Linn-Benton Community College

ROADRUNNER ROBOTICS

The LBCC Remotely Operated Geological Explorer Allen Throop

Lead Mentor: Gregory Mulder

Team Members: Joel Alvarez, Ryan Blair, Tom Fillmore, Chris Green, Brian Myers Patrick Ramsing, Carrie Rebhuhn, Matthew West

Table of Contents

Dedication

The LBCC team's ROV is named after Allen H. Throop, an LBCC Geology instructor who died a few years ago of Lou Gehrig's disease. Allen had a strong sense of adventure and exploration. This sense of adventure was passed on to his students, fellow coworkers, and his family. Allen's son carries on his father's legacy, and was a member of the Cassini Team's mission to Saturn as well as currently working on the “New Horizons” mission to Pluto.

Abstract

This is the first year that LBCC has competed in the MATE ROV competition. As a rookie team, a lot of design strategies had no experiential basis; many components of the ROV had to be designed and modified through trial and error. The building of the robot was nevertheless hastened by good management and weekly meetings, as well as the choice to divide members into working on subsystems of the robot. Most of the design concerns involved the pressurization, waterproofing, and stability of the robot underwater. Although many team members had prior robotics and machine shop experience, none had dealt with the design of a mechanical system underwater. Cost was an additional parameter. The team applied for and received grants from the LBCC Foundation totaling $4,375, but the price of water- and pressure-proofed motors and pneumatics were frequently in the thousands of dollars. Price restrictions prompted innovations such as using bilge pumps for propulsion and making our own pressurized motor boxes. The robot is controlled by a series of switches that control which pumps are activated, and the pumps are connected to nozzles affixed to different corners of the robots.

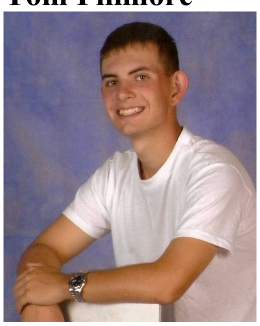
The Team

The team consists primarily of seven members, although the construction of the robot and components of the practice field were assisted by many other casually interested students.

Joel Alvarez

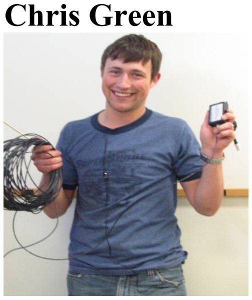
Joel Alvarez grew up in southern Oregon and began attending college at Devry University in Phoenix as a business major. He later found that his true passions are in analyzing businesses and improving efficiency and profits through the integration of new systems and technologies. He is now an industrial engineering major at LBCC and is looking forward to attending OSU this fall. Joel's life ambitions are to help bridge the gap between the science and business world in a ways that will improve the environment and our global society's standard of living.

Tom Fillmore



Tom Fillmore is a 2004 graduate from Lebanon High School. Tom has been enrolled at Linn-Benton Community College for the past 4 years where he earned an Associates Degree in Welding. He has since been a part of Engineering Program and plans to transfer to Oregon State University. His task on the ROV was designing the thrusters, as well as offering his welding experience.

Chris Green



Chris Green worked with Spencer Hull, the team's electrical advisor, on creating a working temperature probe system for the ROV. Chris was last seen on his motorcycle driving into the sunset.

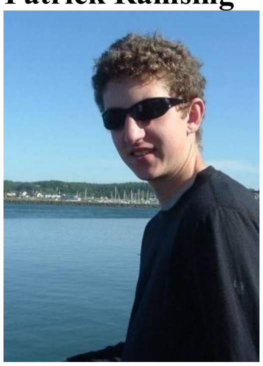
Greg Mulder

Gregory Mulder has been a Professor of Physics at Linn-Benton Community College in Oregon for the past 10 years. Prior to that, Greg received a Masters in Physics from University of California in Irvine and a Bachelors Degree in Physics while studying both at Oregon State University and University of Karlsruhe in Germany. Classes that Greg teaches include: Physics for Engineers and Scientists, Astronomy, Radiation Technology, and a variety of other exciting physical science classes that sometimes take place in interesting places such as Hawaii,on the bottom of a volcanic lake, or on top some of Earth's tallest mountains.

Brian Myers

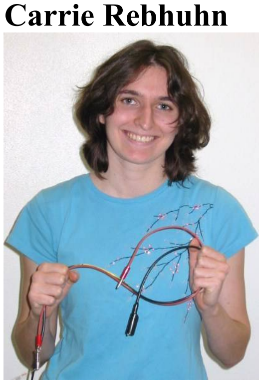
Brian Myers graduated from Highland High School located in Pocatello ID in 1997. He started college in the fall of 1997 where he studied Electrical Engineering. He soon found out that this was not the field he wanted to study. Taking a few years off to reassure himself that a College education was what he really wanted he started taking classes to work on more of a general engineering degree. He found his desire in Nuclear Engineering which he studies currently at Linn Benton Community College and Oregon State University. He will be graduating in 2010, and plans to continue on and get his Master's degree in nuclear engineering.

Patrick Ramsing



Patrick Ramsing is a sophomore at LBCC, and is transferring to Oregon State University in the fall to study Chemical Engineering after which he intends to attend graduate school. He is 19 years old and has spent most of his life in Corvallis, OR apart from two years when he moved with his parents in Cambodia 95'-97'. Outside of work and school he enjoys rock climbing, backpacking, beekeeping and spending time with his fiancée.

Carrie Rebhuhn



Carrie Rebhuhn grew up in Corvallis, Oregon with two parents who worked at Hewlett-Packard as technicians. In high school she developed an interest in robotics, and joined the FIRST Robotics team 955 during 11th and 12th grade. At present she is dually enrolled in the LBCC and OSU engineering programs, with the intent to earn a Bachelor's degree in mechanical engineering from OSU.

Matthew West

Matthew West has won several awards and scholarships in welding, and has an associates degree in welding technology from LBCC. After his first year in college, he began working for West Coast Industrial systems as a professional welder, and has worked as a fabricator traveling the Northwest working primarily on sawmills. He is presently studying engineering at LBCC with the intent to transfer to OSU for a Bachelor's in mechanical engineering.

Challenges

Building a robot to function underwater was a new challenge to all involved in the project. Underwater gears were prohibitively expensive, making the designing of the arm difficult, and thus we needed to improvise waterproofing devices. We avoided waterproofing the thrusters by using bilge pumps, but these came with their own problems. When the pumps were attached to the frame of the robot we discovered that they did not provide enough thrust to overcome the friction of the bottom of a pool. When the robot was positively buoyant, the thrusters were able to move slowly, but the cord on the robot still added enough drag to negate much of the thrust. A larger-motor solution would have been problematic in that it would be more resource-intensive.

We solved this problem in a number of manners. To deal with the issue of friction at the bottom of the pool, we added flotation devices to make the robot more neutrally buoyant in the water. It could still fully submerse, but would not have as much friction. The drag from the umbilical cord was ameliorated by adding flotation devices to the cord as well; there was much less friction on an umbilical cord that floated on the surface rather than one that was submerged to the bottom of the pool, which the robot to go faster. Finally, we added more power by reducing the cross-sectional area of the output pipes attached to the thrusters. This was cheaply and easily done by attaching nozzles to the open pipe ends, thereby increasing the velocity of the water leaving the pumps.

An additional problem we faced was the problem of neutral buoyancy. Originally we had used foam pool toys attached around the robot to change buoyancy. We found that the density of the foam changes easily, and would not stay consistent enough to provide neutral buoyancy. To fix this problem, we replaced the pool toys with PVC piping filled partially with air. It takes much more pressure for the PVC to noticeably change in volume than it does for foam toys, allowing for better calibration of the buoyancy.

Troubleshooting Techniques

Largely our techniques for troubleshooting were trial and error. By coming up with a variety of low-cost solutions, we were able to implement more than one idea at minimal expense. The best example of this technique is the design of the buoyancy system to bring the robot up from the bottom of the pool. Originally the idea was to inflate a balloon-like object (a beach ball) in the middle of the robot, which would bring it to the surface. The problem with this idea was the balance of the robot—one end of the robot came up before the other end, although it was functional in bringing the robot to the surface. Then we experimented with water wings; when inflated by mouth, these were very effective at evenly floating the robot when spaced correctly across the top of the robot’s frame. Unfortunately, when inflated with a Scuba tank, these exploded. The end result was to work on a similar concept as the water wings, but with different materials; four thick rubber tubes were placed on the top of the robot and inflated gradually; this eliminated popping and provided a system to bring the robot to the surface evenly.

The Field

Construction of OBS and Hydro Thermal Vent

<u>I. Ocean Bottom Seismograph (OBS)</u>

Parts List:

- One (50cm)X(50cm) 1/8 inch ABS sheet
- Two (3 inch) 28cm long ABS Pipe
- One (3 inch) 20cm long ABS Pipe
- Two (3 inch) ABS end caps
- Four (3 inch) end covers
- Four (12 inch) Zip ties
- Four half inch PVC T's
- Eight half inch three way PVC corner joints
- Ten pieces of half inch PVC pipe at 25cm long
- Four pieces of half inch PVC pipe at 8cm long
- Four pieces of half inch PVC pipe at 12cm long
- PVC glue
- Four (6 inch) Zip ties

The team members in charge of the OBS construction were Ryan, Patrick, and Chris. The three purchased the majority of the parts for the OBS at Searing hardware in Corvallis, OR. The store manager gave us a 30% discount on our parts. Once all the parts were gathered for the OBS, construction began. A chop saw was used to cut the PVC and ABS tubing to the required lengths. Careful measurements were taken to correctly size the unit. Once all pieces were cut the product was assembled, and measured again to ensure proper dimensions. The three ABS tubes that form the flotation package and the OBS instrument package were placed inside the frame of the OBS and then zip tied together. All fittings (except caps) were then glued using PVC glue, and the ABS sheet was fastened to the bottom of the OBS using zip ties.

II. Hydro Thermal Vent (Black Smoker)

Parts List:

- One (40cm) diameter Oil Pan
- One bag of concrete
- 22 inches of half inch PVC pipe
- One three quarter MHT to half inch PVC hose adapter
- Two half inch 90 degree PVC elbows
- One half inch PVC straight coupling
- Two half inch 45 degree PVC elbows
- One (2 inch) diameter,(10cm) long PVC pipe with a (1 inch) hole in side
- One two to three inch ABS pipe increaser
- One (3 inch) ABS pipe that is (30cm) long
- One (3 inch) PVC end cap
- One (2 inch) PVC coupling

The team members in charge of the Hydro Thermal Vent construction were Ryan, Patrick, and Chris. Most of the parts for the project were also purchased at Searing Hardware in Corvallis, OR. The lengths of PVC were measured carefully and then cut on a chop saw. Parts were fitted together according to the specifications on the Mate ROV site. Once all parts were cut, the product was glued together using PVC glue. To construct the base of the Vent, concrete was poured into the oil pan and formed around the bottom of the pipe.

Both the OBS and the Hydro Thermal Vent were assembled in one day. All the parts were purchased and the products were assembled in less than six hours. The total cost of these two products was under $70.

Design Rationale

The first step in creating a fully functional ROV capable of meeting specific mission objective was to create a communication system that would allow a large number of people, each working on subsystems, to work together to create one complex functional device. To meet these demands, we relied upon Blackboard. As a web-based communication system, we utilized the college's Blackboard system in order to keep track of teach sub-team's subsystem progress.

As we progressed in the creation of our ROV, we discovered that ROV's design would nicely match mission requirements of current geological research at Newberry Caldera in Central Oregon. For only a one-third increase in design costs, we were able to create an ROV that could meet both the San Diego MATE competition objectives and the Newberry Caldera Geological Exploration objective. All of these increased costs were due to extra supplies needed to accommodate the increased depth of the lake compared to the swimming pool

We were also working on a very tight budget, but nonetheless considered it imperative to build a foundation of equipment that future LBCC ROV teams could build upon while maintaining budget limits.

Primary Objectives of the San Diego Competition:

- Retrieval of rock samples: We came to the conclusion stability and precision of control in our means of collecting samples was important. We thus opted to use a motorized arm with a pneumatic gripper that could be easily maneuvered from the surface.

- Temperature data collection from a thermal vent: Once again precision was a primary concern for this objective. Therefore, we decided to incorporate the thermal sensors into the arm.

- Freeing a trapped piece of scientific equipment: Having reviewed the capabilities granted to the ROV for the completion of the first two objectives, we concluded that the arm combined with the gripper should be able to perform this task.

Primary Objectives of Newberry Mission:

- Retrieval of rock samples: Given the greater depths and need for repeated use, we felt it was important that our equipment be extra sturdy. With that in mind we decided that using stronger materials was important as well as the amount of samples we are capable of retrieving. Thus, we used aluminum and steel materials on the arm and left room to add more variable buoyancy to potentially double the ROV's current maximum sample load of 4.44kg.
- Temperature data collection will be handled in the same manner as above.

- Collection of visual data: We thought it important to collect as much visual data as possible and as such we invested in an additional camera.

Secondary Objectives:

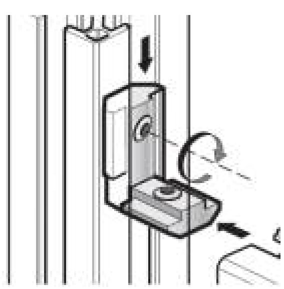
- Maintaining budget: Large efforts were made to cut costs through utilizing local resources such as using spare and discarded materials for our frame and buoyancy, buying used equipment, and making use of local swimming pools and school fabrication equipment.
- Building a foundation for future LBCC ROV teams: We were we pleased with the notion of being able to lend the results of our work and our experiences with future teams. We also made an effort to obtain ownership rather than just use of equipment that future teams could use, thus allowing more of their budget to be spent elsewhere. Some of the items included an air tank, batteries and pressure regulators and well as having influenced the decision to spend over 10% of the design budget on a second camera.

The Robot

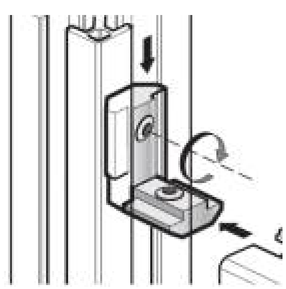
I. The Frame

Our original plan was to weld aluminum angle material to form the frame. While scavenging the local scrap yard for aluminum we came across a 1.22m wide by 3.05m long by 4.57m tall cabinet that HP used in some sort of manufacturing process. The frame was built using Bosch Rexroth Aluminum Structural Framing. This became a huge time saver since there was no need for welding. The cabinet came with metal connectors to secure the aluminum frame together, handles that we used for a carrying mechanism, and rails that we cut and turned into runners for the bottom or the ROV. The rest of the connectors that were needed to attach the platforms for both the motors and the arms and the jets used in propulsion were fabricated using flat steel and set screws. The entire frame was built from the recycled HP cabinet. The ROV's final dimensions are 1.22m long by 7.62cm wide by 7.62cm tall with a density of aluminum being 2.7g/cm³.

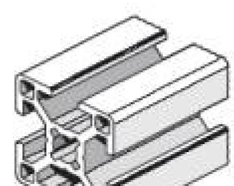
Safety handle



Inside-to-Inside Gussets



30X30 Series Profile



II. Electrical and Cable Components

The following components of the THROOP ROV required electrical hookups:

- Propulsion
- Arm
- Camera

The MATE Competition Rules and responses in the team chat room indicated that we could choose only one of the allowed voltages and a total of 40 Amps regardless of the voltage we chose.

Our ROV is rather large. Since power = (voltage · current) we discovered that we would need at least 24VDC in order to provide enough power to move the ROV while remaining under the 40 Amp limit.

The propulsion system consists of six 12VDC/5.5A bilge pumps. Due to the 40 amp/single voltage source limitation in the competition rules, we decided to run our system on the 24VDC power supply. Then to accommodate both the 24VDC power and the large mass of our ROV we hooked up two bilge pumps in series per directional control. Doing this, we were able to achieve twice as much power for the same amount of current draw.

The cameras required 12VDC. Due to the sensitivity and high cost of the cameras, we did not want to hook up the cameras in series as we did with the bilge pumps. We considered putting a resistor in series with each camera -- however we could not be certain that the resistance of the camera remained the same in all operating conditions and thus did not want to pursue that path. Eventually, we discovered the existence of 24VDC to 12VDC converters and purchased one at a local RV shop.

The arm required 12VDC power to three motors. These motors were controlled by two-way switches in order to accommodate the bi-directionality of the required current for back and forth motion. Again, we decided to draw off the 12VDC converter box rather than other proposed schemes.

For cable to provide electrical current to the propulsion system we used cable provided by Sound Ocean Systems of Redmond, Washington. The SOSI's cable has three #24 AWG twisted pairs and one #20 AWG twisted pair, for a total of eight conductors. The conductors are bundled and wrapped with a Mylar tape followed by braided Kevlar that is surrounded by a yellow polyurethane jacket. The outer diameter of the cables is 1.1cm.

For cable to provide electrical current to the camera and arm motors we used CAT3 24AWG wire.

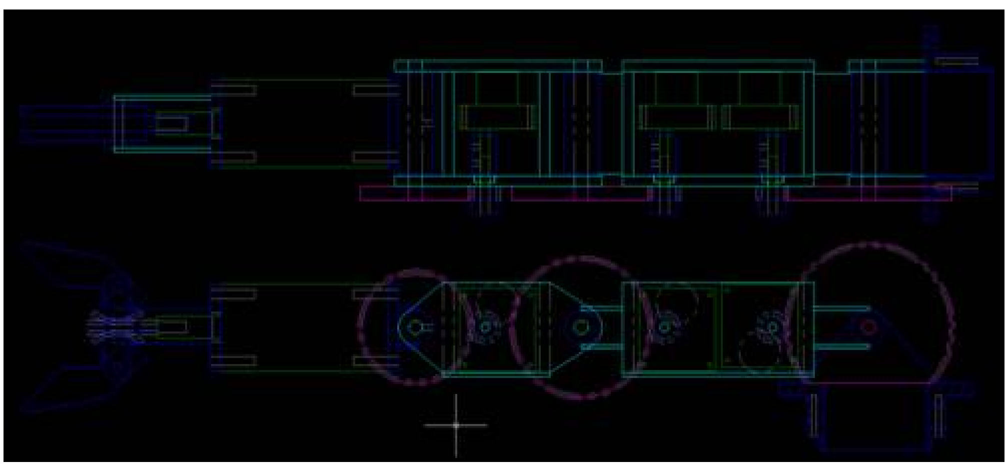
III. Buoyancy

Taking into consideration the mission objective that will increase the weight of the vehicle during operation, we decided to split the buoyancy control into two parts including devices to create a constant amount of buoyancy and a ballast for variable buoyancy control.

The constant devices are made out of PVC pipes that have air sealed inside. These air filled tubes have been both measured and placed such that they provide the vehicle with upright stability and slightly negative natural buoyancy so that the vehicle will sink slowly upon placement in the water.

The ballast was designed with energy consumption limits in mind. As a result we decided to use pressurized air to control the ballast thus eliminating any electrical consumption. The ballast is constructed of two vertical PVC pipes attached to the frame. Each tube is open at the bottom to allow water to enter and leave the tube. Air is fed in through a surface based hose at the top of each tube to force the water out and allow the air to escape as our buoyancy needs change. The pressurized air is supplied by a scuba tank.

IV. Gripper Arm



The arm portion of the ROV is constructed of aluminum, a plastic nylon, and stainless steel. The purpose of the arm is primarily collection of objects from the sea floor, with a secondary capability of taking a temperature reading from a temperature probe mounted on the arm. The arm consists of four axis's of motion and a gripping function. Each axis of motion is powered by a 12 volt DC gear motor with a 7189 to 1 gear reduction.

Axis one is a vertical axis mounted to the ROV that rotates the base of the arm to the right and left. The housing of this axis is machined out of a light weight plastic. The rest of the arm attached to an aluminum spindle that sits inside the housing. One of the gear motors is enclosed inside a watertight aluminum compartment with a 5/16 stainless steel output shaft. This output shaft is attached to a one inch pinion gear that drives a seven inch spur gear that is attached to the spindle. The spindle will rotate at 0.001 revolutions per second.

Axis two is horizontal and constructed on the top of the spindle. This axis rotates the first segment, the second segment, and the gripper of the arm up and down. The first segment of the arm is an aluminum box that encloses two gear motors. At one end of this segment is axis two. On axis two, attached to the top of the spindle, is a six inch spur gear. The first gear motor inside the first segment of the arm turns a one inch pinion gear that rotates this segment around the spur gear on axis two.

Axis three is at the other end of the first segment of the arm and connects segment one with segment two. The second gear motor inside segment one turns a one inch pinion gear that drives a five inch spur gear attached to segment two and rotates around axis three.

Axis four is at the other end of segment two and connects segment two with the gripper assembly. Segment two is another aluminum box that encloses a gear motor. This gear motor turns a one inch pinion gear that drives a four inch spur gear that is attached to the gripper assembly.

The gripper assembly is powered by a 50 mm, spring extend, single acting pneumatic linear actuator. The bottom side of the actuator is attached to axis four. On the end of the cylinder shaft is attached a double sided gear rack. The gear rack takes the linear motion of the actuator and turns two segmented spur gears, one on each side of the rack. Each of these segmented spur gears is attached to two different gripper jaws. The rotary motion of the two segmented spur gears is equal and opposite, so the motion of charging the actuator brings the two sets of gripper jaws together in a pinching motion.

The aluminum boxes that enclose the gear motors for axis's one, two, three, and four, are purged with a mineral oil and pressure compensated by a rubber bladder separating the sea water from the mineral oil. An oil seal is press fit into the aluminum housing for the 5/16 stainless steel output shaft. The output shaft from the gear motor is connected to the stainless steel shaft by a small aluminum coupler. One design flaw with this configuration is that the gear motor must be in a certain position where you could access the set screw in the coupler in order to remove the motor. So if the gear motor failed in the wrong position, it would be difficult to remove the gear motor.

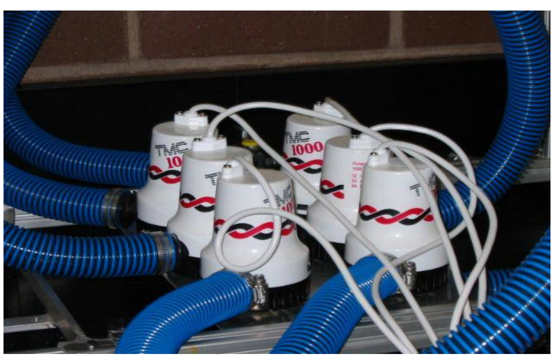
V. Propulsion

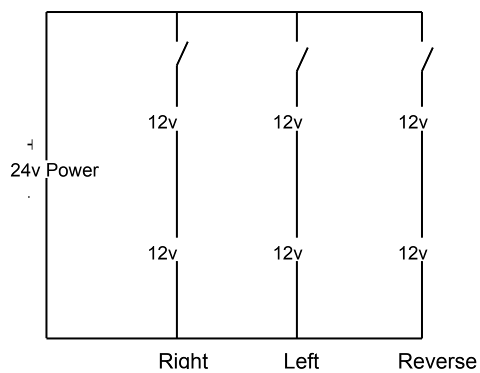
We figured out that we needed a relatively easy way to propel the ROV. Starting out not knowing what everyone else had planned to do with their set up or the weight. I knew that the motors/jets needed to be fairly powerful, so I searched for pre-made thruster set-ups, but found nothing affordable. I then searched the Internet looking for past ROV set-ups, trying not to 're-invent the wheel.' I found a site where the builder used bilge pumps for thrusters. Which made sense to me because bilge pumps are used to remove water from boats that are taking on water, and are really just a water pump.

Weighing my options I immediately searched on eBay and Craigslist respectively. Knowing that we needed 4 to 8 pumps I knew that Craigslist wouldn't have more than 2 of the same pumps, while we preferably needed matching pumps. I found 1000 gallon per hour pumps and the team agreed that 6 of these pumps would be the way to go, especially since we wouldn't have to worry about water proofing electric motors. With the 6 motors we decided that the best route would be to have 2 reverse thrusters and 4 forward thrusters. The middle two forward thrusters were angled inward at 15˚ for turning.

After a few trial runs in the pool we found that the ROV wasn't moving very fast at all. I discovered that if we put nozzles on the ends of the tubing connected to the pumps that the ROV moved 10x as fast as it did previously. I ended up welding brackets for the nozzles.

The thrusters were set up in the rear of the ROV to somewhat offset the weight of the arm on the front. Each thruster is wired up to its own switch on the control board. We intended on keeping the devices as simple as possible, which is the reason for the on/off switches. Because we are limited on amperage and due to the size of the ROV we have to wire the thrusters in series in order to get the necessary power obtained.





The Allen Throop's Second Mission

The LBCC ROV Allen Throop is scheduled to perform its second mission on the 20th and 21st of September, 2008 in Paulina Lake. Paulina Lake is one of two volcanic lakes found inside Newberry Caldera located in Central Oregon.

Newberry Caldera was created when the previously existing volcano erupted via ash, cinder, and lava ejections. The emptied magma chamber below the volcano collapsed, leaving an approximately 8km diameter caldera in the volcano's place.

Over time rainwater collected to form two lakes inside the caldera. Subsequent eruptions have left spectacular obsidian formations which were mined extensively by Native Americans for centuries.

Paulina Lake is the westernmost reservoir, and holds a geologic mystery. As can be seen in the topographical map there exists a 50 meter tall spire near the center of the lake known as "Dante's Peak". The top of Dante's Peak is 20 meters below the surface of the lake and has been investigated by SCUBA divers.

The bottom of the spire, meanwhile, is a full 70 meters below the surface and has never been explored. At this depth and with Newberry's relative remoteness this geologic structure is best explored by ROV.

The THROOP is schedule to explore at least two sides of the spire. The objectives of the mission are:

- collect video data of the length of the spire,
- collect rock samples of the spire at at least three different depths,
- take passive temperature samples throughout each dive,
- if clear evidence of geothermal action is observed via the video-stream, active temperature samples will be taken via the temperature probe situated on THROOP's arm.

Budget Report

Our team is happy to announce that we stayed within our budget when producing the LBCC Alan THROOP Remotely operated vehicle. As this is LBCC's first attempt at creating an ROV we are especially proud of this achievement.

The main source of our team's funding came from a one-time grant of $4374 from the Linn-Benton Community College Foundation. Local companies and MATE sponsors donated at total of $1830.00 in supplies, materials, services and housing.

The THROOP Roadrunner's second mission requires additional equipment and expenditures that total $2015.00. The main sources of funding for the add-on Newberry Caldera mission comes from Linn-Benton Community College and Central Oregon Community College.

Below is a breakdown of each mission cost. We've specifically included the cost of travel and housing in the calculation of each mission along with the cost of materials and supplies for the construction of our ROV. With any mission of exploration, the cost of getting the team to the location and the cost of supporting them while they are there is often the larger fraction of the mission's total cost.

Roadrunner San Diego June 2008 Mission Cost Breakdown

Mission Subsystem	Team Outlays	Donations	Total
Demo Mission Equipment	$17.29	$40.00	$57.29
Arm and Frame Purchases	597.27	700.00	1297.27
Propulsion	166.88	60.00	226.88
Cameras and Probes	369.00	190.00	559.00
Cable and Electrical	28.79	140.00	168.79
Buoyancy	320.63	40.00	360.63
Travel, housing, food	2710.00	700.00	3410.00
Total San Diego Mission Cost:	**$4,209.86**	**$1,870.00**	**$6,079.86**

Roadrunner Newberry Caldera September 2008 Mission Cost Breakdown

Mission Subsystem	Team Outlays	Donations	Total
Camera	$265.00	$265.00	$530.00
Power Supply	356.00	0.00	356.00
Extra Cable	279.00	0.00	279.00
Travel, housing, food	0.00	350.00	350.00
Boat and Remote Support	0.00	500.00	500.00
Total Newberry Mission Add-On Costs:	**$900.00**	**$1,115.00**	**$2,015.00**

Total Two Mission Cost	
Direct Cost of ROV Creation	$3,834.86
Team Travel, Housing, Food	$4,260.00
Total:	**$8,094.86**

Acknowledgments

Funds, donations and/or advice making construction of the Allen Throop possible include:

Vernier Inc., Beaverton, Oregon
Northwest Pneumatic of Albany, Oregon
Norgren Inc., of Albany Oregon
Southside Marina of Corvallis, Oregon
Light, Camera, Action or Arizona
WET Lab of Philomath, Oregon
Sound Ocean Systems of Redmond, Washington
The Linn-Benton Community College Foundation
The Physical Science Department of Linn-Benton Community College
Bob Reynolds of Central Oregon Community College
The Engineering Department of Linn-Benton Community College
The Linn-Benton Community College Welding Department
The Linn-Benton Community College Automotive Department
Salem SCUBA
Joel's Brother
Spencer Hull
Jerrod Jackson

All of our family members who put up with our being away weekends and nights.