Nova Scotia Community College

Remotely Operated Vehicle for Emergency Recovery ROV_{ER}

For
MATE International ROV Competition 2008
"Diving to the Deep: Uncovering the Mid-Ocean Ridges"

By
Nova Scotia Community College Team, Halifax, Nova Scotia
Paul Anstey, Cheryl Hill, Thomas MacDonald, Kevin Pellerin, Kiho Song, and Rick Thibault

Mentors
Gord Wilkie, Glenn MacLeod, Peter Oster and Dan Boliver

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I ROV$_{ER}$'s team

Our team is comprised of a dynamic range of individuals; both on the student side and mentor side. The project would not have been possible without all the hard work from everyone involved. The will and determination to push ahead was what gave us the opportunity to fully realize our potential. Each member was crucial to the team and brought specialized knowledge in particular areas. ROV$_{ER}$ would not be where it is today without the fantastic members of our team.

Paul Anstey was born in 1960 in Botwood, NL and was raised in the little town of Embree. Paul attended Memorial University (St. Johns, NL) from 1977-80 with a concentration in Geography and Education (Teaching). In 1980-81, Paul studied welding and automotive mechanics. In 1983 he began working for the Department of National Defense at the Naval Dockyard, Halifax, NS, as a plater/welder. He is currently working for Defense Research and Development Canada (DRDC) in a prototype shop. Three years ago, he was assigned to a position as a developmental mechanical technologist. He returned to school Sept. 2007 to study math and physics and will be returning to the NSCC this year to study Mechanical Engineering Technology. He is married to Trudy and has two children.

Cheryl Hill is 27 years old, and is a 1st year Electronic Engineering Technology Student. She is currently working as a Trades and Technologies Summer Student in the Electronics Department at the NSCC. Cheryl is the NSCC Student Association VP of Finance. Her favorite part of this experience was the actual hands on building and assembly of ROV$_{ER}$. When she finishes her program she will have time for hobbies again.

Thomas MacDonald is 23 years old and a graduate of the Mechanical Engineering Technology program. He is self-proclaimed as the "biggest video game fan in the world". A large part of his free time is spent trying to finish the dozen games he has on the go at any one time. Thomas has a strong interest in CAD related programs. He hopes to start a CAD consulting firm down the road, as he has the fire of the entrepreneur burning in him. He is currently employed as a Research and Design engineer at Clare Machine Works Ltd.

Kevin Pellerin is 20 years old and a graduate of the Electronics Engineering Technology program. Kevin plans on working in the marine industry as a ROV technician or pilot. For ROV$_{ER,}$ his work consisted of devising a method of controlling ROV$_{ER}$'s motors and cameras using several microcontrollers. He also worked with the Bedford Institute of Oceanography to produce the circuit boards which are currently in ROV$_{ER}$.

Kiho Song is 33 years old and in his 1st year of Mechanical Engineering Technology. He was a product designer in South Korea, before he moved to Nova Scotia in October 2005. After Kiho became a permanent resident in October 2006, he decided to go to NSCC in the Mechanical Engineering Technology program. He has excellent hand-sketching skills, advanced skill in 2D rendering applications and a unique ability to make a 3D rendering with a 2D program.

Rick Thibault is 34 years old and is a graduate of the Electrical Engineering Technology program. He is also an electronics engineering technician. He is currently employed with an engineering consulting firm as a junior electrical technologist. As hobbies, Rick enjoys studying renewable energy and doing small carpentry. Rick enjoyed documenting, designing, and building ROV_{ER}. Even though his field is electrical he enjoyed the mechanical aspects of the project. He is married to Lia.

II Acknowledgments

The team would like to thank:

Gord Wilkie	Mentor
Peter Oster	Mentor
Glenn MacLeod	Mentor
Dan Boliver	Mentor
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Romar Inc.	Donation
The NSCC for all the help and support it gave us.	
Team members' friends and family	
TechNova	Society of Certified Engineering Technologists & Technicans of Nova Scotia
Tom Kyte	NSCC Student assistant, 2007 NSCC ROV team member and Machinist
Dominion Diving Inc.	
Defense Research and Development Canada (DRDC)	

III Abstract

The 2008 Remotely Operating Vehicle (ROV) project at the Nova Scotia Community College proved to be an exciting and challenging endeavor. The main goal of the project was to engineer a ROV capable of completing one mission with three tasks that resemble those in industry. The tasks are:

1. Measuring the temperature inside the smoker
2. Collecting lava rocks (Dive-weights); and
3. Retrieving the OBS (Ocean Bottom Seismometer).

The robot is affectionately named ROV_{ER}: Remote Operating Vehicle for Emergency Recovery.

The construction of ROV_{ER} was carried out by the team and supported by the team's mentors. ROV_{ER} is an original design; a culmination of at least five prototypes. Each part of the robot was carefully designed, planned, created, and installed; relating issues were resolved as they arose. ROVER was built with two concepts in mind: maneuverability and speed. ROV_{ER} measures 66 cm in width, 79 cm in length, 58 cm in height and is 16.3 kg in weight, and is slightly negatively buoyant. The robot's construction involves a variety of materials which include PVC, Komotex, and aluminum. ROV_{ER} carries three cameras, two can change position and one fixed. A mechanical arm is used for some object manipulation. There is also a balloon to help lift the OBS. The horizontal motors provide 58 N of thrust each and the vertical motor provides 135 N of thrust, making ROV_{ER} quick and powerful. ROV_{ER} is controlled by two joysticks and three switches.

IV ROV$_{ER}$'s Profile

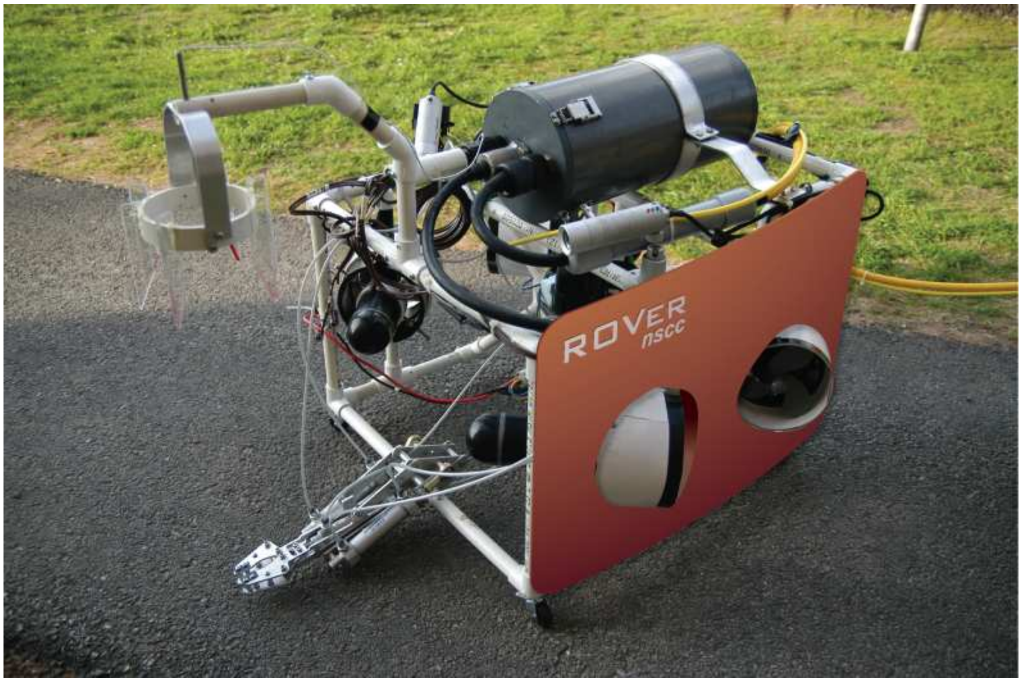

Fig 1 – Completed ROV

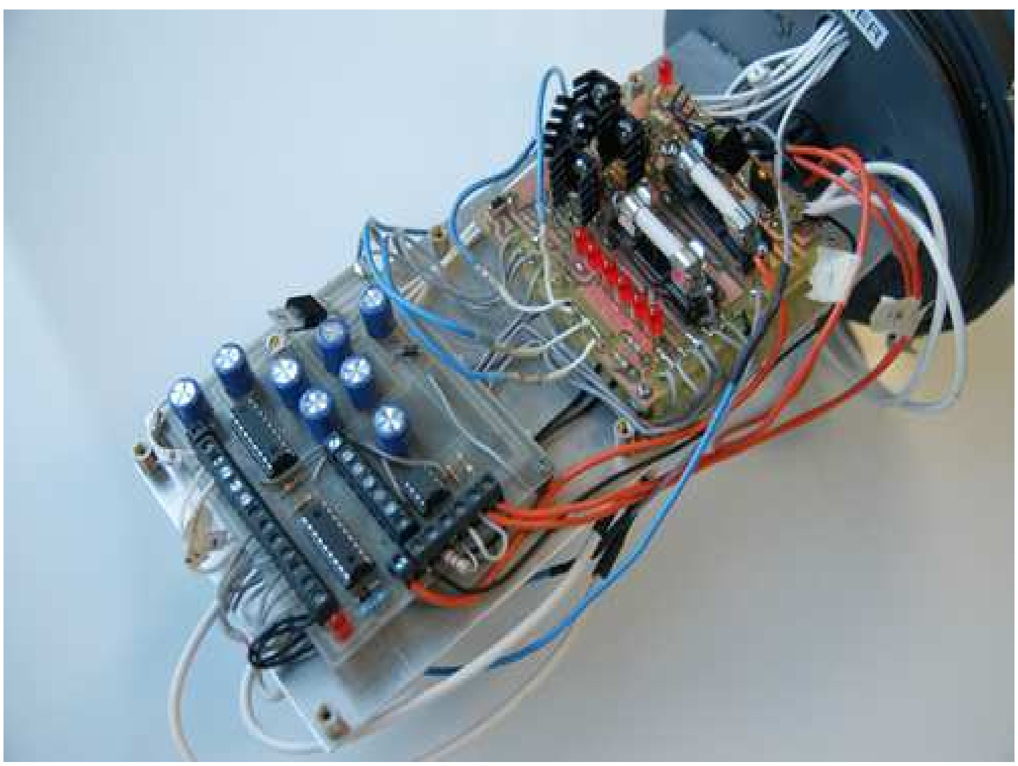

Fig 2 – ROV Onboard Electronics

V Budget/Expense Sheet

Item	Qty	Source	Net Cost	TOTAL
Micro Delring Locking Sleeve, Female	2	Romor Atlantic Ltd.	$40.00	$45.20
Micro Mini Bulkhead 4 Pin Female & Male	1	Romor Atlantic Ltd.	$251.00	$283.63
Micro Mini Inline 4 Pin Female & Male	1	Romor Atlantic Ltd.	$144.00	$162.72
Kworld 1680 EX TV Box Retail	4	Robotnic.Com Inc.	$264.00	$298.32
Lynxmotion Pan & Tilt Kit/Aluminum	3	Robotshop Inc.	$128.10	$155.79
Supplies for OBS and Black Smokers	n/a	Northeast Equipment Ltd.	$229.97	$229.97
Cosel DC-DC Converter	2	TRC Electronics	$291.64	$383.00
Trolling motors	6	Seamasters Services Ltd.	$900.00	$1,024.20
Bulkhead & Inline 8 Pin/Locking Sleeves	1	Romor Atlantic Ltd.	$540.00	$610.20
62.5mm Hose Air OD-30.3m Yellow	1	Princess Auto	$11.99	$13.55
PS2 Glow Controller	3	Buyers & Sellers Depot	$17.97	$20.31
Amphenol Modular Connector	12	Jentronics Limited	$11.76	$13.29
Ex-Cel Low Density hard PVC board	1	ND Graphics	$21.65	$24.46
1.25cm Air hose - 30.3m	3	Princess Auto	$31.83	$35.97
10cm Coupling	5	Home Depot	$22.95	$25.93
Dura Foam	1	Pierceys	$6.99	$7.90
Kepco RKE-48-32K Power Supply	1	Testforce Systems Inc.	$905.00	$1,073.50
Dive weights & batteries		Various Sources	$118.21	$135.14
Meals	12	pizza for dinners	96.44	96.44
Poster	2	Kiho & Staples	$200.00	$200.00
Tether	1	**Donated Materials**	$700.00	$700.00
Connecters	2	**Donated Materials**	$1,200.00	$1,200.00
Canister	1	**Donated Materials**	$500.00	$500.00
Board Manufacturing	4	**Donated Materials**	$300.00	$300.00
Electronics	34	Various Sources	$33.33	$33.33
TOTAL			**$6,966.83**	**$7,572.85**
Airfare		Travel Costs		$5,600.00
Accommodations		Travel Costs		$1,575.00
Meals		Travel Costs		$500.00
Van Rentals		Travel Costs		$1,400.00
Extra baggage charge for ROV_{ER}		Travel Costs		$200.00
Incidentals		Travel Costs		$200.00
TOTAL				**$9,475.00**
GRAND TOTAL				**$17,047.85**

VI Electrical Distribution

1. Power converters

The step-down switching voltage regulators were initially connected directly to the positive 48V side of the supply. This initial connection caused a failure due to the inductive load of the motors. To fix this problem, we added capacitors on both the input and output sides of the supplies.

2. Relays

The relays were incorporated in the beginning to handle all the motors. Our final design used the relays for only the large submerge and surface thruster. There are diodes across the relays. The relays are wired to represent a circuit called “H-bridge” which inverts the positive and negative terminals.

-See Appendix A for Electrical Schematic-

VII Electronics Design

1. Imbedded Controllers

The general flow of the electronics system is shown in Appendix A. Five microprocessors are used to control ROV_{ER}, to transmit data from the RTD temperature sensor and to display the temperature reading. The imbedded controller used through ROV_{ER} is the PIC16F88, an 8-bit PIC. Analog inputs are read into the PIC using an internal Digital-to-Analog module. The microprocessors are sensitive to 0.471^0 of tilt from each axis of each thumbstick. Thumbsticks from Playstation 1 console controllers were chosen because they were available at any thrift store and economical at under $6 Canadian each.

-See Appendix B for Block Diagram of Electronic Schematics-

Each of the 2 thumbsticks controlling the 5 motors is a pair of potentiometers which have spring return mechanisms. The microprocessor determines the direction each axis the thumbsticks are in and also the magnitude of displacement from the center positions. Two switches are used to force ROV_{ER} up or down by latching the vertically-mounted motor. Two relays wired as an H-bridge are used to switch voltage on the vertically-mounted motor’s leads. The power MOSFETs used to drive each motor would generate much more heat if proportional control was used. Because the electronics canister is a confined space, heat build up would be an issue. ON-OFF motor control was used to increase ROV_{ER}’s reliability.

-See Appendix C for Block Diagram of Software Flow-

2. Overall System Layout

All of the microprocessor circuits are fused and operate using 12V. Each microprocessor circuit has a LM7805 series linear regulator to drive its respective microcontroller. ROV_{ER} has two circuit boards inside its electronics canister. One of these circuits has two microcontrollers. The first microcontroller reads in serial data which comes down the tether from the poolside circuits. Some of this data is converted to parallel data and sent to the second circuit board. The second PIC on the circuit board reads temperature data in from ROV_{ER}’s RTD bridge circuit. The microcontroller transmits 10-bit serial temperature data through the tether’s receive line. The temperature sensor utilizes a 3-wire platinum 100 ohm RTD transducer. A bridge circuit is used along with an instrumentation amplifier to produce a voltage dependant on temperature. This voltage is read into the transmitter microcontroller as an analog value. The system resolution of the RTD sensor is 0.063^oC. The second microprocessor transmits the temperature data up the tether. The second circuit board contains six power MOSFETs, which control 5 DC trolling motors. Both of the onboard circuits use the 12V output from the two switching voltage regulators; the three circuits above the waterline are powered by a 24V linear regulator. Communication among each circuit utilizes TTL serial data; there are 8 data bits, no parity bit and 1 stop bit.

Three more circuits are located above the waterline. An NTSC video signal generator circuit displays temperature data in a readable format. The temperature is displayed on a separate LCD monitor, along with motor data. The video circuit receives serial data from the motor controller, servo camera mount controller and the temperature transmitter. The microcontroller reads serial data from the tether transmit line in and displays motor states and two temperature values. The microcontroller reads the transmitted serial data to the tether and sends TTL signals to another microcontroller, the SV2000 distributed by Speech Chips Incorporated. To aid in capturing the most accurate water temperature from the RTD temperature sensor, a covered switch is used to store the current temperature value and display it until the switch is reset to the off position and switched again. The SV2000 video IC generates the NTSC video signal which is sent to a KWorld TVBox 1440. The TVbox module receives the NTSC video signal from the video IC and converts it to a VGA video signal. The VGA output is then sent to a LCD monitor.

VIII Design Rationale

1. Structure

Our first few meetings consisted of discussion pertaining to the missions, including specifics such as measurements and the order we wished to complete them in. As a result of this, we came upon our first shape, dubbed “Swiss Cheese,” shown below in Fig 3. Based on the intended placement of the RTD and the original three thruster design, this design was proposed, but was later scrapped when we found we couldn’t get the maneuverability desired.

After several proposed designs and referencing the design of the school team from last year, we discovered ROV_{ER}. The final design allowed for thruster stability, centralized buoyancy on the upper part of the structure and sufficient space for mounting tools (manipulator, OSB retrieval system, and temperature probe).

Our final frame is constructed of ½” PVC piping and is laid out in a rectangular fashion, typical to the industry, and this design was chosen for a couple of reasons. A rectangular design lends itself to, a four horizontal and one vertical motor set up, which is balanced for weight, size, and thrust distribution. Mounting motors in the vector formation allows a very wide array of motion. PVC provides a great compromise between strength, weight and price so this, coupled with a looming due date, resulted in the decision to keep the frame as is, as opposed to welding up an aluminum frame. The vertical thruster is mounted via a triangle PVC frame on two sides, providing a great amount of support. Between the PVC piping and motor on each side, is a piece of Styrofoam attached with a hose clamp, and this allows us to adjust the position of the motor in the event that bending or deformation of the frame occurs.

Fig 3 – Original structure design, “Swiss Cheese.”

2. Thrusters

a. Motors

We decided to use a total of five motors on ROV_{ER}: four in a horizontal vector formation placed at each corner, and a single one placed at our expected center of gravity. The motors were ordered and when they arrived, we decided to waterproof them to ensure they stay dry even at great depths. We removed the cotter pins and allowed the props to come off, which gave us access to the case screws and subsequently the inside of the case. We added O-rings and closed the casing back up. After that, we inserted a two-part epoxy solution mixed with little bits of cotton into the wire shaft until it hardened and provided a tight seal, even when the wires were pushed and pulled. We allowed the solution to cure for 24 hours; and as a result we have five motors waterproofed and capable of performing at large depths.

b. Shrouds

After several field tests, ROV_{ER} required more control for precise movements to measure the temperature from the smoker and to insure it was fast enough to complete all missions on time. That is why ROV_{ER} required shrouds. The shrouds we constructed began with 4 inch PVC piping. Unfortunately, the propeller blades were slightly too big, so we improvised by adding a lip of flexible material called Komatex around the outer edge of the pipe, mounting it in such a way that the lip was the only part surrounding the blades. Komatex was chosen because it is affordable, buoyant, and durable; capable of withstanding thruster vibration and propellor pressure drop. This provided us with the half centimeter clearance that we were aiming for. Once mounted, holes were drilled on the shrouds 90 degrees from each on the side of the motor opposite the prop and four bolts were inserted as a way to center the motor within the static shroud, similar to the common style of Christmas tree holders. As a result of all these designs, we have adjustable, low cost, effective shrouds for our four horizontal motion thrusters (See Fig 4).

We placed shrouds for two reasons; we wanted to ensure that the props and environment would be safe from one another. We do not want a motor to get destroyed, a tether ruined, or have a team member injured. The other reason is based on thrust; that is, to ensure the water that the motors tread is aimed in a single direction, providing a motor which will thrust in the direction intended and that an optimal pressure drop is experienced as the prop pushes away water, thus providing an ideal push and pull effect.

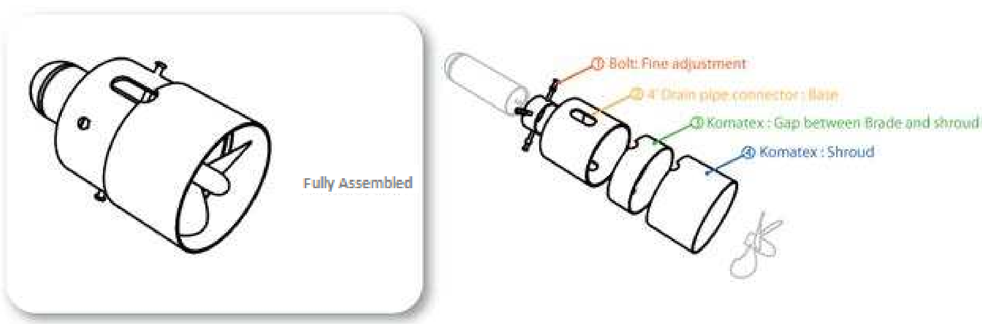

Fig 4 – Thruster shroud fully assembled and exploded view

3. Servo Cameras

We knew from the beginning that a clear view underwater was going to be required to complete the missions. As such, we constructed our servo controller cameras with the capability of panning and tilting 180 degrees. They are controlled via thumb sticks, with movement based on the width of the pulse sent to the control terminal. The 5V cameras provide the ability to get a full view of all aspects of ROV_{ER} and the surrounding environment and also allow multiple views of each of the props. Pushing a thumbstick off its center position modifies the control pulse's width by increasing or decreasing the rate at which the pulse's high time changes. The rate of change is proportional to the amount of displacement of the corresponding wiper from its center position. This allows the user to change the rate at which the cameras pan and tilt. Camera placement was chosen to compliment this range of movement and one static camera was also placed on the top of ROV_{ER} to allow a static view of the top of the smoker, to assist with temperature measurement. All three cameras used on our ROV_{ER} are recycled from the previous year's entrant and this decision was made because they provide a common video hookup, have a small footprint, and provide a fabulous picture underwater.

Each of the four servos used required waterproofing, and this was achieved following instructions from a YouTube video titled "How to Waterproof a Servo." The process began with removing the screws and then covering the exposed electronics with non-conductive silicon. We then removed the horn briefly while we put two O-rings underneath it. Mineral oil was then put inside the gear box using a syringe, O-rings were put under the screws and the box screwed shut. The last step was to put silicon around the wire grommets, to ensure a strong seal.

4. Tether

With our initial design, our tether was bulky and obtaining neutral buoyancy was difficult. However, Romar Inc. donated a 15m long used tether that was slightly positively buoyant – perfect for our application. The gauges and number of wire in the tether were adequate for our application and we designed our communication and power transmission based around this. The tether has eight wires inside: two 18AWG, one coaxial cable (coax), and five 20AWG (surrounded by a shield), and on one end of the tether the shield and outside of the coax are connected to reduce the electrical noise that the motors make when switching on and off.

5. Buoyancy

The adage "what goes up must come down" does not apply in the buoyancy world. The volume of enclosed components adds to the positive buoyancy of a vehicle. This does not pertain to the pressure inside of the components. The total weight of a vehicle adds to the negative buoyancy.

6. Canister / Connectors

With the discovery of last year's electronics canister that was not working due to seal failure, our task was to design a canister that was well-sealed – not just around its cover, but around each connector on the canister. After connecting with a ROV expert, our team discovered a previously-used canister. After admiring its structure, we were ready to design our own only to discover that the canister we received would be adequate. With industry's help, we got two new connector holes milled into the cover after purchasing new connectors and getting used connectors for our canister. The connectors were all inserted with the proper O-rings and O-ring grease, and were sufficiently tightened.

7. Task Tools

a. Manipulator

This area of expertise required several designs before arriving at the final product. Many of the initial designs were conceptual but did not come to fruition. The manipulator is designed using three pistons: two in unison to rotate the arm from full extension to 140 degrees of full retraction. The third piston is designed to close and open the manipulating gripper. With the gripper in its fully opened position, it is designed to roughly guide the vehicle along a smoker/thermal vent. The manipulator arm in its fully extended position can be guided to collect hardball size lava rocks (dive weights). The figures below depict the manipulator arm in various positions.

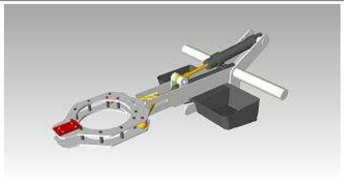

Fig 5 – Manipulator arm lowered

Fig 6 – Manipulator arm raised

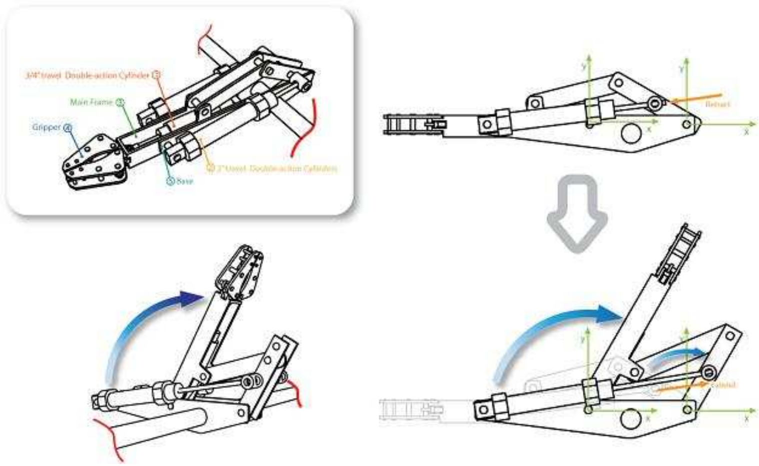

Fig 7 – Manipulator Arm

b. Pneumatics

The choice between using hydraulics or pneumatics for various aspects of the ROV was one that came up early. We settled on pneumatics for several reasons. Hydraulic systems are great because they allow for a fine level of precision because the working fluid, usually petroleum based oil, or as was our plan, water, is fed in slowly, with results in a slowly and smooth extending cylinder. With the working fluid being pumped in, you can throttle the strength of this cylinder by controlling the speed of the pumping pushing the fluid. Pneumatics offer a different option, with air being the working fluid, when a pneumatic cylinder is energized, air rushes in and the cylinder extends very quickly. Based on the requirements of the missions, hydraulics would seem to be the way to go, but they have a couple caveats. Hydrualics would require bilge pumps and an electrical control scheme which creates the potential for serious malfunction and error. This, coupled with the fact that we can take away the advantage of speed and precision with a properly designed manipulating system, told us that pneumatics would be less problematic, easier to implement, approach.

Our final system uses three identical flow control valves, which are push button controlled, and on the surface of the water, near the pilot. The benefit of this system is that there is no electrical component to it, it frees up a lot of space and weight on the ROV, and if a valve has a problem, we can switch hoses up top-all while not adding much weight or resistance to the tether.

-See Appendix D for the piping layout of our pneumatic lines-

c. Temperature Probe

Our RTD is placed dead center in front of ROV_{ER} and approximately 230 mm away from it, with the tip of the RTD approximately 600 mm from the ground. This position allows it to enter the smoker to a reasonable depth and provide an accurate temperature reading. The design is a static one in that the RTD will never move and relies on the precise moving of the ROV_{ER} to feed it into the hole. The RTD consists of a temperature probe, an aluminum cross bar, a PVC rim, four polycarbonate secure bars, and two support rods (See Fig 8). The rim was created first, this is slightly larger than the cap of the smoker, to insure a snug fit. The secure bars were then attached to the rim to act as a guide for correct positioning when attaching to the smoker. It should be noted that as the material used was transparent, a red sticker was applied to the inside edge of each secure bar to maximize visibility. We decided on this method for a variety of reasons with the main one being that it has no moving parts and no electrical component, save for the RTD itself, so it remains simple yet functional, while not providing very many avenues for failure.

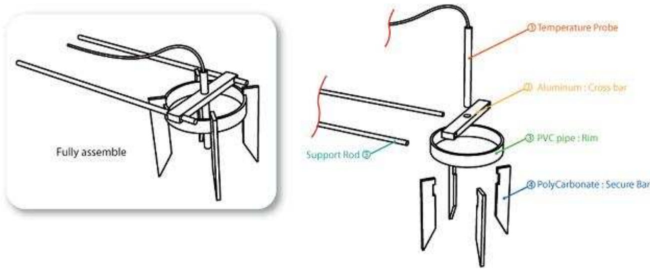

Fig 8 – RTD system

<u>d. OBS Recovery System</u>

After watching an episode of the drama "House, MD" in which an angioplasty was performed, the idea was formed to put a balloon in the bottom section of the OBS and inflate it, providing both an avenue to assist in lifting, and a way to ensure that we keep a grip on it, as the balloon will inflate to fill in the gaps, providing a strong grasp (An angioplasty is the method of using some mechanical device, in this case, a balloon, to widen constricted blood vessels to allow implements such as catheters to get through.) The balloon is filled with air from a tube on the surface found down below along the tether, and is exhausted via the 2 way valve on the surface. Upon testing, both aspects we wanted to achieve with our balloon were realized with as little as 70 kPa was able to provide us with the power and speed we required. The figures below depict ROV_{ER} bringing up the OBS using a balloon as well as a model for our design.

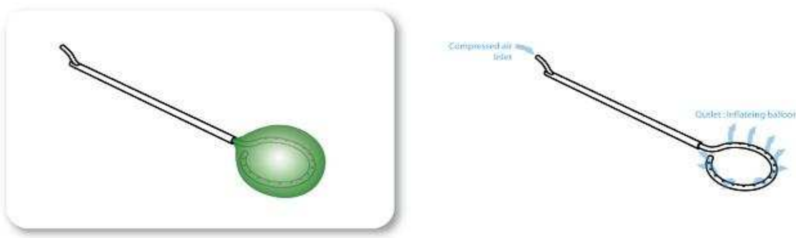

Fig 9 – OBS recovery balloon

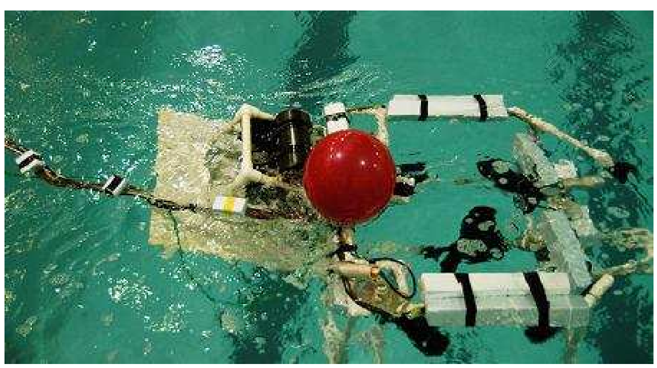

Fig 10 – OBS recovery balloon in action

IX Challenges

The biggest challenge that the ROV_{ER} team encountered was time management. Since the ROV project was not part of the team members' curriculums, and due to the busy schedules and commitments of the members, it was a challenge to rally the team to work together at times that worked for everyone. However, when push came to shove, the team managed to re-group and commit a significant amount of time to finish the project – for instance, in one case the team worked for 12 hours straight after regular business hours to get ROV_{ER} working.

Another significant challenge was deciding on a style and implementation of the manipulation arm. We knew how we wanted to handle the temperature and OBS retrieval, and how we wanted to mount and control our thrusters (though the wiring of those was no small feat) but we went through many different iterations and discussions on various types of arms, and coming to a consensus was very rare. Perhaps this is a challenge that is necessary as this is a very valuable component in relation to the performance of the ROV and a lot of thinking should go into it.

X Troubleshooting

The following are two examples of our trouble-shooting methods:
When our hamburger flipper (shown below in Fig 11) was finally constructed, we put various amounts of pressure on it, which would certainly spring it open, but when retracted, did not provide enough force to kick the dive weight off. We realized it was a power issue, in that we weren't providing an appropriate moment arm for the kicker to act at, so we adjusted various lengths from the hinge in an effort to increase advantage, and while it did appear to rise up more, it wasn't performing as we had hoped, so we scrapped it.

On the night that we first mounted our circuitry within the canister, upon testing we discovered that while power was being received by the thrusters, performance was lackluster or almost non-existent. After various disconnects and reconnects, we began doing continuity tests. We took a multimeter and set it to diode check mode and began checking connections to ensure that the board was sound, which was signaled by a beep if they should be connected, and no beep if they were not connected. Using this method we found our loose wire and subsequently got our thrusters working the way he had intended.

XI Previous Designs

1. Hamburger Flipper

Design: The original idea for a manipulator arm, the flipper consisted of a double acting pneumatic cylinder with about 13 inches of travel. Attached at the end was a 5 inch square piece of stainless steel with an inward facing lip and with another thin sheet of stainless steel attached at the side via a piano hinge. In the bottom of the thin square of stainless steel was a hole which allowed an L shaped piece of metal to protrude, thereby flipping the top. See Fig 11 below.
Rational: Mounted in the proper position, the intent was to position the ROV in such a way that the somewhat flexible flipper could extend out and under a dive weight, catching it and keep a hold of it via the lip. Once secured, the flipper would retract, hitting the L shaped piece of metal, causing it to rotate through the hole in the bottom of the square piece on the flipper, which push the hinged part up, along with the weight and cause it to fall into a strategically placed basket.
Why it failed: Although the team felt we had hit a home run, implementation proved more then difficult. The overall footprint of the flipper meant mounting it was difficult and angling it just right and keeping it there was equally frustrating. Once we finally managed to get it mounted we found that with even 40 psi, the flipper was not able to push the bag off.

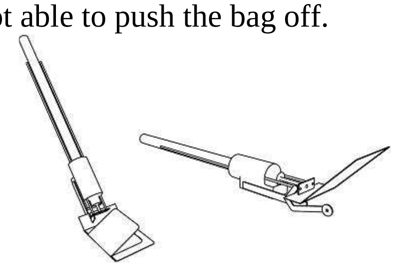

Fig 11 – Hamburger flipper manipulating arm

2. RTD Tape Feeder

Design: The RTD tape feeder consisted of a plastic frame, which housed a spool, which was free to rotate, and that had a piece of an old tape measure attached, which was fed out a hole at a 90 degree angle.

Rational: With precise maneuvering, the ROV would be moved into a position such that the feeder would be located over the smoker, and with the RTD attached to the tape, a motor would rotate the spool, feeding the RTD into the smoker's hole.

Why it failed: The tape feeder did not fail, but it brought along a level of required preciseness and complication that the team felt could be improved upon. The design was great and interesting, but we felt that we could implement our temperature probe in a simpler way, always in our continued effort to avoid malfunction and breakdown.

3. Fork Lift Blades

Design: The forklift blades consisted of two 7mm pieces of wood, with 3mm aluminum plating on the top and bottom and spring loaded hinges with a 7.5cm long piece of aluminum plating screwed onto each hinge. They were mounted about 5 cm apart, on the back bottom frame piece of PVC. See Fig 12 and 13.

Rational: With a properly mounted camera providing an isometric view out the back of the ROV, the blades would slip through the space on the OBS, with the hinged aluminum collapsing down and springing up when it finally came out the other side. With it properly secured, the upward thrust motor or an inflatable balloon would provide enough force to bring it up to the surface.

Why it failed: While the idea seemed good on paper, it was awkward both in its construction and its performance. Having them screwed into the frame of the ROV meant that it was almost twice as long and this proved to make transport and storage a headache. When we finally arrived at the pool, maneuvering the ROV well enough to insert the blades in proved to be more difficult then anyone had expected. With more time and planning, improvements could've been made and functionality could have been realized, but it was decided that we would take it in a different direction.

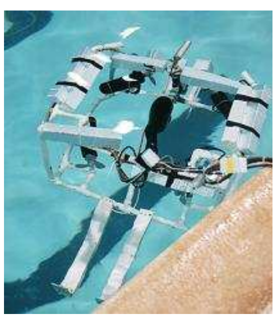

Fig 12 – Fork Lift blades on ROV   Fig 13 – Fork Lift blades in "action"

XII Lessons Learned

The amount of knowledge we have gained as a result of this project is immeasurable, but there are certainly specific things we would suggest to a team for next year's competition.

- Be wary of which terminal is going to which, as a mistake at this point on a day where the team's electronics tech is not available will result in a lot of wasted time and even more frustration. Pay attention to details and always consider the little things.
- It is important to assign a team leader before work on the project gets started. As well, a project charter or description, along with milestone dates and critical paths should be prepared. Having an explicit schedule is a necessity as having a list of dated tasks allows for proper plan, and will help in the event that someone requires assistance.

- Our milling machine at the school broke the same time we were ready to mill our electronic boards. Thankfully, our boards were milled for us by BIO. Once the milling was completed, the boards were populated and tested, and we discovered one did not work, and as a result of added materials the boards would need re-milling. Having a contingency plan in place is crucial, as little mistakes or issues that have no immediate solutions can put you behind weeks and weeks, as our would have, had it not been for BIO.

XIII Future Improvement

The PICs (Programmable Integrated Circuit) used in the video and control circuits proved to be inadequate, due to the PIC16F88's pin count. The PIC16F887A would be a much better choice for this application. The PIC16F887A microcontroller has capability for up to 4 pulse width modulated outputs which could be used to control the servo motors for the 2 camera mounts automatically. The PIC16F88 has only 1 PWM output. It was easier to disable the module and create a function which would accommodate the PWM signals needed. However, due to the program flow, this function causes the servo motors to vibrate for up to 5 seconds after the servo motors stop moving. The RS-485 serial communication protocol could also be used with the PIC16F887A to increase the data rate. This would shorten the time delay from when the onboard microprocessor circuitry begins to transmit data to when the other receiver microcontroller would receive new data and update the motor states. The PIC16F887A could also be clocked by an external 20Mhz crystal; program execution would then increase by 150%.

With more time, we would like to construct a frame out of aluminum. The current shape is functioning as we want it to and it would not change, but if made out of aluminum, it would take up a smaller footprint and be lighter. With a smaller, lighter ROV, transportation would be much easier, and we wouldn't require as much buoyant material to balance it out.

We would like to construct a pneumatic system which operates below the surface if it designed in such a way that it can be easily replaced in the event of a failure, as the advantage of only having two air lines going down as opposed to five is only worthwhile if you avoid potential space and electrical issues, and only if the time is there to implement it.

XIV ROVs and Mid-Ocean Ridges

What is a Mid Ocean Ridge?

Mid Ocean Ridges are the results of the crossing or separating of the tectonic plates of the Earth. As the plates move away from each other (creating gaps), or as they move closer to one another (creating shelving), magma is released from the Earth's core up to the ocean floor, where it becomes lava and hardens, forming a new crust. The result is a ridge typically 1 to 2 km in height.

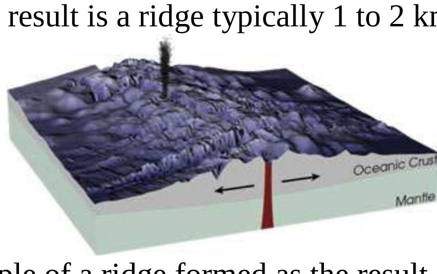

Fig 14 – Example of a ridge formed as the result of plate shifting

Who gets to explore the hydrothermal vents?

On March 27, 2001, a team comprised of engineers, biologist, chemists, geologists, geneticists, and microbiologists embarked on 37 day expedition aboard the RV Knorr, five years in the planning, to explore hydrothermal vents, in an effort to locate black smokers in the Indian Ocean. The team consisted of three sections: the scientists, headed by Cindy Dover, the engineers, headed by Andrew Bowen, and the crew of the Knorr, headed by Arthur Colburn, with all teams being assisted by Jason, the ROV. The final destination of the trip, floating around 25°00'S and 69°00'E, was chosen as the result of data acquired by Japanese scientists and their ROV Kaiko in August of 2000, when they explored hydrothermal activity around the Central Indian Ridge.

What value do the vents offer?

With new crust and ridge being created every year (about 2.4 square km worth) all over the ocean floor, brand new opportunities are being created which are just waiting to be explored. The main question the team set out to answer was whether or not life which exists around the ocean ridge is uniform, i.e. plant and animal life at one point on the ridge is similar to ridge life 100 or even 1000 km away. Similarities or differences in development patterns of plant and animal life around ridges could answer questions about evolution or genetics or even pose new questions we haven't thought of yet. Knowledge created as a result of these expeditions can explain periods of history dating back 3 million years and can drive the study of biology.

What did the team achieve?

The team discovered some very fascinating things. Between the two sites they managed to visit, very different things were happening. The sites, within 100 km of each other, exhibited very different conditions including biological and environmental. Different types of fish and microbes would be plentiful at one location and be scarce or non-existent at another. Smoker temperatures would differ by more then 100^{o}C and rock types and mineral deposits would be very different. At the end of the voyage, they brought back more then 350 pounds of sulfide samples, 1650 pounds of volcanic rock, over 600 water samples from various sites, and backpacks full of tissue samples and specimens, specimens so valuable the biologists refuse to let them leave their persons.

Who couldn't they have done this without?

Fig 15 – Jason being lowered into the water

Jason is a two-body ROV system. It consists of the main body, equipped with sonar images, water samples, video and still cameras, and a manipulator arm capable of collecting samples of rock, liquids, and plant and animal life. Coupled with this is a system referred to as Medea, which acts as a buffer and shock absorber to prevent the rocky motion of the ship from transferring down the 10 km fiber optic tether which connects Jason to the surface. Madea is also used to provide lighting and a bird's eye view of Jason operating on the ocean floor. Most dives with Jason last around 20 hours, but some have been known to last up to 100 hours. Jason's design has been around in various forms for 30 years and has been used to exlore everything from the RMS Titanic and to a 1600 year Roman trading ship. See Fig 15.

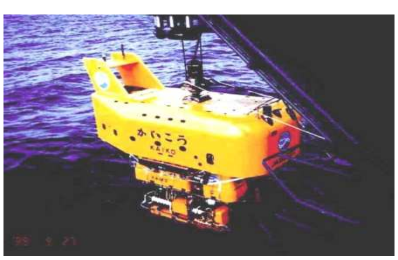

Fig 16 – Japanese ROV Kaiko

Kaiko is a Japanese ROV consisting of 4 horizontal thrusters and 4 vertical thrusters and was designed for deep sea mooring and ocean floor surveying. It is equipped with 6 video cameras, a still camera sonar based avoidance system and sample baskets. All this is equipment is controlled on the surface and is sent over the 7 km fiber optic line which is how Kaiko communicates. See Fig 16

Is team ROV_{ER} really that different?

Epiphanies are fantastic, but they are only of value after they come to fruition. One thing engineers do not like to do is play the waiting game, and sitting on your hands while you wait for a part or component to arrive from a manufacturer is very frustrating. The dive and discover team was forced to deal with a shipping error which ate up 4 days out of an already short trip. It makes it even worse when the part you are waiting on is hindering further advancements of your task or mission. Our team felt this pain when we were waiting for components to help finish the construction of our power supply, something that we could certainly work around, but still of enough importance that key decisions had to be halted.

When everything is laid out and you are ready to tear into your work, the last thing you want to see is a light that is supposed to stay lit go out, or have an arm stop responding. Mechanical and electrical failures are both realistic parts of the design process, but that doesn't make them any less frustrating to deal with. Jason had to be returned to the surface three times as a result of a malfunction or part failure, and while not cataclysmic, it did result in a few long nights for the engineers aboard. Whether it is a broken temperature probe, or a machine read out that appears to be gibberish, exploration had to be halted until the gear was where it had to be. When we had our board layout finally completed and we were ready to mill them out, our school's board milling machine went on the fritz. While ecstatic that the boards were finally ready, we were devastated when we came to the conclusion that yes, the boards are in there, but our motors are not getting any power. We stuck it out until 5 am, but decided we needed 3 hours of rest, and went back at it at 9 am. Dealing with part failures teaches you to prepare and helps you to learn to avoid other problems in the future.

A tool belt with nothing but hammers is certainly of use if you have lot of nails around, but good carpenters know that they need a variety of tools to really attack a broad problem. The dive and discover team is no different. They could have only brought along 50 geologists but they really would not have been able to fully grasp the wonder of all the life around the smokers. Conversely, the ship could be filled with nothing but biologists, but then the full gamut of the environment would go unexplored. The dive and discover team understood that they required a broad range of scientists to examine all the different aspects of the environment on the ocean floor. Our team is comprised of people with many different backgrounds and experiences. We have mechanical, electrical, and electronic engineers, both first and second year, and a wonder kid do-it-all who is great with a pencil and paper, when hashing out ideas for arms, but is even better with a lathe, when we need those ideas to come to life. To be truly successful, you need a very diverse team.

Ocean Ridge Report Resources

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T, Murashima. "ROV Kaiko - Future Plans." 2004. Jamstec. May 23, 2008. http://www.jamstec.go.jp/jamstec-e/rov/pdf/kaiko_e.pdf

Unknown. "Mid-ocean ridges." Wikipedia. 2008. Wikimedia Foundation, Inc. 26 May, 2008. http://en.wikipedia.org/wiki/Mid-ocean_ridge

XV Reflections

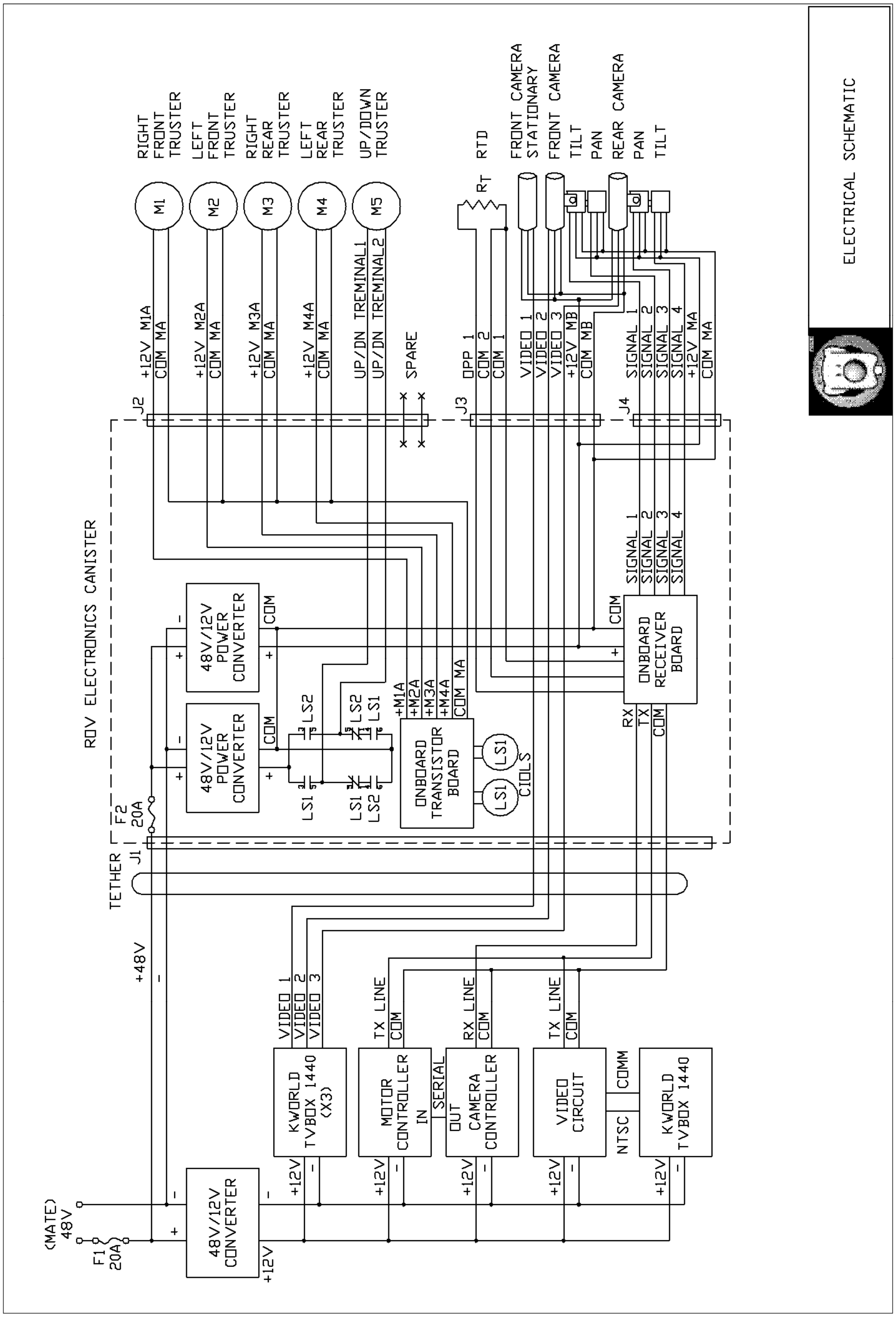
Working on the ROV over the past 7 months has certainly been the most rewarding thing many of us have been involved with thus far in our academic career. At times, we felt a level of frustration few students get to experience in their school lives, but in the end it was certainly worth it. Getting the opportunity to receive crash courses in various topics from programs different from our own was great because all team members have such broad interests and desires to learn. The opportunity to work with both first and second year students from programs proved to be a great learning tool for all members. Balancing family and personal lives, work, and our studies, while finding 8 hours a week to work on ROV_{ER} was difficult but as a result we all have much stronger time management and communication skills. With many of the mechanical and electrical components being put together and not coming from a store shelf, the team has a very large sense of accomplishment. ROV_{ER} is complicated because of its simplicity and being able to produce the results we did, using the technology and budget we had, was very satisfying. As a group we were able to overcome almost obstacles using team work and as result, we are better students, and better people. We wish more students around the world would get to experience the excitement (and the frustration) of being involved with the ROV project and we cannot recommend it enough.

XVI References

www.marinetech.org	MATE site
www.google.ca	parts search
www.ti.com	Texas Instruments for free parts
www.pactecenclosures.com	enclosures
www.youtube.com	servo waterproofing video titled “How to Waterproof a Servo.”
www.maxim-ic.com	parts
www.trcelectronics.com	cosel DC –DC converter
www.tyco.com	15 Amp general purpose miniature relay

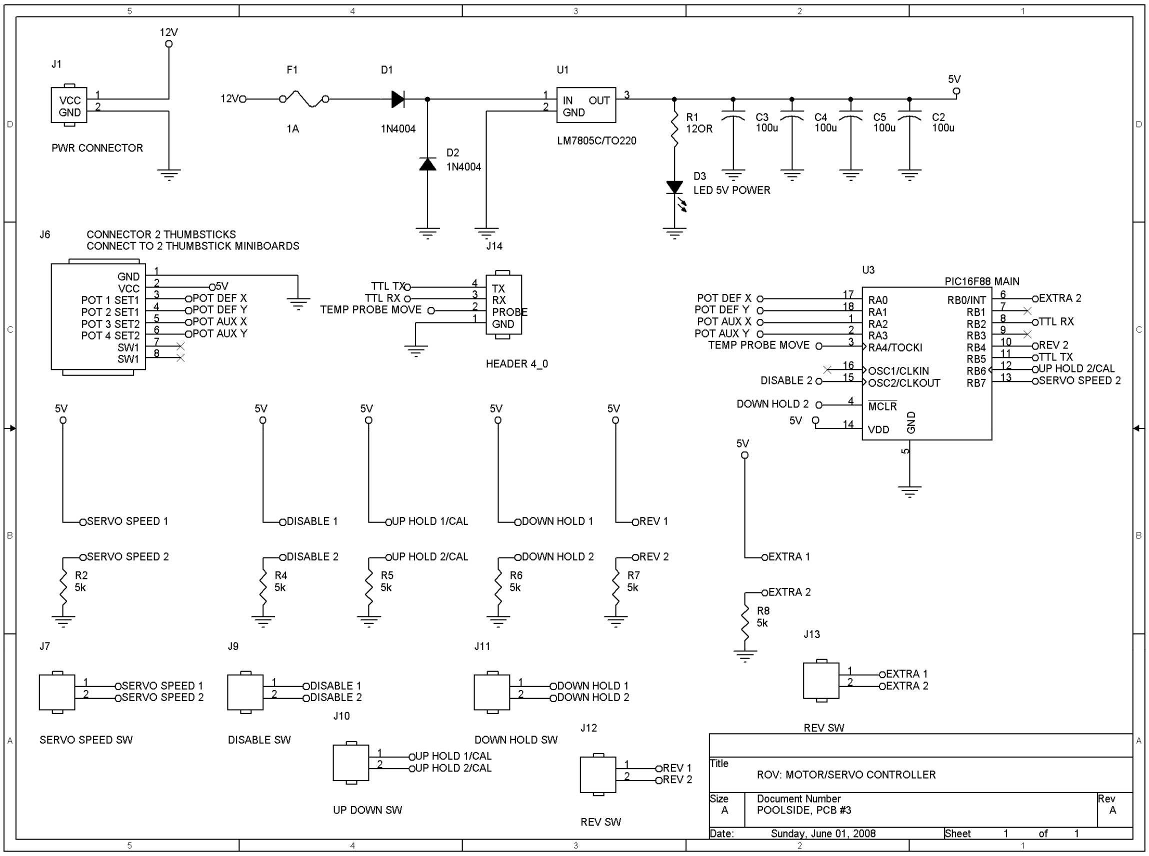
XVII Appendices

Appendix A: Electrical Schematic

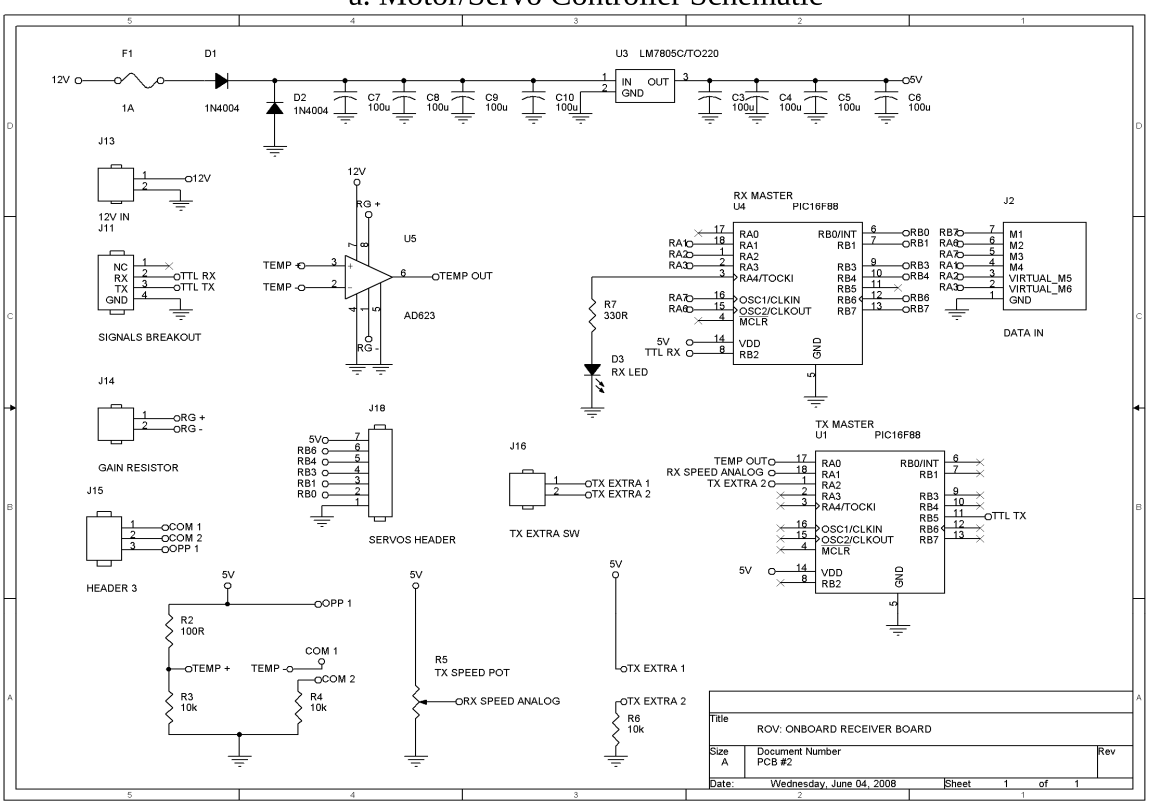


Full electrical layout schematic

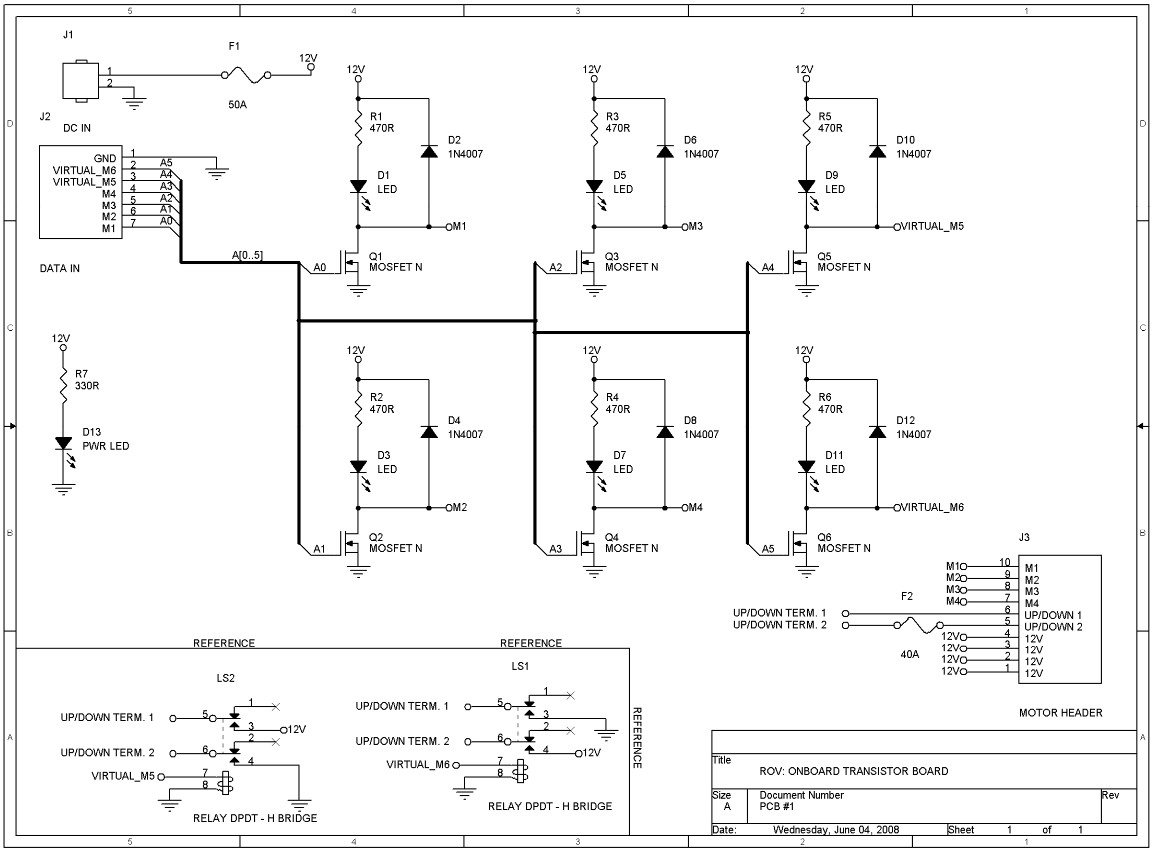
Appendix B: Electronics Schematics



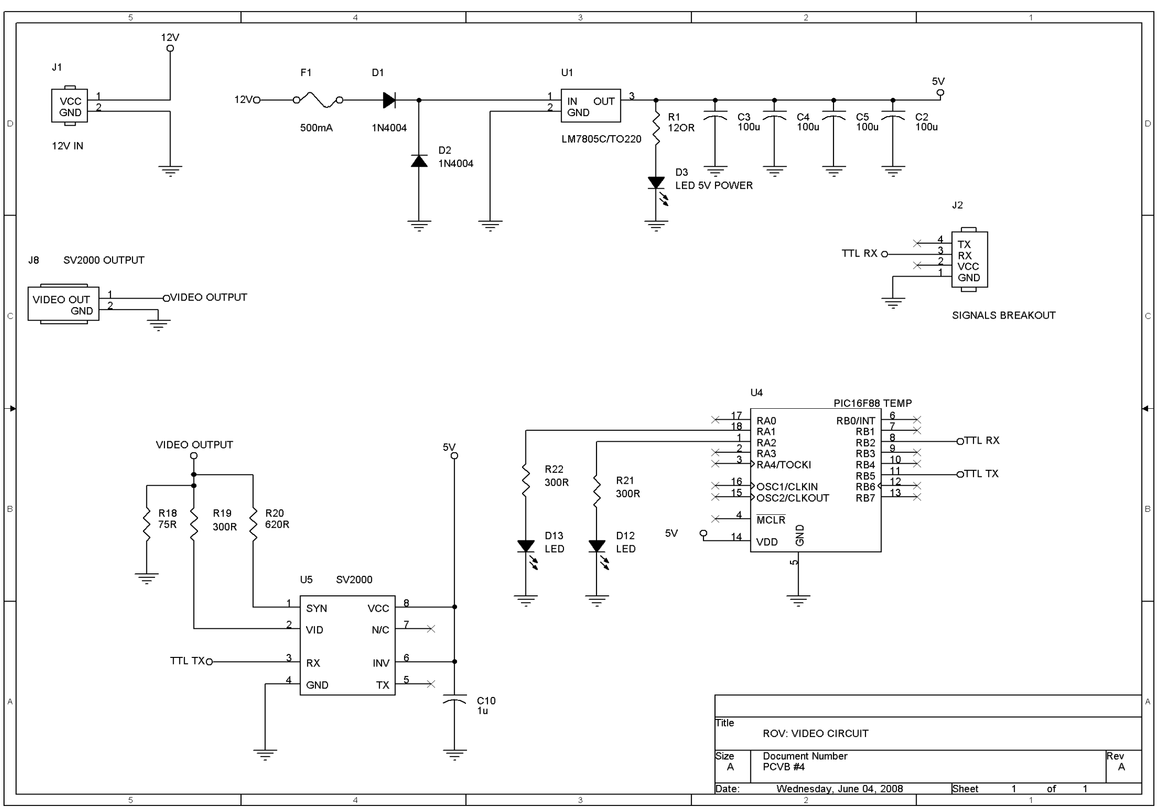
a. Motor/Servo Controller Schematic



b. ROV onboard receiver schematic

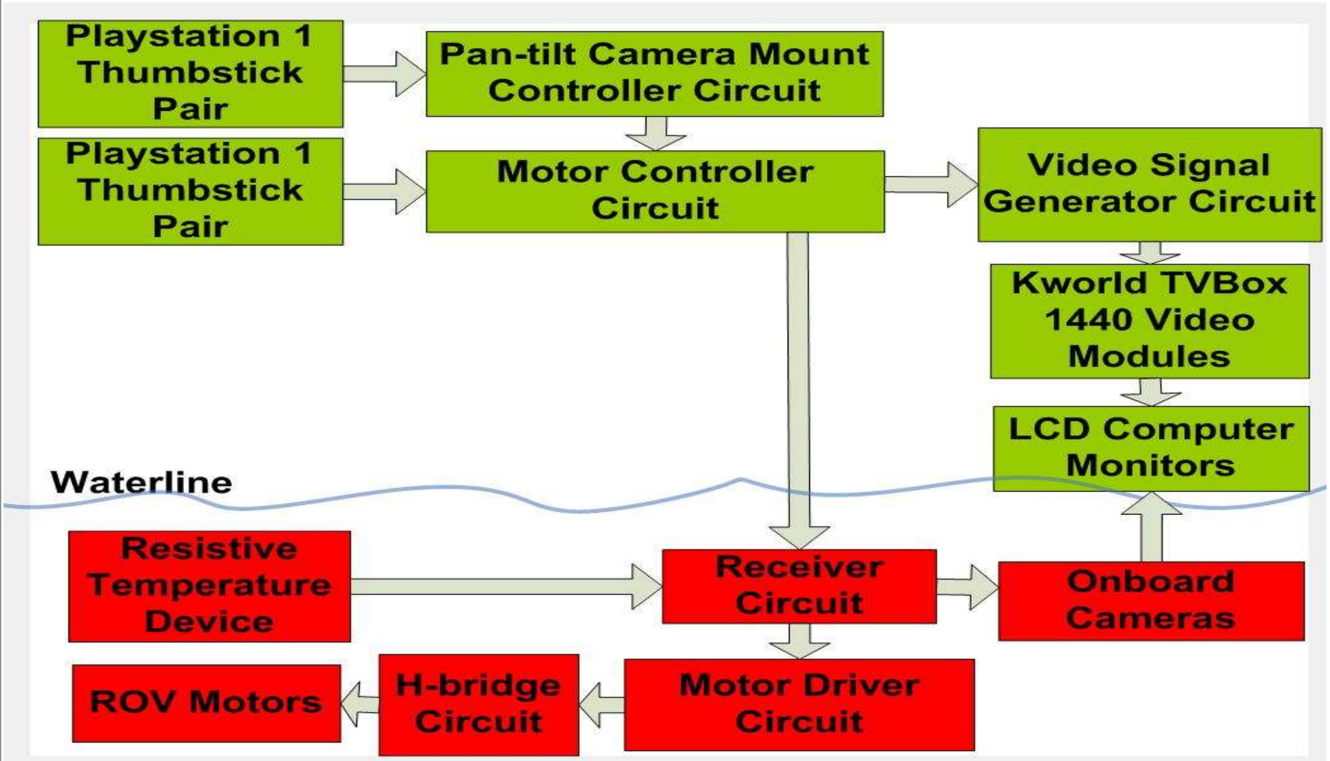


c. ROV onboard transistor board schematic



d. ROV video circuit schematic

Appendix C: Block Diagram of Software flow



Appendix D: Piping Layout for Pneumatics