Technical Report
ROVs *C.I.D. and Everest*

Submitted by the

ROV Chix
White Rock Christian Home Educators

Submitted to the

Marine Advanced
Technology Education Center

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Abstract

This technical report describes the Remote Operated Vehicles (ROVs) *C.I.D* and *Everest* built by the RovChix Team, White Rock Christian Home Educators, White Rock/South Surrey, British Columbia, Canada. The ROVs were designed to compete in the 2006 Pacific Northwest ROV Design Competition sponsored by the Marine Advanced Technology Education (MATE) Center.

The theme of the Competition is ocean observatories, a revolutionary new technology changing how we do oceanography and earth sciences. ROVs play a critical role in the installation of cabled observatories. The Ranger class Competition mission simulates installation of an underwater observatory.

The mission of *Everest* is to transport an electronics module from the surface and insert it into the trawl resistant Observatory frame. To accomplish the mission, *Everest* is equipped with a pneumatic module latching system.

The mission of *C.I.D*. is to open the door of the frame, insert a connector into the electronics module and pull a pin to release a buoy. *C.I.D.* is equipped with a suction tool to grab the connector and a hook for releasing the buoy and opening the frame door.

This paper also discusses the design rationale for the ROVs, the design challenges we encountered, troubleshooting techniques, lessons learned and ideas for the future.

Acknowledgements

The ROV Chix would like to thank the many people and companies that have contributed to the success of our project. We especially thank our main sponsors for believing in us and allowing us to participate in the 2006 ROV Design Competitions in Seattle and Houston.

- Our Inspiration

- Our Parents
  - Rob & Leslee Gawthrop
  - Michael & Sandra Gorman
  - Syd & Anna Pickard
  - John & Carrie O'Sullivan
  - Rick & Kim Dearden

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  - Beckie-Anne Thain, our mentor
  - Dr. Phil Nuytten, Nuytco
  - Harry Bohm, our teacher's mentor
  - Ron Hurtig – Hy-Seco

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  - MATE
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  - Vanessa Stenner
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- Our Suppliers
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  - Glen Roberts, Ellet Industries
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  - Master Airscrew
  - Peace Arch News
  - Ted Brockett, Sound Ocean Systems Inc.
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  - Dean Wandler, Surrey Fluid Power
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  - Belden Cable and Wire
  - Dan Higgins, Canadian Tire
  - Diab
  - Emerson Cumming
  - Home Depot
  - Johnson Pumps
  - MC Media
  - Pacific Fasteners
  - Rona
  - Al Sanders, SMI Electronics
  - Herb Werfl, Terasen Waterworks

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- Jill Zande, MATE ROV Competition Director
- AquaTech Team, Heritage Christian School
- White Rock Christian Home Educators

Introduction

This technical report describes the Remote Operated Vehicles (ROVs) *C.I.D* and *Everest* built by the RovChix Team, White Rock Christian Home Educators, White Rock/ South Surrey, British Columbia, Canada. The ROV Chix are five home school students - Lindsey Gorman, Madeleine Gawthrop, Caroline Dearden, Jessica O'Sullivan and Rebekah Pickard – from White Rock South Surrey who teamed up in January 2006 to compete in the first Pacific Northwest ROV Design Competition.

Description of ROV *C.I.D.*

ROV *C.I.D.* consists of a topside control box, a 13 meter neutrally buoyant tether and the vehicle. *C.I.D.* is effective, good looking, fast, economical, compact, simple, innovative, corrosion resistant and easy to pilot, troubleshoot and transport! See Picture 1 below.

Picture 1 – ROV *C.I.D. control box, tether and vehicle*

1) Control System

C.I.D.'s control system is composed of an ammeter, voltmeter, fuses, a relay, power bus, a DC/DC converter, light and camera switches, power leads with attached banana clips and a terminal strip. The components are mounted on a clear lexan panel, which is hinged to the control box. This allows easy access to fuses and other components. The vehicle tether enters the back of the box through a strain relieved, right-angled connector. The controller is a converted Sony Playstation controller fitted with five DPDT momentary switches. The 600 mm controller tether makes the controller easy to use and the momentary switches don't cause hand strain. We chose to control the ROV using DPDT switches because they are simple, robust, easy to understand and more economical than other methods.

2) Video Camera & Monitor

We navigate *C.I.D*. using an INUKTUN Crystal camera. The colour camera is depth rated to 300 meters, has a ring of 12 LEDs for illumination and provides a superior image. The camera requires a minimum 12.75 volts. By the time the power traveled through the 20 AWG Inuktun cable and reached the camera, there was less than 12 volts. We had no picture on the TV. To solve this problem, the engineers at Inuktun advised us to power the camera through a 15 volt DC/ DC converter to apply a slightly higher voltage down the tether. This ensures a voltage of 13 volts at the camera. The Inuktun video feed is soldered to a female RCA jack on the control panel. An RCA patch cord transfers the signal from the camera to the 23 centimeter AC/DC TV/VCR. The camera and the camera mounted LED array are fused separately. One on-off switch controls the camera and another the LED array. The camera mount allows the camera to pivot up and down.

Picture 2 – Inuktun Crystal Camera with LED array

3) Tether

C.I.D.'s 13 meter tether is made up of three components. First, ten copper clad aluminum (CCA) stranded power conductors were encased in 6 millimeter (mm) Techflex. We chose CCA power conductors because they weigh 40% less that copper. Second, a camera cable was made with one coaxial cable and three 20 AWG conductors encased in 6 mm Techflex. Finally, a string of Cumming macrospheres was encased in 6 mm Techflex for buoyancy. All these components are encased in 12 mm black Texflex, ensuring that no wires get nicked or broken. The tether is thin, flexible and slightly negatively buoyant in pool water. Originally we planned to use commercial ROV tether, but made our own after we increased the number of thrusters to ten.

4) Frame

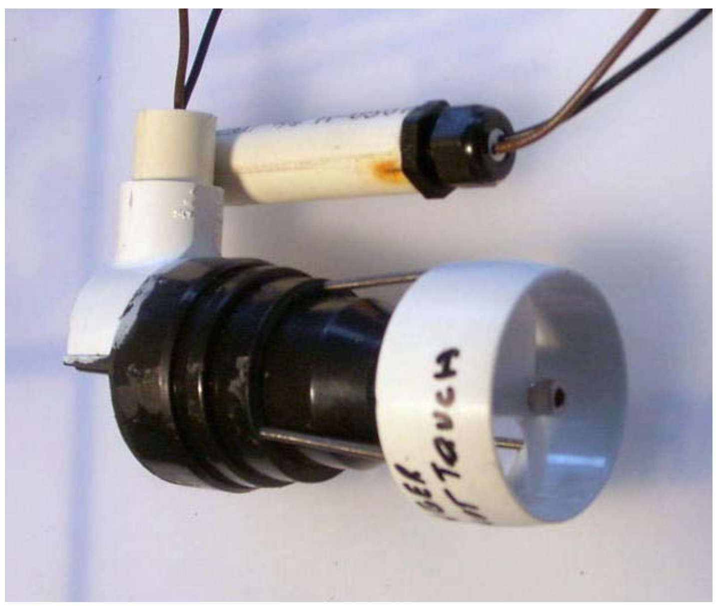
C.I.D.'s frame is made of Starboard plastic. We chose Starboard over polypropylene because it is more buoyant and is easier to work with. We found that when cut with a power saw, polypropylene melts easily. The top support of the ROV is 430 mm long and 280 mm wide. The two sides are 430 mm in length and 230 mm high. The frame was designed to neatly hide all wires between the frame and the float. A termination can at the back of the ROV connects the power conductors from the tether to the motors. The can is sealed with toilet seal wax, which is less expensive than epoxy.

C.I.D.'s pink float was made from sheet PVC foam. We chose PVC foam because it is strong, economical, easy to shape and paint and very buoyant at only 0.25 grams per cubic centimeter. The float is attached to the ROV frame using four 10 mm pegs and lock nuts. The ROV is trimmed with lead weights fit on nylon corner posts and secured with nylon bolts.

5) Thrusters

The ROV is equipped with ten thrusters that enable it to move in all directions. Two thrusters move the ROV vertically, four thrusters move the ROV horizontally and the two strafing thrusters are used to move sideways. The horizontal motors are in a quad configuration and set on an angle to increase turning ability. During construction our thruster wires for the strafing thrusters were not crossed. This caused the thrusters to oppose each other. We were forced to remove the starboard prop to counteract this problem. We also have two thrusters for the sucker unit, which is described below.

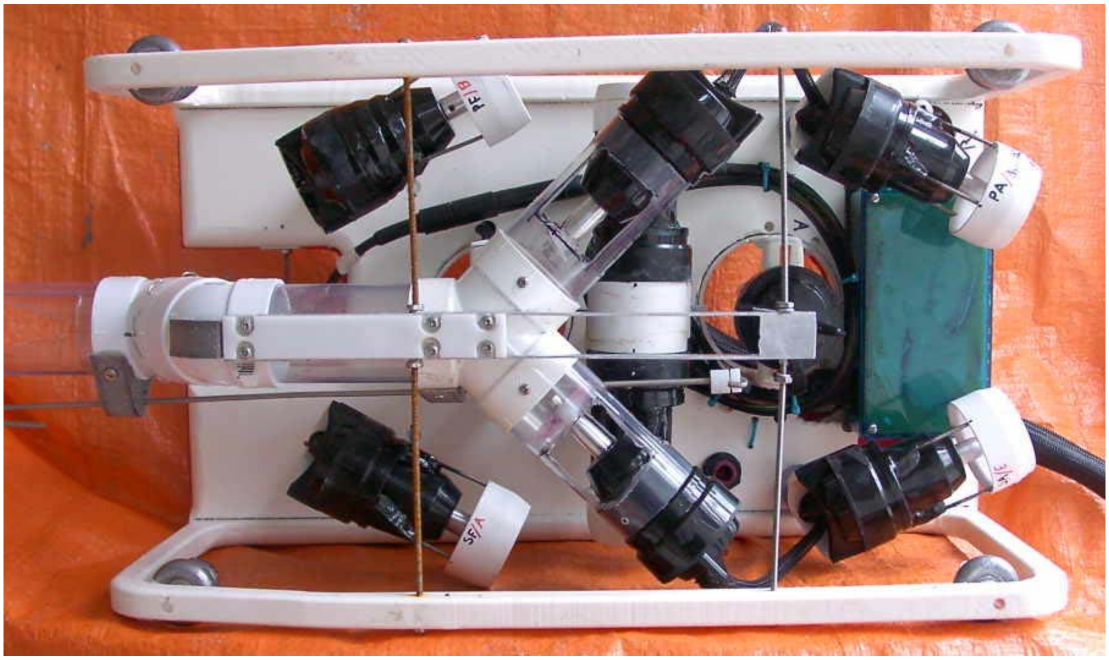
The thrusters are made from Mayfair 1250 Bilge Pump Cartridges. The thruster mounts were cut from a PVC tee. The thruster nozzles were turned on the lathe using the leftover ends from the thruster mount. The nozzles were then drilled and tapped for the stainless steel (SS 316) strut. The 38 mm Dumas propeller is attached to the Master Airscrew hub with a SS 316 cap screw. The hub was streamlined and polished on a small lathe. The hub is attached to the pump shaft with a #4-40 set screw. The first time we tested *C.I.D.* in the water the propellers flew off! We fixed that problem by tightening the hub set screw and cap screw using thread blocker. The thruster draws 3.5 amps.



Picture 3 – Thruster detail showing mount, struts, nozzle and propeller

6) Sucker

C.I.D. has a very strong sucker that is powered by two thrusters. See Picture 4 below. It can both grab objects and shoot them out them depending on which way the propellers are turned. A DPDT switch controls the sucker. The sucker has a SS 316 wire grid in the tube to prevent objects from being sucked into the thrusters. We use the sucker to grab the cable connector and shoot it into the module outlet.



Picture 4 – *C.I.D.* bottom view showing sucker with two thrusters

Description of ROV *Everest*

Picture 5 – ROV *Everest* control box, tether, vehicle, compressors and battery

1) Frame

We chose to construct *Everest's* frame from 12 mm Schedule 200 PVC pipe, which is light, easy to cut, inexpensive and non-corroding. Rather than using PVC cement, we used very small SS 316 bolts to hold the PVC pipe and fittings together. This allowed us to make many modifications to the frame.

The ROV has five PVC floats to offset the negative buoyancy of the thrusters. *Everest* is extremely stable underwater due to the low positioning of the vertical and horizontal thrusters on the frame. We spent several weeks building a variable ballast system for the ROV but abandoned the idea as unnecessary after testing the ROV in the water. The ROV is slightly positively buoyant in pool water.

The frame houses a stainless steel pneumatic linear actuator, which latches and releases the center U-bolt of the module. Four adjustable feet with slots stabilize the four corner U-bolts of the module.

2) Control System

Everest's control system is the same as the *C.I.D.* control system. In addition it has outlets for powering the two 12 volt air compressors.

3) Video Camera & Monitor

We navigate *Everest* using a Lorex color underwater video camera. The camera is mounted on an adjustable boom, which allows for camera angle adjustment. The camera cable goes through the tether and control box to the television. See Picture 5 below.

Picture 5 –Everest Camera boom

4) Tether

Everest's 13 meter tether is made up of 2 pneumatic hoses, a camera cable, 10 CCA power wires encased in 6 mm techflex and a 13 meter strand of macrosphere's encased in Texflex. All these components are encased in 12 mm black Texflex. The tether is slightly positively buoyant in pool water.

5) Thrusters

Everest uses the same type of thrusters used for *C.I.D. Everest* is equipped with 10 thrusters: four thrusters move the ROV vertically, four thrusters move the ROV horizontally and 2 thrusters move the ROV sideways.

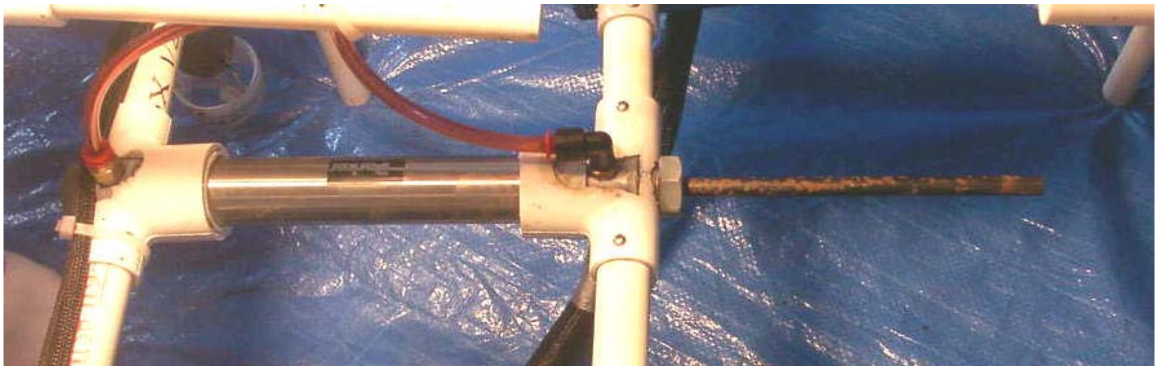
Picture 6 –Jessica O'Sullivan testing thruster on thruster output jig

Thruster power is measured using a thruster test jig using a modified electronic fish scale. See Picture 6 above. Thrust of 1.8 kilograms may have been overestimated due to cycling in the oval test tank.

6) Pneumatic System

Everest has a very effective pneumatic actuator to latch and release the module. The actuator is powered by two electric air pumps. When air from the first compressor is forced into one end of the actuator the actuator rod is pushed out, latching the module. When the second compressor is turned on, the actuator rod retracts into the cylinder, releasing the module. The system actuates with less than 1 kilogram/ square centimeter pressure. See Picture 7 below.

We chose the pneumatic system over a hook and a water-based hydraulic system. The hook was too wobbly and the hydraulics hoses didn't offset weight in the tether. The pneumatic system was simple, the compressors were very inexpensive and we were given the actuator. Ron Hurtig from Hy-Seco and Dean Wandler from Surrey Fluid Power helped us set up the system and taught us how it works.



Picture 7 – *Everest* pneumatic linear actuator

Design Rationale

We designed our ROVs with the following requirements in mind:

- The 2006 ROV Competition rules
- Budget of CDN $5,000 for both ROVs
- Able to fulfill mission
- 25 amp power budget, and
- Capable of diving to 25 feet without leaking/implosion

1) Why two ROVs?

We found many good reasons for using two ROVs to perform the mission. First, it is easier to make two simple ROVs than making one complicated ROV. Each of our ROVs is mission specific. This means they can be smaller which is better. Second, it was easier to build the second control box because of the learning curve. The third reason is speed. Past ROV Competitions have proven that using two ROVs leads to faster mission times. Fourth, with two ROVs the pilots get a better view for navigating and operations. Fifth, recoveries from problems and rescues are easier with two ROVs. This was proven to us in the PNW Regional Competition, when C.I.D. rescued *Everest*, which became stuck in the trawl resistant frame. Finally, making two ROVs is more work and therefore more fun.

2) Frame

For *C.I.D.* we used Starboard because it is strong, neutrally buoyant and it looks clean and professional. *C.I.D.* is small and slim for maximum agility and speed. For *Everest* we used PVC pipe because it is strong, inexpensive and we could make changes to it cost effectively. We also made *Everest* large because it needed to be able to carry down and dock the module with minimum difficulties.

3) Control System

We used an ammeter to watch the amount of current the ROVs were using so that we didn't blow the Competition fuse. We also used a voltmeter to measure voltage from the battery. We used a relay for safe switching of the system on and off. We chose double pole double throw (DPDT) switches because they are simple, inexpensive, and effective. The fuses are a safety measure to protect our equipment. They helped us troubleshoot electrical problems we had early on.

4) Video Cameras

We used the Inuktun Crystal camera for several reasons. They are high quality and high resolution with built in lights and Inuktun graciously donated it. For the *Everest* we used a Lorex underwater camera with high quality and high resolution. It was inexpensive and has a proven track record.

5) Tether

We made the tether length 13 meters because of all the horror stories we heard about tethers being too short for a mission. We used pearl necklaces (macrospheres in texflex) to ensure that the tether is as close to neutrally buoyant as possible. Texflex was used to cover the pearl necklaces and wire bundles for maximum safety measures for the robot.

6) Sucker

We used a sucker that is powered by two thrusters to capture the connector and insert it into the submarine port. The sucker is so powerful it doesn't require perfect piloting to grab the connector. We encountered a bit of a problem with fitting the wires for the sucker thrusters into the junction box. There were only two holes left in the connector seals but we had four wires we needed to fit into the junction box. So we decided on joining the two positive and the two negative wires together in a joint sealed with Scotchfil. This proved effective.

7) Thrusters

Each ROV has 10 thrusters made from Mayfair 1250 Bilge Pump Cartridges, thruster nozzles and 38 mm Dumas propellers. Test results showed that the 38 mm size propeller is the best size; it gave us good propulsion but used less than 4 amps. We made specially designed kort nozzles, which aims our propulsion and protects our propellers. We used four thrusters for the up and down and horizontal on *Everest* for power. *C.I.D.* is much smaller so we did not need as many thrusters in order for it to move fast.

Challenges

Mind Mapping

The ROV project can be overwhelming. When we first started, we decided to use an organizational method called mind mapping. It allows for creative and unlimited brain storming. Mrs. Gawthrop taught us how to use mind mapping to understand and plan out our project. Each team member mind mapped the entire project on a poster. Then we presented our maps to the team. This helped us with communication and planning.

AquaTech

When we started the project we learned that our teacher was also tutoring an all boys team – AquaTech - and that they would be working along side us. When we heard this we thought about turning it into a bit of a "gender war". Our local newspaper mentioned the rivalry factor in the "ROV Gender War" article they wrote about both teams. As we progressed things changed. Instead of opposing each other we came to help each other with design ideas and building. If something needed confirming or if technical details were fuzzy we would ask each other. Working together helped both teams design and build better ROVs. Eventually it was almost as if one team had simply divided itself into a couple of groups yet the friendship remained. It was a lot of fun working beside the AquaTech team and they helped us in some tough places. All in all it was a wonderful experience.

Camera

One of the biggest challenges we faced was when we discovered that the camera on *C.I.D*. wasn't working. We tested other cameras and tested the connections but nothing seemed to be working. Finally we contacted the engineer that designed the camera. She was very helpful and told us that with our tether the camera needs at least 13 volts. So we started to trouble shoot again and discovered another thing. Our old battery produced 12 volts and then when the electrons flowed down the tether to the camera the voltage faded to less than 12 volts when it reached the camera.

In order to fix this problem we contacted Jill Zande to ask permission to use a DC/DC converter. She consented and we installed the DC/DC converter. The DC/DC converter solved our problem by converting the 12 volts from the battery to 15 volts. The voltage drops as it travels down the tether. When it reaches the camera the voltage is still high enough for the camera to operate.

Troubleshooting Techniques

Originally on *Everest*, we had eight 16 AWG wires connecting the controller to the control box. This made the controller tether thick, bulky and difficult to pack in the control box. To fix the situation we soldered the 4 positive wires together and attached them to one 12 AWG wire. We did the same with the negative wires. Having two larger gauge wires works much better than our original 8 smaller gauge wires. Our tether controller is now slim, flexible and easier to store.

Improvements for Next Time

We would definitely change the size and quality in the design for the *Everest* control box. We would make it more compact with a smaller controller tether. We would change the tether thickness using the method, described above, of replacing four wires with one larger gauge wire.

Lessons Learned

We as individuals have gained skills, knowledge and personal benefits beyond what we thought was possible. Here are some examples of a couple of our lessons learned during this experience.

The biggest problem we encountered as a team was communication. Sometimes not all team members were able to attend meetings. Our team was falling behind in getting everyone on the same page. We learned that good communication between team members, parents, teachers and mentors is crucial in making a team function. We solved this problem by keeping the phone lines going and sending out group emails. Our communication is much better now.

We learned make the circuit diagram first, then test our wiring before pouring the sealing wax.

At the start we made a lot of mistakes because team members simply assumed that others knew what was happening. An example of this would be when it came time to send a group email out. Everyone assumed that someone else would do it and as a result the email would never be sent. After several problems like this we decided to take the time to properly communicate and NEVER ASSUME!

Fundraising was another problem we encountered. We didn't begin fundraising until the middle of March. Next time we will begin earlier to ensure that we have enough time to complete our financial goals. We will also re-think our approach to how we fundraise so we can do it more successfully.

Next time we will start building and designing earlier thus we won't have to fit lots of work in before the competition. This would lead to less panic and stress because we had a lot of things completed. Also if we started earlier then we could fit more practice time into the week before the competition and tweaking to create more efficient ROVs.

Budget Summary

A summary of project revenues, expenses and material donations is presented below. See appendix for a detailed list of expenditures.

	Revenues	
Corporate	$1,275.00	
Individual	$3,380.62	
Other	$130.00	
In Kind Donations	$2,798.23	
Total Revenue	$7,583.84	
	Expenses	**Donations**
Control Box	$1,293.97	$77.77
Tether/Pneumatics/Camera	$4,397.10	$2,542.20
Thrusters	$1,140.68	$0.00
Vehicle	$391.97	$64.93
Mission Props	$215.36	$41.04
Poster, Technical paper	$144.76	$72.28
Total Expenses	$7,583.84	$2,798.23
Donations		
GE Polymer plastics	$44.10	
Cummins Macrospheres	$91.20	
Sony Playstation Controller	$68.40	
Diab foam PVC Sheet	$29.69	
Parker 150 mm SS316 Pneumatic linear actuator	$171.00	
Inuktun Crystal Camera	$2,393.91	
Total Donations	$2,798.30	

ROVs, Ocean Observatories and NUYTCO Research

For thousands of years the ocean has been a source of mystery. In recent times ROVs have become a valuable tool for exploring the oceans. ROVs provide for human safety while allowing for dangerous exploration, retrieving scientific instruments, search and rescue missions, servicing undersea equipment, military missions, marine construction, salvage and mining. Nevertheless, as we learned, ROVs have their problems. They are expensive, can only dive for short periods and they break down.

Now a revolutionary new technology is replacing ROVs. The Global Earth Observation System of Systems (GEOSS) is connecting earth sensors around the world into an observation network. This network will help us better understand how the Earth's complex systems work together. The oceanographic division of the GEOSS network is called GOOS – the Global Ocean Observing System. The purpose of GOOS is to study the ocean, help us manage marine resources and to protect life and property along the coasts and at sea. See http://www.earthobservations.org

GOOS is an international cooperative effort to observe the oceans. Ten European countries have formed the European Seafloor Observatory Network (ESONET) consortium. ESONET stretches from the Arctic to the Black sea. See http://www.oceanlab.abdn.ac.uk/research/esonet.shtml. Canada and the US are co-operating in the Neptune Project – an observation network studying the Juan de Fuca Plate. See http://www.neptunecanada.ca. The Neptune project will lay an 800 kilometer ring of cable providing power and communications to instrument nodes on the seabed off British Columbia, Washington and Oregon. Neptune will help scientists study earth and ocean processes. Hopefully Neptune will help warn and protect us from a big earthquake expected in the Pacific Northwest by earth scientists at the Canadian Institute of Ocean Science (IOS). See http://www-sci.pac.dfo-mpo.gc.ca/sci/facilities/ios_e.htm

Our local ocean observatory is VENUS – the Victoria Experimental Network Under the Sea. The purpose of VENUS is to observe the waters around southern Vancouver Island. Measurements, images, and sound will be delivered to scientists from ocean observation instruments through cables with fibre optics. The cables will also deliver power for instruments, lights, and remotely operated vehicles. For the first time, researchers do not have to wait for data from instruments recovered by ROVs. See http://www.venus.uvic.ca

VENUS began measuring the ocean in February 2006. After the components were delivered from OceanWorks (see http://www.oceanworks.cc) to the Global Marine Systems (GMS) ship *Wave Venture*, the system was connected for both dry and wet testing. On February 6, the trawl resistant frame or node (see photo below) was lowered to the sea floor. The cable was then laid to the IOS shore station.

Picture 10 – The Venus Node is much bigger than the module we transported with *Everest*

The next day the instrument module was lowered to the bottom, and connected by the GMS work class ROV (see picture below) to the node. Once physically connected, the deployment transferred control to the IOS shore station where power was turned on to the Node, and then the VENUS Instrument Platform. See http://www.globalmarinesystems.com

Picture 10 – Global Marine Systems ST 200 Work Class ROV at Saanich Inlet

Later in February, the Canadian Scientific Submersible Facility (CSSF) ROV *Ropos* was used to deploy the VENUS digital camera system. The camera was mounted on a two meter tripod, which was lowered into 85 meters of water. *Ropos* located the tripod, released it from its cradle and moved the tripod 30 meters to a location with abundant sea life. See http://www.ropos.com

Picture 11 – CSSF ROV *ROPOS* at Saanich Inlet

Our team had the privilege of visiting Dr. Phil Nuytten, the foremost ocean explorer of our time. His company, Nuytco Research in North Vancouver, provides marine exploration, safety, search and rescue technology to navies, scientists, salvors and motion picture companies. Dr. Nuytten has invented many technologies including ROVs, specialized diving suits (Exosuit and Newt Suit) and submersibles for servicing ocean observatories. During our visit to Nuytco we discussed the necessity of prototypes, engineering and machining, and the improvements with each new version of technology. Dr Nuytten gave us 10 excellent ideas for *C.I.D.* and *Everest* which we used to make the ROVs better. See http://www.nuytco.com

Picture 8 – Dr. Nuytten discussing ideas with us for *C.I.D.*

References

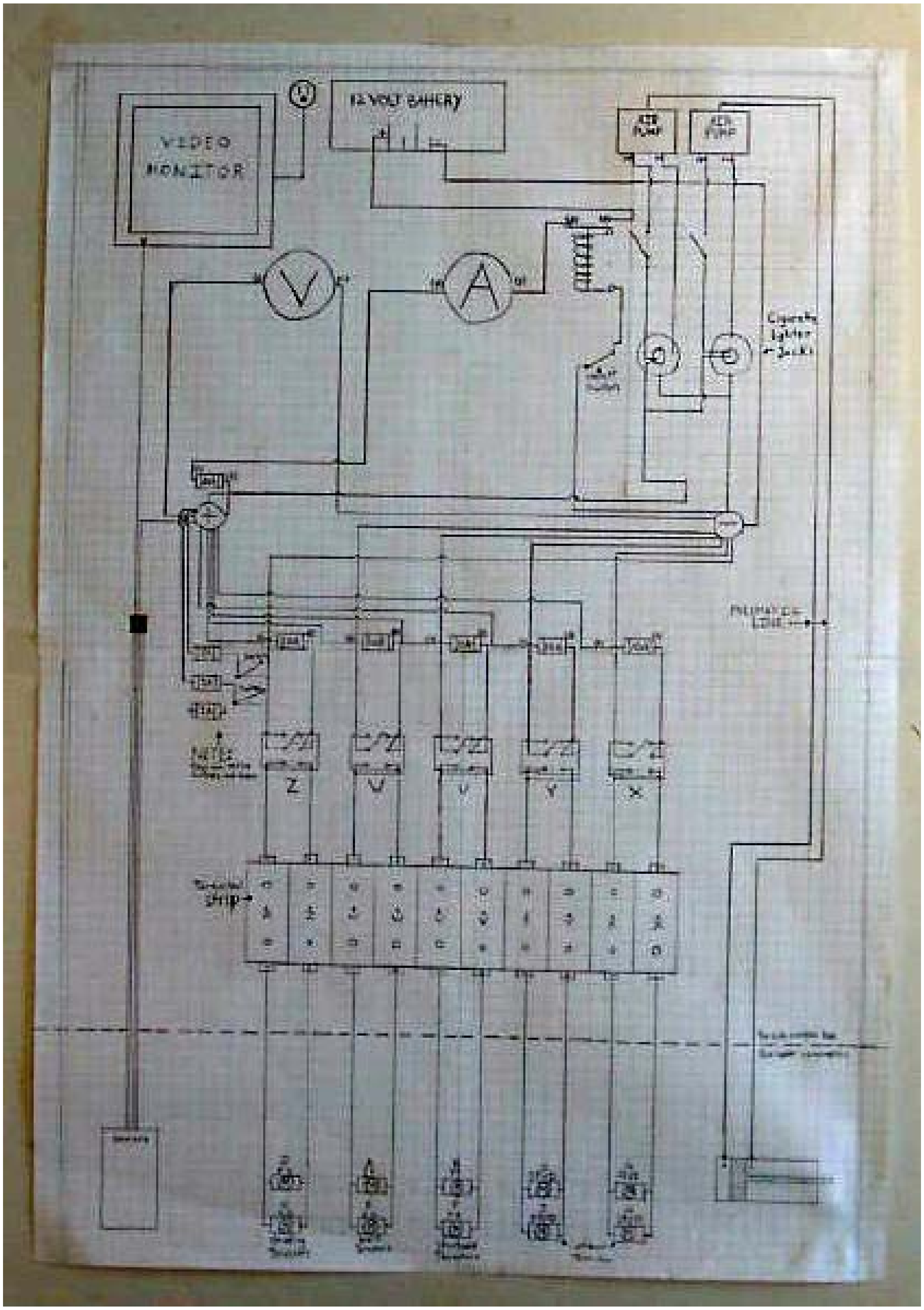
Alexandra Isern, National Science Foundation's Ocean Observatory Initiative, **Sea Technology**, June 2005.

Imants Preide, European Seafloor Observatory Network, **Sea Technology**, October 2005

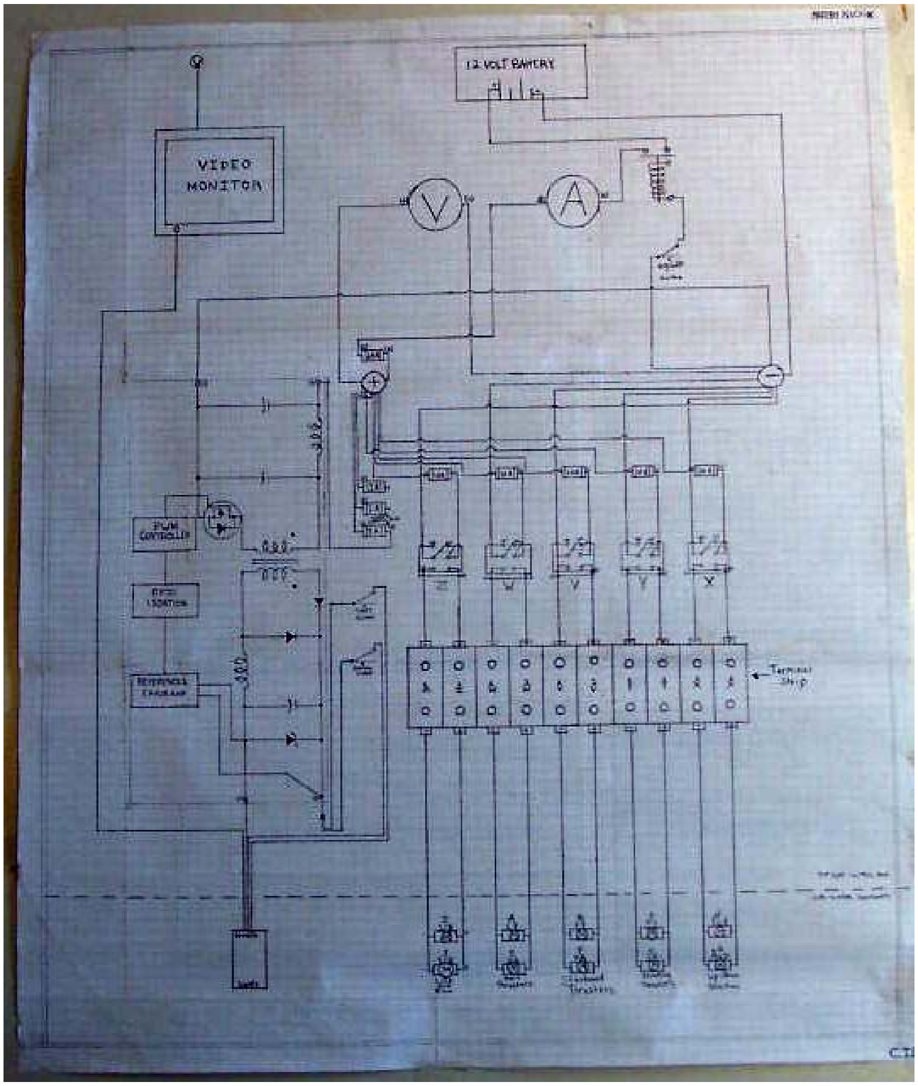
Internet

Visit us on the Internet @ www.rovchix.com Our ROV build diary presents a weekly summary of our design and building progress over the last seven months. See www.rovgirls.blogspot.com

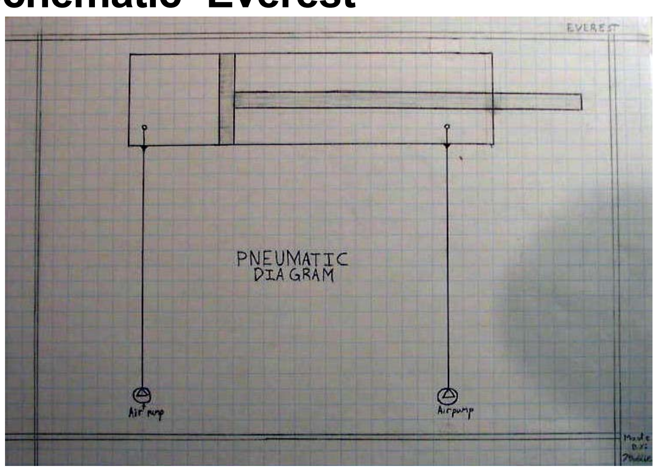
Electrical Schematic – Everest



Electrical Schematic – *C.I.D.*



Pneumatic Schematic- Everest



Detailed Expense List

EVEREST ROBOT DESCRIPTION	Amount	Total Cost
UK Box	1	$119.70
127 mm white handles	2	$6.84
Fuse Holders	9	$16.31
Fuses - 25 amp	5	$4.54
Fuses - 10 amp	10	$9.07
Fuses - 1 amp	5	$4.56
SPST Switches	3	$2.63
Carling DPDT On-Off-On switches	5	$119.70
DC Voltmeter 0 - 15 volts	1	$31.69
DC Ammeter 0 - 50 amps	1	$33.29
Heat Shrink - 3 mm	7	$4.48
Heat Shrink - 6 mm	5	$4.50
Heat Shrink - 12 mm	5	$6.21
solder	1	$2.28
solder flux	1	$2.28
10 AWG stranded power wire	7	$11.17
3 mm Black texflex	5	$2.53
3 mm White texflex	5	$2.53
Banana male jack	2	$5.84
Banana female jack	2	$4.31
9 mm Hummell dome connector	2	$2.76
9 mm locknut	2	$0.71
12 mm Hummell dome connector	2	$3.17
12 mm locknut	2	$0.80
Dual Position Cigarette Lighter female	1	$11.39
Piano Hinge SS316	2	$3.42
Hinge SS316 #6 bolts	8	$1.64
Hinge SS 316 #6 acorn nuts	8	$2.83
Hinge SS 316 #6 washers	16	$2.19
PET White Plastic Bus 25 mm X 75 mm X 12mm	1	$0.29
Big Panhead bolt SS 316	14	$3.51
Small Panhead bolt SS 316	2	$0.21
6 mm x 50 mm Brass bolt	2	$0.71
6 mm Brass nut	2	$0.39
6 mm Brass washer	8	$1.55
#10 SS316 Screws	8	$2.10
Cable Ties	23	$0.52
Trombetta 12 DC Contactor	1	$19.04
Termination Strip	1	$1.88
Red Wire 16 gauge	1	$4.10
Green Wire 16 gauge	1	$4.10
White Wire 16 gauge	2	$8.21
Black Wire 16 gauge	2	$8.21
Spade Connectors	24	$6.84
Ring Connectors	24	$6.84
Wire labels	1	$28.43
Wire Management Clamps	1	$0.23
Lorex Underwater Color Camera	1	$250.80
Velcro ties	7	$7.98
6 mm Texflex	80	$40.49
12 mm Texflex	140	$130.23
16 AWG CCA stranded wire	420	$143.64
6 mm Pneumatic nylon tubing	92	$53.01
SMC male elbow fitting	1	$3.82
SMC male fitting	3	$9.44
Master Air Screw 550 Prop Adapter	10	$58.69
#8 SS 316 Capscrew	10	$2.62
#4-40 X 3 mm SS 316 Set Screw	10	$1.25
38 mm Dumas Plastic Propeller	10	$16.42
32 mm ABS Compression Ring	10	$2.28
SS 316 Nozzle Strut 2 mm rod	7.5	$0.73
38 mm X 38 mm X 12 mm PVC Tee Thruster Mount	10	$51.53
38 mm PVC Tee Nozzle	10	$0.00
Bilge pump cartridge	10	$342.00
Epoxy putty	2	$18.10
Permatex threadlocker	1	$5.64
6 mm black texflex	15	$0.63
12 mm 90 deg PVC Elbow	6	$4.17
12 mm 90 deg sweep grey Elbow	4	$5.15
12 mm 45 deg PVC Elbow	8	$5.56
12 mm PVC End Caps	4	$2.05
12 mm PVC Tee	25	$21.38
12 mm PVC Cross	6	$14.71
12 mm PVC side outlet 90 deg	4	$13.95
12 mm PVC Connector	4	$2.28
12 mm grey PVC Terminal Adaptor	6	$2.80
12 mm X 12 mm X 25 mm PVC Tee	2	$5.34
12 mm Sched 40 PVC Pipe	24	$8.21
32 mm PVC End Caps	10	$14.93
32 mm x 32 mm x 12 PVC Tee	4	$10.03
32 mm PVC Pipe	8.66666667	$7.51
Epoxy	150	$23.94
#4-40 SS 316 6 mm bolt	106	$7.25
#4-40 SS 316 9 mm set screw	12	$2.60
150 mm X 50 mm blue Junction Box	1	$8.21
12 mm Dome Connectors	3	$4.75
18 mm Dome Connector	1	$1.36
Toilet Seal Wax	4	$4.51
Cable Ties	12	$0.27
Everest Total		$1,830.81

CID ROBOT DESCRIPTION	Amount	Total Cost
UK Box	1	$105.29
Panel handles	2	$22.69
Fuse Holders	9	$16.31
Fuses - 25 amp	5	$4.54
Fuses - 10 amp	10	$9.07
Fuses - 1 amp	5	$4.56
SPST Switches (on/off switches)	3	$2.63
Carling DPDT On-Off-On switches	5	$95.76
DPDT On-Off-On 10 amp continous switch	1	$10.05
DC Voltmeter 0 - 15 volts	1	$31.69
DC Ammeter 0 - 50 amps	1	$33.29
Astrodyne DC/DC Converter	1	$33.72
Heat Shrink - 3 mm	8	$5.13
Heat Shrink - 6 mm	5	$4.50
Heat Shrink - 12 mm	5	$6.21
solder	1	$2.28
solder flux	1	$2.28
10 AWG stranded power wire	6	$9.58
3 mm Black texflex	5	$2.53
3 mm White texflex	5	$2.53
Gold plated Banana male jack	2	$5.84
9 mm Hummell dome connector	2	$2.76
9 mm locknut	2	$0.71
12 mm Hummell right angle connector	1	$7.61
12 mm Hummell dome connector	2	$3.17
12 mm locknut	3	$1.20
24 mm SS 316 Piano Hinge	2	$3.42
Hinge SS 316 #6 bolts	8	$1.64
Hinge SS 316 #6 acorn nuts	8	$2.83
Hinge SS 316 #6 washers	16	$2.19
PET White Plastic Bus 20 mm X 63 mm X 12 mm	1	$0.29
25 mm SS 316 Panhead screws	22	$5.52
12 mm SS 316 Panhead screws	2	$0.21
6 mm x 50 mm Brass bolt	2	$0.71
6 mm Brass nut	2	$0.39
6 mm Brass washer	8	$1.55
Capscrews	8	$2.10
Tie straps	23	$0.52
Trombetta 12 DC Contactor	1	$19.04
Termination Strip	1	$1.88
Red Wire 16 gauge	1	$4.10
Green Wire 16 gauge	1	$4.10
White Wire 16 gauge	2	$8.21
Black Wire 16 gauge	2	$8.21
Spade Connectors	24	$6.84
Ring Connectors	24	$6.84
Wire labels	1	$28.43
Wire Management Clamps	8	$1.82
Inuktun cable	1	$148.77
Inuktun camera connector	1	$180.69
Velcro ties	7	$7.98
6 mm Texflex	80	$40.49
aluminum camera mounts	1	$4.56
12 mm Texflex	140	$130.23
16 AWG CCA stranded wire	420	$143.64
Master Air Screw 550 Prop Adapters	10	$58.69
#8 SS316 Capscrew	10	$2.62
#4-40 X 3 mm SS 316 Set Screw	10	$1.25
38 mm Dumas Plastic Propeller	10	$16.42
32 mm ABS Compression Ring	10	$2.28
SS 316 Nozzle Strut 2 mm 4/40 thread	7.5	$0.73
38 mm X 38 mm X 12 mm PVC Tee Thruster Mount	7	$36.07
12 mm grey PVC Terminal Adaptor	6	$2.80
#4-40 x 6 mm SS 316 Panhead Screw	16	$1.09
75 mm PVC thruster mount	2	$12.36
38 mm PVC Tee Nozzle	10	$0.00
Bilge pump cartridge	10	$342.00
Epoxy putty	2	$18.10
Permatex threadlocker	1	$5.64
6 mm black texflex	15	$0.63
PVC Paint	2	$14.99
Sched 80 9 mm nipples	4	$8.94
Sched 80 9 mm nuts	4	$1.41
6 mm nylon rod	1.4	$2.36
6 mm nylon nuts	8	$2.83
6 mm nylon spacers	3	$0.34
#6 SS 316 screws	14	$3.35
#6 SS 316 washers	16	$2.74
#6 SS 316 nuts	16	$3.28
#6 SS 316 Acorn nuts	6	$2.12
3 mm SS 316 Tool mount struts	1.67	$1.96
Al channel mount	1	$2.28
Ti 3 mm rod	1	$2.51
SS 316 wire	3	$0.86
Camera mount strut	0.6	$0.70
#6 Camera mount nuts	8	$1.28
50 mm VAC PVC Y	1	$2.51
50 mm VAC PVC 30 deg Elbow	2	$2.99
50 mm VAC PVC Clear Pipe	1.5	$3.42
32 mm PVC Pipe	8.67	$7.51
150 mm X 50 mm blue Junction Box	1	$8.21
6 mm NPT brass plug	1	$2.26
12 mm Dome Connectors	4	$6.34
12 mm Whip Connector	1	$7.48
Toilet Seal Wax	4	$4.51
Cable Ties	18	$0.41
PB 30 grams	2	$1.32
PB 60 grams	4	$3.15
PB 90 grams	2	$1.78
PB 120 grams	4	$4.10
CID Total		$1,801.75