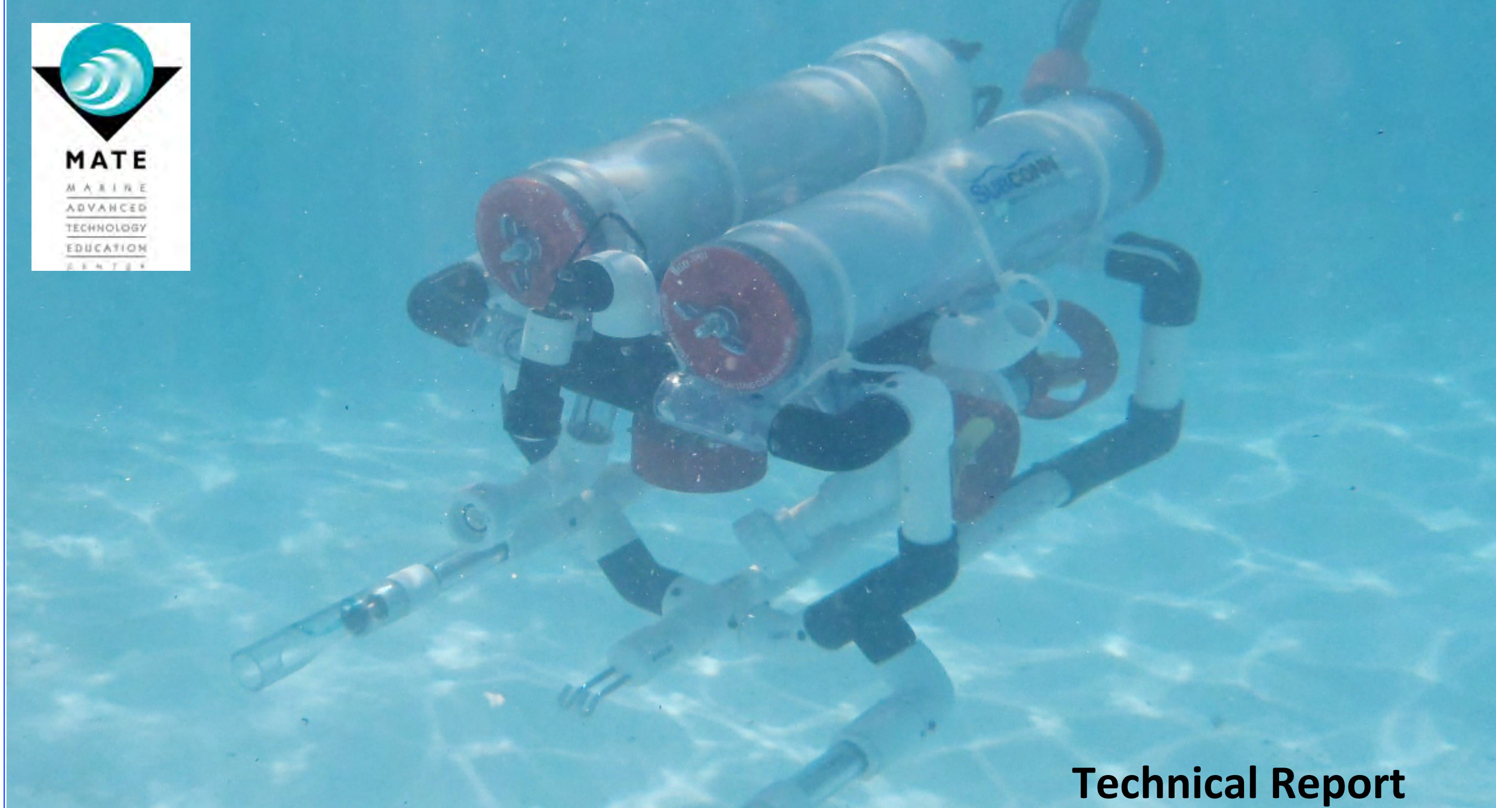
2013 MATE International Competition, ROVs and Ocean Observing Systems



Technical Report

First Descent Solutions - First Flight ROV

(Photo: Fish)

Ashton Harrell: CEO; Senior, Wake Forest University, Fall 2013
Adam Fish: CFO, Pilot; Senior, UNC-Chapel Hill, Fall 2013
Daniel Martin: OSHA Officer, Poolside Technician; Senior, Stevens, Fall 2013
Calvin Schmidt: Public Relations, Navigator; Senior, NC State, Fall 2013
David Cubler: ROV Operations, Tether Management; Senior, UNC-Chapel Hill, Fall 2013
Scott Blankenburg: ROV Testing, Poolside Technician; Senior, COA, Fall 2013
Matthew Thibodeau: ROV Electrical; Sophomore, Class of 2015
Matthew Gray: ROV Engineer; Sophomore, Class of 2015
Andrew Thomas: Mentor; Physics and Oceanography Instructor

Staff Photo: from left; Adam Fish, David Cubler, Matthew Gray, Danny Martin, Scott Blankenburg, Matthew Thibodeau, Calvin Schmidt, Ashton Harrell

(Photo: Thomas)

"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; at FDS we take ROVs to new depths."

First Flight High School, 100 Veterans Drive, Kill Devil Hills, North Carolina

Abstract

First Descent Solutions (FDS), located on the Outer Banks of North Carolina, has designed and produced award-winning Remotely Operated Vehicles (ROVs) since 2007. This year, off the coast of Washington, the Ocean Observatories Initiative (OOI) will be installing Regional Scale Nodes (RSNs), which are collections of instruments and sensors above and below the surface that provide real time data collection. These include ocean temperature changes, ocean acidification and sea level rises. A global system of ocean observatories is now emerging that uses a suite of technologies to answer many different questions about the state of the oceans. This year's ROV, built to accommodate the needs of the OOI, can easily install a variety of instruments on the seafloor (such as a temperature sensor), replace parts of the RSN, and remove any harmful biofouling on Node infrastructure. Our main focus was to keep the machine compact, while allowing the maximum workspace within the ROV. This allows the ROV to be maneuverable while maintaining the ability to complete the tasks with precision and efficiency. The ROV has one multi-functional manipulator, a Cable Termination Assembly Extractor and Injector Manipulator (CTAEIM), six thrusters, and four cameras. These aspects maximize functionality, thrust, and angles of viewing. Throughout the design and build process, the team logged over one thousand hours and employed significant real-world problem solving techniques. The result is an exceptionally capable and professional product.

Table of Contents

Company Philosophy

FDS's core philosophy is one of simplicity and efficiency. All of our components and tools are designed and manufactured in-house to reduce costs and maximize capability. The ROV itself is designed to be large enough to fit all required tools without wasted space. This improves simplicity and maneuverability. The *FDS 2013* control system is entirely composed of switches and relays; we believe this substantially reduces complexity while maintaining superior functionality.

Design Rationale – Task Integration

FDS has designed and constructed a ROV that meets the needs for the OOI and the Axial Seamount Hydrothermal Emissions Study (ASHES) subsidiary. By using the tasks set forth in the Request for Proposal (RFP), FDS prioritized a step-by-step design and planning process to build the current ROV. The mobility and versatility of FDS 2013 (figure 1) allows for precise movements with ease of task completion within a timely manner. The ROV was completed according to strict company design parameters; incorporating time, safety, and a strict financial budget.

Figure 1: Image of completed FDS 2013 (Photo: Fish)

Task 1: Complete a primary node and install a scientific instrument

FDS found the first task to be the most complex and thus implemented several modifications to our base design. To transfer the Science Interface Assembly (SIA) to the seafloor FDS developed the Double Hook Assembly (DHA), which consists of two hooks attached to a 1" PVC endcap. The U-bolt on top of the SIA is attached to the DHA while the ROV is on the surface; when the ROV maneuvers the SIA into position, the DHA can easily release the SIA within the Backbone Interface Assembly (BIA).

Grasping the Cable Termination Assemblies while on the seafloor proved to be problematic with our general-purpose manipulator. In response, FDS developed the Cable Termination Assembly Extractor/Injector Manipulator (CTAEIM), which allows the screw hook is protruding from the top of the CTA to slide into forward position. The CTA is then locked in place within the CTAEIM by a linear actuator. This proprietary tool allows us to easily grasp and manipulate CTAs (as well as other cable connectors) throughout the Regional Scale Node (RSN).

In order to seize the Ocean Bottom Seismometer (OBS) with greater ease, FDS designed the manipulator to have teeth that interlock in such a way as to fully enclose one side of the U-bolt that extends from the top of the OBS. This allows us to grasp and manipulate the OBS accurately.

Opening the door of the BIA was also factored into the design process. By allowing our manipulator's fingers to open to a large angle, the handle of the BIA door was easier to grasp.

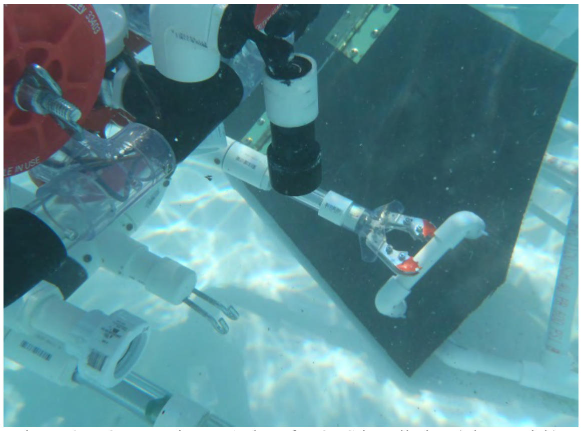


Figure 2: ROV opening BIA door for OBS installation (Photo: Fish)

Task 2: Design, construct, and install a temperature sensor

In order to measure the temperature of a hydrothermal vent, FDS was required to design a sensor (see Figure 3) to be attached to the vent opening. This device is constructed from a 2" PVC endcap attached to a 2" PVC coupler via a 5cm length of 2" PVC pipe. This assembly is mated to a 2" to 3" flexible coupling. The device is lowered and placed over the vent opening with its own weight holding it in place. A series of flow holes were drilled through the endcap to allow a constant flow of hot vent fluid through the sensor, facilitating superbly precise measurements.

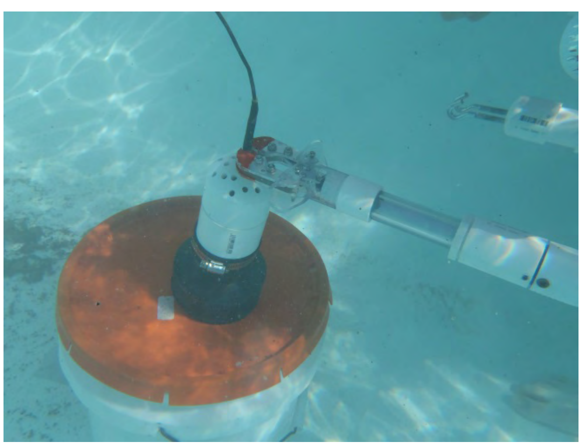


Figure 3: Temperature sensor installed on the seafloor (Photo: Fish)

Task 3: Replace an Acoustic Doppler Current Profiler (ADCP)

For this task we found that no additional tools were required. However, modifications were made to the base design of several components, including the manipulator. The teeth of the manipulator's fingers were designed to enclose the U-bolt protruding from the dorsal surface of the ADCP. The wide-angle action of the manipulator (discussed under ***Task 1***) also assists in grasping the handle of the locking mechanism of the ADCP Mooring Platform (see Figure 4).

Task 4: Remove biofouling from structures and instruments

Following our longstanding tradition of innovation through simplicity, FDS developed a revolutionary system of organism collection: the Bio-Magnet. Capitalizing on the natural ferromagnetism of biofouling organisms native to the Axial Seamount, the Neodymium Iron Boron Magnet Apparatus (NdFeBMA) is attached to the DHA to form the NdFeBMA+DHA (see Figure 5).

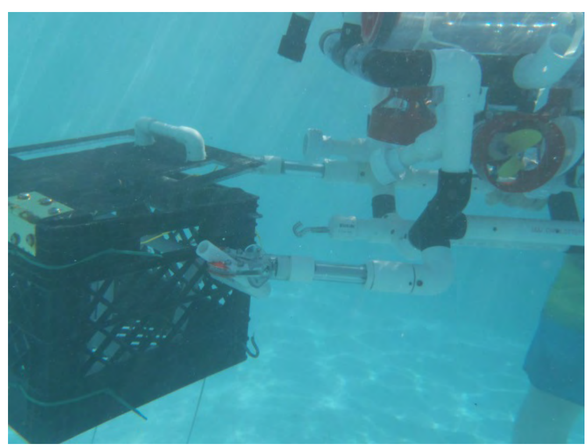


Figure 4: Manipulator attached to the mooring platform (Photo: Fish)

Design Rationale – ROV Components

While designing the components of our ROV we focused on manufacturing our own parts out of PVC whenever possible. By primarily constructing all of our components out of PVC, we minimized cost while maintaining build flexibility. Our machine, designed to be multi-functional, preserves its simplicity through the wide variety and abundance of readily available PVC fittings. This year we incorporated the ability to break down our machine into three basic components, the control box, the tether and the ROV to allow for ease in transportation and deployment.

Frame

For the 2013 ROV, FDS began with a SolidWorks isometric rendering created from a hand-drawn isometric sketch (see Appendix A) to the computer representation of the frame. This allowed our design team to visualize theoretical payload tool and thruster locations, while also reducing frame construction cost. FDS, contrary to previous years, decided to use a simpler frame design consisting solely of PVC pipe. In previous years large pieces of Low Density Polyethylene (LPDE) were used on the sides of the machine for support.

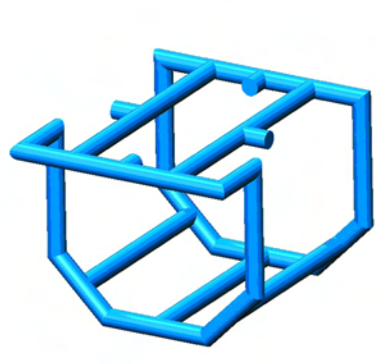


Figure 6: A Solidworks rendering of the frame (Render: Gray)

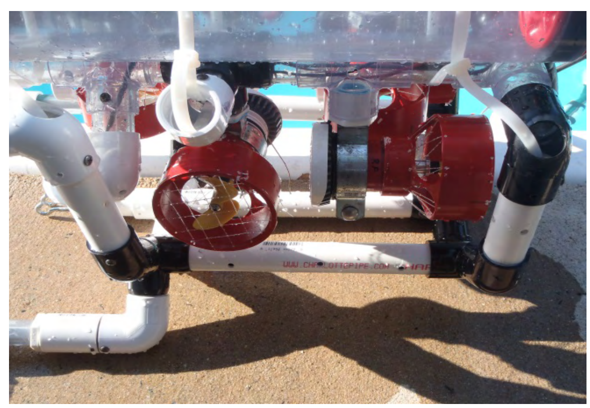
Through extensive water testing we determined that the side walls upset the balance of the ROV due to their positive buoyancy. The large surface area also hindered lateral strafe motion. For these reasons we migrated to a wholly-PVC frame (see Figure 6).

Thrusters

This year, the goal with our thrusters was to maximize the force, so we switched from 3780 liters per minute to 4536 liters per minute bilge pump cartridges, increasing our forward thrust from 8N to 11N. We tested several propellers of varying diameters and pitch. We found that dual blade, 70 mm, 1.4 pitch propellers provided us with the most thrust. The housings are similar to those of last year, machined from 3’’ to 1½” PVC reducers into kort nozzles. The housings have multiple purposes: preventing prop wash and directing thrust, while adding safety. The housings are painted red to show there is a hazard and prevent injuries (see Figure 7). The thrusters are mounted to the ROV PVC framework with 1½” conduit hangers.

Our ROV contains two forward thrusters, two vertical thrusters, and, new to this year, two lateral action strafe motors for precision maneuverability.

Figure 7: The red kort nozzles with safety netting (Photo: Harrell)

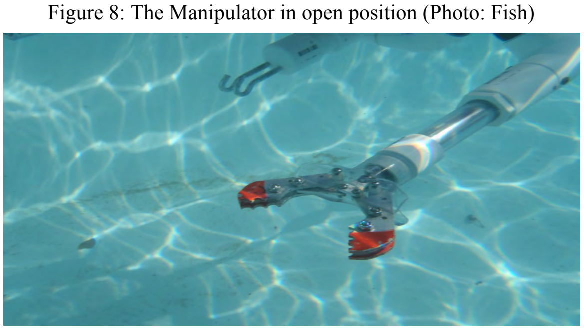


Due to the many cable assemblies (ropes and strings) present in this year’s mission, FDS developed a netting system to prevent debris from contacting the propeller. For this, monofilament fishing line was woven in a tennis racquet-like pattern across all opening in each kort nozzle. We have found this system to be most effective in preventing foreign debris from becoming entangled in the propellers.

Manipulator and Payload Tools

Our manipulator configuration consists of one linear actuator housed in a ¾" clear PVC and enclosed with rubber grommets, PVC bushings, and PVC end caps. We packed the moving parts and the shaft in marine grease to prevent water intrusion. The linear actuator controls the opening and closing of the fingers. The fingers are cut from aluminum stock to maximize durability and precision while minimizing weight and bulk (see Figure 8). The manipulator is placed on the left side of the machine, attached by a pivoting 1" PVC 90° elbow to allow the manipulator to swivel out of the way during the operation of other tools.

Figure 8: The Manipulator in open position (Photo: Fish)



The CTAEIM is FDS' solution to the challenge of grasping the CTAs off the seabed. After failing to be able to latch onto the dorsal screw hook with the manipulator our development team created a custom tool that descends onto the screw hook and latches it in place with a linear actuator (see Figure 9), allowing the ROV to move freely while carrying the CTAs.

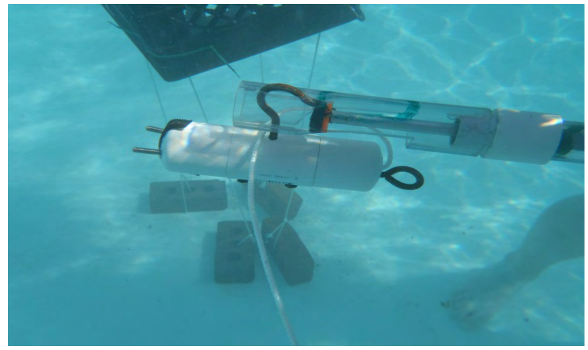


Figure 9: The CTAEIM holding the CTA in locked position (Photo: Fish)

Temperature Sensor

To complete ***Task 3*** a deployable temperature sensor, separate from the ROV, must be designed, built, and placed over a hydrothermal vent. The probe is a Vernier LabPro long-cord thermocouple, and is one of the only commercial components FDS is using. The probe housing is composed of a 2" PVC coupler mated to a 2" PVC endcap with a 5 cm piece of PVC pipe and a 1½" to 2" bushing. Holes were drilled through the endcap and bushing to allow a constant flow of hot vent fluid. The probe was attached to the housing with waterproof silicone sealant. This sensor communicates with Vernier monitoring software (see Appendix B) installed on a Ti-84 Silver Edition calculator located on the surface via a 15 m cable.

Cameras

The cameras on our ROV are designed as compact outdoor surveillance cameras with an IP-67 rating. While these cameras are rated for sever weather conditions, they are certainly not designed to withstand deep-water pressure. In past competitions we have built and waterproofed our own cameras; however, inconsistent waterproofing has convinced us to buy "weatherproof" cameras to waterproof and house ourselves. Our cameras are housed inside 1-inch PVC unions, sealed using an O-ring coupled with a thin piece of Plexiglas, cable entries are epoxy-potted to prevent water intrusion through wiring. We used this process for three 92° 550 line high-resolution cameras, one of which is our main drive camera, while the other two provide for specific angles on our CTAEIM and manipulator. Our ROV also features a 170°, 470 line wide-angle camera (see Figure 10) which provides an overhead view of both tools.

Figure 10: The wide-angle camera (Photo: jetviewcam.com)

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 4'' clear PVC capped with one fixed end and one removable mechanical plug. The fixed end is constructed from a 4'' slip end cap and Plexiglas 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 11).

Figure 11: Removable electronics housing (Photo: Cubler)

Tether

The tether is the lifeline to our ROV because it supplies power to our motors, cameras, and sensors. It consists of a 2-conductor plus 1-drain 18AWG camera tether and an 18-16AWG tether, which powers the motors. By consolidating all motor conductors into one compact cable, we have reduced the bulk of our tether, thus minimizing drag and complications. Additionally, the tether is designed to disconnect from the control box when not in use, which allows the entire system to be mobilized and demobilized efficiently and safely.

The first 5 m of our tether is incorporated with foam fishing floats to make it neutrally buoyant. This enables the ROV to move with relative ease while not being weighted down by the tether. The remaining 10 m of tether is shrouded in pool noodles to keep it afloat at the surface and out of the way of the ROV.

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 6 mm Plexiglas cover so that all of the relays could be easily viewed from outside the control box. Both joysticks are used for thruster control while the four buttons are used to control the manipulator and CTAEIM. The placement of these controls insured simple routing of all wires.

Both joysticks employ cherry switches wired to the relay inputs. The relays route current from the battery through the 18-16 AWG tether directly to each thruster and linear actuator, decreasing voltage loss and thus increasing available power. This hardware-based approach was employed in accordance to the FDS core philosophy: efficiency through simplicity.

The use of relays as opposed to software-driven H-bridges allowed for exponentially simpler troubleshooting and error correction. The hardware approach is also more resilient to jostling or other external physical influences.

Cost and reliability were also major factors in choosing the hardware option. Each relay is rated for 100,000 switching operations, much more than FDS would require year-to-year. Our relays are also an order of magnitude less expensive than H-bridges: $4.00 for a relay vs. $40.00 for an H-bridge. At our budget this was an easy decision.

Safety and Design Considerations

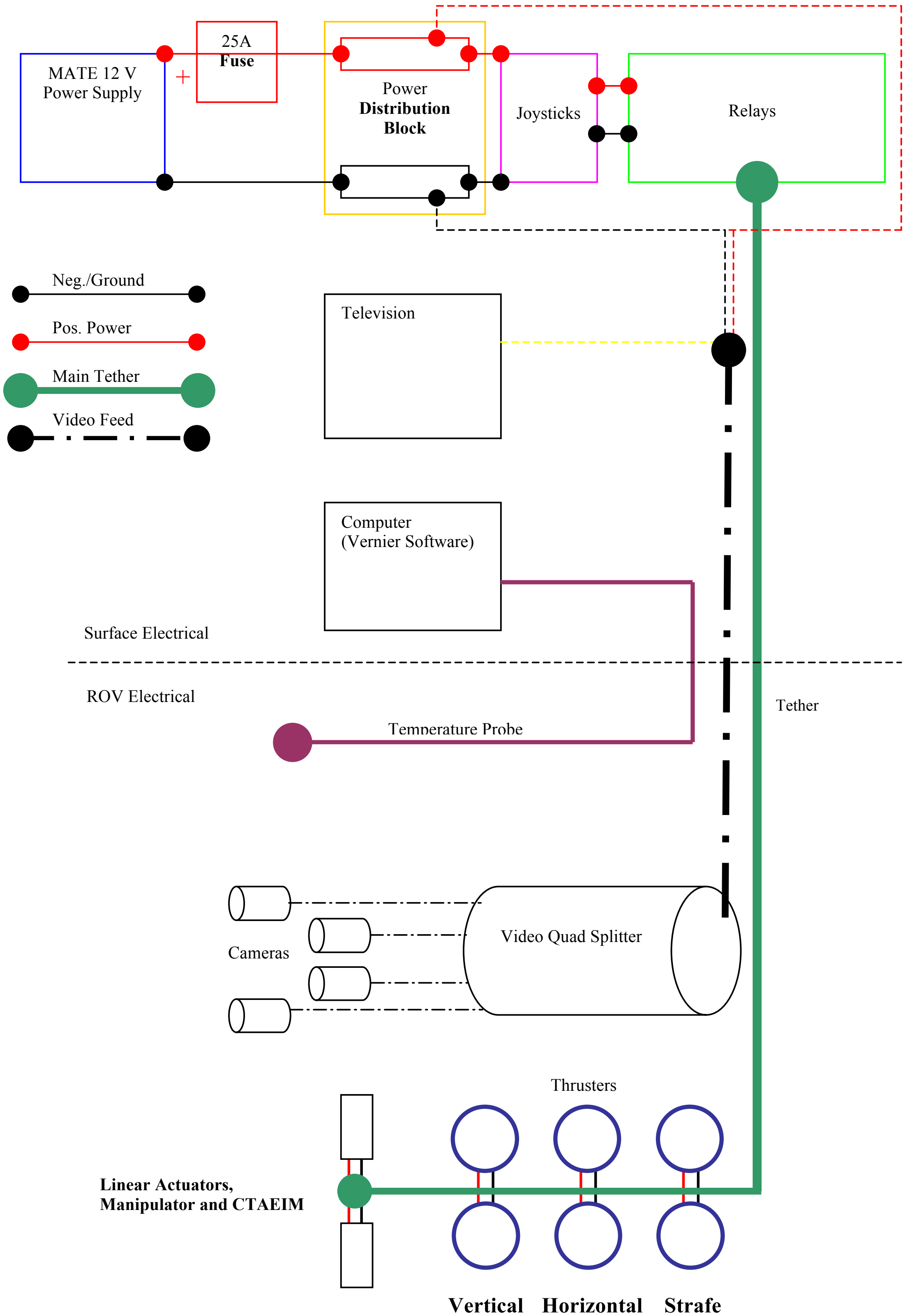
Throughout the design and build process, safety feature integration was continually discussed and implemented. Our team developed our own safety checklist and designated an OSHA Officer to be responsible for monitoring workshop and poolside safety. Key safety elements of the *FDS-2013* design include: kort nozzles around all of the thrusters, which not only add hydrodynamic flow but also protect wiring and body parts from the propellers; possible hazards are painted bright red to draw attention, such as the kort nozzles and tube caps; and safety netting around the kort nozzles to prevent foreign objects from entering the propellers.

There are several safety features on the surface within the control box. A 25 amp fuse located on the positive input cable prevents any potential fires in the off chance we exceed safe current limits. The Plexiglas is securely held in place with high-strength Velcro to prevent accidental dislodgement.

All members must wear safety goggles at all times while machines, soldering irons, and other hazardous equipment are in use. FDS has isolated equipment to prevent members from entering a power tool's working zone, thus, specified areas for soldering, engineering, and manufacturing are consistently monitored by the OSHA Officer to ensure the safety of the company's employees.

Safety also remains our top concern while on the poolside. To protect the safety of each poolside employee FDS assigned specific jobs to each person. This reduces confusion and creates an efficient operating environment. The ROV has specified handle points on the ROV to prevent damage or entaglement when mobilizing or demobilizing. Furthermore, we have secured all poolside wires and electronics to avoid possible issues with water compromising the security of the wires, the ROV, and, most importantly, our poolside workers. Before and after every mission, our safety officer uses the FDS Safety Checklist to ensure a safe and secure working environment (see Appendix C).

Wiring Schematic



ROVs and Ocean Observatories

The Ocean Observatories Initiative (OOI), funded by the National Science Foundation (NSF), offers new opportunities to monitor the physical, chemical, geological, and biological variables of the ocean seafloor. Intended to persist for the next 25 years, OOI institutes a network of over 1,000 kilometers of fiber optics cabling in order to establish an infrastructure of sensor systems off the coast of Washington and Oregon.

Figure 12: The global system of OOI (Photo: MATE)

First Descent Solutions offers our request for proposals (RFP) to the University of Washington in order to perform maintenance on the Axial Seamount site, further benefiting the Axial Seamount Hydrothermal Emissions Study (ASHES) located on the Juan de Fuca plate.

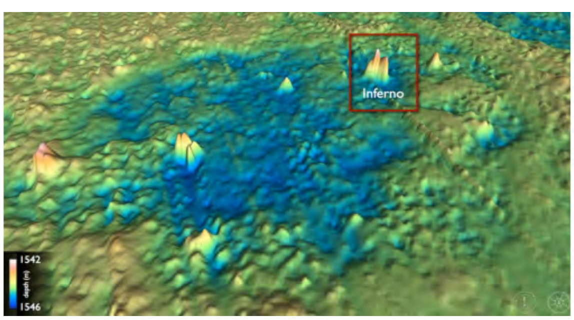


Figure 13: Bathymetric map of the ASHES site (Photo: MATE)

In addition to servicing, we intend to deploy an ocean bottom seismometer at the ASHES site, as well as designing and installing our own temperature sensor over the hydrothermal vent. These instruments will give researchers real time ocean bottom data that can aid in long-term predictions utilizing environmental clues previously inaccessible without ROVs and live data technologies.

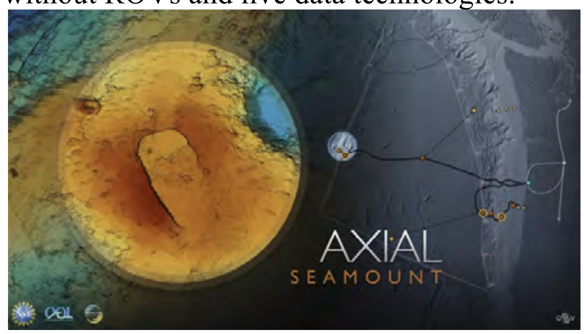


Figure 14: Cabled network extending from Oregon Coast (Photo: http://www.interactiveoceans.washington.edu/files/)

Troubleshooting Techniques

Throughout the design and construction process FDS employed a number of methods for troubleshooting any unforeseen problems. This year we had a leak in the onboard electronics housing that threatened the integrity of the power distribution block and the quad-splitter. This forced us to reconsider the design of the housing.

There were five possible sources of water: the 4” PVC end-cap, the Plexiglas cover, the two SubConn electrical connectors tapped through the Plexiglas, and the removable mechanical plug. We isolated each possible source and tested it in our pool. First we tested the SubConn connectors, ensuring that the holes tapped through the Plexiglas were aligned and that 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 4" end-cap and the clear Plexiglas cover. To correct this problem we generously applied waterproof epoxy and allowed it to cure overnight. After the epoxy had completely cured we retested the seal and found the housing to be watertight.

The availability of our own pool this year has proven to be a vital resource. Along with testing seals the pool has allowed us to measure thrust of the motors, maximum current draw under full load, and the ballasting of the ROV. For this process trial and error through placement of lead weights was the best course of action.

Challenges

Technical

The largest technical challenge faced by FDS this year was manufacturing a tool to retrieve the CTAs from the seafloor. In the orientation of the CTA on the seafloor, it was very prone to being knocked over, thus making it irretrievable. After much troubleshooting we decided that it was easier to ensure picking up the CTA on the first try, rather than trying to reorient the CTA after it has fallen. In order to do this we specifically designed our CTAEIM for grabbing the CTA by its eyehook, allowing for easy retrieval and maneuvering while the CTA is held.

Interpersonal

FDS has also faced a non-technical problem involving this year's budget. Being a school organization with limited funds, we have been hard pressed to meet this year's monetary requirements. Traditionally we have sought out donations from local businesses and in return provided advertisement and positive public relations. However, as a result of the destructive forces of Hurricane Sandy on our island community, business donations have been not as plentiful compared to previous years. By taking unconventional methods, such as in-house contributions and merchandise auctioning coupled with a more aggressive advertising and public relations campaign, we were able to overcome this issue.

Figure 15: Damage done to local roadway (Photo: Rocky Mount Tribune)

Future Improvements

This year, FDS continued with the three-year plan on electronics associated with the machine. This plan, starting years back, grew from on-machine electronics, to relays, located in the control box on the surface. In next year's machine, FDS will have developed an entirely computer-based control system, which will result in improved maneuverability of the ROV.

With this year's manipulator, simplicity was our main goal. As a result, this rigid tool has no axes of motion, therefore rendering itself incapable of performing meticulous tasks, putting more pressure on the pilot. In the future, FDS plans to incorporate multiple axes of motion while keeping the design compact and efficient.

Lessons Learned

Technical

As in years past we focused on machining our own parts. All of the custom PVC parts, such as the CTAEIM, and all custom metal parts, such as the fingers on the manipulator, were designed and manufactured by FDS. This developed important power tool skills as well as an appreciation for precision and accuracy. Brainstorming spurred competition and produced a think-tank like working environment.

Valuable experience was gained while designing the control system. With an entirely new development team, FDS opted to use a simple mechanical relay-based control scheme. This gave insight towards the overall engineering process and will be useful in future control scheme endeavors.

Interpersonal

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. 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 car wash. 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 raised funds out of necessity for purchasing parts as we went through the construction process. Consequently, we continually found ourselves having to halt construction while we waited for parts to arrive.

Budget

With initial fundraising of $1475 and a donation from the PTSO of $500 we were financially prepared for the design and building process. FDS limited the amount of reused parts from previous machines and took advantage of parts donations from SubConn and FlexPVC we were able to stay within our on-hand cash budget of $1975. The total value of the ROV this year is $4018.87. Currently FDS is raising funds for our travel expenses to Federal Way, Washington.

Budget and Expense Sheet

Quantity	Item	Donated	Reused	2013 Cash Budget
	PTSO Donation			$500.00
	CarWash fundraiser			$1,475.00
1	Aluminum Bar			($12.00)
2.7 kg	Ballast (lead)			($20.50)
1	Wide Angle Camera			($149.99)
3	90º FOV Bullet Cameras			($358.97)
	SubConn Connectors (MacArtney)	$1032.40		
	Clear PVC Pipe			($21.71)
	Clear PVC Ts			($151.70)
	Black PVC Fittings (Flexpvc.com)	$46.58		
	Electrical Connectors			($80.00)
	Epoxy			($52.74)
	Fasteners			($79.50)
	Tether			($184.32)
	Heat Shrink			($47.00)
2	Heavy Duty Joystick		$311.14	
2	Clear PVC 4” electronics housings			($99.45)
	Molykote Packing Grease			($16.21)
2	J-Hook			($2.18)
	Kort Nozzles		$41.25	
	Linear Actuators			($160.00)
3	Mechanical Plugs 4"			($20.10)
	Control Box wood			($18.50)
	Miscellaneous Wire			($45.93)
6	1.5" Conduit hangers for thrusters			($32.17)
6	Thrusters			($210.00)
	Plexiglass for camera lenses/control box			($45.98)
	Power Distribution Blocks			($14.00)
	Prop and Adapters			($60.00)
	Quad-splitter		$59.99	
	Relays		$164.26	
	Shop Supplies			($75.30)
	Solder			($15.00)
	Television		$300.00	
	Temperature Probe		$90.00	
	Totals	**1078.98**	**966.64**	**1.75**
$1.75 under construction budget. **$4018.87** for fair market vehicle value including reused and donated parts.				
	Flights			($7,120.00)
	Accommodations			($2,974.00)
	Meals			($1,500.00)
	Miscellaneous Costs in Seattle			($500.00)
	Total Sponsorships/Donations as of 5/23/2013			$8,790.00
	Total to Still Raise to get to Seattle			**($3,304.00)**

Reflections

Ashton Harrell

Remotely Operated Vehicle team has positively affected my future as a student and an individual. With a club that requires such depth of thought and problem solving skills, ROV has taught me that no situation can go unsolved. During my two year run with the ROV team, I have gained knowledge of advanced electronic and engineering techniques that aided in the completion of the machine. With the manufacturing of an ROV, a hands-on approach has given me immense familiarity with power tools. Working in a garage with seven other individuals has proven valuable to group problem solving as well as togetherness. My involvement with the team has given me comfort in public speaking and presentation, which will prove a valuable asset in college and beyond. All lessons from ROV have proven invaluable to my future as an academic and individual.

Calvin Schmidt

ROV has positively affected my future, offering me many advantages from the past two years that I have been participating. Preparation for the MATE ROV Competition has taught me advanced aspects of electrical wiring as well as problem solving techniques from both technical and non-technical standpoints. In addition to these techniques I have become a more comfortable and confident public speaker, as a result of the ROV competitions. After having to rely on fellow team members, ROV has taught me team working abilities, and has played an important part during the preparation for this year's competition. ROV club has also reinforced my college applications, as well as influencing my decision for an engineering major. The experiences and lessons I have taken from ROV have been completely worth my effort and time, as well as proving invaluable towards my future.

References

Ocean Observatories Resources

http://www.oceanobservatories.org/infrastructure/ooi-station-map/regional-scale-nodes/
http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=6197&org=OCE
http://www.oceanleadership.org/2013/program-update-ocean-observatories-initiative-april-2013/
http://www.marinetech.org/files/marine/files/ROV%20Competition/Missions%20and%20Specs/2013MANUAL_RANGER_FINALa.pdf
http://ooi.washington.edu/file/An+Intro+to+Axial+Seamount+and+Hydrothermal+Vents

Construction Resources

Electrical Wiring: http://www.homebuiltrovs.com/
Underwater Cable Connectors:
http://www.subconn.com/default.asp?objtype=mproductgroup&func=showdetail&id=1391&ilanguage=dansk&siteid=1031
Clear PVC: http://www.clearpvcpipe.com/?gclid=CN_NhoXG8qECFRUhnAodtiGUnA
Linear Actuators: http://www.firgelli.com/
Black PVC Fittings: http://www.flexpvc.com/
Cameras: http://www.supercircuits.com/
http://www.mcmaster.com/

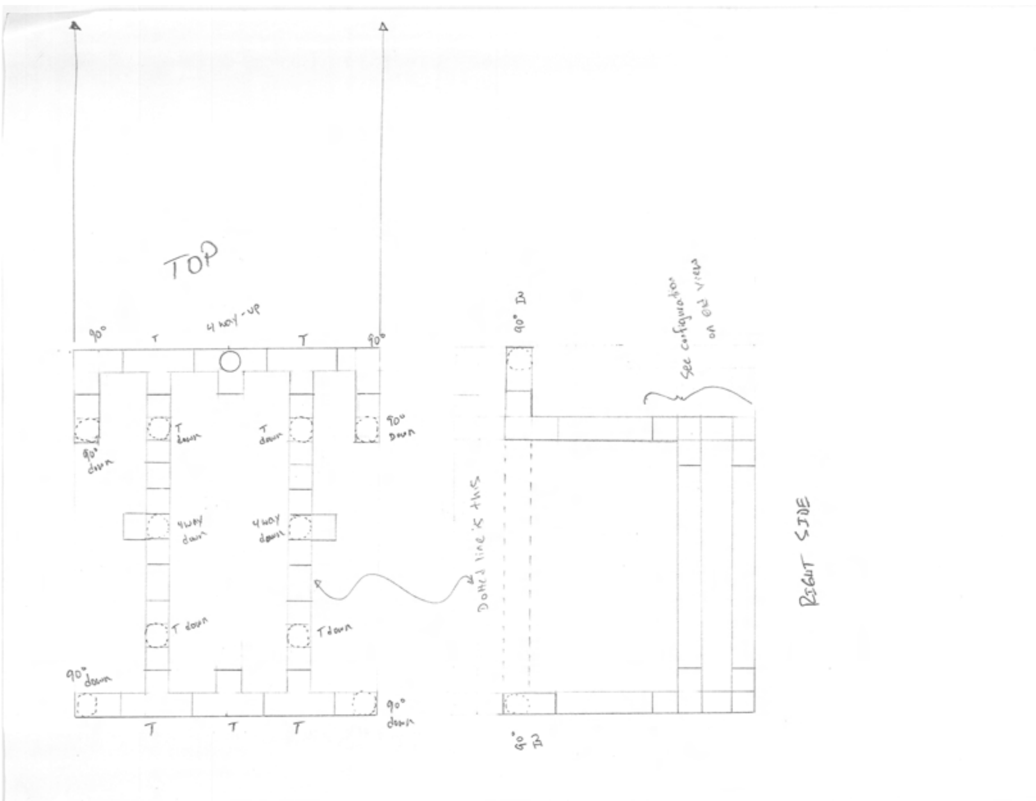
Acknowledgements

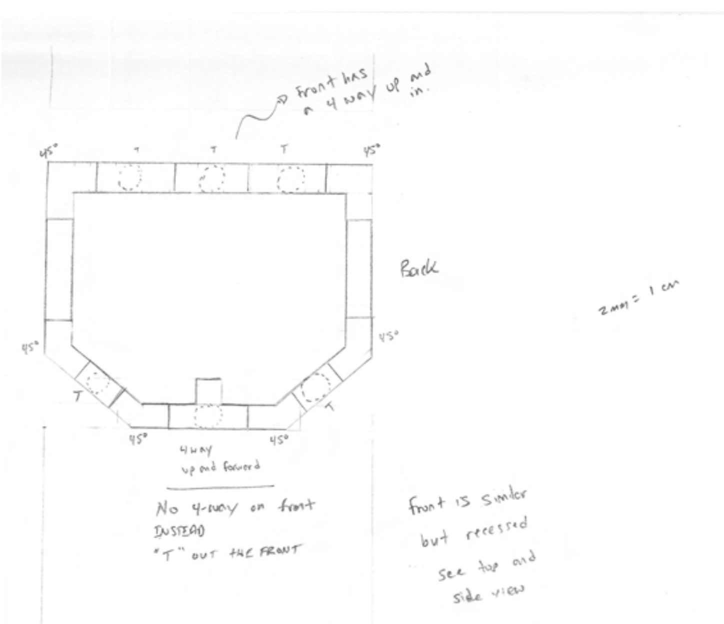
Local Donations

Lawn and Order
Joe Lamb Realty
Coastal Cottage Watch
Jo-El Quinlan
Danny Miller
Sea Swept Design
Dare County Board Of Education
Carl Worsley
SeaScape Golf
Larry Gray
Anne Hunter
Georgia Finch
Janine Harrington
Tommy's Market
Marie Gabrielle
James Pickren
Bonzer Shack
Roy Archbell
Richard Baer
Julie Gray

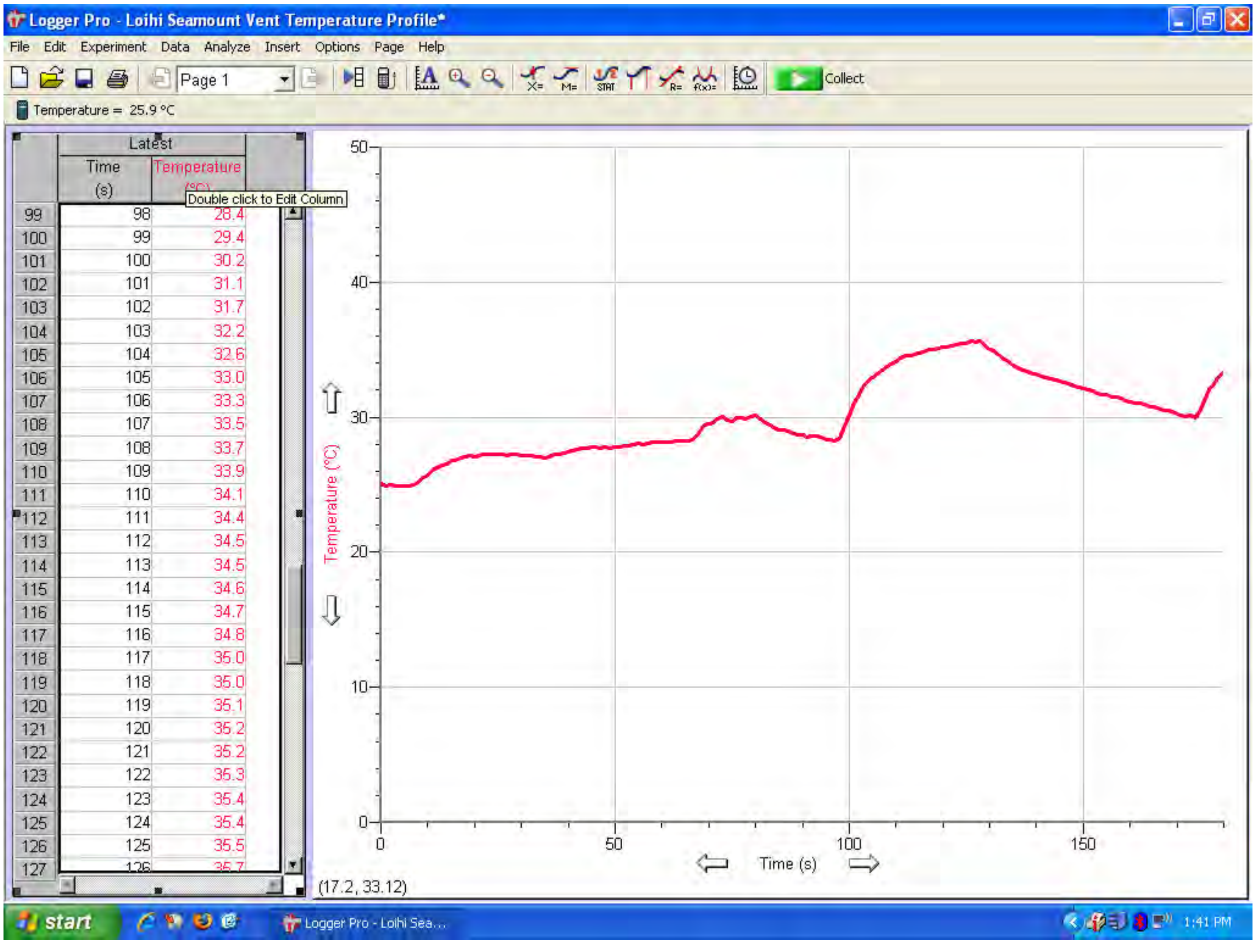
Appendices

Appendix A – Frame Sketches





Appendix B – Vernier Software Temperature vs. Time Plot



Appendix C – FDS Safety Checklist

First Descent Solutions/First Flight HS ROV Safety Checklist

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

Electrical ROV
- ☐ Single attachment point to power source.
- ☐ Standard male Banana plugs to connect to MATE power source. (International)
- ☐ 25 amp Single Inline fuse or circuit breaker within 30 cm of attachment point.
- ☐ No exposed copper or bare wire.
- ☐ No exposed motors.
- ☐ All wiring securely fastened and properly sealed.
- ☐ Tether is properly secured at surface control point and at ROV.
- ☐ Any splices in tether are properly sealed.
- ☐ Surface controls: All wiring and devices properly secured.
- ☐ Surface controls: All control elements are mounted with wiring inside an enclosure.

Mission Control Station
- ☐ Monitors set up and not in jeopardy of tipping.
- ☐ AC power is plugged into a surge protected and GFI outlet
- ☐ Chairs are sturdy
- ☐ Extension cords and plugs are in dry environment
- ☐ No tripping hazards from extension cords and cables

Mission Deck
- ☐ Cones are out and mission deck is cordoned off to keep passer Byers safe
- ☐ Tether is not a tripping hazard
- ☐ All tether and launching personal are wearing life vests (if applicable) and sturdy, closed toe shoes
- ☐ OSHA Safety Officer is on site
- ☐ A-Frame has been cleared and in shape for the days tasks

OSHA Officer Signature ____ Date _________

Print Name ______________________________________ ID badge # ________________