Rhasta ROV

Version 2.0

Six Rivers Charter High School

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Abstract

Throughout this entire project, the goal has been to build an inexpensive, flexible, and simple ROV that will effectively complete the mission. The original ROV was built of PVC, had only three motors and could barely complete the missions. After the regional competition, the team decided to build a completely new ROV using the lessons learned during the competition. With the use of the Carrillo Underwater Systems lab the team designed and constructed the second ROV. The second ROV uses an aluminum frame, which is lighter, easier and stronger than PVC. The new ROV has many enhancements; different manipulators, more motors, better stability, more power, better controls and better cameras are only a few of the improvements. Throughout this project, the entire team has been pushed to learn and try new things that many of them never would have tired otherwise.

Budget/Expense Sheet

Table 1: ROV Construction Expenses

Item	Price	Number	Total Price
Mayfair 500gph Bilge Pumps	$15.00	4	$60.00
Octura Propellers	$12.00	4	$48.00
Pulse Width Modulators*	$19.95	4	$79.80
Marshall Color Bullet-Sized Cameras*	$490.00	4	$1,960.00
200ft Speaker wire*	$55.98	1	$55.98
Aluminum Frame*	$22.50	1	$22.50
Control Box*	$28.49	1	$28.49
Nalgene Bottles	$8.00	2	$16.00
50ft Polyethylene Tether Weave *	$12.25	1	$12.25
Total			**$2,254.77**

* Donated

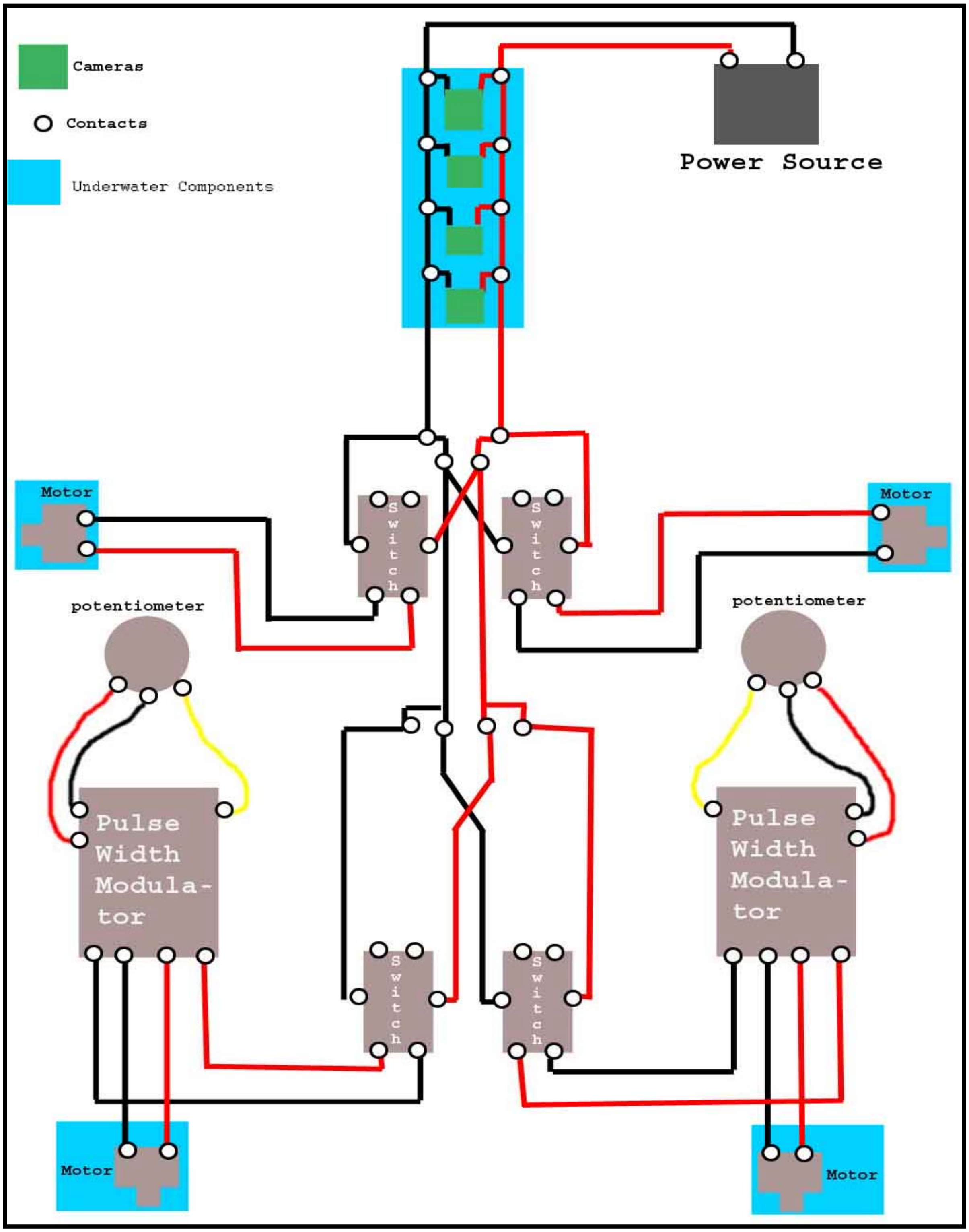
Table 2: Traveling Expenses

Item	Cost
Car (ACV to SFO)	$121.99
Gas (300mi/20mpg*$3.50/gal)	$52.50
Flight (SFO to IAH/IAH to SJC)	$2,159.28
Car (Houston)	$238.53
Gas (500mi/20mpg*3.50/gal)	$87.50
Car (SJC to ACV)	$121.99
Gas (331mi/20mpg*3.50/gal)	$58.00
Total	**$2,839.79**

One of the most difficult aspects of this project was raising funds for the ROV. Finding the money to purchase the parts needed could have been organized much better. During the first parts of the project the team had very little money and few sponsors. Businesses were asked to give discounts to the project and many businesses helped a lot. The main expense was the cameras and bilge pumps. Once these were taken care of, the other parts were rather simple to pay for. Team members and their families bought most of those parts. After the local competition, the team decided that they were going to build a new ROV. It became apparent that more materials would be needed. At this point, the team was almost out of funds. After working on the Carrillo scholarship for a few weeks, Mr. Carrillo came to the local competition and gave us guidance and awarded two cameras. The company donated over one thousand dollars worth of cameras and other parts.

Through the entire process, the team has been very conscious of budgeting. For example, the buoyancy that is used on the ROV consists of used hard plastic bottles. This is a cheap, effective way to create a buoyancy system. Also CUS has been extremely generous in donating the materials that the team needed. If CUS had not donated so much, the second would have never happened. This combined with the team's resourcefulness made the project finally come together. Unfortunately, no amount of resourcefulness can lower the cost of traveling expenses. During the construction phase of the ROV, the team met with the company president of TMT technologies. After a short meeting where the team explained the competition and their project to the company president, it was agreed the company would donate one thousand dollars to help the team travel. The team will also receive a thousand dollar scholarship from MATE, which will go directly to help the team travel.

Electrical Schematic



Design Rationale

Frame

The ROV is built using 15 mm channel aluminum. This material was decided on after using PVC for the original ROV. Aluminum is a stronger material, that is also lighter and holds together better. Instead of having to use screws to hold it together, rivets are used which are lighter and take up less space. The overall weight of the original was 3.6 kilograms compared to the ROV which weighs a mere 1.8 kilograms. The shape of the Rhasta ROV is a simple design of a rectangular prism, with the dimensions of 35cm X 15.5cm X 40.5 cm. The ROV has two manipulators, one in the middle to hold the power node and one protruding from the front. The manipulator protruding from the front has three hooks, to manipulate the door, pin, and to pick up the power plug. Cameras are mounted to have direct views of the manipulators for accurate movement and angles. There will be four cameras mounted all connected to a quad splitter. This way all angles can be seen on the same monitor.

Motors

The propulsion system utilizes four Mayfair 500 gph Bilge pumps, two for vertical movement and two for horizontal movement. Having four motors on the frame provides the minimum number of motors needed to be able to perform a full range of motion. Two horizontal motors are used for rotation and forward and backward movement. These motors are mounted at a seventy-degree angle in relation to the ROV's main body (see Fig. 1.0). This position allows for faster turning due to the angle of the motor. The two vertical motors are mounted at a twenty-three degree angle in relation to the ROV's main body (see Fig. 1.1). The reason for the angle is that when the motors thrust, there are no obstacles to block the flow of water. If the motors were mounted at a ninety-degree angle they would be pushing on the same object that they were trying to lift. As well as creating a clear path for the thrust, mounting the motors at an angle allows for lateral movement. If one vertical motor is thrusting and the other is idle, the ROV will move directly sideways without having to turn.

Thrust tests were conducted to determine the amperage, voltage, thrust and wattage of the motors (see Fig. 1.2). The motor was placed on the end of a PVC pipe, a wire pivot was placed at its center, and then a spring scale was connected to the top of the PVC. It was determined that the vertical motors, with pulse width modulators and potentiometers, generated 6 Newtons of thrust at full power while drawing 3.6 amps and 12.4 volts. The horizontal motors generated 7.9 Newtons of thrust and drew 3.6 amps and 12.4 volts. Each motor at full power drew 44.46 watts. For more detail see Table 3.

Table 3: Data From Motor Thrust Test

Speed	Volts	Amps	Newtons
Low	12.4	3.29	2
Medium	12.4	3.31	3.9
High	12.4	3.35	6
Un-regulated	12.4	3.6	7.9

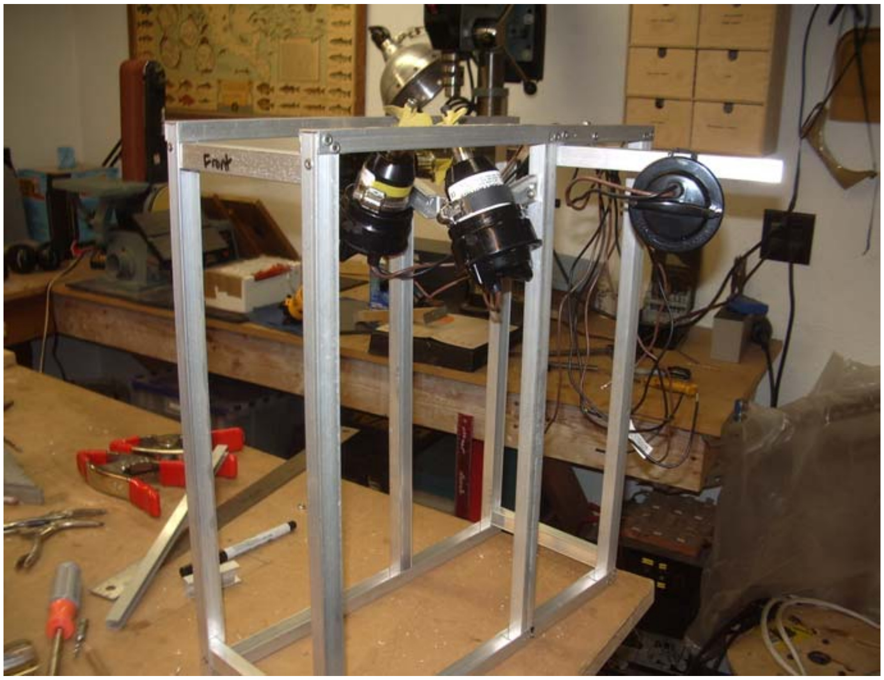


Figure 1.1: The two vertical motors are mounted at a twenty-three degree angle.

Figure 1.0: The two horizontal motors are positioned at a seventy-degree angle.

Figure 1.2: The motors being tested for thrust.

Control System/Cameras

The control system is designed to be simple and easily constructed. The rationale for this is that with more complex components and systems there is more chance of failure. Each motor uses one pair of 16-gauge speaker wire. There will be four of these wires running through the tether. The control system is based on simple DPDT momentary contact switches for the horizontal trust and on-off-on toggle switches with pulse width modulators and potentiometers for the vertical thrust.

Two momentary contact switches control the horizontal rotation of the ROV. Turning off a motor on a side while keeping the other at full power will turn the ROV. The motors can also be run so that one is thrusting forward and the other runs in reverse. This will also turn the ROV from side to side.

For vertical thrust, DPDT toggle switches are used. To control motor speeds, pulse width modulators (PWM) that were build from kits (see Fig. 1.4) and potentiometers are used. Due to the fact that the ROV has the requirement of carrying a payload, the vertical motors had to be capable of sustained controlled thrust. When weight is added the ROV must be able to maintain vertical thrust. If the ROV can maintain a certain depth due to constant thrust, the pilot can focus on payload placement rather than depth. This was accomplished by using PWMs, which send short pulses of energy, the length of which can be adjusted, thus giving the motor more or less power. The potentiometers are used to adjust the amount of power the motors receive. This is beneficial because once the payload is attached, the vertical motors can be set so that the ROV and payload achieve neutral buoyancy. Then the pilot can direct their attention to the task. Once the payload is dropped, the vertical motors can be turned off, returning the ROV to its original buoyancy and weight.

Four Marshall color cameras are used. Each camera is assigned a certain task. The first camera will focus on the main load hook, which is located directly below and between the buoyancy and vertical motors. The second camera is mounted 30 cm behind the ROV. It will provide views of the payload and assist in placing the payload in the correct spot. The third camera provides a forward view of the operating environment in order to pilot the ROV. The fourth camera is focused on the forward manipulator hook. It will allow the pilot to conduct fine operations and accomplish the other tasks in the mission. A quad screen splitter allows all four cameras to be viewed on one monitor.

All wire in the tether will be waterproofed using shrink tubing as well as five minute epoxy in order to prevent short-circuiting. The control box is also waterproofed. A watertight diver's box was used and all the openings will be sealed using silicone sealant. All of the wiring will be insulated to prevent the system from short-circuiting. The ROV was also built using minimal sharp edges to make it safely portable. The tether is 15.24 meters. This will allow for the entire range of motion needed to accomplish the missions.

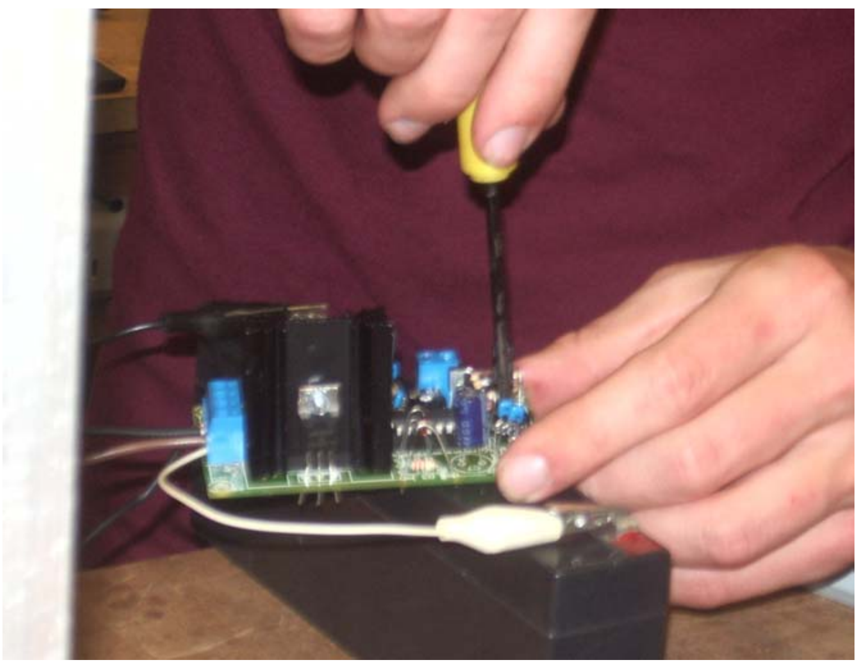


Figure 1.4: The control box has DPDT toggle switches and pulse width modulators.

Ballast/Buoyancy

The four bilge pumps near the top of the frame and fishing weights on the bottom of the frame will provide ballast. This will even out the amount of weight on the ROV to give it stability. Stability is necessary because it allows the ROV to right itself while in the water. Hard plastic water bottles are attached at the top of the ROV for buoyancy. Within these bottles, levels of water can be changed depending on how much buoyancy is needed. Water bottles are used because they are inexpensive because they allow for quick modifications to the buoyancy.

Manipulators

There are two main manipulators on the ROV (see Fig. 1.5). One manipulator is 9.53 cm long and is made of 15 mm aluminum channel. There are two grooves cut in the sides. The hoops attached to the node box will sit snugly in the grooves, making the box easy to move around. The payload manipulator is centered at the bottom of the frame. This positioning will make lifting easier because all of the weight will remain at the center of gravity, which will not make the ROV lopsided and difficult to maneuver. The second manipulator arm has two small hooks. This design will allow the power/communications cable connector to be picked up easily and placed in the correct spot. The hooks will attach quickly and easily to the acoustic transponder's release loop.

The second manipulator will be attached 30cm away from the main frame.

Figure 1.5: The manipulator centered at the bottom of the ROV.

Description of at least one challenge/Explanation of troubleshooting technique(s)

Many different technical and team-related difficulties were encountered. The team had a chance to really use their problem solving skills. At one point, there was a soldering problem. A switch was being soldered and in the process of heating the metal, the bottom of the switch contacts melted, causing it to slide sideways. This problem was easily fixed because one of the bilge pumps was backordered so an extra switch was used instead. After the core construction was completed, a test run was done in a local pool.

During the process of wiring, the control box some wires had been switched. This made some of the switches work backwards. For example, pushing one of the switches backwards caused the motor to actually move forward. To fix this problem, the switches were rewired.

In another problem, wires of the tether became tangled up with the camera wires. In the midst of untangling, it was found that one of the motor lines had been used in the place of the power line, and instead of the power line was the motor line. Since the wire was a different length, this meant that there was an extra long power line and a motor line that was too short. To fix the problem, the shorter motor line was cut and re-soldered adding in extra motor line making it equal with the others. The soldered was waterproofed with shrink-wrap.

The next problem proved to be a bit more challenging to solve. When the camera was plugged in there was no display on the monitor and no sign of the camera working. On the power bus, electricity flowed to the tether line attached to the motors first, then flowed to the power line attached to the monitor. The control box was opened, the camera wires were clipped and re-soldered to the power bus.

During the building process, a few problems arose with the circuitry. When the first pulse width modulator was tested, it did not work. The battery connection and each of the other external connections were checked. When this did not solve the problem, it was time to examine the actual circuit board. After careful examination, the team mentor, Mr. Carrillo, pointed out that multiple transistors were on backwards. Once they were re-soldered the correct way, the PWM worked fine.

The biggest challenge faced as far as teamwork is concerned was learning how to confront problems within the team rather than hide them. In the beginning, working well together and listening was easy. However, as the project developed, bickering broke out, as is expected when people work closely for long periods of time. Trouble only occurred when feelings weren't communicated as they came up. Doing that built unnecessary amounts of tension within the group and only made things worse. Finally, something had to give. There was a group break down. Unfortunately, the frustrations that were released were not done so in a constructive way and people's feelings ended up getting hurt. To follow up, the team decided to put the ROV on hold and have a group discussion. A more comfortable, appropriate space for dialogue was created and everyone had a chance to speak. This time, the emotions that came forward came from a place of concern and progress rather than anger and impatience. Conflicts still arise within the group, of course, but the important thing is that the team handles the conflicts maturely, constructively and promptly.

Description of at least one lesson or skill gained

I have learned a great amount on this project. There have been such a variety of things, from wiring a control box, to building an aluminum frame. I must say that the biggest lesson that I learned was that the phrase, "Oh, we'll do it the next day" is absolute death. Through this project I have developed a great interest in engineering and robotics. I never realized how interesting this could be.

-Jeff Friedman

Patience is a virtue. This couldn't be truer. Patience has been more important during this ROV project than ever. It takes patience to work intensively with the same three people on a long and challenging project. It takes patience to constantly practice compromise. It takes patience to plan ahead and work consistently. It takes patience to learn the countless new skills required to build a fully functional ROV. This is an irreplaceable lesson. In the words of the wise Axl Rose, "All we need is just a little patience".

-Laura Zettler-Mann

I have learned more from this project than I ever thought possible. The lessons that I discovered went way beyond just how to design and build an ROV. One of the most vital lessons I learned was to accept that things don't always go the way that you plan them to. This proved to be true in the actual construction process, the teamwork aspect, and the project preparation. The preparation for this project was almost harder than the actual designing and building process. Several times parts were backordered or just didn't come for one reason or another. One time the person who packed the shipment counted wrong and shorted us a bilge pump. Things happen. If you always expect things to go perfectly, you will go insane. By accepting this principal, it made this project much easier and certainly a lot more fun.

-Christina Cornwell

The main thing that I learned during this project is that the world of electronics is not out of my reach. When I first started working on this project I thought that I'd never have any real interest in working in the scientific field. I have always thought that I my main interest was in art. When I began to learn how to wire motors and such, I began to realize that I really could work in the field of science. Now, after I have worked on the ROV project I feel really confident that I would like to pursue studies in science and electronics.

-Mackenzie Greene-Powell

Discussion of future improvements

After the regional competition, there were so many opportunities for improvement that the team decided to construct a whole new ROV. Along with all the planning problems, the team also learned a lot about how the ROV could have been better engineered based on the performance at the Regional Competition. Of the mission tasks, the only one not completed was placing the box in the cage. The problem was determined to be due to the manipulator placement. The manipulator was too far forward of the vertical thrust. When the ROV attempted to lift the box, the whole frame tilted forward which made control of the ROV nearly impossible. This problem was fixed by placing the manipulator on the new ROV directly under the vertical thrust. This makes the ROV much more stable.

Another problem was the placement of the buoyancy. The bottles used were too far forward of the vertical thrust. The result of this was that when the ROV attempted to ascend or dive it would tip forwards and backwards. In the new ROV, the buoyancy is directly above the vertical thrust.

Along with the problems associated with thrust and balance, there were many problems with the tether. Many times during the competition, the tether got tangled up, which made everything much more difficult. Beyond being more careful while handling the tether, the team also implemented another measure to prevent tangles. The tether is now wrapped in a polyethylene tether weave, which prevents tangles.

The team also realized that better cameras were needed. On the new ROV, four cameras are used instead of two. This provides a much better view of the entire area and tasks. The placement of the cameras is much more carefully chosen. A quad-splitter is used so that all four views may be seen on one screen. This eliminates the need to look back and forth between screens.

Description of organization that supports ocean-observing systems

Carrillo Underwater Systems (CUS) is a company that supports ocean observing, underwater research, and underwater sports by building underwater cameras, lights, and video and diver communication systems. The lights are used for video and photography, the cameras are used for viewing and navigational purposes, the video systems are used for search and rescue work, inspection and documentation, and the diver communication systems are used for clear communication between the diver and his/her base ship. The CUS website, www.carrillounderwater.com, gives a description of the equipment. These tools allow scientists and technicians to directly observe underwater work and operations.

Acknowledgments

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- ACE Hardware in Sunny Brae—for donating materials and providing a discount on all purchased parts.
- Jan Magneson—for donating money towards traveling expenses.