N.O.V.A.

The Linn-Benton Community College Remotely Operated Vehicle Club's Nautical Observer of Volcanic Activity

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http://rov.linnbenton.edu

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ABSTRACT

Linn-Benton Community College returns to the 2010 Marine Advanced Technology Education Center's Remotely Operated Vehicle competition for the third consecutive year with the LBCC "Nautical Observer of Volcanic Activity". The NOVA is an explorer class ROV designed to perform the full series of underwater challenges created by MATE based around the exploration the undersea Loihi seamount.

Our team started work during the Fall term. As the majority of our new team had not competed in a MATE event before, we focused on identifying and creating possible sensors and subsystems that could prove useful on an ROV in the oceans off Hawai'i. We met twice a week with Mondays being reserved for group communication and Wednesdays being used for construction days.

For the first time, our team also had the benefit of having dedicated workspace on campus. Much of Fall term was spend turning this workspace into an ROV lab. Our lab features a homemade CNC machine that we used to make parts and etch circuit boards, a drill press, and space that we modified to be a safe and effective workspace for the approximately 20 students who help construct the NOVA.

When the actual mission tasks were released we, as a group, quickly settled upon a frame and payload design that could complete each mission. Again, the team focused on a work schedule that valued communication and collaboration. By the end of Winter term every component of NOVA had a functional "proof-of-concept". During Spring Term we focused on integrating all the various subsystems into the small, maneuverable, but incredibly robust ROV that we call the NOVA.

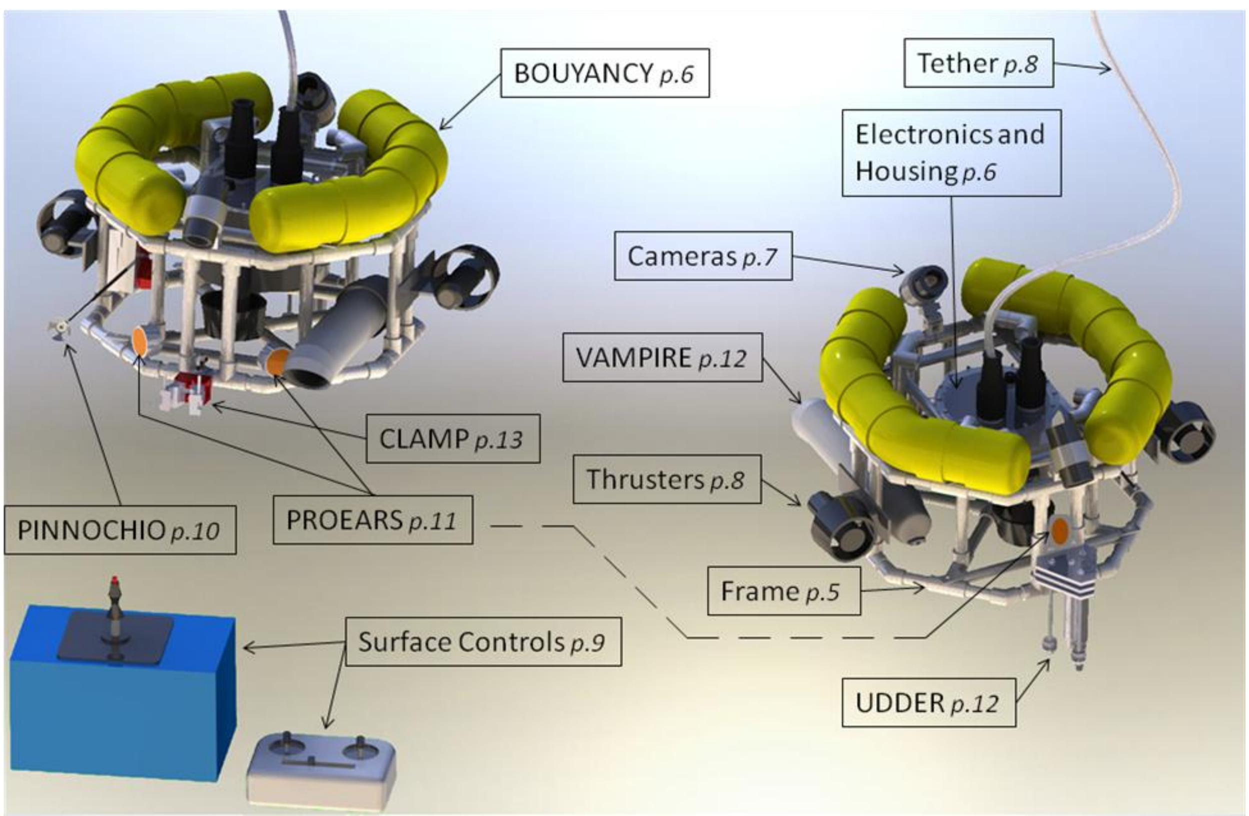


Figure 1: **The LBCC Nautical Observer of Volcanic Activity, its various components and corresponding page numbers.**

The Team and the Plan

The 2010 Linn-Benton Community College Remotely Operated Vehicle consists of students from multiple departments in the Science, Engineering and Technology Division. Besides dreaming, designing, constructing, and competing with a ROV for the MATE competition, we also provide outreach activities in science and technology for at-risk high school students and explore the bottoms of volcanic lakes in Oregon

During our first meeting during the 2009-2010 academic year, we crafted the following mission statement: "*We are a group of students who have come together to create a highly functional ROV that will contend at the 2010 MATE competition. The innovative nature of underwater robotics provides us with a unique opportunity to apply classroom knowledge and inspire other students in our community.*"

During our second meeting, we developed an engineering schedule for the next nine months leading up to the 2010 MATE competition in Hilo, Hawai'i.

Over the course of the academic year we grew together as a team and, with the aid of mentors from every department on campus and several long-nights in the ROV lab, we were able to stick to our original time-line.

Figure 2: **Team Photo** (in order from front-left to back-right)**: Nicholas Cantrell-Pneumatics/Fabrication, Ben Dean-Shop Manager/Frame, Daniel Roberts-Electrical Systems, Mark Overholser-Imagineer, Greg Mulder-Team Advisor, Nathan Murrow-Team Cheerleader, Ivan Merlin-UDDER/Tether, Justin McLeod-Propulsion/Electronics, Mike Hussey-VAMPIRE/Tech.Report/Technical Consulting, Keith Smee-Public Relations, Michael Tilse-Machinist/PINNOCCHIO, Raven Dorr-Solidworks Designer, Jesse Lowther-Bouyancy/Tech.Report, Louanne Van Beek-Frame/GUI/Tech.Report Editor/PR, Matt Seidlitz-PROEARS, Savannah Van Beek-UDDER/Fundraising, Julia Morrison-PINNOCCHIO/ Tech.Report, Justin Hussey-VAMPIRE/Tech.Report Coordinator.**

Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Recruitment									
Brainstorm Possible Mission Objecives									
	Designed and Constructed Prototypes								
			Mission Release						
			Revised Prototypes						
			Constructed Props						
				Constructed Frame					
				Constructed and Tested Individual Mission Components					
				Technical Report Development					
						System Intergration			
							Water Tests		
								Regionals	
									MATE 2010

Figure 3: **The time-line followed by the Linn-Benton Community College Remotely Operated Vehicle Team in preparation for the Marine Advanced Technology Education Center 2010 International Competition.**

DESIGN, FUNCTION and RATIONALE

DESIGN RATIONALE

In following pages we will discuss the individual components of the NOVA, but we would like to note that before we designed the ROV and its components we identified three overall design goals that we labeled: specialization, size, and safety.

Specialization: In previous years' competitions, the LBCC ROV team designed their ROV around one primary component built to fulfill all mission tasks. Due to this design focus, any single failure could be catastrophic and render us unable to complete any of the tasks. This year, we have simplified our design and assigned to each mission its own specialized component – this way if one component fails we can still complete the remaining parts of the mission.

Size: A further design consideration for the NOVA was the size of the cave it is designed to enter. We were forced to deviate from our tendency of creating large ROVs and restrict ourselves by setting a goal of maximum size of 50cm by 50cm by 70cm.

Safety: As always one of our main concerns was safety thus we built in several precautions to prevent accidents. We have made a water resistant cover for our power converter, enclosed our motors in shrouds with appropriate warning labels, ground down any sharp corners to avoid cuts, installed extra fuses to protect our systems, painted it bright colors for visibility from the surface and divers, designed for a lower supplied air pressure with a gage, and added legs to prevent damage to the pool.

Furthermore, during all work done on and practice using the NOVA we wore safety glasses, appropriate attire, and utilized equipment following recognized safety measures

A major asset that allowed us great flexibility and ability to maximize our creativity was accomplished due to our home-made milling machine.

Figure 4: **Our home-made milling machine, controller and enclosure constructed from parts found on Internet auction sites, surplus vendors and parts that we fabricated. Most components of the NOVA were wholly or partially created via this CNC mill.**

ROV COMPONENTS

ROV FRAME

The frame of the NOVA is simple, light-weight and is constructed of materials appropriate for an aquatic environment. The NOVA's frame size of 48cm x 48cm x 25cm and its octagonal geometry make it easy to maneuver in tight spots. We used ½" PVC pipe and fittings to create two octagons stacked on top of each other and connected by a series of vertical support bars at each corresponding vertex. These support bars are used as rigidity points to attach various components such as the thrusters, and mission-specific modules. Buoyancy tubes and cameras are attached directly to the dorsal octagon.

The octagon frame allows for increased maneuverability inside close-quarter environments. The small octagonal shape allows for easy adjustments of attached components in order to control of the position of the center of mass of the overall ROV. Furthermore, the shape allows for optimal placement of the thrusters to maximize torque allowing the ROV to be able to rotate sharply around its central axis.

Our symmetric frame geometry also allows us to attach the tether into the frame from the top minimizing the external torque exerted upon the frame. Furthermore, an aft mounted camera allows us to pilot the ROV backward which allows us to exit a tight space with minimal complication.

BOUYANCY SYSTEM

The Hawai'i mission requires no lifting of heavy objects. Thus, early on in the design process, we chose to construct the NOVA neutrally buoyant. We used 3" PVC pipe, capped at each end to achieve the desired buoyancy. This leaves all control over vertical maneuverability to the vertical thrusters.

We have, however, left room for the installation of a variable buoyancy system. A micro-controller operated variable buoyancy system could allow the ROV to surface, dive and maintain a target depth with great precision. A good start has been made on a variable buoyancy system, described in the "Future Improvements" section of this report.

ELECTRONICS and PRESSURE HOUSING

ROV Electrical Schematic

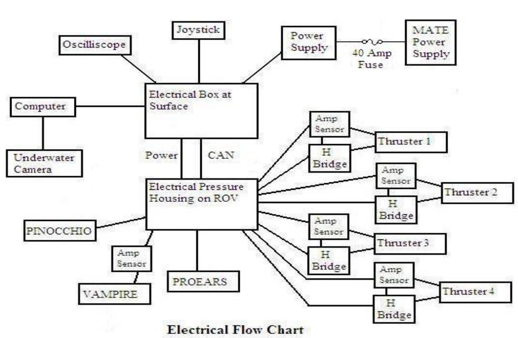


Figure 5: **The electrical schematic for the ROV.**

The main part of the control system enables the maneuvering thrusters to vary in speed allowing the ROV to turn port or starboard, dive or surface and move forward or backward.

The NOVA uses a wired "Remote Controller" for maneuvering thrusters. This controller has two control sticks that are individually connected to a corresponding variable resistor and sampled by a microcontroller. Each of the variable resistance values are converted into numerical values. We chose to control NOVA's maneuvering thrusters utilizing Pulsed-Width Modulation (PWM).

Microcontrollers can only handle small amounts of electric current, but the electric motors needed to propel NOVA require a larger amount of current. The H-Bridge receives the PWM pulse from the microcontroller to limit the amount of power to the motor. Each electric motor requires one H-Bridge.

H-Bridges are used when and electric motor needs to have variable speeds and variable direction. For constant speed motors, or single direction motors, simpler electronics can be used.

NOVA's electronics housing is constructed of tubular aluminum with a welded end cap and a welded flange at the other end. To close the housing, a .953cm thick polycarbonate plate

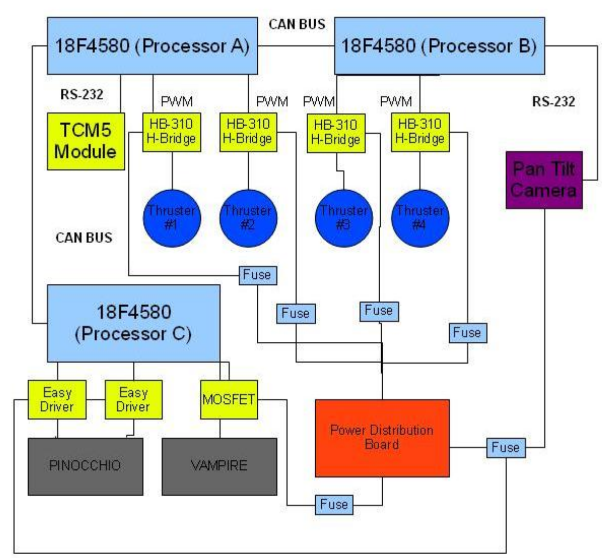


Figure 6: **The electrical diagram of components run by electronics located in the pressure housing.**

was machined to hold the tether connections, an o-ring was used for waterproofing and screw holes were drilled for securing the plate to the flange. Profiled holes were machined in the aluminum end cap for the thruster power connectors.

All electronics, those which receive commands over the Controller Area Network (CAN) and those which operate various systems on-board NOVA, are contained by the waterproof electronics housing.

The NOVA has four maneuvering thrusters and one bilge pump. Additionally, two stepper motors extend and tilt the temperature sensor.

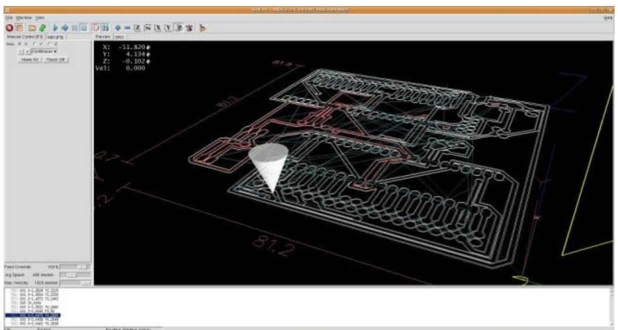


Figure 7: **A screenshot of the machine-tool path which fabricated the electronic board for NOVA's propulsion system.**

CAMERAS

The NOVA has four primary underwater cameras, all of which were manufactured by Lights Camera Action, LLC, based out of Arizona. All were donated to the LBCC-ROV Team at cost.

Camera A,B, & C Specifications:
Model: LCA-7700 series
Depth Certification.....................................60m
Operating Temp............................-10° to 50° C
Operating Voltage.................................12VDC
Current Draw...................................... <250mA

Camera D Specifications:
Model: Blu Vue 3-100
Depth Certification..................................305m
Operating Temp............................-10° to 50° C
Operating Voltage.................................12VDC
Current Draw...................................... <250mA

The cameras are mounted in positions that are favorable for monitoring our equipment during the competition. Two of the cameras are positioned in the front and back at 45 degrees down from the horizontal. The front camera will give us a clear view of the VAMPIRE, PINNOCHIO, and CLAMP which will allow us to better choreograph our movements when operating these components.

One of the rear cameras allows us to simply back out of the cave rather than having to turn around. The remaining rear camera is mounted on the higher portion or the frame to give us a good view of the UDDER. With this configuration, we will be able to see all of the necessary systems and have clear view of our surroundings.

Video Monitors

After experimenting with several types of software, we finally settled on Microsoft VidCap because of its superior frame rate. To incorporate video monitors into the system, we purchased and installed EasyCAP Video Capture Cards which allow us to capture composite video signals from each camera. We were able to utilize several EliteBook Tablet PCs donated to LBCC by Hewlett-Packard Corp. to install this software and run our main Graphical User Interface.

Video Switch

In order to reduce the number of computers required for operation, as well as decrease system complexity, we integrated a VDX 404 software-controlled video switch. The switch allowed us to use one EasyCAP capture card per laptop pair to function as a monitor for several video input signals.

Camera Mounts

A large number of the components on the NOVA were fabricated by team members in LBCC's Advanced Machine Tool Technology lab. Among them were the mounts used to affix the cameras to NOVA's frame. The camera mounts were manufactured to the specific dimensions of the frame, and then placed in locations for optimal viewing of the ROV's devices.

In order to function without worry of corrosion, all components were machined from inert plastic, aluminum, or stainless steel.

THRUSTERS

Propulsion

The thrusters chosen for our ROV are SeaBotix BTD150's. These thrusters were chosen due to their size-to-thrust ratio. The BTD150 operates at 24V, with a maximum current of 4.2A. At this power level, the thrusters produce a maximum of 18.1 Newtons of thrust in the forward direction, and 17.7 Newtons of thrust in the reverse direction. To mount the thrusters to the frame, an aluminum bar was drilled for the mounting holes on the thrusters, and then the bars were drilled in order to attach them to the frame with hex cap screws.

The position of the maneuvering thrusters on NOVA is based on a control scheme similar to that of a tank, or tracked vehicle. The two thrusters controlling forward and backward movement are positioned on opposite sides of NOVA. They are horizontal and parallel to one another, to provide a wide degree of maneuverability. Both thrusters are able to run full forward or reverse and any speed in between via PWM based on the position of the sticks on the controller.

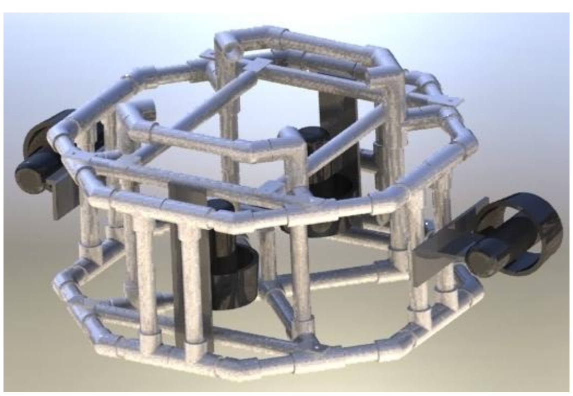


Figure 8: **A SolidWorks image depicting the ROV's thruster mounting and design**

Two more thrusters are positioned vertically and parallel within the frame of the NOVA. These thrusters power ascent and descent. They can also run in reverse to allow the ROV to pitch forward or backward. We have mounted the thrusters at equal distances from the center of the NOVA.

This combination of thrusters gives our surface controller the ability to maneuver with ease, and more importantly, level the vehicle on all axes.

Propulsion Electronics

Propulsion control for the NOVA consists of a Futaba R/C car remote. The wireless transceiver has been removed and a custom circuit board installed in its place. This allows the controller to be connected via a serial cable to the surface side microcontroller. The left stick controls the left horizontal motor and the right stick controls the right horizontal motor. In addition to joysticks, a slide potentiometer and toggle switch have been added to the controller, which are used to control the vertical thrust motors. The switch is used to toggle the vertical motors between synchronized or pitch mode.

TETHER

The NOVA's tether is composed of two different types of wire; 12 gauge water-rated cable for supplying power to the ROV, and four pairs of twisted pair wire[4]. The total length of the tether is 22m. One of the twisted pairs is used for data communication to the ROV, while the other three pairs are used for analog data transmission by the PROEARS to the surface. Wire sizing was chosen in compliance with American Wire Gauge and National Electrical Code sizing guidelines. The electrical connectors that come in contact with water are IP68 rated connectors made by Bulgin. We chose the Buccaneer 400 and 900 series connectors because of their relatively low cost and waterproof design. The Buccaneer 400 and 900 series connectors remain waterproof for up to two weeks of continuous service at 10m depth.

The tether is wrapped in a .006354m x .005m housing of Volara® brand closed cell foam to make it neutrally buoyant and sheathed in nylon to relieve snag points along its length. The amount of foam needed to make the tether neutrally buoyant was determined using this equation derived by the physics members of our team from Archimedes Principle:

$$m_{foam} = \rho_{foam}\left(\frac{m_{tether} - \rho_{water}V_{tether}}{\rho_{water} - \rho_{foam}}\right)$$

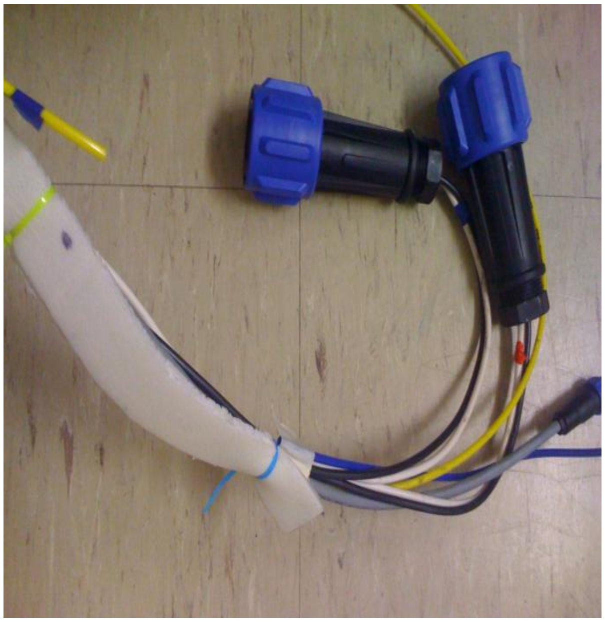


Figure 9: **A photo of the Tether connectors and neutrally buoyant cable.**

SURFACE CONTROLS

Communication Network

Due to of the large number of motors and devices needed to complete these missions, a digital network was chosen for the NOVA's method of control. The network is used to communicate between the surface and the ROV. It can be used to monitor and control devices with analog, digital, RS-232 Serial and Control Area Network (CAN) networks.

A CAN type network is much easier to implement, and thus the Microchip PIC18F258 with Microchip MCP2551 CAN Transceiver on an off-the-shelf controller board from Modtronix Engineering was chosen for this task. Our HP tablet computers interfacing the CAN type network will utilize the USB-to-CAN Interfaces from APOX Controls.

An additional advantage in the utilization of a CAN type network is that it is able to maintain communication over long distances. While this is not necessary for the MATE competition, it is a very desirable feature that was merely a consequence of using an otherwise useful network type.

Microcontroller and Personal Computer Programming

After comparing many similar products, the team decided to continue using the "PICkit2 Debug Express" from Microchip.com to program our microchips.

The current design incorporates: the Microchip PIC18F4580 for PWM and direct control motors, the Microchip PIC18F258 for the communication processor, the CAN system, and the APOX USB-to-CAN Interfaces for the PCs. The USE-to-CAN is for the monitoring and auxiliary control systems. Programming Languages will be PIC Assembler, PIC 'C', and JAVA for the PCs.

All Microchip processors are setup for in-circuit programming and debugging. We have made it a priority to interface our custom circuit boards could interface with the programmer so we don't have to interchange our microchips each time we update the code. We have prepared spares to readily replace any malfunctioning components.

Graphical User Interface

The graphical user interface (GUI) will be a Java based platform which imports data from C programs that are running on the micro-controllers on-board the ROV. Dynamically linked libraries (DLL) will be used to allow effective transmission data between the micro-controllers and the GUI.

SENSORS and MANIPULATORS

Sensor and Manipulator System Electronics

The NOVA's electronics and programming allow control of the roll, pitch and yaw of the ROV. Four cameras for underwater viewing allow for optimal maneuverability. Five very important mission-oriented subsystems are integrated into its final design. These include:

- a temperature sensor (the PINOCCHIO),
- a poly-phase hydrophone (the PROEARS),
- two electrically and pneumatically assisted devices for the procurement of underwater life-forms (the VAMPIRE and UDDER),
- as well as a pneumatically-controlled manipulator (the CLAMP).

Each subsystems performs a function that is integral to accomplishing each mission task.

PINOCCHIO – The Temperature Sensor

The *Precision Instrument for Nautical Observation and Collection of Celsius from Hydrothermal Instances of Outflow* or **PINOCCHIO** is the NOVA's highly maneuverable temperature sensor.

PINOCCHIO was designed to accurately obtain temperature readings from hard to reach places. We chose to use an epoxy coated NTC thermistor to obtain resistance values that could then be converted into accurate temperature readings at the surface. This type of thermistor was chosen for its wide temperature range, durability and economy. We collected ninety points of calibration data that fit a second order polynomial to better than a 0.1% discrepancy.

The temperature sensor's delivery mechanism consists of two stepper motors, pinch wheels, a large pitch gear, a pitch drive gear, and three plates made out of a polymer plastic. Most of the parts were manufactured by team members using our homemade CNC Milling machine.

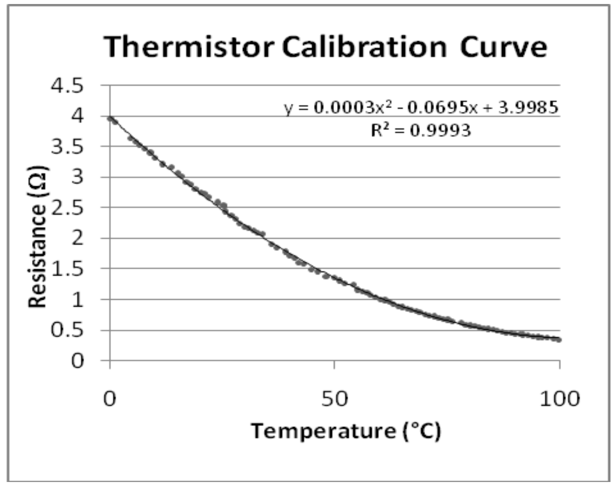


Figure 10: **Calibration Graph of the PINOCCHIO's NTC Thermistor**

The sensor's nose is a carbon fiber tubular wand designed to probe the hydrothermal vent. An NTC thermistor soldered to wire threaded through the length of the wand is positioned at the "nose" where it obtains resistance values.

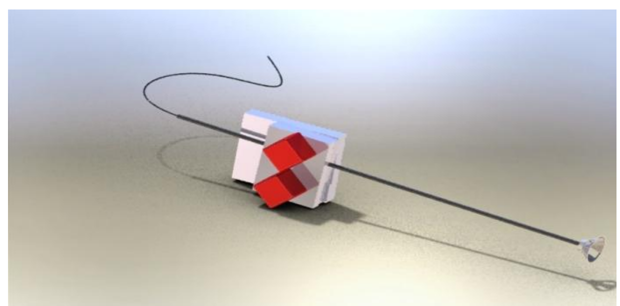


Figure 11: **The PINNOCHIO is the NOVA's highly maneuverable temperature sensor.**

The stepper motors used to extend, retract, or tilt the wand, were waterproofed using cast silicone to ensure functional longevity and reliable performance in an aquatic environment. One stepper motor powers the linear motion of the wand, while the other stepper motor rotates the plates so that the wand can pitch up or down. The vertical angular range of motion provided by the stepper motor is plus or minus 45 degrees from center. With this range of freedom, the wand can be more easily maneuvered into the opening of a hydrothermal vent for temperature observation.

The thermistor's resistance varies with temperature. This resistance is measured by a voltage divider, and compared to the measured values for temperature. A function was derived by calibration. The thermistor's output is converted to binary values that can be read by the surface controls. These values, ranging from 0 to 1024, are then received by a computer terminal surface-side utilizing a C program, and converted into temperature readings observable on the monitor.

PROEARS — The Polyphase Hydrophone

The *Phaseshift Receiving Omni-directional Electronic Acoustic Ranging System* or **PROEARS** is our sound identification device.

To pinpoint which rumble site is active, we designed and manufactured a poly-phase hydrophone for receiving and interpreting sound wave data being emitted from the source. The received information is transferred from the ROV to the vehicle's surface operators, and then displayed using an oscilloscope or computer software. The displayed data can then be used to discern the location of the sound waves' source and frequency.

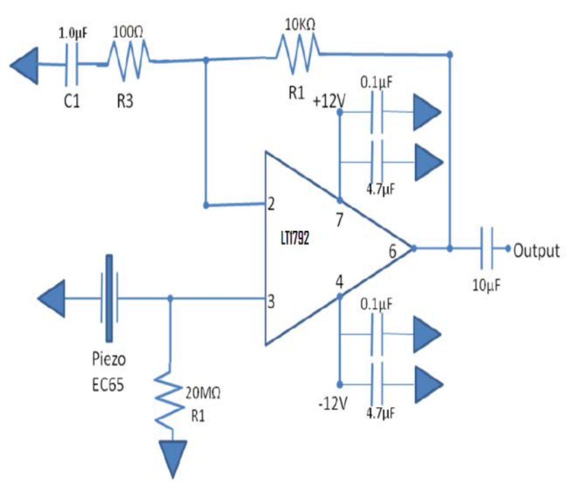


Figure 12: **An electrical schematic for PROEARS.**

We designed a poly-phase hydrophone using three Piezo Element 1500-3000Hz transducers (Radio Shack model #273-073) placed at the vertices of an equilateral triangle. Since the speed of sound underwater is $1.5 \cdot 10^3$m/s a quick calculation using $v=\lambda f$ convinced us that the physical width of the ROV would be appropriate to use the relative phase of incoming sound signals to discern the directionality of a sound source.

The three microphones are positioned on a horizontal plane that can spin about the NOVA's vertical axis. As the ROV rotates the sound waves from the sound emitters reach each hydrophone at a different time due to their difference in relative distances. By comparing the phases of the waves received by each hydrophone, we can determine the direction of the source of the sound.

The phaseshift and amplitude of sound waves received by each microphone changes, thus sound-waves will become dampened as the distance between the ROV and source of sound increases. For clear analysis, the amplitude of the sound waves received must be magnified, which is accomplished by utilizing pre-amplifiers in series for each individual microphone.

In order to ensure functionality in an aquatic environment, the polyphase hydrophone was waterproofed. A coating of oil was applied to the internal components and waterproofing was enforced by sealing them in polyurethane plastic.

In our original design all three microphone inputs were fed into a single output, which made it difficult to accurately identify each microphone's sound. In order to eliminate this problem we decided to dedicate a channel for each hydrophone, which consist of two wires per channel in order to differentiate each wave on the oscilloscope.

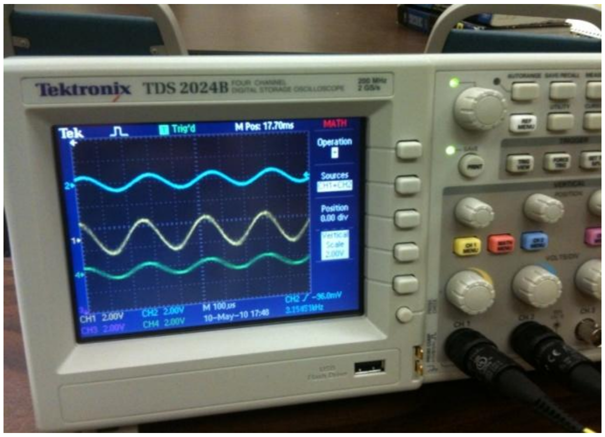


Figure 13: **A photo showing the oscilloscope display of the PROEAR sound waves while in phase. The in-phase behavior signifies a sound source is directly in line with either the fore or aft camera.**

The information obtained by the hydrophone is displayed as three separate oscillating waves that provide the operator with insight to the sound waves' direction and relative distance in relation to the ROV's position to the source. The oscilloscope we are using for displaying the sound waves received is a model 2024b, and was kindly donated by Tektronix, for which we are exceptionally grateful.

UDDER – The Bacterial Mat Collector

The *Underwater Dynamic Displacement Entity Retriever* or **UDDER** is used to collect samples of the simulated bacterial mat or agar. This design is the fourth prototype we have developed and is the first to work successfully under all conditions described within competition rules. It is comprised of three 60mL, off the shelf, irrigation syringes arranged within a triangular polymer framework. The framework is supported by machined aluminum shafts and actuated using a pneumatic piston to raise the machined aluminum plungers. The operational capacity of the UDDER is approximately 130mL due to the length of the piston rod. This falls within the range of the 101mL-175mL competition guideline.

The single 40psi air line is pressurized. Pressurization causes the plungers to rise slowly, decreasing the pressure within and at the apertures of the syringes. A sudden decrease in pressure causes the agar to be displaced into the syringes until the maximum volume is reached. The design of this system came from the need to work within a small region and draw a significant sample, while leaving the sample area relatively undisturbed.

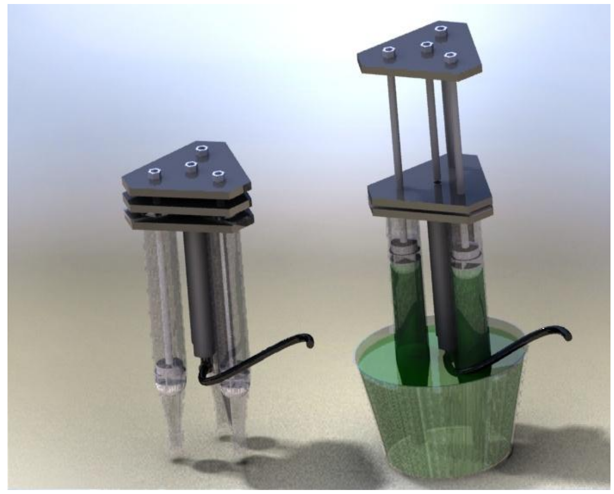


Figure 14: **A SolidWorks rendition of the UDDER; at rest (left) and sampling a bacterial mat (right).**

VAMPIRE – The Invertebrate Capture Device

The *Vacuum Assisted Manipulation and Procurement of Invertebrates for Research and Experimentation* or **VAMPIRE** is constructed to obtain samples of marine invertebrates by rapidly displacing the water surrounding the target invertebrate. It creates a strong flow through the length of an aluminum tube mounted to a bilge pump, and draws the life-form to the end of the tube into the safety-screen fixed in front of the pump. Due to the effectiveness of the process, coupled with the fact that it could be accomplished without undue harm befalling the captured invertebrates, this method of procurement gave us logical reason to design the device based upon the compact dimensions of the TMC 1000 centrifugal bilge pump manufactured by TMC Technology Corp.

Operating at a nominal 12 Volts DC, the bilge pump draws an average of 5.5 Amperes. Constructed of aluminum/chrome alloy tubing, it is 40 cm. long, and 9 cm. at its maximum diameter. The intake is angled at 40º to facilitate the acquisition of specimens from the sea floor.

This device has an ultimate vacuum of 33.8kPa with a maximum flow of 15 L/min at 12V. The maximum depth of submersion, as determined by the factory seals, is 5 Meters.

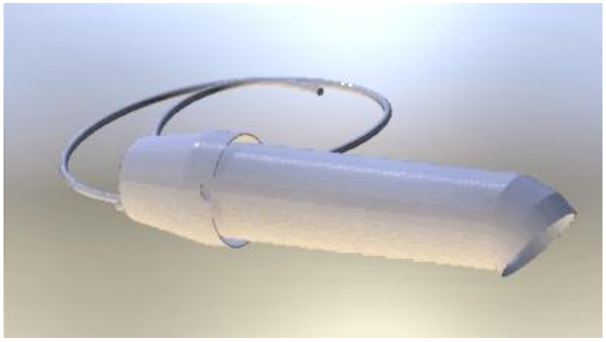


Figure 15: **A SolidWorks depiction of the VAMPIRE; the device used to procure underwater invertebrates.**

The VAMPIRE was designed with a focus on simplicity and functionality. Designing a simple, single part device will most likely function as designed without operational problems. This design was chosen over a more heavy and cumbersome complicated arm configuration since the dimensional constraints of the cave require a more compact and maneuverable device that would still effectively perform the required task.

CLAMP – The ROV's Manipulation Tool

The *Claw-Like Appendage for Manipulation of Parts* or **CLAMP** functions as the NOVA's pneumatic manipulator. The base pneumatic manipulator was manufactured by Barrington Automation, (Model # B-1W). To assist in accomplishing mission objectives, custom aluminum "softjaws" were made to team specifications. This included a negative of the coral spire and several press-fit pins designed to simplify manipulation of the various components of the "HUGO" Objective.

The CLAMP will enable us to pull the pins securing HUGO, lift and transport HUGO to the location near the active vibration source, plug in the hydrophone connector and to acquire and transport the "spire" sample from the hydrothermal vent location It is extended and from NOVA and retracted via a 15.24mm stroke pneumatic cylinder controlled by surface supplied air pressure.

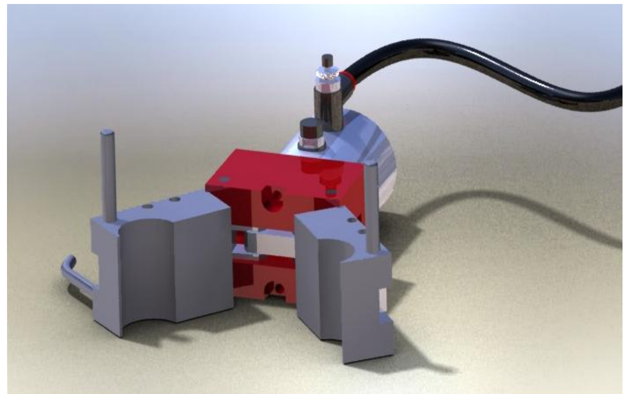
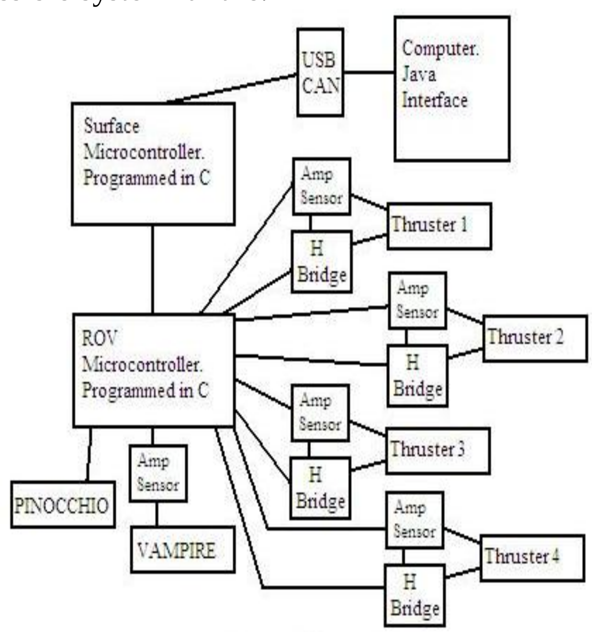


Figure 16: **A SolidWorks rendition of the CLAMP; the pneumatically driven manipulator used to "grab" task-specific items.**

SOFTWARE

The software interface is a Java based platform which imports data from the micro-controllers on-board the ROV. These microcontrollers are programmed in C and a dynamically linked library (DLL) is used to allow the two languages to talk to each other. The interface displays diagnostic information on critical systems and collected mission data. Showing important information on various systems will provide us with a warning of overheating or possible system failure.



Software Flow Chart

Figure 17: **Flow Chart describing the data interactions between the various systems used to control the ROV underwater.**

REFLECTIONS ON THE EXPERIENCE

The team as a whole found the experience of designing, building, and fine-tuning the NOVA, a truly memorable and beneficial experience. The project encouraged each of us to employ all of the group's ingenuity, technical experience and scientific understanding that we had at our disposal. It pushed all of us to our limits of understanding and experience, and forced us to collaborate to

The long hours spent on the NOVA were challenging. However, this time together allowed team members to become well acquainted, which allowed us to work very well with one another throughout the process.

Michael Tilse, our team's main CNC machinist stated, "I've enjoyed being on the team…helping make something that works! It has enlarged my world, and helped me to re-learn some important lessons. Lessons about mentoring, responsibility, and not doing everything myself, which I had forgotten."

The challenges we faced, and problem-solving techniques that we had utilized, throughout this experience will undoubtedly continue to help us in additional projects in the future. We all gained more knowledge in the many various fields needed to complete these tasks than we had previous to this experience, and inasmuch has created in each of us a stronger aptitude to succeed within a team.

"Working on NOVA was an incredible learning experience not only in the relevant disciplines of science, but also in effective team work. I learned that it's not enough to simply be a team player. Long term projects of this complexity require more than willingness, but the ability to effectively communicate, and contribute to both team motivation and organization." said Nick Cantrell, one of the primary team-members working in pneumatics and fabrication.

learn additional information in order to continue to improve NOVA's capabilities.

Team member, Keith Smee learned a lot this year, he went on to say, "This year I learned how to solder. It was a great experience and something that I will be applying in my future career as an electrical engineer. I also learned that getting 20 people to work on one thing simultaneously is quite a feat."

CHALLENGES and TROUBLESHOOTING TECHNIQUES

During the course of this year, there have been many trials and tribulations; challenges that have tested the fortitude of this year's ROV Team. Those involved in the ROV Club consistently derived methods to troubleshoot these obstacles. These are but a few of those obstacles that were found to be of particular note.

Troubleshooting the PINNOCHIO

Waterproofing the stepper motors was a technical challenge. The motors have exposed electrical connections within the housings, which could short out, as well as ball bearings that could freeze up with corrosion. The first waterproofing plan was to replace motor bearings with simple sleeve bearings made from slippery UHMW polyethylene plastic and have the motors run 'wet'. The accuracy required to do this and still have the steppers operate was beyond our skill.

Also, it was found the original motors used did not have enough torque to reliably extend the wand or pitch it up and down. Slightly larger motors were substituted and now the device works as intended.

The second part of the waterproofing plan was to cast silicone rubber material around the exposed connections and windings to keep out water. This method has worked well. The alternate solution for keeping water out of the bearings is fabricating 'face' seals at the motor shaft openings that seal tighter the greater the depth. They are made of slippery UHMW polyethylene plastic discs on the shafts, pressed into contact with polished steel rings mounted on the motor. Combined with an overall exterior coating of silicone waterproofing material and the internal cast silicone, the motors will work well submerged.

One of our largest design challenges was choosing an optimal material from which to cut the sensor mechanism. Nylon was first chosen and was cut exactly to size, but our cuts, however precise, also roughened the surface of the material. A frayed surface made both the linear motion of the wand and the angular motion of the plates slightly irregular. Nylon also absorbs water and changes dimensions in doing so.

Once we changed the material to a polyethylene plastic that did not roughen when milled, the recesses we cut were smoother. Changing the material of the gears and motors in this way provided the desired fluid motion when changing the sensor's orientation. We confidently consider this sensor a: product of rigorous experimentation, optimal instrumentation, and solid design.

Electronics

The PIC microcontrollers used required custom circuit boards to be made. The circuit boards had to be small enough to fit into the housing along with the other components. The boards were designed by the team using EAGLE electronic design and layout software. G-Code was produced for the double-sided board using the open-source PCH-GCode plug-in for EAGLE and then exported to our home-made milling machine.

Milling the board was chosen because we had the machine in-house and thus responsive to a iterative design process. Milling the board moves an etching bit through the copper layer to form the circuit pattern by removing unwanted copper and thus "isolating" the desired circuit traces. The board is then drilled for the components, turned over and the second side milled.

One of our challenges was to produce circuit boards of adequate quality.

Initially, shop-fabricated circuit etching bits were tried but produced burring of the copper and uneven trace widths. Changing the fixture to a flatter plate, using thin carpet tape to hold the board and using commercially produced carbide etching bits and circuit board drills improved the quality.

Learning proper settings for cutting depth and rate of feed resulted in good quality boards. The double-sided board also required the fixture to precisely locate the board so the second side could be milled in alignment. A number of poor quality or simply bad boards were produced in learning this process but the final good quality circuit board is now the 'brains' of the NOVA.

LESSONS LEARNED

As the ROV Club encountered their challenges, and employed their solutions, they came from the experience with some very important lessons learned. The experience alone was an apt teacher, but there were many subtle challenges that were often pointed out by Greg, the ROV Club's amazing team advisor that had truly helped the team achieve a solid understanding of those problems faced. All in all, much was learned by the team and these are but a few direct quotes from some of the team members that worked on this year's ROV: the NOVA.

"[To] ask and offer work is better than [to] demand and insist. Everybody has valuable things to offer. Balance." - Michael Tilse

"The most important lesson that I had learned in my contribution to this year's ROV is that communication can be exceptionally difficult to coordinate, but absolutely necessary. Inasmuch, I had to make several changes to my established method of communication in order to better suit the lifestyles and capabilities of tech. report team, and so with what I have learned this year, I have an amazing insight in how to coordinate next year's technical. report. I am excited!" – Justin Hussey

"This entire process has been new for me and the learning curves steep, but awesome. I come away from this experience with these few lessons: buy at least twice as much as you think that you'll need; allow twice as much time as you think that it will take to complete each project; ask a lot of questions even if they seem silly, and; have someone else check your calculations at least once before committing materials. Building relationships, overcoming challenges, and the opportunity to adapt are skills I will take away from this year's competition and I look forward to returning next year." – Ivan Merlin

"From a team perspective I would like to see a "team-center" type collaboration software implemented from the very beginning. While we were very successful at using what organizational tools we put to use: I believe documentation of responsibility is a crucial component to effective communication and accountability to timelines. Collaboration software streamline's the process of achieving these ideals." – Nick Cantrell

"This year I learned how to make agar, and that things never work out the first time around, but it is fun to keep trying new ideas." – Savannah Van Beek

FUTURE IMPROVEMENTS

As with any team of dedicated engineers, there are always thoughts and plans for future improvements, and that also stands true with an ROV team. There were several ideas that were posed by the several members of the team, and while we were not able to incorporate these future improvements, they were important ideas that should be documented for future use. These future improvements, while generally aimed at the ROV's overall efficiency, are quite different in nature. One of the main ideas that the team wishes to later incorporate into future designs is a variable buoyancy.

Variable Buoyancy

The variable buoyancy system is designed to achieve different magnitudes of buoyant force using Archimedes' Principle which states that the buoyant force is equal to the weight of fluid displaced. The configuration of the system changes to displace more or less fluid as desired, thus altering the buoyant force on the system. This allows the ROV to surface, dive, and maintain a target depth. The key component to this system is the Bellofram™ rolling diaphragm which was donated by the Bellofram™ Corporation.

Figure 18: **A diagram depicting the different stages that the variable buoyancy device goes through its process.**

The core of the system is enclosed in an outer body tube 45.72 cm in length and had an inner diameter of 7.62 cm. An internally mounted linear actuator drives pistons with an outer diameter of 6.8326 cm, which allows a 0.7874 cm clearance for the Bellofram™ diaphragm to be displaced, as shown in the diagram above.

The linear actuator uses a double threaded rod to simultaneously drive two pistons, one at each end of the buoyancy tube. Because the pistons are simultaneously actuated in opposite directions, unwanted pitch of the ROV is avoided during the systems use.

Several other ideas were proposed for future improvements as well by the club members, some of which would greatly increase the functionality of the ROV. These are a few of the prominent ideas for future implementation:

Frame, Manipulator Arm, and Tether

“The PVC frame was very effective in the prototyping stages however as a finished product it could be improved upon in terms of mounting hardware. Either standardized mounting hardware which straps to the PVC should be used to facilitate ease of mounting accessories, or the frame should be remade from aluminum extrusion.

A manipulator arm takes an ROV to the next level in functionality, and if an effective hydraulic servo could have been developed I think it would have made this feasible. This was made a low priority as it was not a necessary feature, but human anatomy suggests that a pair of manipulator arms is a highly functional accessory if the Inverse Kinematics can be hammered out.(which in fact: willow garage may have accomplished)

Eventually a fiber optic tether and deep water pressure housing are a top priority on the teams wish list. These two improvements will greatly increase the variety of missions NOVA can tackle.” – Nick Cantrell

With many great ideas and dedicated team members such as these, future improvements each year will continue to push the limitations of consequent ROVs through the teamwork, scientific insight, ingenuity, and well managed imagination.

BUDGET/EXPENSE SHEET

The Linn-Benton Community College ROV Team has greatly benefited from gracious equipment and cash donations from a variety of sources. The team spent $1678.75 on actual construction costs for the ROV during the 2009-2010 academic year. However, if we were to attempt to construct the ROV from scratch with only new and equivalent equipment the actual value of NOVA totals $18,241.70.

As is true in most research to remote locations and/or extreme environments, the largest single cash cost to the team is in the form travel and housing which totals $9645.78.

Equipment Purchases and Donations

Item	**Team Cash Costs**	**Donations**
Fall Term Prototyping Equipment	$336.33	$55.00
Electronics for Thrusters	203.19	33.50
Frame and Tether Materials	522.26	56.00
PINNOCIO Parts	44.52	
PROEARS Parts	46.30	
VAMPIRE Parts	0.00	10.00
UDDER Parts	9.98	
48VDC to 12VDC Converter	281.54	32.45
Labor (paid in the form of pizza, Thai and Chinese food)	234.63	
TCM5 Tilt Compensated 3-Axis Compass Module		1200.00
Oscilloscope TDS2024B		2490.00
Cameras and Thrusters from OUVET		7740.00
2 HP 2730p EliteBook Tablet Computers		4946.00
Travel and Housing in Hawai'i	7967.03	
Total Cash Cost to Team	**$9,645.78**	
Total Cash Equivalent of Donations		**$16,562.95**

Cash Donations

LBCC Student Government	$5,000.00
LBCC Science, Engineering, and Technology Divison	1550.00
MATE Team Contribution ($150 each)	1350.00
Physical Science Department	600.00
Team Dues	420.00
Income for Work with OUVET	800.00
Total Cash Donations	**$9,720.00**

As the LBCC team prepares for departure to Hawai'i the team has a grand total of $74.22 in its saving account.

Acknowledgements:

Equipment donations are greatly appreciated from:

Hewlett-Packard
Tektronix
PNI Corporation
Bellofram Corporation
Parallax Inc.

Items sold to us at cost are greatly appreciated from:

Lights, Camera, Action
SeaBotix
Burcham's Metals
United Pipe

Logistical Support and Equipment Loans are greatly appreciated from:

The Oregon Underwater and Volcanic Exploration Team
The Oregon Consortium and Workforce Alliance
Oregon State University

Thanks for the technical support from LBCC Faculty and Staff:

David Kidd	John Sweet
Karelia Stetz-Waters	Bryan Miyagishima
David Mack	Deron Carter
Bridgid Backus	Marci Bailey
Paula Weiss	Patty Petzel
Perry Carmichael	Sandy March
Cressey Merrill	Parker Swanson
Erik Rau	Dana Emerson
Dan Lara	Dave Kettler

Thanks to the following Linn-Benton Community College Departments:

Physical Sciences
Engineering
Computer Science
Drafting and Engineering Graphics
Welding
Health and Human Performance
English
Speech
Student Life and Leadership
Media and Computer Services

Cash donation to ensure future work by the ROV team greatly appreciated from:

Dr. Ann and Douglas Brodie

Special thanks to the Linn-Benton Community College Security Department for keeping us company during many weeks of very long nights and special thanks to our family members who put up with us being away those very same long nights.