

Technical Report

Cornerstone Academy ROV Team

2007 MATE International ROV Championship



GROVER

Team Members:

Paul Eccleston, Kirk Fraiser, Jeff Marchand, Joe Pratt, and Ben Still
Electronics Instructor, Coach/Mentor/Facilitator: Jeff Knack

Report and Presentation Advisors:

Debbie Eccleston, Doug Fraiser, and Susan Marchand

Abstract

The Cornerstone Advanced Robotics team is a rookie team that constructed our ROV, **GROVER**, to compete at the international level. Having no prior experience with ROVs, we visited the 2006 MATE Florida Regional competition. While there, we consulted with judges and industry representatives about design features. From our observations and conversations, we determined that the most prominent features of our 2007 ROV would focus on gripper structure, independent movement along the three directional axes, and the absence of adjustable-volume ballasts. Our propulsion system is comprised of four motors for lateral movement, four for forward and reverse movement, and four for vertical movement. By making our ROV buoyancy-neutral, and relying on vertical thrusters instead of adjustable-volume ballast tanks, we were able to eliminate imprecise vertical movement, thereby enabling the ROV to accomplish tasks more rapidly. We have constructed the ROV so that we can quickly install trim weights to keep the ROV neutrally buoyant at all times. This keeps us from relying on unpredictable adjustable-volume ballasts. The gripper on **GROVER** was milled in-house out of 6061 aluminum. This design utilizes a worm gear to open and close the claws, making the gripper easily adaptable to an already-waterproof bilge pump motor. We have two grippers on **GROVER** so that we can hold the gasket while simultaneously holding the hot stab. Therefore, we only have to make one trip to the well head. The ROV is equipped with the adaptable equipment to reflect the changing nature of this year's missions.

Design Rationale

Frame

We used $\frac{3}{4}$ " (1.91 cm) PVC pipe for the construction of the frame because it is lightweight, durable, easy to work with, and inexpensive. The frame was made in the shape of a box having a length of 71.1 cm and a height and width of 35.6 cm.

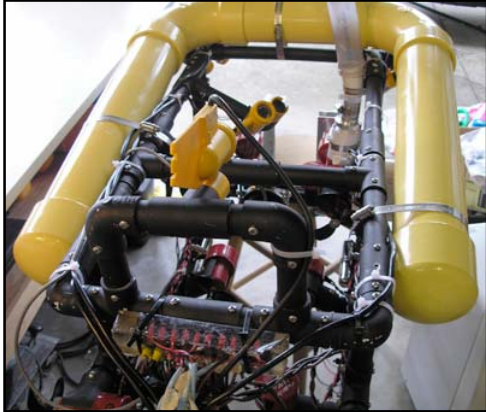


Figure 1. Our oversized ballast tanks allow us to weigh down the sub to increase stability.

It was designed to allow us to easily attach, position, and orient systems. The frame is also bolted together with #8 machine screws to ensure that it does not unexpectedly fall apart, yet allows us to disassemble if necessary.

Buoyancy System

Table 1. Weight test.

Environment	Weight (kg)
Dry Weight	22.6
Submerged Weight	15

form of 3" (7.6cm) PVC pipe shaped in a "U" to make the ROV slightly positive in fresh water. Our weight test determined the volume of the ballast which, in turn, affected the length of the pipe. Then, we placed mounts for trim weights on the four bottom corners of the ROV in order to adjust buoyancy for different solutions of water. The PVC

We decided that making **GROVER** neutrally buoyant would make it easier to control. In order to achieve neutral buoyancy we first mounted all of the systems then added enough flotation in the



Figure 2. We placed a large ballast tank so that we could properly trim our ROV.

“U” wraps around the front of the ROV on the upper side in order to compensate for the additional weight on the front of the vehicle.

Propulsion System

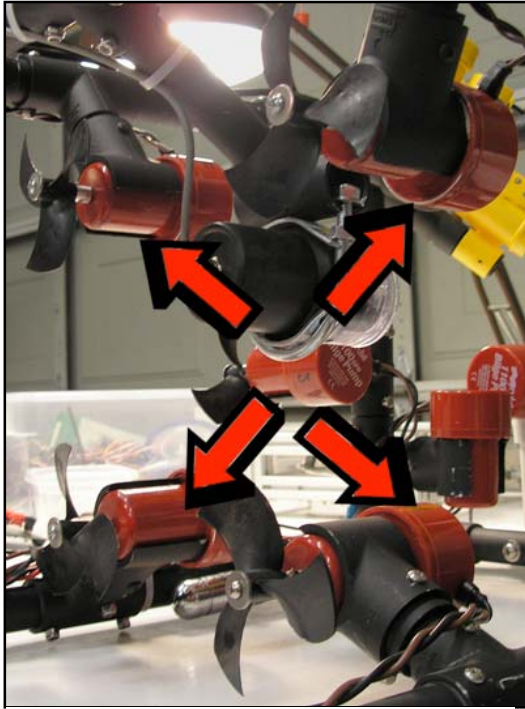


Figure 3. The longitudinal motors have been mounted on the interior of the frame so that they cannot catch on obstructions.

In total, the ROV has 12 thrusters, four for each axis of movement (x, y, and z). This arrangement allows us to move independently in any direction without having to turn, and gives us a zero turning radius. We decided to use this arrangement because it allows us to move sideways, and the turning is more efficient.

To power our thrusters, we used Rule 1100 gph (4,164 L/h) bilge pump motors due to the fact that they are factory waterproofed, cheap, and provide a reasonable amount of thrust when

combined with our propellers. For propellers, we used 90 mm propellers from Video Ray and 70.7 mm

propellers from Prather Products. The 90 mm propellers are used for lateral and longitudinal movement, and each produces approximately 10 N of thrust. The 70.7 mm propellers are used for vertical movement, and each produces approximately 7.5 N of thrust. We made our propeller selection based on data displayed below. The reason we chose the Video Ray propellers is that we wanted near-uniform forward and reverse thrust.

We collected this data using an Extech 475044 force gauge.

Table 2. Propeller thrust test.

Propeller	Forward Thrust (N)	Reverse Thrust (N)
Swan Precision A1/3022/3/RH 75mm	13.07	4.1
Video Ray 3 Bladed 90mm	9.7	5
Prather Products S 250 Stainless Steel Prop	7.45	3.5

Collection System

After reviewing the mission tasks, it was decided that in order to accomplish all of the missions in the most efficient manner we would need at least four manipulating devices. For the devices, we decided to manufacture two grippers with specialized claws for each, a hook, and a vacuum.

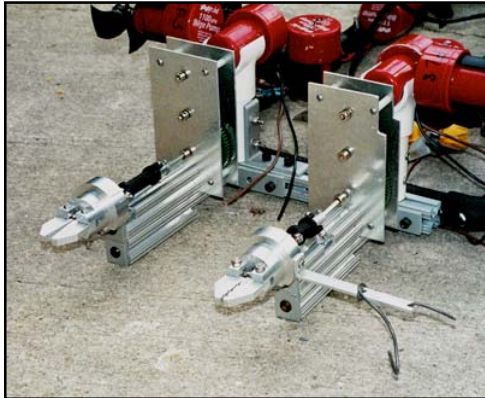


Figure 5. This claw combination works perfectly for our tasks.

The grippers are constructed out of aluminum alloy 6061 5.08 cm rod. These were first refinished and cut down on a lathe. Then, two perpendicular grooves were milled to our specifications and two holes were drilled for the hinges of the claws, and a third hole was drilled and tapped for the actuation mechanism. The two grippers have specialized claws. Claw one was designed to deploy the gasket, the line header, and the PAS, while claw two was designed specifically for deploying the hot stab. Claw one has three notches cut into the gripping surface in order to have a better grip on the gasket, line leader, and PAS. Claw two has a notch cut at a $\pi/4$ radian angle and a slot cut at a $\pi/2$ radian angle to the notch.

The grippers are powered by two bilge pump motors. Power is transferred to the gripper by a gearbox which reduces the operating speed of the gripper by a factor of forty-nine. The

The grippers are constructed out of aluminum alloy 6061 5.08 cm rod. These were first refinished and cut down on a lathe. Then, two perpendicular grooves



Figure 4. This is gear box we used on our claws.

gear train consists of four gears. The drive gear is a 12-tooth spur gear that drives an 84-tooth idler, which is paired with another 12-tooth spur gear that drives a second 84-tooth follower gear.

The grippers, gearbox, and motors are all mounted on an 80/20 framework which is mounted onto the lower front of the ROV via two ¼" x 20 (6.4 mm x 20) stainless steel machine screws.

The hook is made of steel wire that is bent to shape and mounted to the side of the grippers. The hook is used for collecting the jellyfish and the line header.

The vacuum is a bilge pump with a piece of PVC tubing connected to the intake. In order to connect the tubing to the pump we had to build a coupler. We made it out of aluminum alloy 6061 stock 5.08 cm round which was machined on the lathe. The vacuum is mounted inside the front right corner of the ROV by two pipe clamps, with the intake on the upper side. It is used for collecting the algae sample.

Control System

The control system consists of two control boxes, a tether, and a terminal block. The control boxes consist of six double pull double throw (DPDT) momentary switches and one SPST toggle switch. The longitudinal, front lateral, rear lateral, and vertical thrusters are each controlled by a separate DPDT momentary switch on the main control box. The claws are also controlled by two DPDT momentary switches but are located on a separate, smaller control box along with the SPST toggle switch which controls the vacuum.

The tether links the control box and the terminal block together. The tether is composed of fourteen 16 AWG (1.3 mm) wires for motor control, four S-video cables for the Atlantis cameras, and one RCA/power cable for the SeaMaster camera. (See next section for details.) The tether also has floatation to help ensure that the ROV does not get tangled in it.

The terminal block is used to connect sets of motors to a single pair of wires in the tether. It also serves to strengthen the connection between the tether and the ROV. Because the terminal block had open electrical connections, we encased it in DP270 dielectric epoxy made by 3M.

Monitoring System

The monitoring system for our ROV consists of five cameras which are positioned to provide complementary views of the operating environment. The four Atlantis cameras are paired and connected to two monitors which can switch view between two inputs, while the SeaMaster camera is connected to a larger monitor. Our main navigational camera is a SeaMaster SMM-50-C which is positioned near the



Figure 7. We strategically placed our black-and-white cameras so that we can have a good field of vision.



Figure 6. We used four inexpensive cameras but we invested in one good camera. This way we can cut costs and still have a good sense of our environment.

center of the ROV. The other four cameras are all Atlantis AUW-502 underwater sportscams. The first of those cameras is a secondary navigational camera which is positioned on the upper rear of the ROV facing forward. This position allows us to see our front corners, and also gives us an above-water view when the ROV is surfaced. The next camera is positioned just above and to the left of the main camera, and is oriented to give us a view of the intake of the vacuum from below. We found that this was the best position for monitoring the collection of the algae sample. The other two cameras

are positioned on the top front corners and are oriented to give a cross view of the grippers and hook. For example, the camera on the right side monitors the left gripper. This arrangement gives us some depth perception and a larger viewing area.

Electrical Schematic

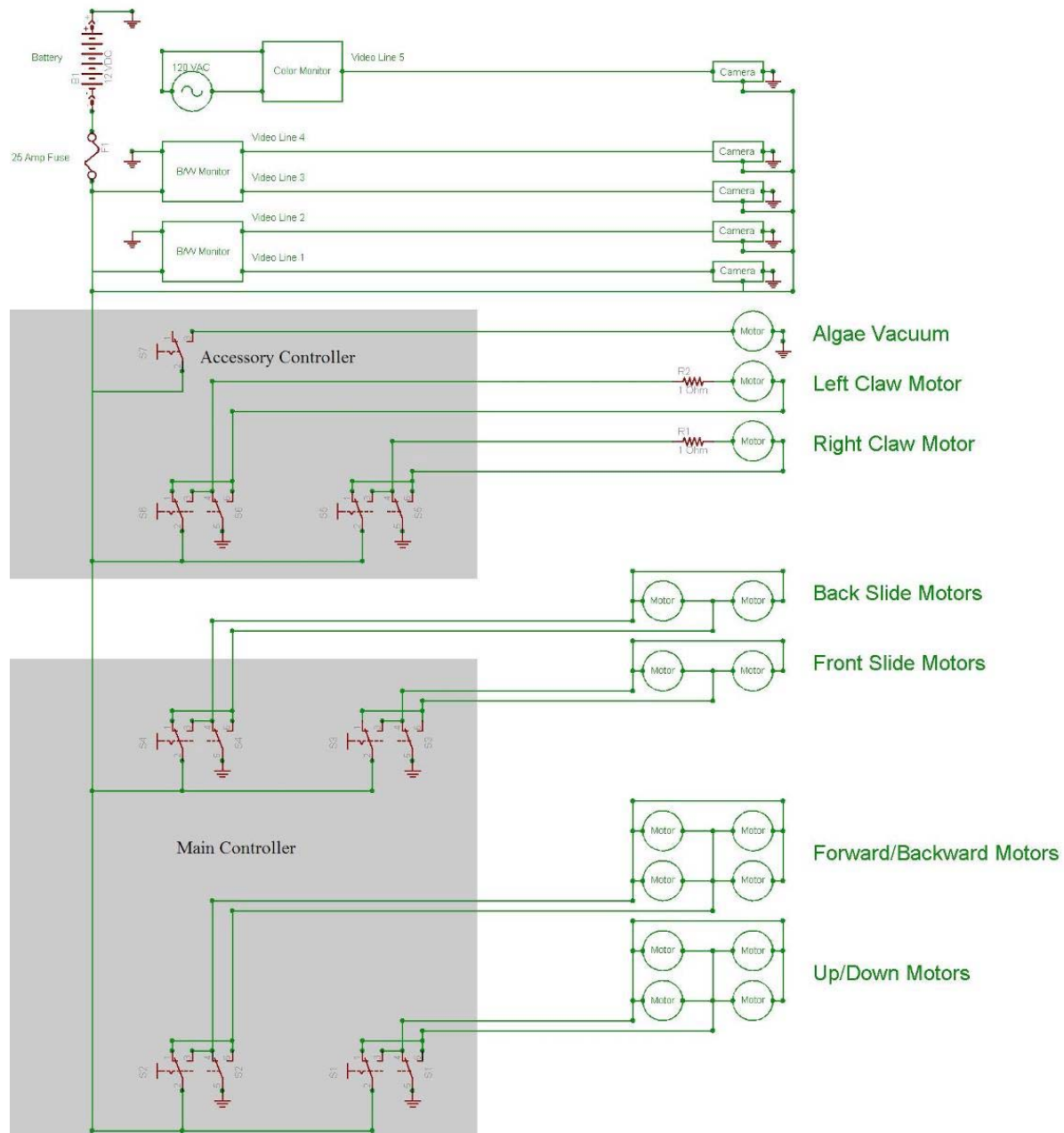


Figure 8. Schematic diagram of ROV circuitry.

Challenges

Since we are a rookie team, we had to learn some of the basic ROV principles even before we could begin design and construction. Our visit to the 2006 MATE Florida Regional competition was extremely beneficial in our understanding of basic ROV principals and the skills required for ROV construction.

The first issue we encountered was tether management and construction. As we began our first tests, we soon realized how important proper tether material, construction, and management were to the operation of the ROV. Our first tether was insufficient to carry enough current to energize our motors, so we constructed a new tether out of 16-gauge (1.3 mm) wire, which greatly improved the performance. Tether management was also a significant challenge; we realized that unless the tether is flexible and **GROVER** is allowed to move freely, then **GROVER**'s maneuverability would be adversely impacted.



Figure 9. Closed frame version of ROV.

Another challenge we encountered in the beginning stages of design and construction was frame design. After deliberating over the frame's design, our team finally came to the conclusion that a closed frame and an open box frame each have their own advantages.

By that time, we had already built an open frame ROV, so we began designing a closed frame version. After several weeks of work on the closed frame, we realized that it was beyond our construction capability; we were unable to build the appropriate H-bridges to control the ROV and we were having trouble waterproofing the joints. We finally overcame that challenge by salvaging the parts from the fuselage and improving our open box frame ROV.

An additional challenge was gripper design. Our first problem was that our gripper was unable to secure the hot-stab properly. We therefore designed another interchangeable claw which could hold the hot-stab at a perfect $\pi/4$ radian angle. Our second problem was that we

had only one gripper. At the regional competition, we had to return to the side of the pool to place the hot-stab into the gripper. We have now added a second gripper which will hold the hot-stab while the other gripper holds the gasket. These grippers, combined with a small hook to remove the cap, will cut down our mission times and earn us valuable points.

One of the greatest challenges we have had to overcome is the environment in which the ROV will be deployed. The difficult environmental features include tank current, the dimensions of the hole in the ice, and the temperature. Tank current was a major challenge, which we adapted to by equipping the ROV with larger propellers, which will endow it with more thrust.

We have encountered many challenges and we think we have overcome all of them. The design stages of our ROV were long, as we had to accommodate such factors as frame design, tank current, amperage limits, tether, and the maximum dimensions. We were able to fine-tune our ROV to not only meet the minimum requirements to run in this competition, but to excel and produce a genuinely workable product.

Troubleshooting

In any electrical component, there is going to have problems. We found we had problems with our ROV as well. We used a basic flow chart (see Figure 10) to keep ourselves focused on the particular problem to easily find a solution.

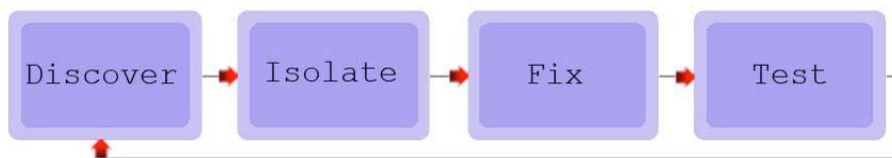


Figure 10. Troubleshooting flowchart.



Figure 11. Team members testing amperage of ROV.

We used this method when we had a problem with the tether. We originally wanted to use H-bridges to minimize the size of the tether wires. We were at that time using eighteen gauge wire. We wanted to use the Video Ray neutral tether to give our tether less profile. This would allow us to maneuver underwater without difficulty from the impact of current. We had problems with manufacturing the H-bridge. We

needed to make them small, yet still be able to withstand large amounts of current. We also had problems with the etching of H-bridges. They continued to short circuit and in general not work. We resolved the problem by abandoning the idea of using H-bridges on **GROVER** and instead used sixteen gauge (1.3 mm) wire for the tether along with momentary switches. (For more information please refer to the electrical schematic.)

Lessons Learned

This past year in preparation for the ROV competition, we learned numerous lessons. Probably the most important lesson we learned while designing and building **GROVER** was to keep the design simple. Our early prototypes of **GROVER** were too complicated, so they did not operate efficiently, if at all. We decided to fall back to our initial simpler ROV design and now it performs much better.

Another lesson we learned was the necessity of keeping spare parts and tools on hand, so we are prepared for equipment failures. For example, when we were setting up for a mission at the Florida Regional ROV competition, we discovered we had no power to the ROV. Since we had all the right tools with us and the necessary knowledge, we were able to use a digital

multimeter to trace and then fix the problem quickly. We also learned it is best to buy quality parts, in order to minimize the occurrence of failures.

We have found that using multiple, customized grippers with interchangeable claws is one of the most important keys to being competitive, enabling us to accomplish specific tasks without returning to the control station.

One last lesson learned that helped us complete the missions was the principle that “control is speed,” as imprecise movements waste time. Our ROV may not have the highest velocity in the competition, but it is very easy to control, which enables it to complete each task in minimal time.

Reflections

Paul Eccleston



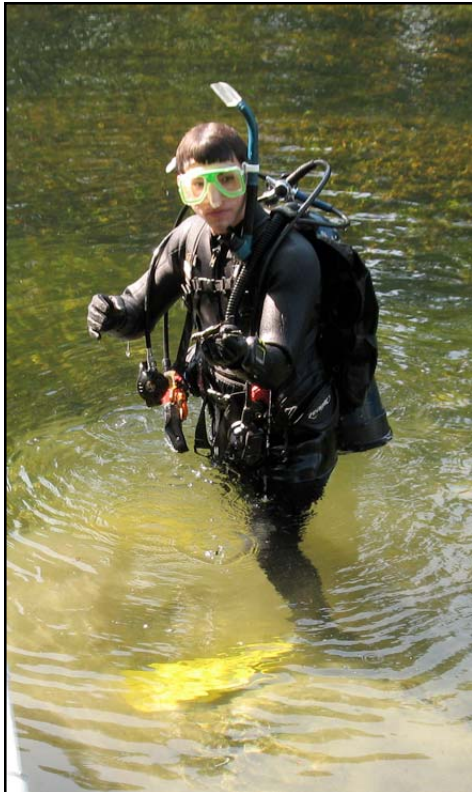
Machining the grippers and claw helped me become more confident at using heavy machinery and applying mathematics. In addition, I became more precise in the design and building of the different parts of the gripper. The exposure to the ROV competition helped me to decide that I would like to pursue mechanical engineering as a career.

Kirk Fraiser

While working on this project, I have learned the importance of teamwork. One example of our need for teamwork was when we were at the Florida Regional competition. We were about to start the second mission when we found that we did not have power on our ROV.



A judge nearby said that it was too bad that we would not be able to compete. At this critical moment we decided that instead of starting to blame others on our team, we were going to fix the problem. We used our problem-solving technique (see p. 9). We soon found that one screw on a bus bar was loose. We were able to fix it and get our ROV in the water by the end of the allotted set-up time. In any occupation, I will be able to use the skill of teamwork.



Jeff Marchand

Looking back over this past year I feel that I become better at giving constructive advice. Several members came to me with their design and construction problems, and I was able to help my teammates through some of their difficulties. Another thing that this experience has taught me is how to manage my time better. As a senior in high school there were a lot of things that I had to do before graduation, and between that and robotics I didn't have much time for other things. Having a tight schedule, helped better prepare me for the demands of college.

Joe Pratt

When I joined Cornerstone Robotic in October of 2006 I was somewhat of a novice. My experience was very limited in the areas of electronics and machining. Throughout the year I have been able to gain experience in building electrical circuits and using the mill and lathe. This year I used the mill to construct mounts for the aerodynamic



domes on the motors and I used the lathe to turn couplers to mount propellers on the propulsion system. This past year has been an excellent learning experience for me. The use of the machinery in the shop has heightened my interest in mechanical engineering and the career that may follow.



Ben Still

I learned that when using thrusters instead of variable-buoyancy ballast tanks, one gains predictable control and maneuverability. Thrusters also render the ability to dive deeper, and eliminate the need for pneumatic lines in the tether. I also learned while working with the team that respecting others' ideas is a necessary part in building a successful ROV. A lot of effort, practice, and patience can produce a highly functional ROV.

Budget and Expense Sheet

See Table 3 (p. 18).

Future Improvements

There are several things that we would like to add to our ROV, given more time and experience. The three most beneficial of these are a joystick control, a digital compass, and a depth gauge.

Joystick

The first improvement that we would make is to replace the control switches with a joystick. This modification would entail several changes, which would reduce inefficiencies in our design. Two changes that would be necessary would be to make H-bridges, and replace



Figure 12. Picture of joystick that we might use in the future.

the tether with wires of a smaller diameter. The reduction in tether size would also reduce the amount of drag created by the tether which, in turn, would allow the ROV to operate more efficiently in a current. The joystick would also give us variable speed in all directions. This feature would be extremely helpful for operating in a current, because it would allow us to counteract the current exactly without having to operate multiple switches.

Digital Compass

The next improvement that seems necessary is to add a digital compass. This feature would allow the ROV to operate better in water with low visibility, allowing the operator to find his objective based on a specific direction. Through my experience with scuba diving, I have found myself in water in which I could not see my hand if I extended it. In such an environment I found that it is very easy to get turned around, and to lose one's bearings. Having a compass will allow our ROV pilot to conduct instrument navigation.

Depth Gauge

The last improvement is to add a depth gauge. By adding a depth gauge we can keep track of depth, and also use it for instrument navigation. Keeping track of one's depth in this line of work is important because it helps ensure that your ROV does not exceed its crush depth.

Life at the Poles

It all began when ancient Greek philosophers theorized that the earth was spherical with a north and south pole. From there, human curiosity took over and the exploration of the South Pole began. Some of the first expeditions south include Gabriel de Castilla to 64° S and Abel Tasman to 44° S. Neither of these men made it to the pole, but both were greatly rewarded when they met new people and saw new lands.

The first French expedition that had the goal to reach the South Pole was Yves Joseph de Kerguelen-Trémarec. He discovered the Kerguelen Islands, but once he returned he was imprisoned for finding nothing more than a desolate and useless spit of land. The first-ever expedition to successfully reach the poles was the Nimrod

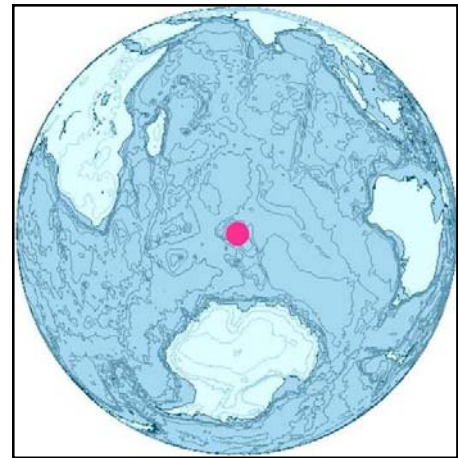


Figure 13. Location of Kerguelen Islands. From “Heard Island and McDonald Islands.”



Figure 14. Roald Amundsen. From “Roald Amundsen.”

expedition of January of 1909, led by Ernest Shackleton. Almost a year after they set sail, they made it to the magnetic South Pole, but this was not good enough for everybody else. Even though Shackleton wanted to press on and be the first to reach the South Pole, he realized that there had already been enough sacrifice and that he must turn back. But on December 14, 1911, Roald Amundsen triumphed and became the first man to ever set foot on the South Pole (Figure 14). He reached 90°S after great planning, saying that he did it to fund his greater expeditions to the North Pole.



Figure 15. Amundsen-Scott South Pole station. From “Amundsen-Scott South Pole Station.”

As of today, robots are being used to explore the parts of the Arctic which we cannot access. This includes a robot called Cryobot. It uses hot water and gravity to sink into the ice, which allows its entrance hole to refreeze above it, thereby limiting the pollution that may enter through it (Figure 16).

Cryobot is currently being tested in the Arctic, but will soon be coupled with an

ROV and deployed to Europa, a moon of Jupiter. The Cryobot will heat its copper nose using nuclear power; then, when it reaches standing water, it will release an ROV called Hydrobot. Hydrobot will be able to search Europa’s sub-surface oceans and determine whether the moon has enough geothermal activity to sustain human life. Scientists expect that the heat necessary for human life to exist on Europa will only be found in a geothermal environment.

As many countries continue to participate in the International Polar Year we will witness the continuing advancement of technology. The International Polar Year is a collaborative effort of many countries, coming together to collect data on the polar regions, which will show how

The current structure at the South Pole is mainly a 7,400 square meter two-story building that cost \$150,000,000 to construct (Figure 15). It houses up to 200 people in the summer months, but in the winter, to remain self-sufficient, its population drops to a little over 80 people. During the winter months, the station’s power is supplied by three generators running on jet fuel.

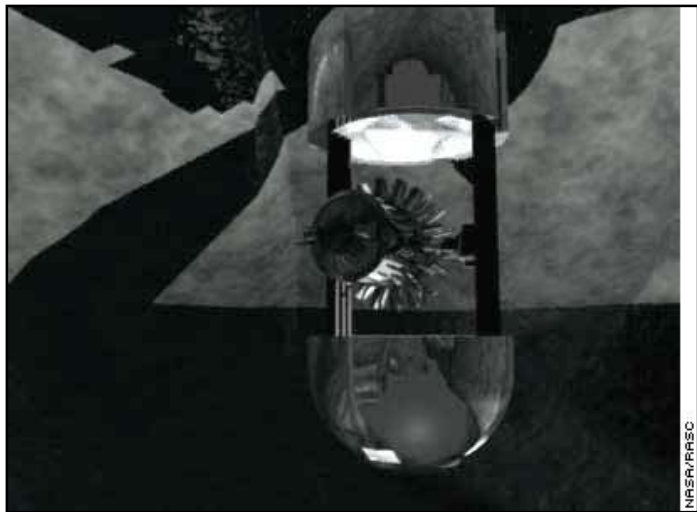


Figure 16. The Cryobot, prepared to release its ROV, Hydrobot. From Leonard (2001).

those regions affect the world we live in. The ever-increasing technology complements these initial discoveries, and will continue to facilitate the achievement of future missions.

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Acknowledgements

Local

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- Debbie Eccleston, Doug Fraiser, and Susan Marchand – Communication advisers
- Arlene Still – Fundraiser
- The Administration of Cornerstone Academy
- The Constantines – Pool
- Paradigm Management (The Gardens and The Laurels) – Pools

Sponsors

- B W Gaskets
- MATE
- Ernie and Tina Euler
- Crockett’s Challenge Award (see Appendix)
- O’Steen Brothers, Inc
- WordPro
- Exactech, Inc
- Townsend and Townsend and Crew, LLP

Table 1. Budget and expense sheet.

Period:
 From: 9/1/2006
 To: 5/17/2007

School Name: Comerstone Academy

Instructor/Sponsor: Jeffrey Knack

Date	Deposit/Expense	Quantity	Units	Description	Notes	Unit Cost	Amount	Balance
9/1/06	deposit			beginning balance			\$ 2,000.00	\$ 2,000.00
9/1/06	expense	24.75	IN	80/20 1010 Extrusion (From Stock)	Gripper Arm	\$ 0.21	\$ 5.20	\$ 1,994.80
9/1/06	expense	2	PC	80/20 4 Hole 2.5" Inside Corner Bracket (From Stock)	Gripper Motor Mounts	\$ 3.90	\$ 7.80	\$ 1,987.00
9/1/06	expense	2	PC	80/20 2 Hole Inside Corner Bracket (From Stock)	Mounting Hardware for Gripper	\$ 2.75	\$ 5.50	\$ 1,981.50
9/1/06	expense	3	PC	80/20 2 Hole Joining Strip (From Stock)	Mounting Hardware for Gripper	\$ 3.20	\$ 9.60	\$ 1,971.90
9/1/06	expense	2	PC	80/20 4 Hole Joining Strip (From Stock)	Mounting Hardware for Gripper	\$ 4.55	\$ 9.10	\$ 1,962.80
9/1/06	expense	8	PC	1/4-20 x 1/2" Button Head Socket Cap Screws (From Stock)	Mounting Hardware for Gripper	\$ 0.21	\$ 1.68	\$ 1,961.12
9/1/06	expense	10	PC	1/4-20 x 1/2" Socket Cap Screws (From Stock)	Mounting Hardware for Gripper	\$ 0.13	\$ 1.30	\$ 1,959.82
9/1/06	expense	6	PC	1/4-20 Single Economy T-Nuts (From Stock)	Mounting Hardware for Gripper	\$ 0.20	\$ 1.20	\$ 1,958.62
9/1/06	expense	2	PC	1/4-20 Double Economy T-Nuts (From Stock)	Mounting Hardware for Gripper	\$ 0.65	\$ 1.30	\$ 1,957.32
9/1/06	expense	4.5	IN	2 Inch Alloy 6061 Aluminum Rod (From Stock)	Milled to Form Gripper Body	\$ 1.55	\$ 6.98	\$ 1,950.35
9/1/06	expense	10	IN	3/4 x 1/4 inch Rectangular Aluminum Stock	Milled to Form Gripper Body	\$ 0.13	\$ 1.30	\$ 1,949.05
9/1/06	expense	11	PC	3/4" Slip x Slip 90 Degree PVC Elbow	ROV Frame	\$ 0.28	\$ 3.08	\$ 1,945.97
9/1/06	expense	28	PC	3/4" PVC TEE	ROV Frame	\$ 0.38	\$ 10.64	\$ 1,935.33
9/1/06	expense	20	FT	3/4" PVC Pipe	ROV Frame	\$ 0.36	\$ 7.20	\$ 1,928.13
3/31/07	expense	4	FT	3" PVC Pipe	ROV Frame	\$ 2.62	\$ 10.48	\$ 1,917.65
3/31/07	expense	2	PC	3" PVC Pipe Cap	ROV Frame	\$ 3.65	\$ 7.30	\$ 1,910.35
5/17/07	expense	2	PC	3" PVC Pipe Elbow	ROV Frame	\$ 4.28	\$ 8.56	\$ 1,901.79
1/10/07	expense	2	PC	3/4" 45 Degree PVC Fitting	ROV Frame	\$ 0.59	\$ 1.18	\$ 1,900.61
1/10/07	expense	14	PC	1" PVC TEE	ROV Frame	\$ 0.38	\$ 5.32	\$ 1,895.29
5/16/07	expense	14	PC	1" to 3/4" Reducers	ROV Frame	\$ 0.32	\$ 4.48	\$ 1,896.13
5/10/07	expense	3	PC	3" to 4" Stainless Steel Hose Clamp	ROV Frame	\$ 1.85	\$ 5.55	\$ 1,890.58
9/1/06	expense	16	PC	3/32"x3/4" Cotter Pins (From Stock)	ROV Frame	\$ 0.02	\$ 0.32	\$ 1,890.26
9/1/06	expense	121	PC	#8-32 x 1 1/2" Pan Head Stainless Steel Machine Screws	ROV Frame	\$ 0.08	\$ 9.68	\$ 1,880.58
9/1/06	expense	121	PC	#8-32 Stainless Steel Lock Nut with Nylon Insert	ROV Frame	\$ 0.08	\$ 9.68	\$ 1,870.90
9/1/06	expense	15	PC	Rule Pump Bilge 1100 GPH	ROV Motors	\$ 36.99	\$ 554.85	\$ 1,335.41
5/19/06	expense	4	PC	Prather Products S 250 Stainless Steel Boat Prop	Prop Thrusters	\$ 14.12	\$ 56.48	\$ 1,278.93
5/12/07	expense	8	PC	Video Ray 3 Bladed 90mm	Prop Thrusters	\$ 19.25	\$ 154.00	\$ 1,124.93
1/12/07	expense	1	PC	SMM-50-C SeaMaster SuperMini Color Camera	ROV Camera	\$ 199.99	\$ 199.99	\$ 924.94
4/3/07	expense	4	PC	Atlantis Underwater Cameras and Monitors	ROV Cameras	\$ 99.99	\$ 399.96	\$ 524.98
2/19/07	expense	500	FT	2Wire 16 Gauge Cable	Tether	\$ 0.20	\$ 100.00	\$ 424.98
9/1/06	expense	200	PC	10" Zip Ties	Hold Wires to ROV	\$ 0.05	\$ 10.00	\$ 414.98

Appendix



GROVER

Named in honor of, and in gratitude to, Crockett Wise.