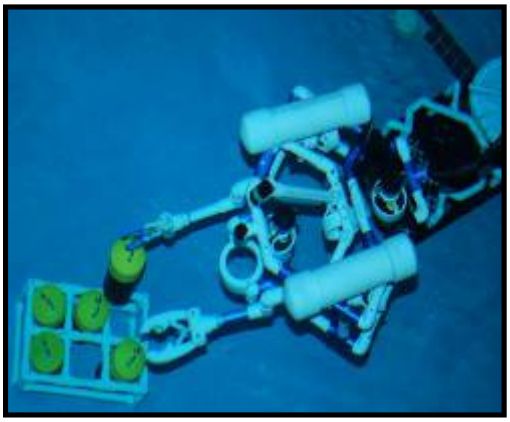
ROV Calli Ray

ROVs: The Next Generation of Submarine Rescue Vehicles
2009 MATE ROV International Competition
Massachusetts Maritime Academy, Buzzards Bay, MA

Technical Report
Ranger Class

First Flight High School
Kill Devil Hills, NC



Mid-Atlantic Regional Champs

FFHS ROV, Team Nighthawk:
Rebecca Charalambous, Miles Thomas,
Jacke Vaughan, Patrick Gray,
Barry Lawler, Sean O'Neal,
Andrew Radtke, Charles Brady,
David Spruill
Mentors: Andrew Thomas & David Thomas

I. Team Nighthawk

(From Left): Sean O'Neal, David Spruill, Patrick Gray, Andrew Radtke, Barry Lawler, Miles Thomas, Charles Brady, (Seated) Rebecca Charalambous, Jacke Vaughan

Rebecca Charalambous: **Team Manager**. FFHS Senior. Rebecca is still undecided about where to attend college, but holds a Naval Reserve Officer Training Corps (NROTC) Scholarship. Her interests include biomedical engineering.

Miles Thomas: **Tether Man and Poolside Technician**. FFHS Senior. Miles plans on attending UNC-Charlotte for architecture and design. He enjoys mechanical and computer challenges.

Jacke Vaughan: **Navigator**. FFHS Senior. Plans on attending NC State University and wants to pursue environmental engineering.

Patrick Gray: **Airline Specialist and Poolside Technician**. FFHS Junior. Patrick is interested in aerospace engineering with hopes in attending Duke or Cornell.

Barry Lawler: **Team Captain.** FFHS Junior. Academic interests include engineering. Barry is hoping to attend UNC Chapel Hill or NC State.

Sean O'Neal: **Poolside Technician**. FFHS Junior. Sean would like to pursue a career in mechanical engineering and hopes to attend NC State.

Andrew Radtke: **ROV *Calli Ray* Chief Pilot**. FFHS Junior. Andrew is interested in pursuing a professional career in ROV piloting.

Charles Brady: **Navigator**. FFHS Sophomore. Charles is interested in biomedical engineering.

David Spruill: **Design and CAD Software Computer Specialist**. FFHS Sophomore. David is interested in physics and computer science.

II. Abstract

Team Nighthawk set out to build a Remotely Operated Vehicle (ROV) that could be adapted for use as a Remotely Operated Rescue Vehicle (RORV). Within the spirit of cost to performance, Calli Ray was built from locally available, off the shelf PVC connectors that could be machined in our workshop to fit the needs of the design. This year's competition is centered around using ROVs as rescue vehicles for trapped submariners. Team Nighthawks' key goal was to complete each task given by the competition committee with the highest efficiency, so as to simulate a rescue vehicle's expediency and importance where peoples' lives are at stake. To complete this goal Team Nighthawk focused on integrating features that would aid in rescue missions. Four video cameras were incorporated into the design with one positioned to survey and inspect the stranded submarine for damage, while the other three obtain the best view of the onboard tools. A mating skirt was incorporated into the structural design of Calli Ray to mimic an air tight hatch connection between the rescue vehicle and the disabled submarine. *Calli Ray's* two mechanical manipulators are multifunctional in order to open doors, hatches, and carry the Emergency Life Support System (ELSS) Transfer Pods which contain vital medical supplies, food, oxygen candles and CO_2 absorbent. More specifically, one of the hands is designed to carry the ventilation nozzle to the submarine at the specific angle of the insertion point, while still being able to open the hatches and carry ELSS pods. These design choices have led Team Nighthawk to develop an ROV that is cost conscious while producing results that are highly efficient and effective.

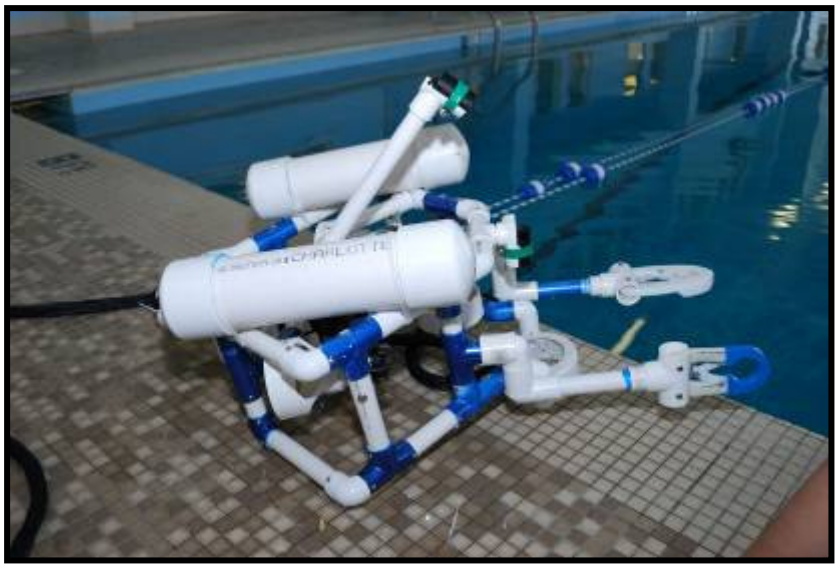


Figure 2.1

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Completed Photo of ROV *Calli Ray*

III. Discussion of a Submarine Rescue Organization

We have paralleled our ROV mission tasks with the rescues of the United States Navy Unmanned Vehicles Detachment (UMV) and other organizations using Super Scorpio ROVs. The UMV was organized in the 1970s to help with search and survey missions in shallow waters off American coasts. The program has since been expanded to a worldwide mission as part of the International Submarine Escape and Rescue Liaison Office (ISMERLO). The United States is one of several nations that participate in rescue training exercises associated with ISMERLO. The importance of ISMERLO was brought to the forefront of public attention when in August of 2000, the Russian submarine *Kursk* experienced an onboard explosion during training exercises. Norway and the United Kingdom offered to help the Russian Navy rescue 118 trapped submariners. Although the two were unable to help the 118 Russian sailors that perished in the ordeal, the expansion of a rescue network was well noted. The *Super Scorpio*, an extremely advanced ROV in the UMV lineup, weighs 2000 kilograms, has a forward speed of 4 knots, and is one of the main vehicles of the Detachment (as seen above). This ROV is similar to our own *Calli Ray* in that it has two manipulator arms and its purpose is the rescue of disabled submarines. The *Super Scorpio* also has a total lifting capacity of over 2000 Newtons and can reach a depth of 1500 meters. Comparably, our ROV has a total lifting capacity of 10 Newtons and a maximum depth of 30 meters. The *Super Scorpio* ROV has been essential in numerous rescue missions, one specifically, that relates to our mission's tasks was the rescue of the Russian *Priz* submarine. During a second Russian submarine accident in August 2005, ISMERLO was immediately notified and the world came to the aid of the trapped submarine. In this mission, the *Priz* was entangled in fishing cables and a *Super Scorpio* dove down and freed the sub, thereby saving the seven Russian sailors within 6 hours of their air supply running out. The United States and the United Kingdom both have their *Super Scorpio* ROVs on standby ready to be transported at a moments notice (see above).

Figure 3.1

<http://www.navsource.org/archives/08/0835305.jpg>

Figure 3.2

<http://www.navsource.org/archives/08/0835320.jpg>

IV. Design Rationale

IV.i Framework

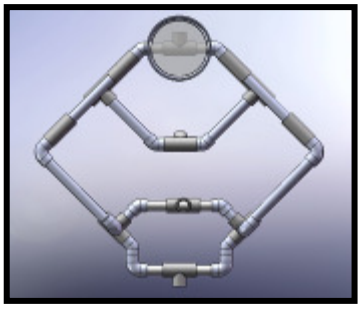


Figure 4.1

To stay within what we feel like is the spirit of the Ranger division, we used the most readily available and cheapest building material that we could find in our local hardware stores. Calli Ray's frame, a hexagonal prism, is constructed solely from 3/4" PVC and fittings. The shape mimics that of other agile sea creatures like rays and crabs. Our onboard tools, kort nozzles and camera mounts are also constructed from PVC fittings which allowed us to easily incorporate them into our frame. If we could not find the exact fitting we were looking for in the hardware store, we machined/altered a common fitting with the drill press or Dremel® tool to fit our needs.

IV.ii ROV Control System

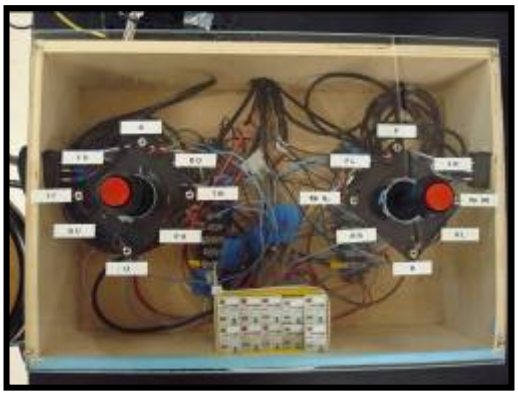


Figure 4.2

Calli Ray is controlled by two five function joy sticks wired through ten double pole double throw (DPDT) relays. Additionally, the two manipulator arms are operated with momentary rocker switches. The relays and rocker switches allow all of the DC motors to be reverse polarized so that the motors can run in opposite directions. The left joy stick controls all z-axis movements, while the right joy stick controls all x- and y-axis movements. On top of each joy stick, the "fire" button controls left and right strafe respectively.

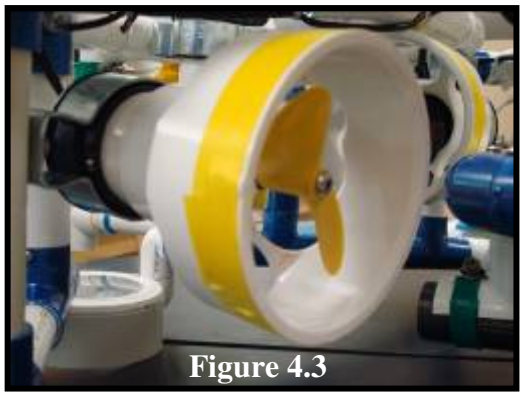


Figure 4.3

IV.iii Thruster Construction

Calli Ray has five thrusters. These were converted from 1000 gph bilge pump cartridges with the addition of 4.5 mm drive dogs, 4.5 mm prop adaptors, and 70 mm 1.4 pitch R/C boat propellers. The bilge pump cartridges have also been fitted with 1½" to 3" PVC reducers that were machined to act as kort nozzles. This configuration gives each of the thrusters 8 Newtons of thrust in the forward direction and 5 Newtons of thrust in the reverse direction.

IV.iv Thruster Configuration

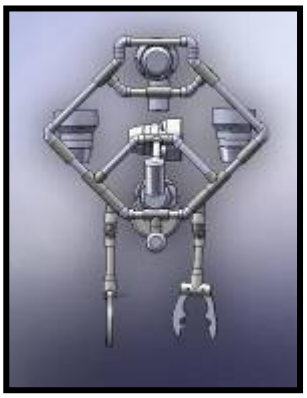


Figure 4.4

Calli Ray's shape allowed Team Nighthawk to place the two x/y thrusters farther apart on the x/y axis. By reversing the direction of opposing thrusters, Calli Ray can spin on this axis while remaining stationary in the forward/reverse and up/down directions. Two thrusters were also placed fore and aft in the downward direction. This accounts for movement in the z direction. These thrusters can also be reversed to oppose each other and control the ROVs pitch and yaw. By pointing the thrusters upward, ROV Calli Ray can take advantage of the extra thrust for lifting pods and opening the hatches. A fifth thruster is located in the center of the ROV to allow Calli Ray to strafe left and right. Again, the thruster has been pointed in the direction that allows the ROV to complete the task most efficiently.

IV.v Onboard Tools

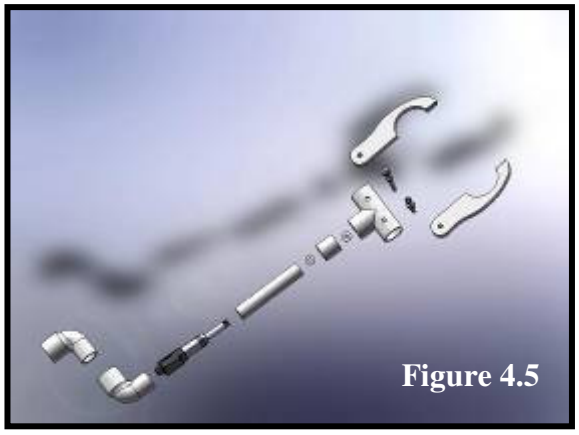


Figure 4.5

Two manipulator arms highlight Calli Rays onboard tools. The manipulators were manufactured in the team workshop by starting with a Firgelli Technologies mini linear actuator. The actuator has 100 mm of travel, a 210:1 gear ratio, and 150 Newtons of backdrive force. The hand will fully open and fully close in ten seconds. The linear actuator is waterproofed with double o-ring seals inside of PVC pipe and fittings. The fingers were cut from HDPE plastic (plastic cutting board) and attached to the actuator arm with plastic linkage and stainless steel nuts and bolts through a PVC "T". Each of the two hands has been designed to carry out several tasks. This includes opening hatch doors, carrying the air line, and movement of the ELSS pods.

IV.vi Mating Skirt

Our mating skirt was constructed from a 4" PVC end-cap where the top was removed and replaced by a plexi-glass cover. With the proper camera placement, the pilot is able to land directly on the escape hatch by looking through the glass top.

Figure 4.6

IV.vii Onboard Sensors

ROV Calli Ray currently has four cameras that are fed through the tether to a four channel color splitter so that all camera views are displayed on one monitor. The main drive camera is a Lights Camera Action (LCA) 7700 CW that is depth rated to 66 meters. This color camera has a 54° field of view in water and is mounted in the center of the ROV looking out through the mating skirt and manipulators. Directly above the mating skirt we have placed a Speco Technologies B/W Bullet Camera that is rated to 30 meters (see Figure 4.6). The camera looks directly through the plexi-glass top of the mating skirt. The tool camera (see Figure 4.7) is mounted on an extension above the ROV. This camera was an emergency replacement for a second Speco Technologies camera that leaked in less than three meters of water. The temporary replacement is a *Fish TV Plus*, rated to at least sixteen meters. The fourth camera on Calli Ray is a starboard view camera (see Figure 4.6, yellow camera). It is a Harbor Freight B/W camera with a 70° field of view with the ability to be at a depth of twenty meters. Its primary function is for observing damage to the submarine.

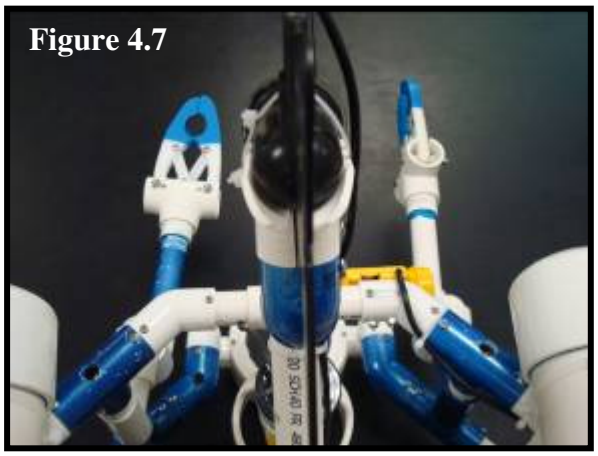


Figure 4.7

IV.viii Tether

Our tether consists of twenty-six conductors, fourteen of which are for the five thrusters and two manipulators, the remaining twelve are for the four cameras, with three small conductors in each camera cable. With a sixteen meter tether, we felt comfortable having twenty-six conductors because the power loss over this short distance is not significant. Also, having this many conductors allowed us to eliminate waterproofing all of our electronics onboard Calli Ray. All electrical connections below the water are made with waterproof butt connectors. The conductors are all bundled and wrapped with Velcro, side entry, expandable nylon sleeving.

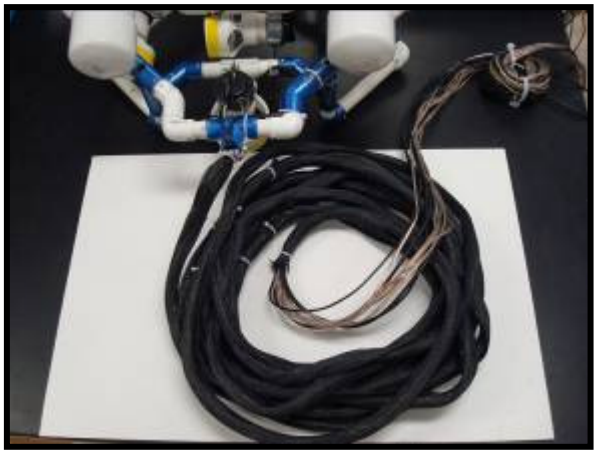


Figure 4.8

V. Description of at least one challenge

For the past two years our biggest challenge has been camera failure. At Regional's last year, the team spent three hours searching for a replacement camera the night before the competition. Then, during Internationals in San Diego, another camera blew out. Fortunately, Deep Sea Power and Light loaned us a camera. From day one this year, we knew that cameras would be an issue. We initially ordered two LCA-7700-CW cameras, unfortunately they were back ordered and we only received one. Even with this purchase, we found out that we were not immune to failure as the LCA-7700-CW failed during water trials. The camera was replaced two days before the regional competition. Again, this year, the same problem reappeared the night before the Regional competition. We were adjusting our cameras when our tool camera (a SPECO B/W Bullet Camera) went black. We disassembled the camera and found that water had leaked into the housing. As a temporary solution, we went to Bass Pro Shop and purchased a *Fish TV Plus* camera. We are continually seeking solutions to solve this major dilemma.

Another major obstacle was organizing meetings to work on the ROV. With many members of the team involved in other extracurricular activities, time management was very difficult. In order to overcome this, we developed a monthly calendar in which members were assigned certain days to work, with each day having a stated objective that needed to be achieved. Something that also helped us stay in contact with one another was our enrollment in the advanced placement physics class at First Flight High School; all but two of Team Nighthawk took this class. This time allowed for quick reminders to one another allowing our time we had with one another to be the most efficient and effective.

VI. Explanation of troubleshooting techniques

Throughout the building process, the design of ROV Calli Ray changed multiple times due to insight and a clearer understanding of the mission tasks. After we saw the props, we realized that the scale of our ROV did not match the scale of the submarine. We were able to save all of our PVC fittings and cut the ¾" pipe by a scale of ½. Troubleshooting in this instance was simple as trial and error. Further design flaws surfaced as a result of observations during water trials and construction of ROV components. After building our first waterproofed manipulator, it failed during water trials. To diagnose the source of failure we dissected the manipulator and its waterproof housing with a Dremel® Tool cutting blade. Through this process we were able to determine that it was a mechanical problem with the linear actuator and not a waterproofing issue. As a team we were able to take input from all members and brainstorm for the best solution.

VII. Lessons Learned and Skills Gained

During the design process every team member learned skills and lessons applicable to future careers and life. In order to make the ROV before the deadline, everyone had to come together as a team, working effectively and efficiently. FFHS ROV team learned that working in unison is much more effective than trying to solve problems on our own. We approached all problems as a team and collaborated, yielding a broad range of solutions, then chose the most effective one. These skills can easily be transferred to all areas of life, making a more effective person.

Few of the members knew how to wire anything before participating in the ROV team. Through the building process, everyone learned how wiring works and gained a technique useful for many careers. Often, parts used in building ROV *Calli Ray* did not fit exactly or needed to be modified. To solve this, Team Nighthawk learned how to use various tools to machine the parts to fit their need. This is demonstrated though our modification of the kort nozzles. To machine our kort nozzles, we used a drill press with a hole saw bit to modify 1 ½" to 3" PVC couplers to those we had seen on full sized ROVs.

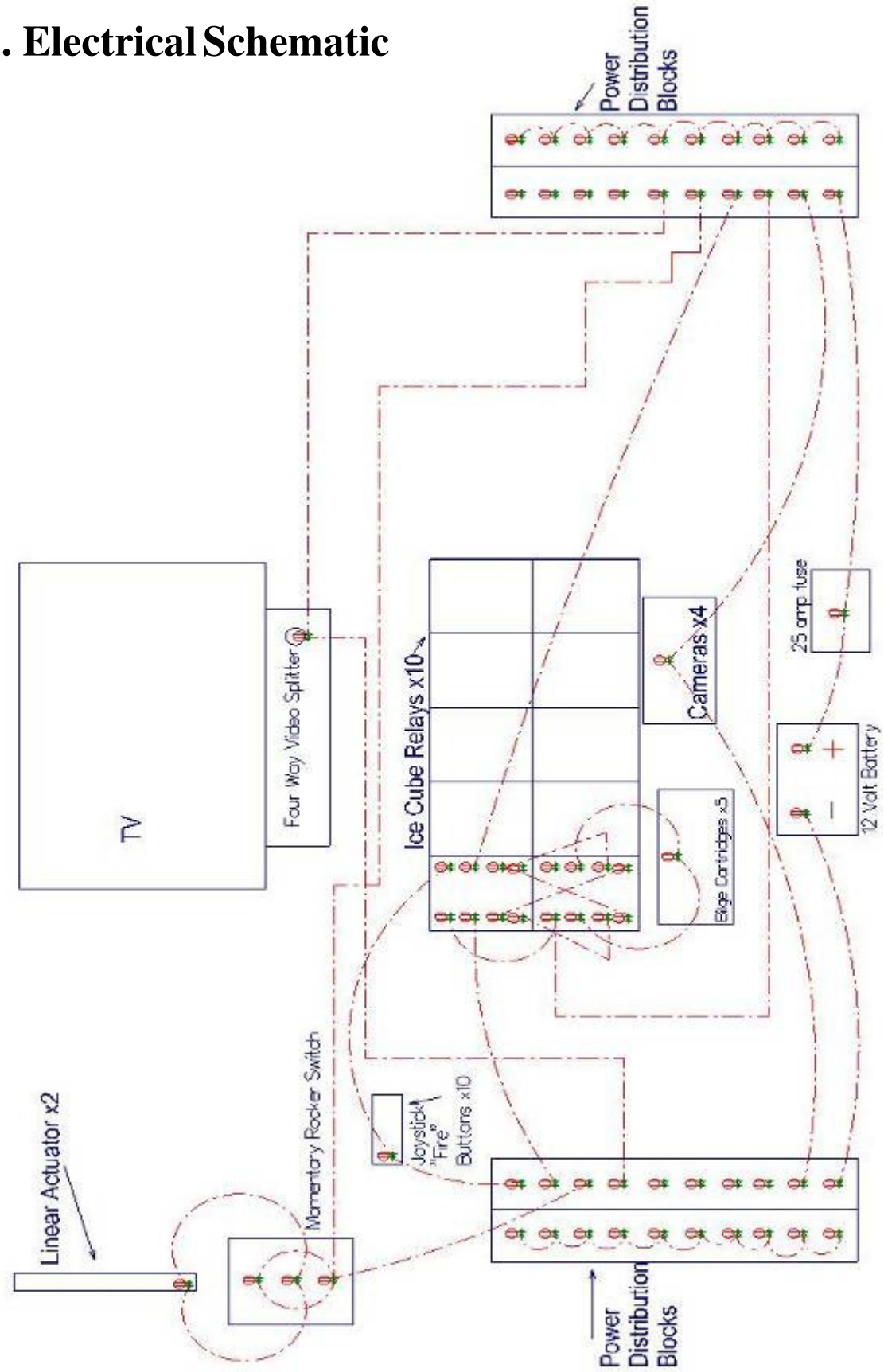
VIII. Discussion of future improvements

Even with a first place finish in the Mid-Atlantic Regional ROV Building Competition, there is room for improvement. In preparation for Internationals, we plan on water proofing our own cameras instead of using commercially sealed cameras to insure their quality. The cameras will be waterproofed by using PVC unions and 32mm, color, board cameras. PVC unions already have a build in o-ring. Epoxy and silicon will be used as a sealant to prevent the entry of any water into the camera housing through the wire connection. Therefore, not only will the quality of waterproofing be insured, as it will be our own manufacturing, we intend on increasing our field of view by ordering wide angle cameras to put in our housings.


Figure 8.1

A second design change involves incorporating a motor to turn the hatch. Our current plan is to use a 12V DC motor that has been attached to the rear of *Calli Ray*. One of our new cameras will be positioned so that a modified 4" PVC end cap attached vertically to the motor can be seen as the device approaches the hatch. The end cap will be lowered over the hatch wheel, and the DC motor can be turned on to unlock the hatch.

IX. Electrical Schematic



X. Budget/Expense Sheet

Description	Electrical	Hardware	PVC	Thrusters	Sensors	Misc.
2/1 electrical	$69.93					
2/1 props				$15.89		
2/1 drive dogs				$16.74		
2/1 prop adaptors				$23.64		
2/1 Harbour freight b/w camera					$119.99	
2/1 Speco b/w camera					$124.98	
2/23 LCA 7700 CW					$277.33	
2/24 linear actuators	$129.20					
2/25 PVC fittings			$12.54			
2/27 hardware		$7.03				
2/28 tools						$18.39
2/28 hardware		$33.85				
3/2 bilge pumps				$145.78		
3/2 electrical	$274.62					
3/6 electrical	$21.14					
3/10 PVC fittings			$6.74			
3/11 PVC fittings			$2.77			
3/12 PVC glue			$5.79			
3/12 PVC fittings			$3.58			
3/12 cutting board						$24.86
3/14 PVC fittings			$5.07			
3/21 hardware		$3.86				
3/22 paint						$16.98
3/22 silicon						$6.49
3/22 electrical	$6.58					
3/24 PVC fittings			$24.32			
3/31 PVC fittings			$1.98			
3/31 joy-sticks	$43.70					
4/1 PVC fittings			$3.58			
4/1 paint						$8.49
4/1 PVC fittings			$22.14			
4/2 PVC fittings			$35.86			
4/5 tarp						$18.99
4/6 color quad splitter	$59.99					
4/6 BONAR box plug						$10.25
4/7 electrical	$9.12					
4/7 PVC fittings			$6.08			
4/7 hardware		$6.60				
4/8 DPDT relays		$16.98				
4/8 linear actuators	$144.49					
4/10 joy-sticks	$89.16					
4/11 hardware		$0.36				$104.45
4/12 hardware		$21.03				
4/13 hardware		$0.72				
4/13 PVC fittings			$7.56			
4/14 hardware		$8.52				
4/14 relays	$68.05					

Description	Electrical	Hardware	PVC	Thrusters	Sensors	Misc.
4/15 shrink wrap		$67.05				
4/16 TV	$336.93					
4/17 hardware		$4.84				
4/17 plexi-glass						$17.34
4/17 tools						$10.99
4/17 hardware		$2.16				
4/18 hardware		$13.03				
4/18 hardware		$0.67				
4/18 tools						$32.01
4/22 PVC fittings			$4.37			
4/22 tools						$3.79
4/23 electrical	$16.97					
4/25 hardware		$1.58				
4/26 hardware		$9.34				
4/29 office supplies						$68.59
4/30 hardware		$24.30				
5/1 hardware		$2.57				
5/1 FOOD						$239.07
5/1 camera	$148.65					
5/1 Hotel						$267.81
5/2 office supplies						$25.05
5/2 office supplies						$7.29
5/15 Newspapers						$2.50
5/19 office supplies						$19.20
5/22 PVC fittings			$14.60			
5/24 FOOD						$56.46
Category Totals:	$1,418.53	$224.49	$156.98	$202.05	$522.30	$959.00
Cost to reproduce vehicle and controls						$1,900.64
Research and development cost						$764.04
Total of Reused Parts						$371.17
Hotels, Food, Printing						$447.15
Total Expenditures						**$3,483.35**

*red color denotes reused parts from 2007-2008

Donation/Fundraiser	Amount
Cheesecake Fundraiser	$1,254.00
Martha Hamed	$300.00
Dowdy and Osbourne	$300.00
Dare County Schools Tech Ed. Program	$512.00
Monica Thibodeau	$200.00
DCS	$2,500.00
OB Chamber of Commerce	$1,000.00
First Flight Rotary	$500.00
Total Reciepts	$6,566.00
Total Expenditures os of 5/27/09	-$3,111.83
Remaining Balance as of 5/27/09	$3,454.17

XI. Reflections on the experience

Patrick Gray: The ROV team was an incredible learning experience. With little electrical or engineering knowledge to begin with, the building process helped me become familiar with the tools needed to bring a pile of PVC, a few cameras, and some cutting board material into a functioning ROV able to complete the missions. During the time spent with the ROV team I have learned some terms and language that engineers and designers use which will no doubt help me in future engineering endeavors. Overall the ROV Competition was an enjoyable and educational journey through the depths of ignorance and into the heights of knowledge.

Jacke Vaughan: I found this experience very worth while. I had never built anything as complex or worked on a project that required this amount of time and effort. I am a cheerleader so my usual meetings were comprised of yelling and/or gossiping. This club was beyond anything I have ever done before. During the time I spent working with the ROV team I gained basic engineering skills which I'm sure will be applicable in my future at North Carolina State University.

Sean O'Neal: For me, being a member of this year's ROV team was a very beneficial experience. I was attracted to the team through my prior interests in engineering. Besides being a learning experience, the ROV team was very enjoyable. Through designing and building the Calli Ray I learned numerous engineering terms and techniques that I'll be sure to carry on with me as a seek to pursue a future career in engineering.

Charles Brady: Being a member of the ROV team has been a great experience for me. The best part for me was being able to apply what I learned in my AP Physics class to what I was doing in ROV. I learned things from how motors work, to how to wire relay switches for joysticks, and it actually made sense. Also, I will be able to take the engineering skills and techniques that I have gained from the ROV program with me for the rest of my life. Throughout this ROV season I have also realized that it is important to have spare parts or good improvisation because things don't always go as planned.

Rebecca Charalambous: Until this year, my understanding of engineering was limited to that of a civil engineer; however, after this year my mind as been opened to a whole world of engineering possibilities. At the beginning of this school year I enrolled in an advanced placement physics class. Through this class I was exposed to the Remotely Operated Vehicle Club and between the two, my appreciation of applied sciences has been expanded. I had no experience in wiring before building the ROV and now I feel confident in cross polarization. I had never fully understood the extent of what we as a club could do when we put our heads together. I am proud to say that I have taken part in the construction of Calli Ray and because of this experience I know that I want to continue this creative building in my future. My only regret is that I attended First Flight High School before my senior year because then I would have been able to enjoy this experience another year.

Andrew Radtke: This is my second year being a member of the First Flight High School ROV Team as well as my second year piloting the machine. I enjoy learning new things everyday, and this year one my most valuable experiences was learning from a fellow teammate how to properly wire the control box. I am glad that I chose to join the ROV team two years ago as it has given me numerous experiences I feel I might have otherwise missed out on. Last year I was interested in pursuing a career in the field of Remotely Operated Vehicles, and this year I am very interested in learning more about the growing field of Oceanography. I am extremely grateful to have been afforded all the opportunities that have been presented due to the ROV team.

Barry Lawler: I gained a lot of knowledge and experience participating in this year's ROV team. Before joining the team, I knew little or nothing about wiring and electronics. Through the building process, I learned many useful techniques for wiring and for general engineering. Also, I became familiar with various tools and how to use them effectively to make work easier and more efficient. This experience was interesting to me because I finally got a chance to apply information learned in school and AP Physics. Being a junior, I look forward to continue building on my knowledge next year, giving me a stronger foundation for college and a future career.

Miles Thomas: Returning for my second year with the First Flight ROV Team I felt that I brought a lot of knowledge from last year's competition to the new team. I was able to give my new teammates insight into what things just didn't work last year and provide them with ideas for how we could rework the ROV to better suit the mission tasks this year. The ROV was a great preparation tool for college in that it gave me the chance to work as a group and share my own ideas and receive constructive criticism, as well as listening to others and giving them feedback in return. ROV also bestowed in me substantial knowledge about the Marine Industry and got me interested in a variety of job opportunities in the field of Oceanography.

David Spruill: I've always been interested in engineering and robotics. This year being a member of the ROV team was a valuable experience. I learned a lot about more advanced electronics, such as relays. Throughout this team experience I have been able to incorporate what I learned in my AP Physics class into this project. I think that the best part for me was working together with several other people and ending up with something successful. The whole ROV experience has taught me mainly to be careful to with all important parts and to get plenty of extras because you will make mistakes.

XII. References

Mohl, Michael. *NavSource.org*. Web.29 Apr 2009.

<http://www.navsource.org/archives/08/0835320.jpg>.

Mohl, Michael. *NavSource.org*. Web.29 Apr 2009.

<http://www.navsource.org/archives/08/0835305.jpg>.

Thone, Steve. "Homebuilt ROVs." *Homebuilt ROVs*. 12 April 2009

<http://www.homebuiltrovs.com/>.

"International Submarine Escape and Rescue Liaison Office ." *Submarine Search and Rescue*. 14 May 2009. ISMERLO. 27 May 2009 <http://www.ismerlo.org/>.

XIII. Acknowledgements

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