

# FFHS ROV Team Technical Report

Completed photo of ROV *Romvy* (Photo: J. McCord)

Barry Lawler: Pilot, Team Captain; Senior, UNC Chapel Hill, Fall 2010

Patrick Gray: Accountant, Navigator; Senior, UNC Chapel Hill, Fall 2010

Sean O'Neal: Design Specialist, Poolside Technician; Senior, NC State, Fall 2010

David Spruill: Computer Specialist; Junior, Class of 2011

Charles Brady: Safety Officer, Poolside Technician; Junior, Class of 2011

Chris Brennan: Construction, Navigator; Sophomore, Class of 2012

Andrew Thomas: Mentor; Physics and Oceanography Instructor

From left to right: Spruill, Brady, Brennan, Gray,  
Lawler, Thomas, O'Neal (Photo: McCord)



**“We hail from Kill Devil Hills, North Carolina, the location of Orville and Wilbur Wrights’ first historic flight. They took the world to new heights; we are taking our talent to new depths.”**



## Abstract

The First Flight High School ROV team returns for our third year at the 2010 International MATE Remotely Operated Vehicle (ROV) competition in Hilo, Hawaii with ROV *Romvy* (My ROV scrambled), by winning the Mid-Atlantic Regional for our third consecutive year. This year, our challenge involves restoring communication with the Hawaii Undersea Geological Observatory (HUGO), and while on the site at Loihi, collecting samples of bacterial mats and crustaceans, gathering data for seismic activity, and the temperature profile of a volcanic vent. This year's ROV has a frame made from low-density polyethylene (LDPE), which we machined ourselves into the shape we have today. Our ROV is 56.5 cm wide by 46 cm tall by 56.5 cm long. Our main focus was to keep the machine compact, while allowing the maximum workspace within the ROV. This allows the ROV to fit into small places, like caves, while still being able to collect samples and store them onboard in the sample net. The ROV has one multi-functional gripper, five thrusters, and four cameras; these aspects maximize functionality, thrust, and angles of viewing. An agar collector is attachable to the frame for maximum stability while collecting samples. These features allow the pilot to do his job with minimum interference and maximum awareness. Throughout the design and build process, the team logged over a thousand hours and learned a lot about what to do and what not to do while building an ROV.

## Table of Contents

<b>Abstract .....</b>	<b>2</b>
<b>Design Rationale – Task Integration.....</b>	<b>3</b>
Task 1: Resurrecting HUGO .....	3
Task 2: Collecting a New Species of Crustacean .....	4
Task 3: Sampling a New Vent Site .....	4
Task 4: Sampling a Bacterial Mat .....	4
<b>Design Rationale – ROV Components ....</b>	<b>5</b>
Frame .....	5
Thrusters .....	5
Manipulator.....	6
Sensors.....	6
Cameras.....	7
On-Board Electronics .....	8
Tether .....	8
Surface Controls .....	8
Safety and Design Considerations.....	8
<b>Software Flow Chart.....</b>	<b>10</b>
<b>Exploring Loihi.....</b>	<b>11</b>
<b>Troubleshooting Techniques.....</b>	<b>12</b>
<b>Challenges .....</b>	<b>12</b>
<b>Balance Sheet .....</b>	<b>13</b>
<b>Future Improvements.....</b>	<b>14</b>
<b>Lessons Learned .....</b>	<b>14</b>
<b>Reflections.....</b>	<b>15</b>
Sean O'Neal.....	15
Patrick Gray .....	15
<b>References .....</b>	<b>16</b>
Loihi Seamount Resources .....	16
Construction Resources .....	16
<b>Acknowledgements .....</b>	<b>17</b>



## **Design Rationale – Task Integration**

With the MATE ROV competition this year focusing on restoring HUGO and gathering scientific data off the South Coast of Hawaii, the team wanted to create a sleek, multi-functional, efficient work class ROV (see Figure 1), that can easily achieve all of the tasks. However, it is not limited to these challenges and can be applied to a wider range of traditional ROV tasks.

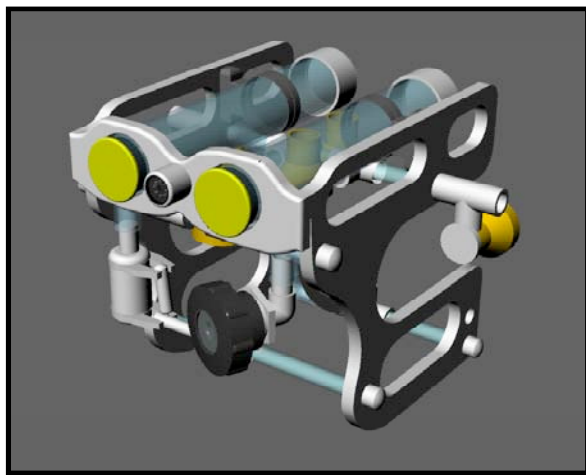


Figure 1: Computer Rendering of Romvy (Model: Spruill)

### ***Task 1: Resurrecting HUGO***

The first mission that the ROV will perform involves determining the location of “seismic activity.” After locating the specific area, the ROV must navigate to an underwater elevator and remove a pin

holding the replacement high rate hydrophone (HRH) to the elevator platform. After bringing the HRH to the region of seismic activity (see Figure 2), the ROV

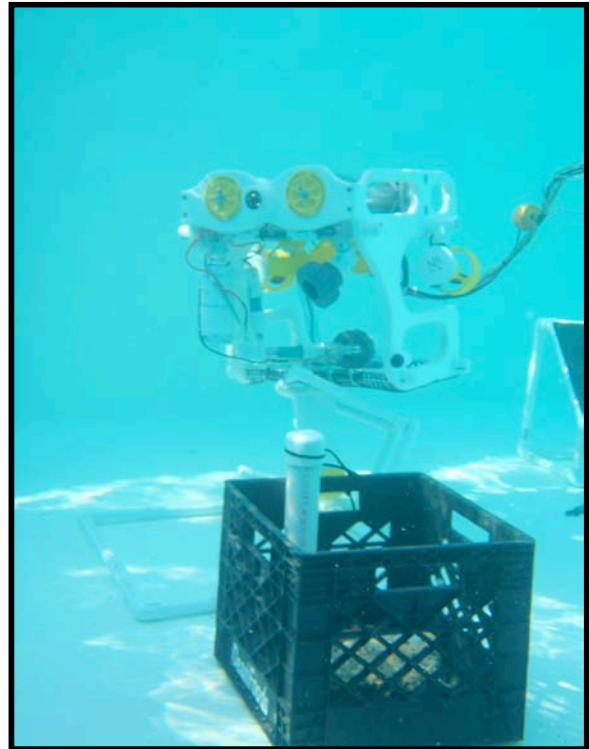


Figure 2: Romvy moving the HRH and locating the seismic activity. (Photo: Lawler)

must remove the cap (see Figure 3) from the HUGO junction box, and insert the HRH power and communications connector. To accomplish this task, the ROV employs an onboard hydrophone and topside software, written by our team computer specialist, to analyze sound and isolate the seismic

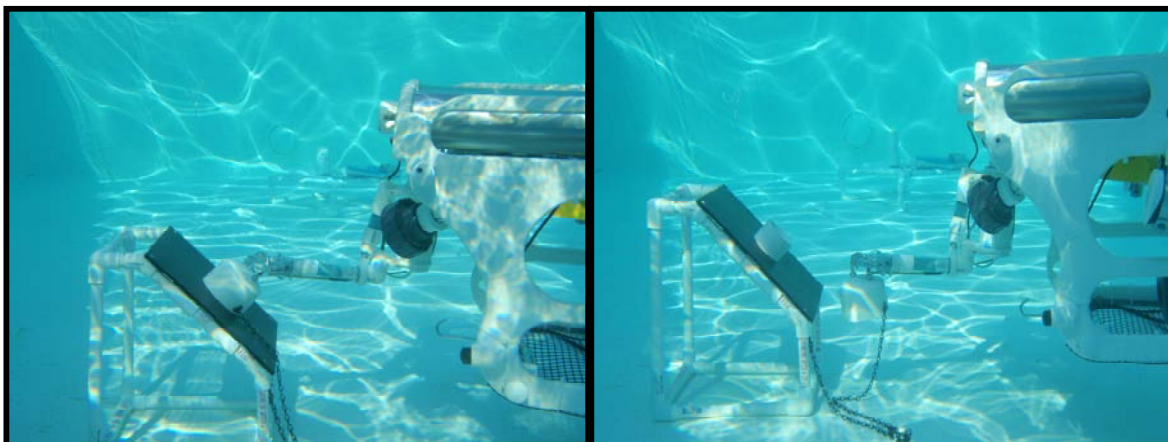


Figure 3: Romvy removing the junction box cap. (Photo: Lawler)

## FFHS ROV TEAM

### TEAM NIGHTHAWK – ROV *Romvy*

frequency and determine the location of the seismic activity. The multifunctional manipulator and a hook serve as onboard tools to remove the elevator pin, lift the HRH, take off the junction box cap, and insert the power and communications connector.

#### ***Task 2: Collecting a New Species of Crustacean***

Our second task requires that we collect three samples of a crustacean species from either a cave wall or floor. For maneuvering into and out of the cave, we have multiple camera views that monitor our position in relation to the cave walls along with a reverse camera. The aluminum fingers of the manipulator are designed to grip into the body of the crustaceans (see Figure 4) and not lose hold while

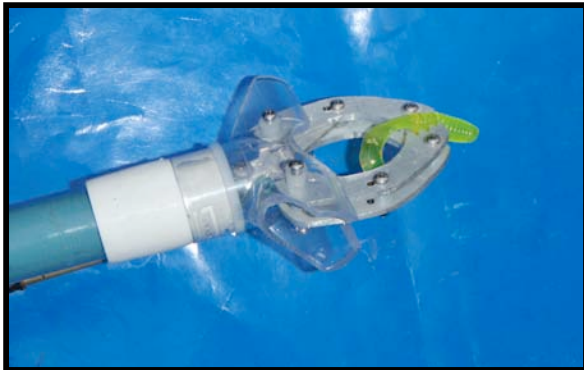


Figure 4: The manipulator gripping the crustacean species. (Photo: Lawler)

transferring them into the sample net. The hand can move horizontally and vertically, increasing manipulative capabilities, thus making it easier for the pilot to collect crustaceans. Our onboard sample net is porous, allowing the crustacean to stay inside without slipping through, while minimizing water resistance.

#### ***Task 3: Sampling a New Vent Site***

For this task we found a way to measure the temperature of vent fluid at multiple heights along a spire and make a

graph of the temperature versus position. We also collected a sample of a spire from the bottom of the vent. To accomplish these challenges we have placed our thermometer on the manipulator where it can be maneuvered and seen clearly by our cameras. Due to the versatility of our hand, we can easily complete this portion of the task quickly and efficiently. To collect the sample from the spire, we use our multifunctional hand with its precise gripping capabilities.

#### ***Task 4: Sampling a Bacterial Mat***

This task requires collection of 101 – 175 mL of a bacterial substance from the ocean floor. To accomplish this, we placed a 2 cm segment of 1¼" clear PVC into an 19 cm section of 1½" clear PVC and shaped the end to be sharp and serrated. The insertion of the 1¼" PVC section creates a ledge for the agar to sit on, while the pointed tip overcomes the forces of surface tension. On the clear 1½" PVC we made two marks, visible from our cameras, that show the minimum and maximum amount of agar required for full points. (see Figure 5)



Figure 5: Agar collection. (Photo: Lawler)



## **Design Rationale – ROV Components**

In designing the components of our ROV, we focused on making or machining parts on our own whenever possible. Our machine was designed to be multi-functional while staying simple enough to be used effectively.

### ***Frame***

Our frame this year is the result of early discussions where we decided to use a material that was positively buoyant in water, cost efficient, and easy to fabricate for use as the exterior walls of our frame. After researching our options we decided to use Low Density Polyethylene (LDPE). With a density of  $0.6 \text{ g/cm}^3$ , LDPE is positively buoyant. As we began drawing up the frame design we emphasized the importance of keeping the majority of functioning parts within the interior of the ROV. This not only aids in safety, but also reduces the overall size of our machine. The interior structure of our ROV is constructed with  $\frac{3}{4}$ " clear PVC pipe. We chose to use a clear PVC pipe so that we can see all wiring inside the pipes; this way, should we have a problem, we can easily locate where any repair is needed. Once we had the basis of our frame structure we made a template out



Figure 6: Cutting the template for our framework out of MDF. (Photo: Thomas)

of Medium Density Fiberboard (MDF) (see Figure 6). The two vertical frame components are held together by horizontal sections of clear  $\frac{3}{4}$ " PVC. Additional sections of the template were later removed to add peripheral views for our cameras and provide handles for safely deploying and removing the ROV from the water. To transfer the template from the MDF to the LDPE we used a router to create a precise copy (see Figure 7).



Figure 7: Using the router to transfer the frame template to LDPE. (Photo: Brennan)

### ***Thrusters***

This year, the goal with our thrusters was to maximize the force, so we switched from a 3780 liters per minute to a 4536 liters per minute bilge pump cartridge, increasing our forward thrust from 8N to 11N. We tested several propellers of varying diameter and pitch. We found that a dual blade, 70 mm, 1.4 pitch propeller provided us with the most thrust. The housings are similar to those of last year, machined from 3" to  $1\frac{1}{2}$ " PVC reducers into kort nozzles. The housings have multiple purposes: preventing prop wash and directing thrust, while adding safety. The housings are painted yellow to show there is a hazard and prevent injuries. The thrusters are mounted to the ROV PVC framework with  $1\frac{1}{2}$ " conduit hangers.

## Manipulator

Our manipulator configuration consists of two linear actuators and one 12V DC gear motor. The linear actuators are housed in  $\frac{3}{4}$ " clear PVC pipe and enclosed with rubber grommets, PVC bushings, and PVC end caps. We packed the moving parts and the shafts in marine grease to prevent water intrusion. The linear actuators control vertical movement and opening and closing of the fingers. The fingers are cut from aluminum stock, maximizing durability and precision, while minimizing weight and bulk. The 287-RPM gear motor is also housed in PVC fittings and has epoxy on the wired end with grease-packed rubber grommets on the end with moving parts. This motor provides the manipulator with horizontal movement, allowing the gripper to deposit crustaceans into the sample net.

## Sensors

Two onboard sensors were integrated into the design, including a thermistor, located on the bottom of the manipulator, and an Aquarian Audio hydrophone, located on the front left bottom of the frame. The thermistor was located on the manipulator in order to have increased maneuverability so as to place it directly in the vent fluid flow. The thermistor cable runs to the surface along our tether to a Vernier Lab Pro and Logger Pro software data analyzer (see Figure 8). The hydrophone is located on the bottom of the machine to distance it as much as possible from sources of interference within our ROV. The hydrophone cable also runs along the tether and is plugged into the microphone jack of our laptop. We wrote software to analyze and isolate the specific frequency being emitted by the piezo buzzers (see Figure 9 on following page).

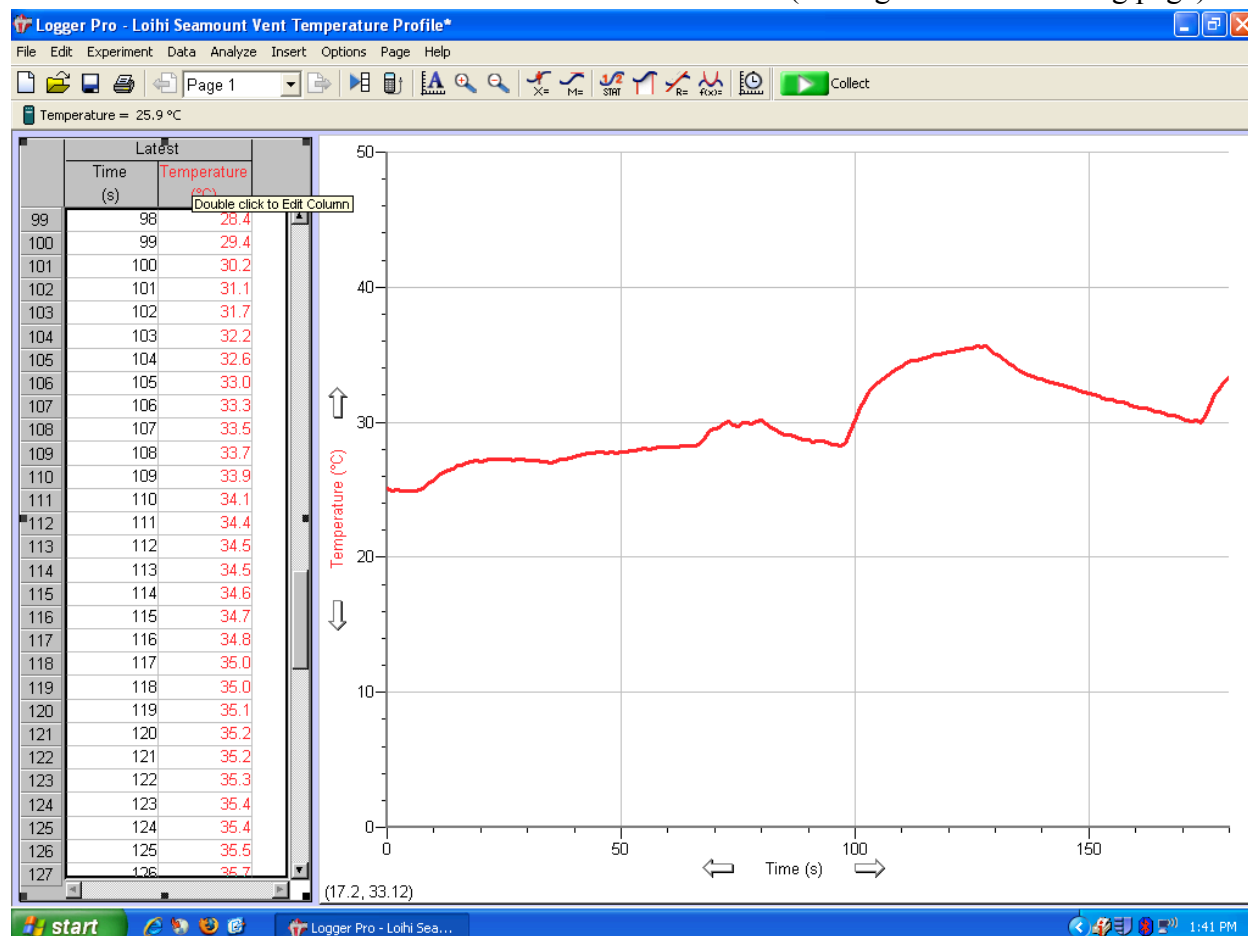
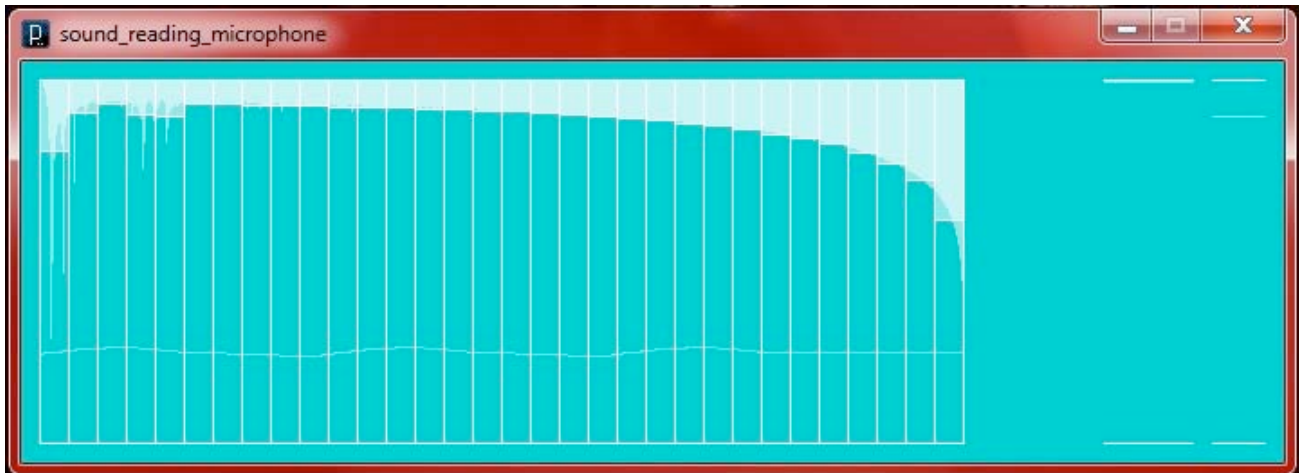


Figure 8: Monitor screenshot of temperature readings



(Figure 9: Sound reading software)

## ***Cameras***

For this year's cameras, we used the same design from last year. We purchased 1½" PVC unions and put a wide-angle board camera inside. To make the cameras waterproof, we epoxied the wiring into the housing and made an o-ring seal on the front with a piece of ¼" plexi-glass (see figures 10 and 11). The board cameras give us a 120° field of view above water and 90° field of view in water, due to the index of refraction. We have two board cameras; one color, white LED camera; and one infrared, black and white camera.

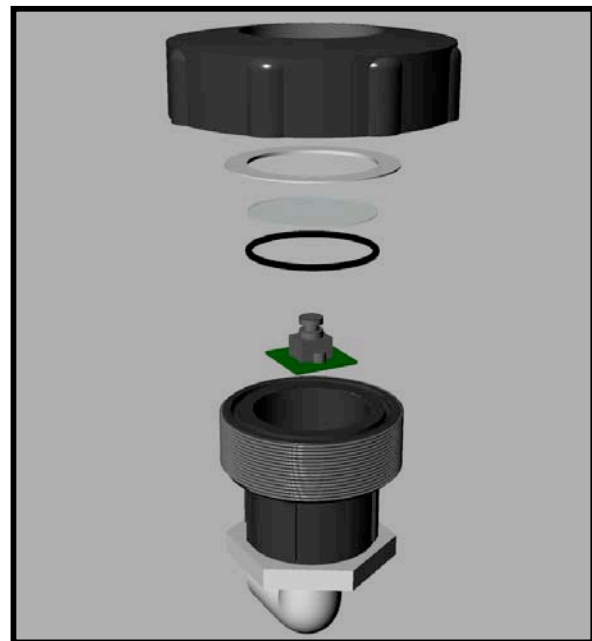
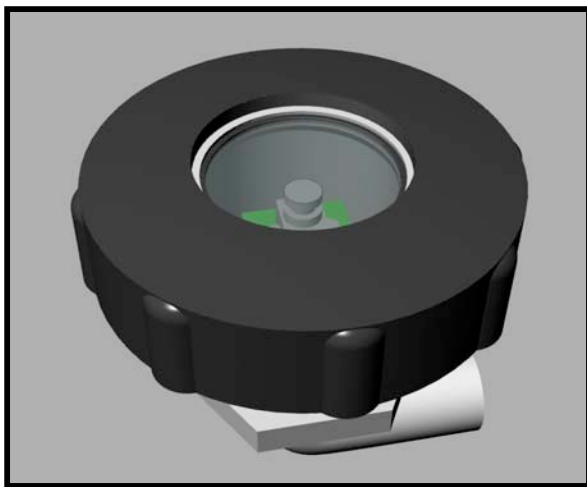


Figure 10: Exploded view of PVC union cameras.  
(Model Spruill)

Figure 11: Assembled View of PVC union cameras.  
(Model Spruill)



### ***On-Board Electronics***

To simplify our tether we incorporated our color quad-splitter on the machine in a waterproof housing. The housing is constructed from 3" clear PVC capped with one fixed end and one removable mechanical plug. The fixed end is constructed from a 3" slip end cap and plexi-glass to give us a flat surface to mount our SubConn waterproof connectors. All four cameras feed into the housing and are soldered to our disassembled quad-splitter, with one camera cable returning to the surface (see Figure 12).



Figure 12: Removable electronics housing.

### ***Tether***

The tether is literally the lifeline to our ROV, supplying power to our motors, video, and sensor data communication. Our tether consists of a camera cable, an 18-18AWG cable, a hydrophone cable, and a thermistor cable. By consolidating all motor conductors into one compact cable, we have

reduced the bulk of our tether, thus minimizing drag and complications. Our tether employs fishing floats to make it neutrally buoyant in the water for the first 6 m, with the remaining 9 m floating on the surface of the water. Having our tether neutrally buoyant is significant because it reduces the risk of getting entangled on the roof of the cave.

### ***Surface Controls***

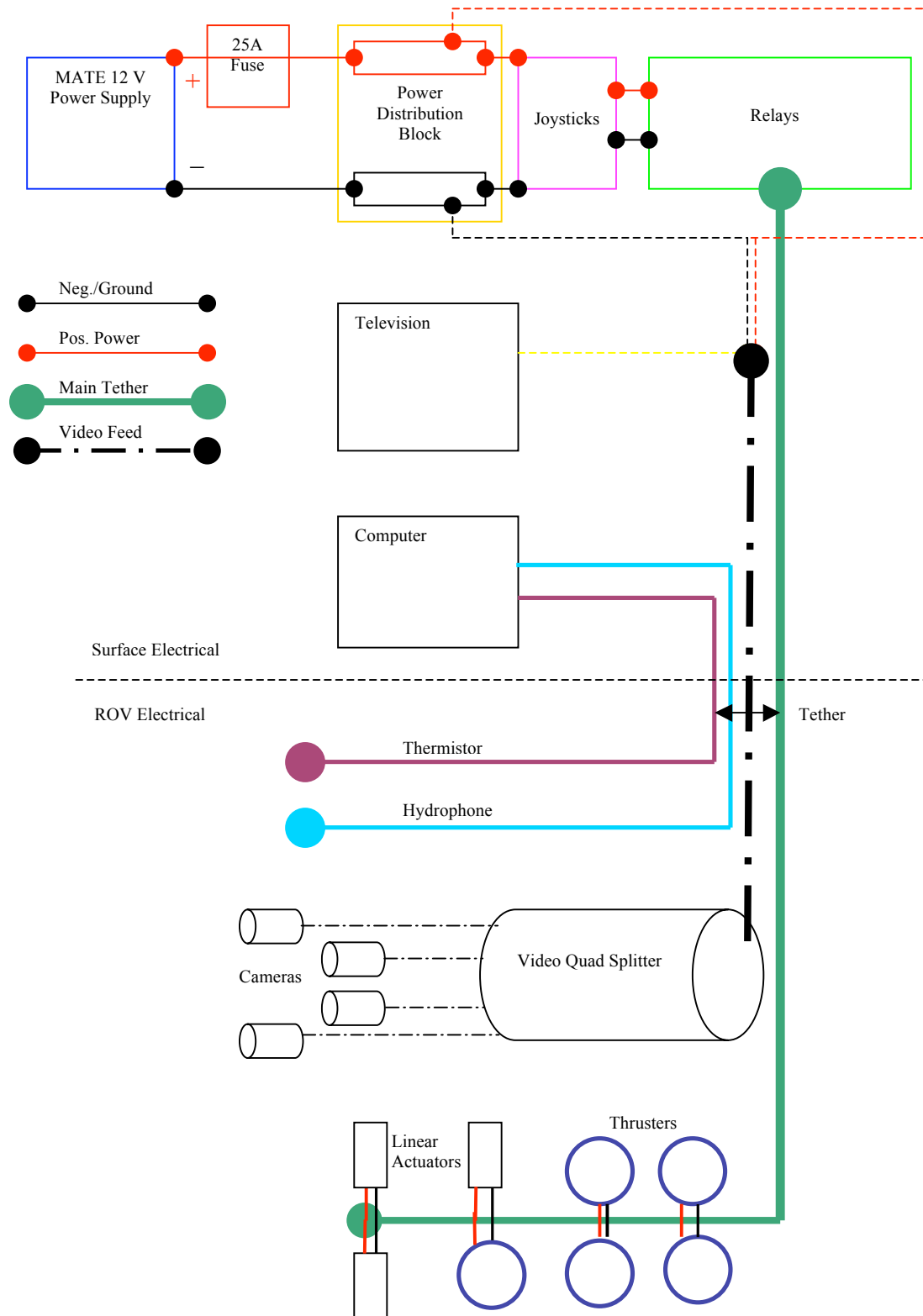
The control box was designed with simplicity in mind; we wanted all of the systems to be easily accessible. We mounted two joysticks to a ¼" plexi-glass cover so that all of the relays could be easily viewed within the control box. One heavy-duty joystick is used as a control for the thrusters on the ROV while another arcade joystick, along with two circuit buttons, are used to control the hand. The placement of these controls insured simple routing of all wires. Both joysticks employ cherry switches, which are wired to relays. We used relays to remove the necessity of most electronics on the ROV. This coupled with our 18-18 AWG tether, enables full power to be supplied to each thruster and DC linear actuators during max load.

### ***Safety and Design Considerations***

Throughout the design and build process, safety feature integration was continually discussed and implemented. Our team designated a safety officer that was responsible for monitoring design, shop habits and mission protocol. Key safety elements of *Romvy's* design include: kort nozzles around all of the thrusters, which not only add hydrodynamic flow but also protect vital systems, wiring, and hands protection from the propellers; possible hazards are painted bright yellow to draw attention, like the kort nozzles; and attention was paid to keeping all systems and thrusters within the exterior frame while designing the ROV structure.

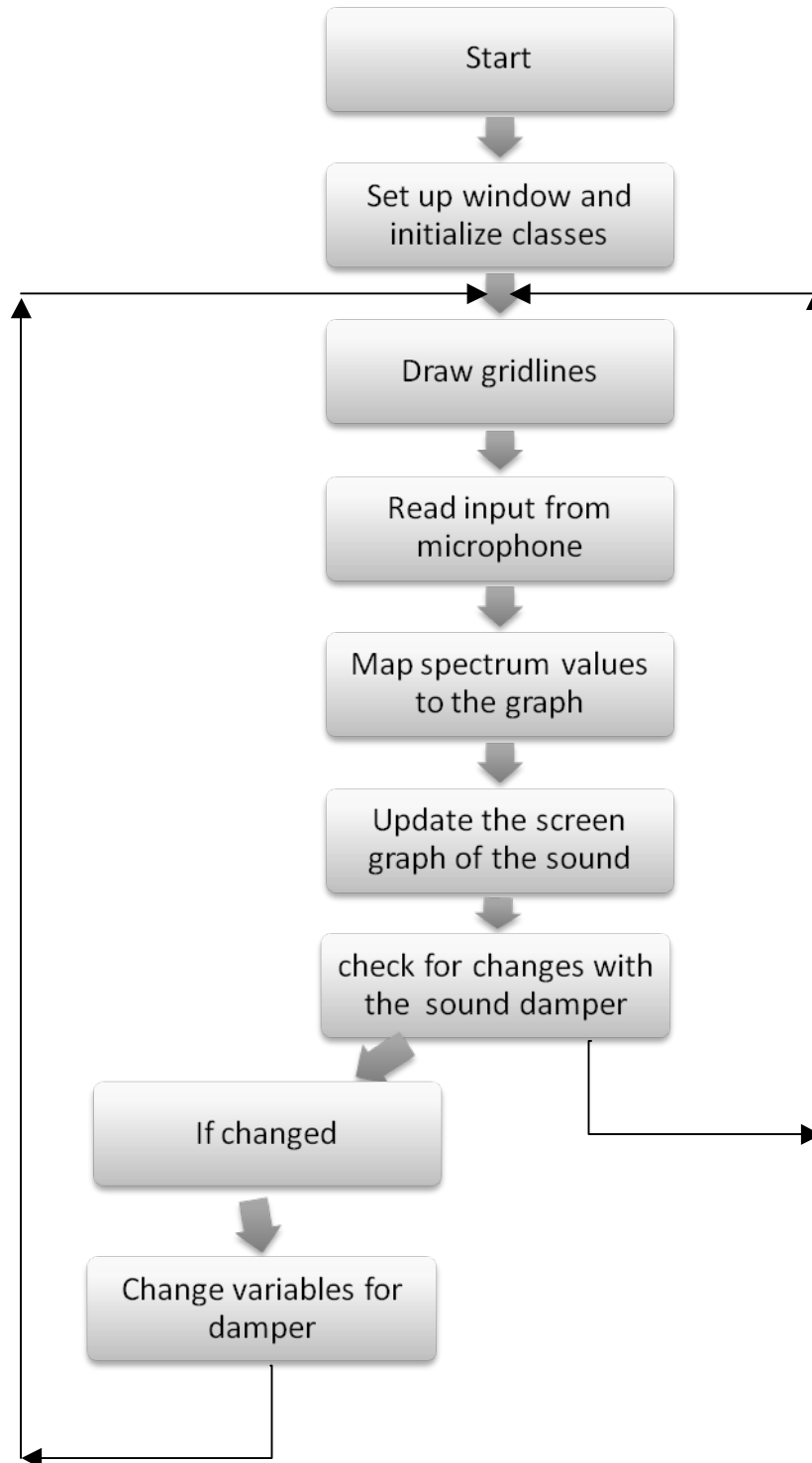


## Wiring Schematic



## Software Flow Chart

*David Spruill, our computer specialist, designed his own computer software to read and isolate the seismic activity coming from the rumbler as shown in this flow chart.*



## Exploring Loihi

The Loihi Seamount is a unique opportunity for researchers and explorers alike to witness the birth of a new island. Since its discovery, Loihi has provided researchers with as many answers as it does questions. Not only is there the emergence of a new island but in and around similar hot spot



<http://oregonstate.edu/dept/ncs/photos/seafloor.JPG>

vents life may have emerged and evolved into what we see today inhabiting the Earth. These hostile environments continue to give us insight into biogenesis and the possible initial spark of life billions of years ago on the surface of a hostile planet. Lessons learned on hot spots and deep-sea vents may eventually lead us to understand how life could begin on other planets or how life may have even come and gone. ROVs are one of the best tools available to researchers as they can withstand pressure at extreme depths while minimizing the risk to human life and at the cost of valuable resources. ROVs may well be the best tool available to repair non-functioning equipment like this junction



[http://www.soest.hawaii.edu/soest/facilities/esf/Projects/HUGO\\_Approach.jpg](http://www.soest.hawaii.edu/soest/facilities/esf/Projects/HUGO_Approach.jpg)

box that *ROV Jason* removed from Loihi. The current junction box on Loihi is now non-functioning and could be replaced by modern ROVs like our *ROV Romvy* (see Figure 13).

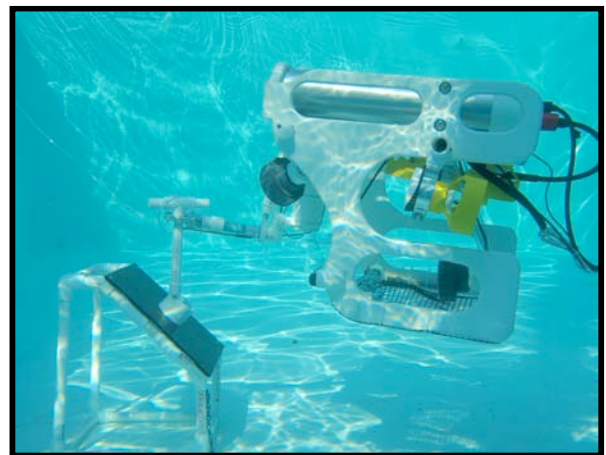


Figure 13: ROV Romvy restoring power to the HUGO junction box. (Photo: Lawler)



## Troubleshooting Techniques

Throughout the design and construction process we employed a number of methods for troubleshooting any unforeseen problems. This year we had a leak in the onboard electronics housing. This threatened the integrity of the power distribution block and the quad-splitter; which forced us to reconsider the design of the housing. There were five possible sources of water: the 3" end-cap, the Plexi-glass cover, the two SubConn electrical connectors tapped through the Plexi-glass, and the removable mechanical plug. We isolated each possible source and tested it in our water tank. First we tested the SubConn connectors, ensuring the holes tapped through the Plexi-glass were correct and true and determined if the o-ring seals were making proper contact. After tightening the connectors we inserted tissue paper into the housing and submerged it into the test tank and again found water in the housing but not around the tissue paper. To test the mechanical plug we repeated this process, this time the paper around the plug seal remained dry, but yet again water was in the housing. After a thorough investigation we determined the glued connection between the 3" end-cap and the clear 3" PVC housing was the source of the leak. To correct this problem we generously applied 3M 5200 Marine Sealant and allowed it to cure overnight. After the sealant had completely cured we retested the seal and found the housing to be watertight. The availability of our own water tank this year has proven to be a vital resource. Along with testing seals the tank has allowed us to measure thrust of the motors, max amp. draw under full load, and ballasting of the ROV. Even though we had predicted ballasting and ROV balance in the water with our computer design program, the ROV still required some fine-tuning. For this process trial and error was

the best option, which we accomplished by placing lead fishing weights in various locations around the ROV.



Chris working by the test tank. (Photo: Thomas)

## Challenges

One of the largest problems we encountered this year involved coordinating time schedules for individual systems of the ROV to be completed. The initial design of our ROV for 2010 included an onboard micro-controller and H-bridges for thruster and manipulator control. Initially we were having trouble with communication, but our computer specialist was able to rewrite the software code and remedy the situation several times. A few days later, thinking we had all problems solved, a pool test proved otherwise. We pulled all of the electronics out of their housing, testing all H-bridges with an ammeter and verified all connections, but we were still unable to isolate a power issue to our thrusters. When the software proved to be ineffective and power supply to be too low, we decided to revert to our 2009 relay control system. Changing over to the alternate system required a significant amount of time and a fair amount of money. We had to cut our tether cable and rewire the entire ROV. This change in design cost our team valuable time and money, placing us behind schedule and in jeopardy of going over budget.

**FFHS ROV TEAM****TEAM NIGHTHAWK – ROV *Romvy*****Balance Sheet**

Item	Donated	Reused	Purchased 2010
Aluminum			\$12.00
Ballast (lead)			\$18.36
Speco Bullet Camera (CSI)	\$124.98		
Wide Angle Board Cameras			\$138.00
3" PVC Brackets			\$20.70
Clear PVC Pipe			\$85.15
Clear PVC T's			\$57.23
DC Arm Motor		\$48.00	
Electrical Connectors			\$80.00
Epoxy			\$30.00
Fasteners			\$81.99
LCA - 7700 Camera		\$277.33	
Heat Shrink			\$47.00
Heavy Duty Joystick			\$155.57
Hinges			\$2.25
Hydrophone			\$169.61
J-Hook			\$1.09
Joystick		\$12.00	
Kort Nozzles		\$27.50	
Linear Actuators			\$160.00
Low-Density Polyethylene (UNC-C)	\$30.00		
Mechanical Plugs 3"			\$9.51
Medium-Density Fiberboard			\$10.00
Miscellaneous Wire			\$20.00
Motor Mounts			\$8.75
Motors			\$150.00
Paint			\$5.00
Plastic Hardware Cloth			\$13.98
Plexi-glass Cameras			\$11.50
Plexi-glass Control Box			\$18.50
Ply Wood			\$10.00
Power Distribution Blocks			\$14.00
Prop and Adapters			\$60.00
PVC Fittings			\$22.68
PVC Unions			\$14.98
Quad-splitter		\$59.99	
Relays		\$150.00	
Rocker Switches		\$12.50	
Shop Supplies			\$20.00
Solder			\$15.00
SubConn Connectors	\$1,013.60		
Television		\$300.00	
Temperature Probe		\$90.00	
Tether			\$150.00
<b>Totals</b>	<b>\$1,168.58</b>	<b>\$977.32</b>	<b>\$1,612.85</b>
Total Cash Donations	\$4700.00		
Cheesecake/ Barbeque Sales	\$1475.00		
Flights			\$6400.00
Accommodations			\$1500.00
Meals			\$1000.00
Miscellaneous Costs in Hawaii			\$1800.00
<b>Total to Still Raise</b>			<b>-\$6138.00</b>

## **Future Improvements**

Our design plans for next year have already begun. First and foremost we plan on incorporating micro-controllers and H-bridges into the onboard control system. With a last minute switch from the aforementioned control system to our more familiar and reliable relay wiring system, valuable time was lost that could have been used for water testing.

Increasing the forward speed of our ROV is another priority in next year's design. The use of bilge pump cartridges and a 12V power supply limits us from using traditional ROV thrusters. One possible solution would be to construct and waterproof our own thrusters. This requires machining that is not readily accessible to us on the Outer Banks, so we would have to go out of our area to find assistance.

Transporting our ROV sometimes proves to be troublesome, as it now requires three people to simultaneously move all components of the complete ROV and its controls. This year before our electronics failed, we could detach the tether from our ROV allowing for unobstructed maintenance and transportation. Next year we plan to have a fully detachable tether, thus eliminating problems associated with clutter.

The bulkiness of our arm configuration directly correlates to the size of the DC motor that is used to rotate the manipulator into and out of the ROV. When shopping for a suitable motor we had design requirements that dictated that the shaft placement must be in the center of the motor in order to waterproof it. Many of the available motors did not have enough torque combined with low RPMs, and if they did, the shaft was off-center. The motor we had to settle for is extremely bulky and once waterproofed in PVC fittings, it becomes cumbersome, obstructing camera views and skewing the ballast of our ROV. If we could

find a suitable motor, we feel that we could greatly improve the functionality of our manipulator.

## **Lessons Learned**

One of the first lessons we learned concerns time management. If we had started our planning earlier, we would have known what parts to order based on our design. This would have allowed us to assemble our ROV and begin testing at an earlier date. As a result, we did not have enough time for adequate troubleshooting and subsequent repairs or redesigns. A more flexible time frame would have made it easier to work around our conflicting schedules when planning around extracurricular activities and rigorous coursework.

Our design and construction budget comes entirely from fundraising events like our cheesecake sales. We have learned that it is better to fundraise before the project and have surplus funds, than to be short of money. This year, we fundraised out of necessity for purchasing parts as we went through the construction process. Consequently, we continually found ourselves having to halt construction while waiting for parts to arrive.

As in years past, we concentrated on machining our own parts. This year, for the first time, we used LDPE as our frame material. While most teams send this job elsewhere, we machined the frame ourselves rather than using a CNC machine, which we do not have readily available. This remained consistent with our efforts to make everything within our garage, thus allowing us to learn how to use new tools and adapt creative methods to overcoming our obstacles. To machine the frame we made a template out of MDF by transferring our computer-generated model. We then cut the template, matched it up with the LDPE, and used a router to cut the final frame.



## Reflections

### *Sean O'Neal*

In the past two years, ROV has offered me a hands-on opportunity to apply, in a real world situation, what I had learned in school. The experience of working in unison with others to achieve a desired goal has been as valuable as the technical knowledge. After two years with the club, I am better prepared to meet similar challenges in college. The skills I've obtained from my experiences with the ROV Team can easily be transferred to all areas of my future studies. As a freshman at NC State, I will seek out opportunities to work effectively with my peers. My involvement with ROV made it clear to me that working with others can be an effective and satisfying way to meet my own goals. Additionally, over the past two years, our team has been fortunate enough to be involved with the MATE international competition travelling to Buzzards Bay in 2009 and to Hilo, Hawaii this year. This experience is invaluable as we have been able to interact with professionals in the industry. I look forward to using the lessons I have learned as I pursue my degree in engineering.



### *Patrick Gray*

The two years I have spent with the MATE ROV Competition has been an invaluable part of my high school experience. When my AP Physics teacher asked me to join the ROV team at the beginning of last year I was not sure what I was getting into, or if it would even be worth the time I knew it would take. The following months I was immersed in engineering and design, learning everything I could that was pertinent to the ROV and marine technologies. When the time for competition came around I had gained an interest and amount of knowledge about ROVs that exceeded my expectations. The machine that my team had constructed received sixth place at the international competition in Massachusetts; a strong showing but not satisfying my desire for victory. As this year snuck up on me and the challenges were presented I realized I had a really long Spring ahead of me. This year, with last year's knowledge to draw on, we have developed a much more capable ROV with more advanced systems to succeed in the competition missions. The knowledge I have gained as a result of The MATE Center's ROV program will not only prove applicable to my future but has instilled a passion for marine sciences and undoubtedly was worth the time.



## **References**

### ***Loihi Seamount Resources***

<http://www.soest.hawaii.edu/GG/HCV/loihi.html>

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

[http://volcano.oregonstate.edu/vwdocs/volc\\_images/north\\_america/hawaii/loihi.html](http://volcano.oregonstate.edu/vwdocs/volc_images/north_america/hawaii/loihi.html)

<http://www.mbari.org/volcanism/Hawaii/HR-Hydrothermal.htm>

<http://www.nature.com/nature/journal/v335/n6190/abs/335532a0.html>

### ***Construction Resources***

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

Underwater Cable Connectors:

<http://www.subconn.com/default.asp?objtype=mproductgroup&func=showdetail&id=1391&language=dansk&siteid=1031>

Clear PVC: [http://www.clearpvcpipe.com/?gclid=CN\\_NhoXG8qECFRUhnAodtiGUnA](http://www.clearpvcpipe.com/?gclid=CN_NhoXG8qECFRUhnAodtiGUnA)

Linear Actuators: <http://www.firgelli.com/>

## Acknowledgements



**MATE**

M A R I N E  
A D V A N C E D  
T E C H N O L O G Y  
E D U C A T I O N  
C E N T E R



SURFRIDER FOUNDATION  
*Outer Banks Chapter*



More saving. More doing.™