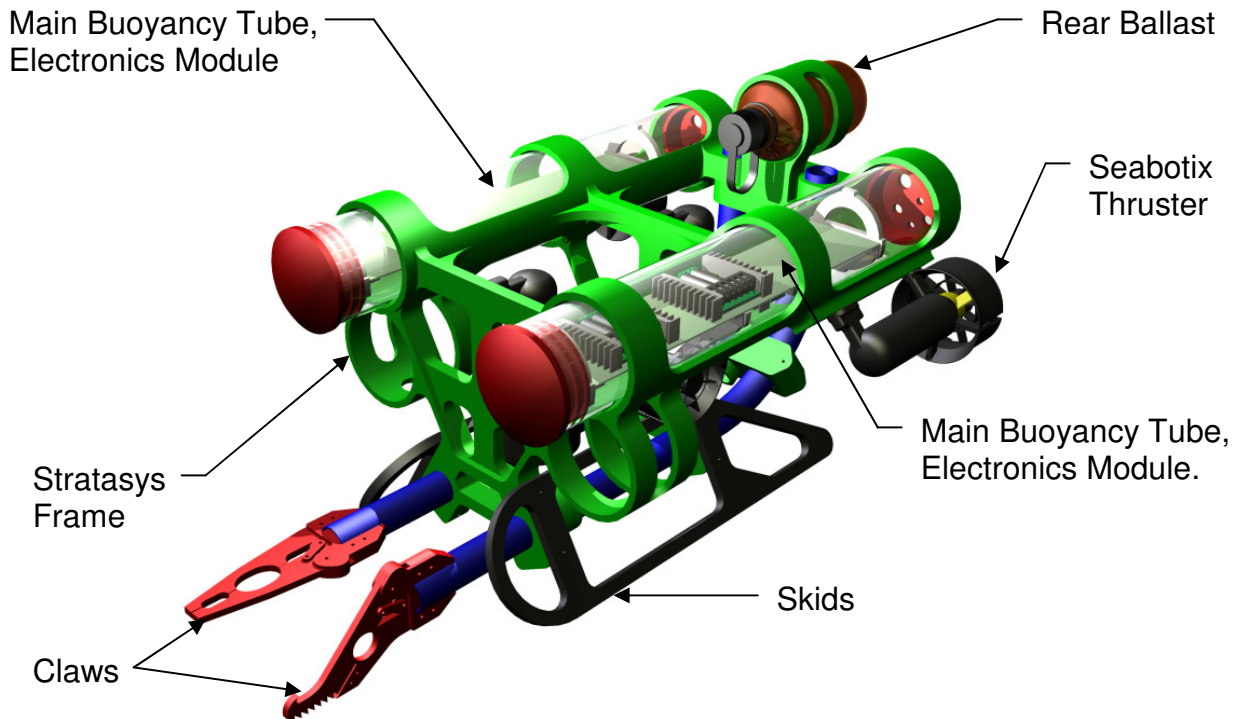
With so many tasks to complete this year, speed and maneuverability will be crucial. For this reason, we chose to reuse the small profile, open monolithic frame developed last year, along with the five Seabotix thrusters. This year, we are taking advantage of the increased voltage offered in the Explorer class. Using a DC/DC converter, donated by the Vicor Corporation, we can take the 48VDC surface source and transform this into a 12VDC and 28VDC split supply. We use the 12VDC supply for the operation of the microcontroller components, air solenoids, video card and cameras. The 28VDC supply is used to power the thrusters and motor controllers.

The mission tasks this year involve extensive claw manipulation with the opening of hatches, rotation of valves and ELSS pod placement. For this reason, we modified our claw system and attachments. The original ROV design allows for easy replacement and relocation of new attachments. We used a variable ballast system last year for heavy lifting, but removed this optional component since it was no necessary for this year's competition.

We used a tether last year with a split end connection at the ROV. This reduced the ROV mobility, added weight to the rear end and complicated the ROV set-up. This



year, we have reworked our tether to have only one 10 pin Seacon connector with a locking sleeve. The tether drag and weight are reduced, and the turning radius of our machine has improved tremendously. Re-evaluating existing systems is part of the design process. However, our primary focus is always on keeping our design simple.



Rendering of CAD drawing

3.1 Frame Construction

After weeks of searching for monolithic construction techniques, we discovered FDM, Fused Deposition Modeling. This process is a type of rapid prototyping or manufacturing commonly used in engineering design for preliminary part design. This process works on an additive principle by laying down materials in layers. A plastic filament or wire supplies material to an extrusion nozzle which can turn the flow on or off. The nozzle heats the material and deposits the layers. This process has an accuracy of .15 percent.

Several materials can be used in this process, including ABS and Polycarbonate. Both thermoplastics offer properties that would work well with our design. Although Polycarbonate has stronger strength properties, ABS is more economical and more buoyant. For these reasons, we chose to use ABS which has a specific gravity of 1.05, a tensile strength of 22MPA and a flexural strength of 41MPA. Although rapid prototyping is not typically intended to provide the final product, the material properties



of ABS work well for our final application. After contacting several companies, we selected Stratasys, Inc./RedeyeRPM to be our manufacturer.

A large portion of our project effort was concentrated on the design and development of the PETSUCHOS frame. Using 3D CAD design software, we were able to produce a frame that is exact and allows for the incorporation of all ROV accessories, including claws, motors, ballast tanks, electronic and buoyancy tubes, end caps, cameras, skids and tether interface. The great benefit of 3D CAD software is that the process allows us to position all accessories on the frame to check the weight and balance, center of thrust, center of buoyancy, camera line-of-site, and potential physical conflicts without spending any time on actual construction. Problem areas were discovered and quickly revised.

During the entire design process, we stayed in close contact with Stratasys, Inc./RedeyeRPM engineers to make sure that we were coordinated and could produce the final CAD file for production. Knowing that this was the most expensive part of our project, we could not make any mistakes. We were now ready for the manufacturing process. After one week of waiting we received our package from Stratasys. Everything was perfect. The entire FDM process had taken about five days and the final frame weighed just over 1.81 kg.



Stratasys Frame

3.2 Buoyancy System

The primary buoyancy for PETSUCHOS II is provided by two 90 mm diameter x 558 mm clear polycarbonate tubes. The end of each tube is sealed by a machined aluminum end cap. These end caps are designed with double radial o-rings and tight tolerances to prevent water infiltration. The acrylic tubes are also used as the electronic



housing modules. The tubes are positioned high on the machine frame and spread apart approximately 26.6 cm to provide stability. Additional stability is gained by centering the mass of all other non-buoyant frame components exactly between and below the center of buoyancy. The overall length and volume of the tubes was determined using 3D software, but slightly modified after testing.

Additional buoyancy for payload lifting is provided by two 1000 ml Nalgene bottles, in the front of the frame, and one 400 ml Nalgene bottle in the rear. We can adjust the air volume in each bottle to offset payload weight as required. For the 2009 MATE competition, the front bottles have been removed, since the anticipated payload weight is small and the thrusters can provide the necessary lift.

The buoyancy tubes were modeled in 3D CAD and load tested at various depths to determine the incremental deformations and ultimate failure mode. Tube failure is not an issue at competition depths.

3.3 Thrusters

We have had great success with the underwater thrusters made by Seabotix, Inc. and decided to use them again on PETSUCHOS II. Prior to this year, we ran all thrusters and electronics on a 12VDC source. The Seabotix thrusters are designed to operate at a voltage as high as 28VDC. Since the maximum potential of these thrusters had hardly been tapped, we saw an opportunity to utilize much more power and speed this year by increasing the voltage supplied to the thrusters. The power requirements for the Explorer class are limited to 48VDC and 40A. Using this source and our donated Vicor DC/DC converter, we can now provide split reduced voltage sources to our ROV. We are now supplying 12VDC to all electronic components and 28VDC to the thrusters.

With our calculated and confirmed voltage drop of 8.5VDC over 22.8m of tether, our thrusters run at 19.5 VDC and pull 2.8A each. The thrust for each motor is approximately 2.2kg at full power.

The final configuration for thrusters is as follows:

- 1) Two vertical thrusters that provide up and down movement
- 2) Two horizontal thrusters that provide forward, backward and turning movement
- 3) One horizontal thruster that provides sideways movement

All thrusters are positioned for maximum efficiency and accessibility for removal, repair and replacement. Thruster whips are modified for proper length from the point of attachment on the frame to the rear bulkhead connection into the ROV electronics module. In an effort to reduce possible water leaks at bulkhead penetrations and to provide independent quick disconnect for all thruster whips, we chose Seacon and



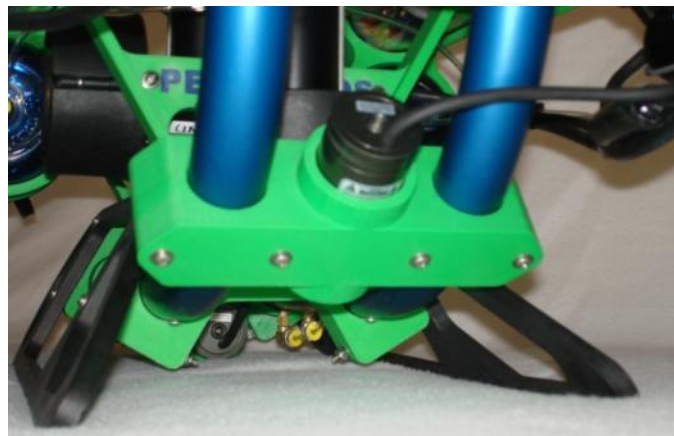
Subconn wet-mateable connectors. The connectors are specifically designed for this purpose and have o-ring seals.

3.4 Lights and Cameras

Knowing that the MATE 2009 Competition will be held in a well lit pool environment, the need for special ROV lights was eliminated. As for cameras, we have had great success with the waterproof infrared LCA -7700 cameras sold by Lights Camera Action. Our ROV is equipped with two of these cameras for visual maneuvering guidance. These cameras are waterproof, have infra-red LEDs for low light conditions, are small in size (.5 cm diameter x 10 cm long), operate on 12VDC, have a current draw of only .15A, and are functional to a depth of 60 m.

Continuing the theme of “quick disconnect” and modular construction, we ordered special Seacon wet-mateable whips and connectors to modify our cameras and eliminate the need for multiple hard mounted camera cables running to the surface along the tether. We removed and redesigned the existing camera back plate to accommodate the Seacon connectors. This part was developed using 3D CAD software and machined out of brass. We used 3M - 2130 splicing kits to make shortened cables between cameras and bulkhead fittings. The 3M kits provide waterproof connection for inline cable splices. These modified camera whips, now only 46 cm long, can now be plugged into our rear end cap bulkhead Seacon/Subconn fittings for quick disconnect and servicing.

The positioning of the cameras was critical to performing our mission tasks. We placed one LCA -7700 camera at the front of the frame, looking forward, to provide general visual maneuvering guidance, allowing the driver to locate mission props and monitor claw activation movement. We placed a second LCA – 7700 camera at the rear of our machine at 45 degrees downward, providing a view of the mating skirt. Our only complaint with the LCA – 7700 cameras is their limited depth perception. All camera cables were connected to our video mixer board within the electronic modules. The quad mixer allows us to send four views simultaneously through a single coax within the tether and up to the surface control box for a split screen display.



Mating Skirt
Camera



3.5 Control System

Our ROV control system was developed using component parts selected from several vendors. We did not use any complete plug and play units similar to Innovation First products. The main ROV control system is separated into two packages: (1) the surface system and (2) the ROV underwater system. Our goal was to build a control system with readily available electronic components, learn PBASIC programming skills and utilize analog controllers for proportional motor control. Our original program control code was developed by our mentor, but eventually was understood and managed by several team members. Our program flow chart and code could not fit within the report page limitation, but we will bring both to our engineering evaluation. With our modular approach to design this year, the connections between the surface control system, the tether and ROV underwater system make for quick assembly.

The surface unit includes our analog joystick controllers, Vicor DC/DC converter, Parallax Board of Education (BOE) with BS2 Basic Stamp microcontroller, Parallax AppMod/Transceiver board, a 15A ammeter, a 50A ammeter and two 12 pole power blocks. In an effort to avoid the use of standard on-off toggle switches for motor control, we chose to use the standard analog joystick. The joystick provides much better control and allows for proportional mixing of motors for the forward, backward and turning movements. The joystick position is determined by potentiometers, or variable resistors, attached to the joystick gimbals. Varying the resistance of the potentiometer alters the electrical current and sends the analog resistance readings to the AppMod board and then to the BOE, the ROV brain. All surface components have been placed in a watertight laptop box for quick connection to the tether. The functions of each individual component are outlined as follows:

The Parallax Board of Education (BOE) Functions:

- 1) Provides platform for the BS2 Basic Stamp microcontroller.
- 2) Provides serial connection between computer, BASIC Stamp Editor and BS2 for PBASIC programming.
- 3) Converts the resistance readings from joystick potentiometers into servo values using RCTIME instructions (PBASIC Language) and sends this information back to the AppMod/Transceiver board.

The Parallax AppMod/Transceiver Board Functions:

- 1) Provides connection between joystick and BOE.
- 2) Receives 12VDC power from battery, powers BOE.
- 3) Receives signal data from BOE and transmits to underwater ROV Co-Processor board.



- 4) Separates serial data going to and from the underwater Co-Processor board. This is necessary because the Co-Processor (servo controller function) requires separate wires for the data in each direction, but allows us to use one data wire to limit tether size.

The ROV underwater system includes our Blue Bell Design Transceiver/Driver board, Blue Bell Design Co-Processor board, two double Dimension Engineering motor controllers, one single Dimension Engineering motor controller, one QVC Video quad mixer, one Sizto Tech solenoid and two miniature board cameras. All electronic components of the ROV are placed within two 90 mm diameter x 558 mm long polycarbonate tubes (electronic modules).

Transceiver/Driver Board Functions:

- 1) Receives serial data coming from the AppMod surface unit and sends data to Co-Processor board.
- 2) Separates serial data going to and from Co-Processor board.
- 3) Drives reset to Co-Processor which stops the servo signals to motor drivers.



Transceiver/
Driver Board

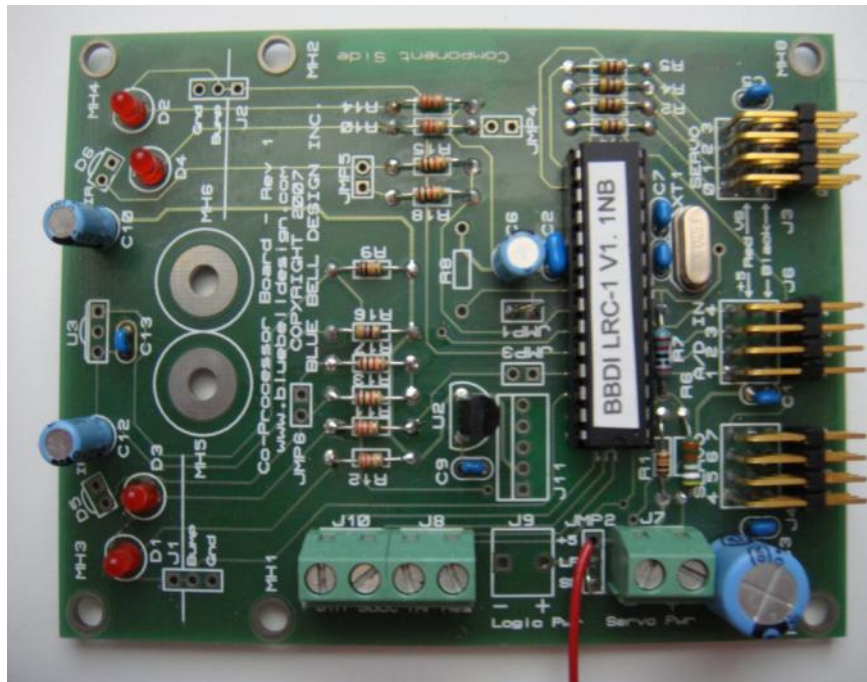
Co-Processor Board Functions:

- 1) Receives commands from the BOE, through Transceiver/Driver Board, and converts them to servo pulses to the motor drivers. The Co-Processor chip converts serial data signal into a high level pulse from 1 to 2 ms in length.



Servo pulses repeat every 20 ms. A 1.5 ms pulse will cause a motor driver to stop. A 1 ms pulse will cause the motor to go full speed in one direction. A 2 ms pulse will cause the motor to go full speed in the opposite direction.

- 2) The board also has other features not used, such as bumper sensors, voltage measurement and timers.

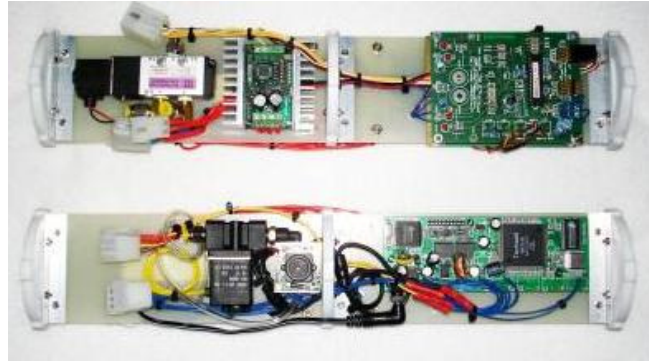


Co-Processor Board

Motor Driver Functions:

- 1) The Dimension Engineering Syren 25 motor controller is rated to 15A continuous/25A peak and 30VDC max. The Dimension Engineering 2 x 25 Sabertooth motor controller is rated to 25A continuous/50A peak and 30Vmax.
- 2) A signal servo wire is connected from the Co-Processor board servo port to each motor controller. Power to each motor controller is supplied directly from the power block in the electronics module.
- 3) Uses Pulse Width Modulation (PWM) to control motor speed.

All ROV electronic components noted above are placed inside our buoyancy tubes. Each end of the polycarbonate tubes is sealed by a machined aluminum end cap. The rear end cap permits all penetrations and bulkhead connections for the electrical and air supply. All bulkhead connections are either Seacon or Subconn wet-mateable style. All electronic components are supported on linear trays, which slide in and out of the tube for quick access. This modular concept was adopted for ease of serviceability. Molex connectors are used between all Seacon/Subconn bulkhead connectors and electronic tray components.



Electronics trays

During the testing phase of PETSUCHOS II, we never encountered leak problems with the polycarbonate tubes. The only concern we had for the electronic module was heat generation from motor controllers. We specifically selected motor controllers that had much higher voltage and current capacities than required to reduce potential heat effects. Through our testing, heat generation has not been a problem. We learned how to bring together several components, made by different manufacturers, making a complete control system. Our team organized and installed the wiring and components, and soldered all preprinted circuit boards for “PETSUCHOS II.”

3.6 Electrical Schematics

Schematic diagrams for both the surface control system and ROV control systems are shown in Appendix B and C.

3.7 Tether

Our goal for tether construction this year was to eliminate as many conductors as possible and to use a commercially available tether with quick disconnects. We also realized that a thick and stiff tether would add drag and weight and decrease maneuverability. Fortunately, the Storm/Teledyne Company is located in Dallas and we contacted them for help. After meeting with the Storm personnel and defining our conductor and power requirements, we selected a cable. Using our pre-selected Seacon connector whips, Storm provided the molded connection between whips and the cable. The cable selected provided us with dual voltage transmission, 12VDC and 28VDC, at a voltage drop we could tolerate.

Unfortunately, neutrally buoyant cables were not in our budget, so flotation is required. Since the tether has negative buoyancy, we have additional foam flotation segments about every four feet to achieve neutral buoyancy. The flotation elements are doughnut-shaped polyurethane. The positioning and length of foam flotation was resolved by trial and error. Because these foam doughnuts are extremely dense,

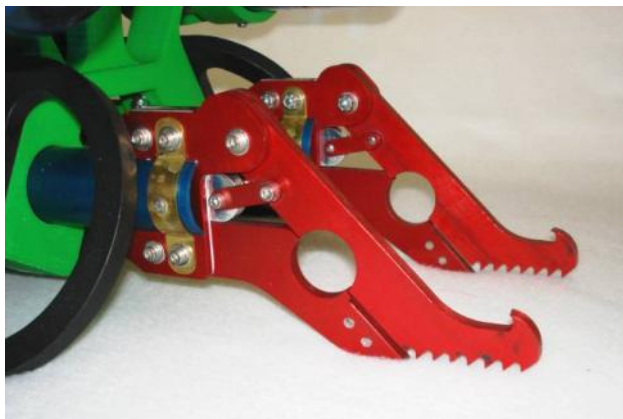


crushing and loss of buoyancy has never been an issue at contest depths specified. We would need to re-evaluate this situation for greater depths.

The length of the cable was chosen based upon the maximum vertical and horizontal distance to the mission prop location (2.5m down and 10m out from the wall). This gave us a total length of 12.5 m at the pool shell surface. We added another 82% for maneuvering around the competition props. The total length of the tether is now 22.8 m.

3.8 Mission Tools

PETSUCHOS II is very maneuverable and fast, but placement of critical mission specific tools is essential. The missions for this competition are basically broken down into four tasks: (1) Visually survey and inspect submarine damage, (2) Open and close submarine escape hatch, retrieve and deposit ELSS bottles, (3) Open ventilation hatch, insert and remove airline nozzle, turn on and off air valve, (4) Mate the transfer skirt to the escape hatch. The only lifting involved with this year's competition occurs with the ELSS retrieval and deposit. Since PETSUCHOS II has enough power to perform this task without the aid of additional ballast, the original variable ballast system has been removed for this competition. The greatest feature of PETSUCHOS II is its ability to be reconfigured for various missions. Task 1 and 4 will require maneuverability. Task 2 and 3 will require maneuverability and claw manipulation.



The two crocodile-shaped claws on PETSUCHOS II

Claw operation is controlled by the joystick trigger, which operates a solenoid air valve in the ROV. Air is supplied from the surface compressor to the ROV through a 3 mm diameter polyethylene flexible tube attached to the tether. Each claw has a double action, 13 mm diameter pneumatic piston with 3 cm travel. The claws operate perfectly using 40 PSI and can maintain a significant grip. As a backup precaution, we have designed the claw with a hooked nose for lift support in case of claw failure. In order to grasp and control airline nozzle placement, we modified one of the original claws by

replacing the standard blade sets with a custom set of blades and rotated the mechanics horizontally (not shown in the photograph). All other claw manipulation tasks can be performed with both configurations. We are using a PVC end cap for the mating skirt attached to the ROV frame using a Stratasys ABS plastic part.



4. Challenges

During the course of this project, our team encountered many challenges and learning opportunities. We approached every challenge as a team and resolved some issues quickly and others with more deliberate thought. Our most significant challenges were:

- 1) Challenge - Developing a work and communication schedule between three students attending three different schools in three different cities.

Solution - We overcame this problem with constant internet communication and concentrated work sessions during holiday breaks. We also assigned different task to each member of the team with specified deadlines.

- 2) Challenge - Developing all CAD files to work with third party vendors and planning for long-lead fabrication parts.

Solution - We developed good communication with each vendor and verified their requirements and schedules early on during the project and established a sequencing schedule for the outsourced work.

- 3) Challenge - Developing a voltage reduction plan and selecting the proper DC/DC converter to maximize our thruster output and work with lower voltage electronics.

Solution – After determining our requirement needs, we contacted Vicor Corporation and received a donated DC/DC converter, custom made for our use.

5. Trouble Shooting

During the course of the project we resolved several unexpected problems. Most of our challenges were simple and were resolved quickly. Some examples of these problems and solutions are as follows:

- 1) Problem - We had many machined aluminum parts on PETSUCHOS II and discovered that chlorination and salt water can be very aggressive with respect to oxidation.

Solution - We had all aluminum parts anodized.

- 2) Problem - We developed camera interference when we switched thruster voltage from 12VDC to 28VDC voltage.



Solution - We had motor controllers in the same acrylic buoyancy tube as our video quad card. We rearranged our electronics and moved all motor controllers to the other buoyancy tube.

6. Future Improvements

We could definitely make improvements with our current ROV. Our goals for next year will be to improve the following:

- 1) Replace the scavenged video quad board on the ROV, used for mixing, with a digital downlink and fiber optic cable. Our video was adequate, but the card was intermittent at times.
- 2) Add a rotational degree of freedom to the claw. Consider using hydraulics.
- 3) Use larger diameter acrylic tubes for more buoyancy and electronic component storage space.
- 4) Make ROV electronic package more modular and eliminate wiring and wiring connections when possible.
- 5) Add a more sophisticated ballast system for improved vertical movement.
- 6) Use a neutrally buoyant tether cable.

Our list of improvements was created from our experience gained this year during construction and underwater testing. The addition of other sensors that measure acceleration, tilt, temperature, pressure and depth are not necessary for this event. However, if this ROV was used in an actual sea or lake environment, where the depth is unknown and visual reference is obscured, these sensors would be helpful.

7. Lessons Learned/Skills Gained

Team organization and scheduling are essential to a successful project. Without a schedule for task completion, we would have never been ready for the competition. We established a schedule early in the project, which was followed with very little deviation. Reusing elements of our 2008 machine helped reduce our workload this year. Research is a key component of success. Many hours were spent on the internet by all, looking up related links for materials and ideas. We have thoroughly enjoyed this process, and this is what drives us all to become engineers.

We gain knowledge every year. However, we have discovered that the more we learn, the more questions we have. Learning is an endless process. We have a much better understanding of power, current voltage, voltage loss, wire sizing, and component selection. We have become very proficient with the use of 3D modeling and our CAD skills have improved immensely. This was a tremendous help in the development of our ROV design. Time and material were saved. This is a great engineering tool.



8. Reflections

We always look forward to the MATE competition. The competition theme is extremely interesting this year, and the missions are always challenging. The fact that these missions incorporate real life undersea tasks makes our experience seem even more important. What we enjoy most is the path toward problem solving and the ultimate test and competition at the end. We are thankful for all the companies who have donated time and money to make this event possible. We need more competitions and interested sponsors to help promote math, science and engineering beyond the normal classroom experience.

9. Submarine Escape and Rescue

Submarine duty has always been considered more hazardous than surface ship operation. Disasters onboard a submarine can often be sudden, making escape or rescue only possible within the first few hours after the accident. There have been significant developments made in submarine rescue systems in the past forty years. These developments include the traditional DSRV (Deep Submergence Rescue Vehicle) and the newest system, RORV (Remotely Operated Rescue Vehicle), designed to carry distressed submariners to the surface. These systems are now small enough that they can be transported by aircraft to the disabled submarine within days.

Unfortunately, the location of the distressed submarine may be thousands of miles away from the rescue equipment and the delay in mobilization may be the difference between life and death. Furthermore, the position of the sub may not allow for connection between the DSRV or the RORV. With this in mind, the Navy has continued to develop individual self-escape equipment. Although these systems have historically had a low rate of success and can only be used at limited depths, these systems may be the only option available to the submariner. These devices are designed as a last resort for a submarine emergency and bodily injury from extreme pressure and cold water exposure is always possible.¹

The first successful self-escape device was designed by Admiral Charles Momsen of the U.S. Navy in the early 1930's. The "Momsen Lung" was a primitive underwater re-breather introduced before and during World War II. The lung was similar to a life jacket with a bladder. It was initially filled with oxygen and connected to a mouthpiece with twin hoses containing one-way valves. One valve was for breathing in and the other for breathing out. The device recycled the breathing gas by using a counter-lung containing soda lime to scrub carbon dioxide. The first successful use of the the Momsen Lung occurred with the escape of eight sailors from the disabled submarine USS Tang in World War II. The Momsen lung was rated to a depth of 60 m. It did provide minimum breathing capabilities, but no flotation or protection from cold water.²



The Momsen Lung was a first generation self-escape device, but had obvious limitations. In 1962, LT Harris Steinke of the U.S. Navy introduced an improved version of the self-escape device called the “Steinke Hood.” This device was a life jacket with an inflatable hood that completely enclosed the sailor’s head and trapped a bubble of breathing air. The Steinke Hood provided positive buoyancy of the hood, which allowed for a slow ascent. This system also had an improved depth rating over the Momsen Lung. This device was successfully tested to a depth of 97 m. However, there were several drawbacks which were related to operational procedures during the escape and the ultimate exposure to freezing water. To escape from a disabled submarine, several submariners would enter an escape trunk, which is isolated from the submarine by closing an inner hatch. The hoods would then be filled with compressed air and the trunk flooded, followed by escape through the submarine outer hatch. If any procedure was implemented incorrectly, the escape would be doomed. Flotation was not sustained once the surface was reached.³

With limited depth restrictions, no flotation and no thermal protection, the search for an improved self-escape system continued. During the 1990’s. The British began to develop the SEIE (Submarine Escape Immersion Equipment). This system provides a whole-body dry suit for thermal protection and an integral one-man life raft. The device has been successfully tested to a depth of 183 m and also provides sufficient buoyancy to assist a submariner to the surface at a safe speed, two to three meters per second, to prevent decompression sickness. The U.S. Navy is now transitioning to this type of self-escape device for their submarine fleet.⁴



The Submarine
Escape Immersion
Equipment suit



The SEIE on the surface after escape



Sources:

¹ <http://www.omr.navy.mil/focus/blowballast/momsen/momsen4.html>

² <http://www.globalsecurity.org>

³ <http://www.wikipedia.org/wiki/SEIE>

⁴ <http://csp.navy.mil/news/rele04075.html>

10. References

Lindsay, Andy. What's a Microcontroller?: Student Guide Version 2.1. New York: Parallax P, 2003.

Martin, Jeff. BASIC Stamp Syntax and Reference Manual: Version 2.2. New York: Parallax, 2005.

Predko, Myke. Programming Robot Controllers. New York: McGraw-Hill/TAB Electronics, 2002.

11. Acknowledgements

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Harry Lewis – Electrical Mentor
Lights Camera Action
Seabotix, Inc.
National Science Foundation
MATE Center
OceanWorks International
NOAH
Massachusetts Maritime Academy

Without this group, this project would not have been possible. Our mentors are incredible.



Appendix A: Project Expense Sheet

Reused Part Expenses

Expense Item	Part Description	Usage	Quantity	Vendor	Expense
1	Frame Attachment 1	Front Camera Attachment	1	Stratasys RedeyeRPM	\$ 232.34
2	Frame Attachment 2	Rear Camera Attachment	1	Stratasys RedeyeRPM	\$ 397.72
3	Frame Attachment 3	Rear Ballast Attachment	1	Stratasys RedeyeRPM	\$ 558.00
4	Aluminum Front End-caps	Acrylic Tube Closures	2	Heritage Machine	\$ 200.00
5	#233 Buna O-ring Seals	End-cap Water Seal	6	Porter Seal	\$ 7.03
6	12" x 2 1/2" x .125" Aluminum Plate 2024	Claw Parts	2	McMaster Carr	\$ 26.72
7	12" x .50" x .0625" Brass	Claw Parts	2	K & S	\$ 1.25
8	1.25" OD x 1.125 ID T4 Aluminum Tube	ROV Camera Frame	2	Wolf Aircraft	\$ 250.00
9	48" x 3" x .0625" Epoxy Board	Electronics Tray	1	Polymer Plastics Corp.	\$ 67.49
10	24" x 24" x .375" HDPE Board	ROV Skids	1	Industrial Plastics Supply	\$ 41.40
11	.25" x 9" x 15" HDPE Cutting Boards	Electronics Tray Bulkheads	2	Walmart	\$ 15.98
12	.062" x L.50" x L.50" Aluminum Angle	Electronics Tray Connectors	72"	Home Depot	\$ 3.56
13	MCBHM3/15F	Bulkhead Fitting	1	Seacon	\$ 252.28
14	MCILM3/15M	Male Pie Wedge In-line Fitting	5	Seacon	\$ 163.25
15	MCDCM3/15M	In-line Fitting	1	Seacon	\$ 26.82
16	BH6FS	Male In-line Whip	1	Seacon	\$ 75.00
17	IL6MP	Male In-line Whip	1	Seacon	\$ 40.81
19	BH10FSX	Male In-line Whip	1	Seacon	\$ 102.57
20	IL10MPX	Male In-line Whip	1	Seacon	\$ 67.00



PETSUCHOS II
FLOWER MOUND ROBOTICS

Expense Item	Part Description	Usage	Quantity	Vendor	Expense
21	FAWM8PMP0061/ FAWM8SBC3/4	Male Link Whip	1	Seacon	\$ 180.20
22	AWQ	Bulkhead Fitting	1	Seacon	\$ 42.50
23	FAWM8SBC3/4	90 Degree Bulkhead Fitting	2	Seacon	\$ 281.60
24	BH4F	Bulkhead Fitting	2	Subconn	\$ 153.80
25	MCBH2F	Bulkhead Fitting	1	Subconn	\$ 48.60
26	Dimension Engineering SyRen 25	Motor Control For Seabotix Thrusters	1	Dimension Engineering	\$ 85.20
27	Dimension Engineering Sabertooth 2 x 25	Motor Control For Seabotix Thrusters	2	Dimension Engineering	\$ 55.98
28	4V110-1/8-G	5 Way Air Valve	1	Sizto Tech	\$ 56.75
29	Double Action Air Cylinder	Claw Actuator	2	Clippard	\$ 50.82
30	22 GA Strand Wire	Data Wiring Between Surface and ROV	100 Ft.	Jameco	\$ 4.65
31	20 GA Strand Wire	Miscellaneous Wiring	100 Ft.	Jameco	\$ 7.69
32	18 GA Strand Wire	Motor Wiring	100 Ft.	Jameco	\$ 9.65
33	14" Servo Extension	Motor Controller/Co-Processor Data Wiring	4	Parallax, Inc.	\$ 5.16
34	6 Pole Double Row Terminal Blocks	Wiring Terminals	2	Radio Shack	\$ 5.17
35	8 Pole Double Row Terminal Blocks	Wiring Terminals	2	Radio Shack	\$ 5.39
36	Pelican 1470 Black Case	Control Box	1	Pelican	\$ 121.75
37	Eye Connectors 16-22 GA	Wiring Connectors	100	Radio Shack	\$ 12.40
38	1.25 O.D. x 0.058 Aluminum 6061 Tubing	Claw Housing	6 ft.	Metal Supermarkets	\$ 51.01
39	1.125 Dia. x 12" Delrin Rod	Claw Bushing	6 ft.	Interstate Plastics	\$ 135.47
40	Miscellaneous Stainless Steel Hardware(screws, washers, nuts)	Frame, Claw and Thruster Connections	-	Ace Hardware	\$ 30.00



Expense Item	Part Description	Usage	Quantity	Vendor	Expense
41	PQM-EU05	Air Tee Union	2	Clippard Instruments	\$ 7.89
42	PQM-CC05P	Air Male Connector	5	Clippard Instruments	\$ 17.50
43	PQM-SU05	Air Strait Union	1	Clippard Instruments	\$ 3.95
44	PQM-CC05N	Air Male Connector	11	Clippard Instruments	\$ 38.50
45	MQC-3S	Air Bulkhead Fitting	7	Clippard Instruments	\$ 39.97
46	PQ-YU05	Air Y-Union	1	Clippard Instruments	\$ 5.42
47	15004 Fitting	Female Hex Coupling From Air Cylinder	2	Clippard Instruments	\$ 3.89
48	15010 Fitting	Air Cylinder Inlet/Exit Extension	2	Clippard Instruments	\$ 4.58
49	Seabotix BDT150 Thrusters	Directional Control Thrusters	1	Seabotix, Inc.	\$ 410.00
Total Cost					\$ 4,404.71

New Part Expenses

Expense Item	Part Description	Usage	Quantity	Vendor	Expense
1	12" x 3" x .250" Aluminum Plate 2024	Claw Parts	1	McMaster Carr	\$ 29.50
2	Aluminum Rear End-caps	Acrylic Tube Closures	2	Heritage Machine	\$ 200.00
3	48" x 3" x .09375 Epoxy Board	Electronics Tray	1	Polymer Plastics Corp.	\$ 71.35
4	MCBH3F	Bulkhead Fitting	2	Seacon	\$100.24
5	MCIL3M	In-line Fitting	2	Seacon	\$ 52.56
6	MCIL3M/MCIL3/15M	Single Whip W/ Two Connectors	2	Seacon	\$157.66
7	FAWL-3S-BC-R/A	In-Line Fitting	1	Seacon	\$ 90.40
8	FAWL-3P-MP/MCIL3/15M	Single Whip W/ Two Connectors	1	Seacon	\$ 114.65
9	Tether Modification	Tether/Umbilical Power/Signal	1	Storm Cable	\$ 397.42



Expense Item	Part Description	Usage	Quantity	Vendor	Expense
10	MCIL3M	Thruster Whip Modification	1	Storm Cable	\$ 251.93
11	Machining	Claw Part	2	Heritage Machine	\$ 275.00
12	Machining/Material	Camera Back Plate	4	Heritage Machine	\$ 175.00
13	60" x 3.25" O.D. x .125 Polycarbonate Tube	Buoyancy Tubes/ Electronic Modules	2	American Plastics Online	\$ 117.13
Total Cost					\$ 2,032.84

Donations

Donation Item	Part Description	Usage	Quantity	Donor	Expense
1	VA-E Converter	DC/DC Converter	1	Vicor Corp.	\$ 600.00
2	Main Frame	ROV Frame	1	Stratasys, Inc.	\$ 3,300.00
3	SPD-22548 Cable	Tether	75 Ft.	The Core Group	\$ 1,135.47
Total Cost					\$ 5,035.47

Travel Expenses

Travel Item	Description	Expense
1	Airfare for Three Team Members and Two Mentors	\$ 1,400.00
2	Hotel for Five Nights	\$ 900.00
3	Car Rental and Gas	\$ 450.00
4	Meals for Five Members/Five days	\$ 750.00
Total Cost		\$3,500.00

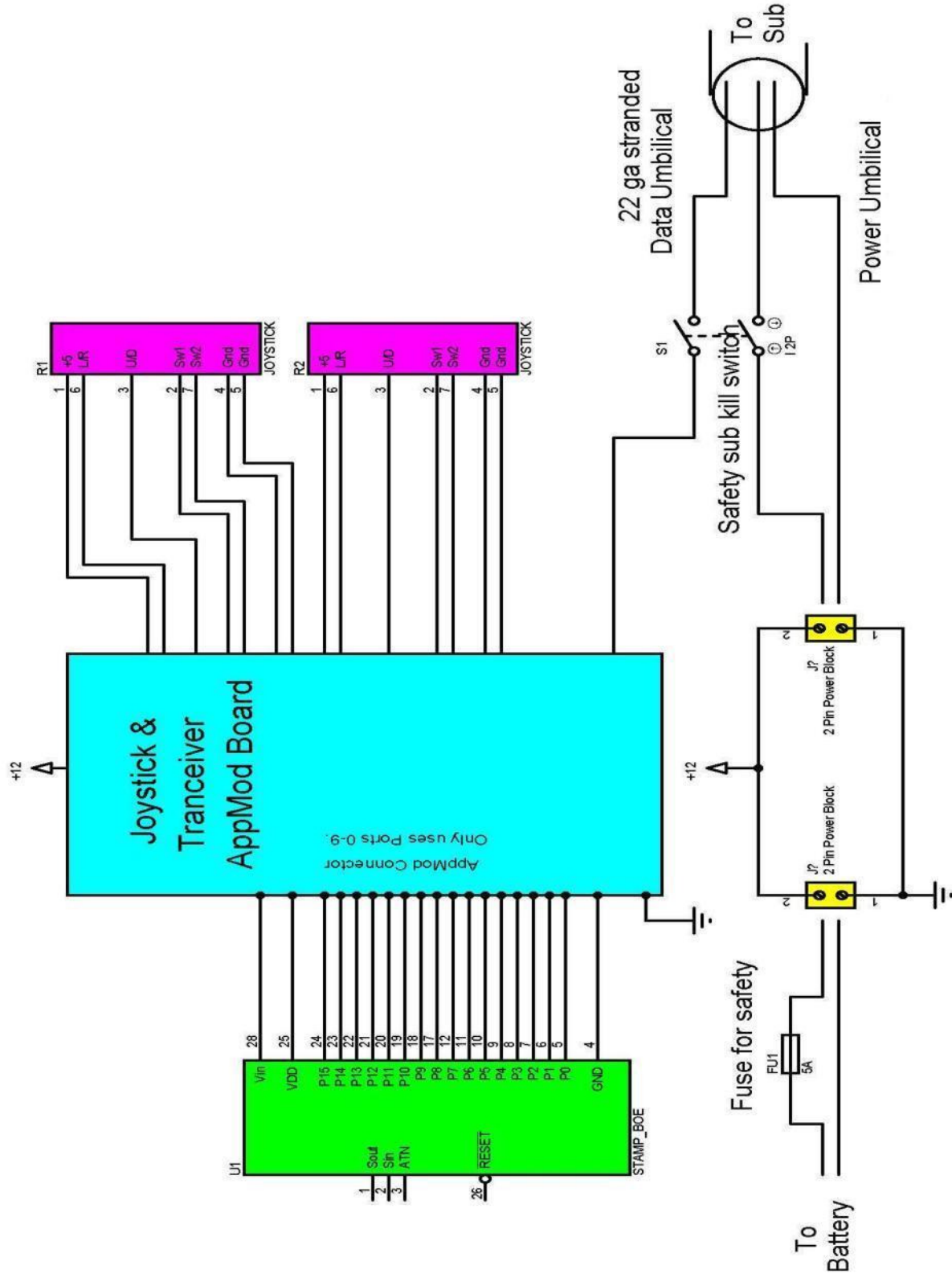


Total Expenses

Item	Description	Expense
1	Reused Part Expense Total	\$ 4,404.71
2	New Part Expense Total	\$ 2,032.84
3	Donation Total	\$ 5,035.47
4	Travel Expense Total	\$ 3,500.00
Total Cost		\$ 14,973.02



Appendix B: Surface Control System Schematic





Appendix C: ROV Control System Schematic

