3rd Annual MATE/MTS ROV Committee
ROV Competition

Technical Report

Long Beach City College

Viking Explorer ROV Project

TEAM VIKING EXPLORERS

ELTC 56B – Robotics Technology

Bischoff,Bryan S
Canul,Francisco G
Golebiewski,Michal Y
Lav,Huot
Mckee,Kevin S
Yean,Vanarit

EIR Club Members

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Meas,Saroeun
Miguel,Edgardo G
Pham, Joe
Ramirez,Israel
Saldana,Jose

DRAFT 51A – Industrial Drafting

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Alailefaleula, Geoffrey I
Cruz, Nelson
Gurule, Cecilia E
Hirsch, Jonathan S
Jager, Jeffery
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Sankey, Daniel

Instructor: Scott Fraser

ABSTRACT

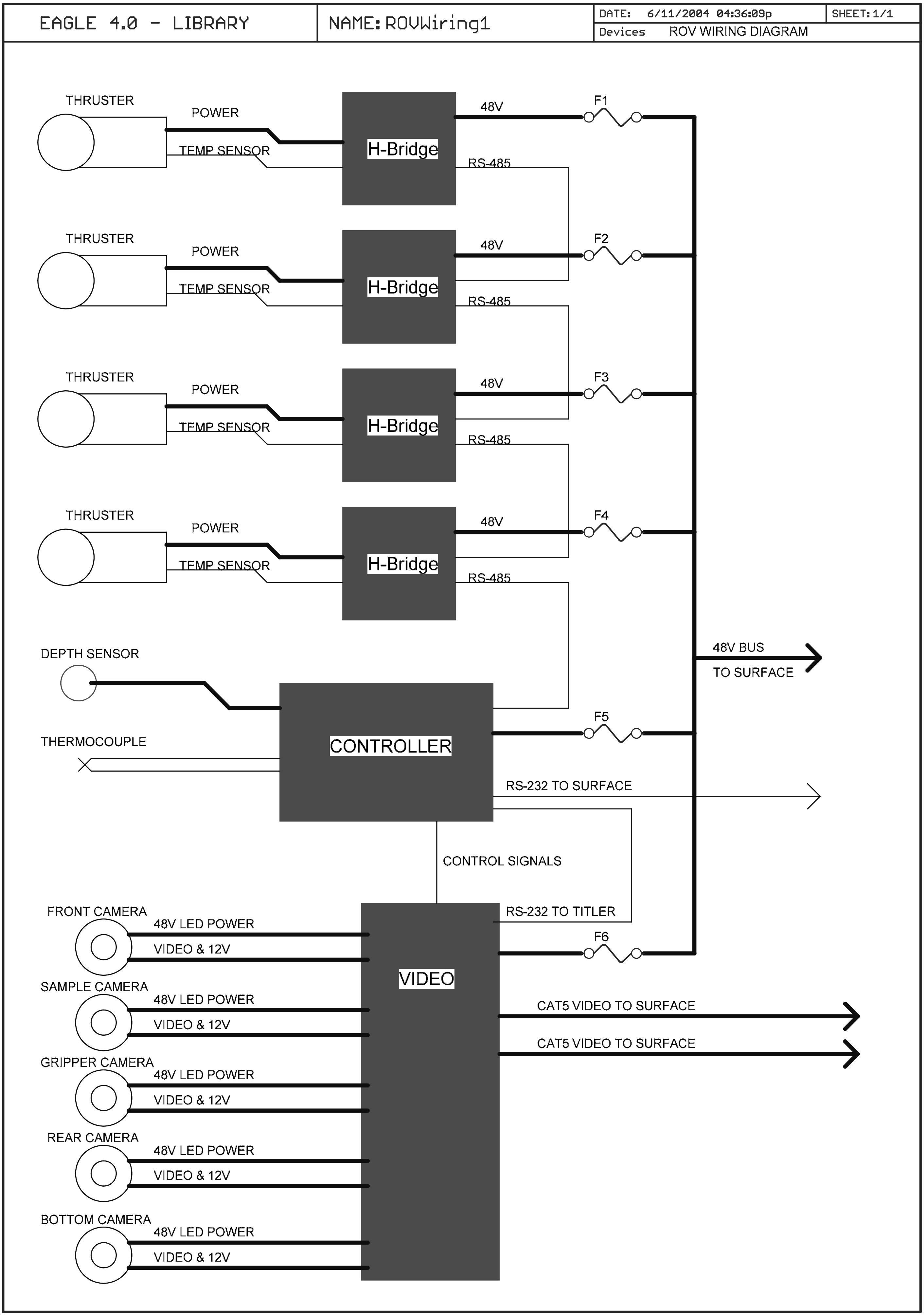
Made of aluminum and stainless steel, this 100% home made ROV can conquer any task. Its grippers are made from bike brakes and can grip objects of up to 10cm in diameter. The two vertical motors have enough thrust to lift about 5 kg under water. Vacuum and differential pressure is used to take samples with its two 1 liter bottles. The brains of this ROV consist of seven circuit boards hand made by the Viking Explorers team. Five video cameras serve as the eyes for surface control and 12 white LEDs surround each camera with variable brightness incase of a night expedition. A microphone at the end of a sealed 2.5cm x 9cm pipe filled with oil and covered with rubber on all but one side serves as a directional microphone to home in on under water signals. There is a thermocouple to take precise temperature measurements and a depth sensor. A step motor releases and retracts a fiberglass measuring tape which travels under the body of the ROV where a video camera can read the distance between two points. For buoyancy there is a hand carved foam float covered in red fiberglass which fits snug inside the body of the ROV. Plastic and rubber bumpers surround the ROV to insure no damage is done during an exploration. The total weight of the ROV approaches 45kg. With the power and strength of this ROV, we are anxious to try an ocean exploration.

Budget/expense sheet

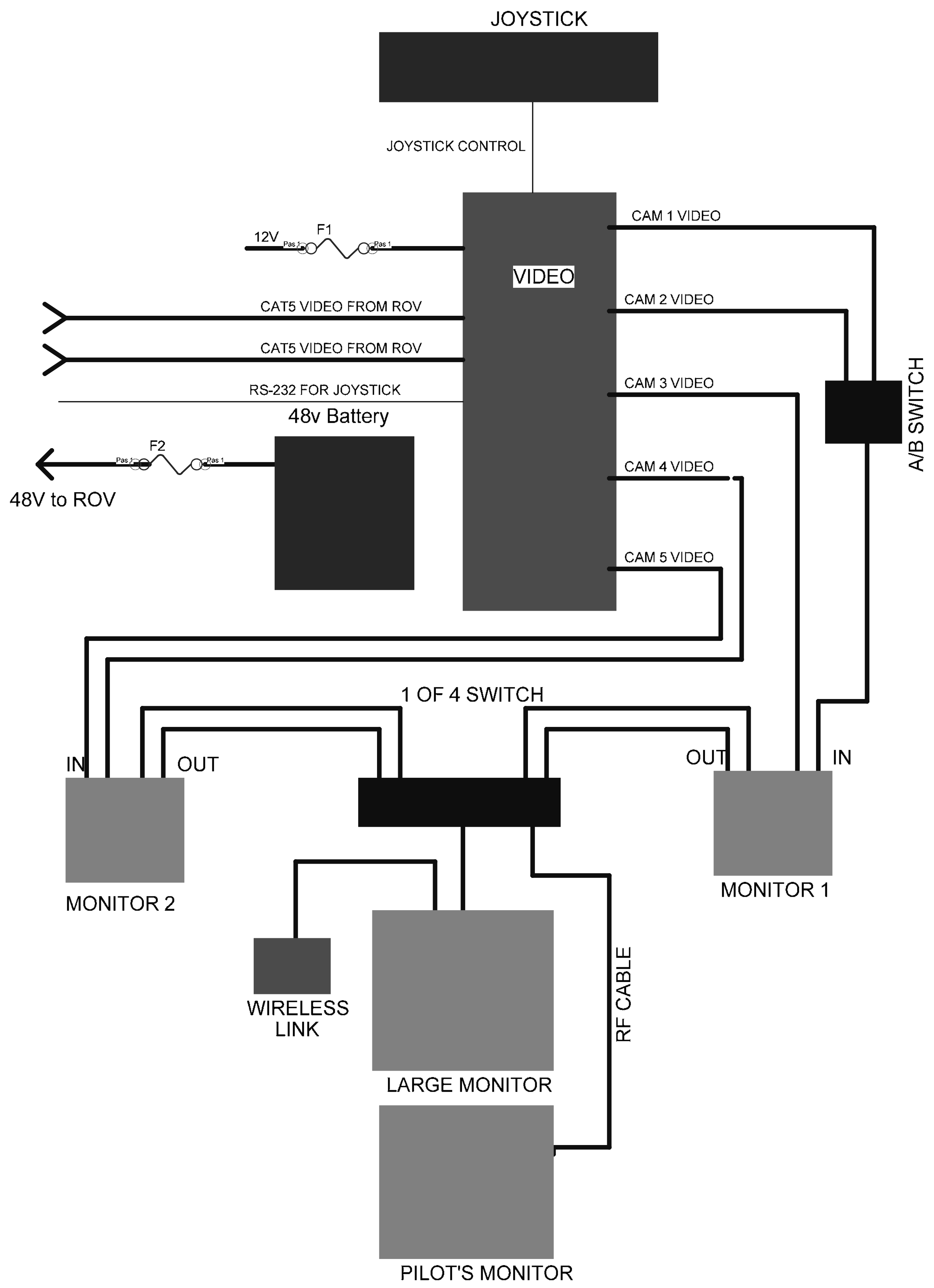
Type	Description	Quantity	Amt/Ea	Donation	Expense	Income
Expense	Batteries	4	$ 106.09		$ 424.34	
Expense	Cameras, BW	2	$ 19.49		$ 38.97	
Expense	Cameras, Color	6	$ 24.90		$ 149.39	
Expense	Circuit Boards	4	$ 35.72		$ 142.89	
Expense	Connectors, Large tether	1	$ 4.03		$ 4.03	
Expense	Connectors, Power	2	$ 1.57		$ 3.14	
Expense	Connectors, small cable	28	$ 1.18		$ 33.04	
Expense	Electronic Components	Misc	$ 410.27		$ 379.00	
Expense	Epoxy & Glue	Misc	$ 37.28		$ 37.28	
Expense	Fiberglass Resin & Coloring	1	$ 75.56		$ 75.56	
Expense	Flight Control Box	1	$ 270.63		$ 270.63	
Expense	Glass Sample Jars	2	$ 13.75		$ 27.50	
Expense	Gripper (bicycle Hand brakes)	1	$ 15.76		$ 15.76	
Expense	Hose Reel, Paint & Misc Hardware	1	$ 48.39		$ 48.39	
Expense	LEDs	100	$ 0.13		$ 12.50	
Expense	Lexan Sample Bottles	2	$ 8.11		$ 16.22	
Expense	Microphone	1	$ 3.99		$ 3.99	
Expense	Mineral Oil	12	$ 3.24		$ 38.88	
Expense	Misc Hardware	Misc	$ 79.85		$ 79.85	
Expense	Propeller, Fwd/Rev	2	$ 10.83		$ 21.65	
Expense	Propeller, Up/Down	2	$ 8.66		$ 17.32	
Expense	PVC End Caps	2	$ 1.79		$ 3.58	
Expense	Rack of 8 Valves	1	$ 26.23		$ 26.23	
Expense	Speaker Wire, 12ga	250	$ 0.65		$ 162.38	
Expense	Stainless Steel Hardware	Misc	$ 121.62		$ 121.62	
Expense	Stainless Steel Straps	12	$ 2.77		$ 33.25	
Expense	Vinyl Tubing for Tether	1	$ 53.04		$ 49.00	
Expense				Total This Page	$ 2,236.37	

Budget/expense sheet (cont.)

Type	Description	Quantity	Amt/Ea	Donation	Expense	Income
FundRaiser	MATE Seed Money					$ 100.00
FundRaiser	Ebay Auction, 2003 3Q					$ 3,575.00
FundRaiser	Ebay Auction, 2004 1Q					$ 2,386.76
Donation	Various Donors - Deposits into our accounts	Misc	$ 375.00			$ 375.00
Loan	LBCC - Carts					
Loan	LBCC - Video Support Equipment					
Donation	IBM - Aluminum Brackets	25	$ 2.75	$ 68.75		
Donation	IBM - Servo Motors	2	$ 75.00	$ 150.00		
Donation	LBCC - Cat5 cable	250	$ 0.08	$ 18.91		
Donation	LESCO - Servo Motors	8	$ 385.00	$ 3,080.00		
Donation	Mesa West - Index Mill, Lathe, Chop Saw, Band Saw	Many	$ 2,000.00	$ 2,000.00		
Donation	Mesa West - Truck Load of Plastic	Misc	$ 2,500.00	$ 2,500.00		
Donation	Phoenix Contact - Electrical Connectors, PCB	Misc	$ 225.00	$ 225.00		
Donation	Prime Resources - Cart Guard Cover, Red	144	$ 0.20	$ 28.80		
Donation	Prime Resources - Cart Guard End Cover Red	20	$ 3.25	$ 65.00		
Donation	Prime Resources - Red T-Slot Cover	6	$ 1.75	$ 10.50		
Donation	Prime Resources - Stainless nuts	75	$ 2.00	$ 150.00		
Donation	Standard Metal Products - Electronics Enclosure	1	$ 576.00	$ 576.00		
Donation	Standard Metal Products - Extrusions	15	$ 30.00	$ 450.00		
Expense	Expenses From Page 1				$ 2,364.31	
	Total Donations			$ 9,322.96		
	Total Expenses				$ 2,364.31	
	Total Fundraising					$ 6,436.76
	Balance Available					$ 4,072.45


EAGLE 4.0 - LIBRARY
NAME: ROVWiring1
DATE: 6/11/2004 04:36:09p
SHEET: 1/1
Devices
ROV WIRING DIAGRAM
THRUSTER
POWER
TEMP SENSOR
H-Bridge
48V
RS-485
F1
F2
F3
F4
F5
F6
48V BUS
TO SURFACE
DEPTH SENSOR
THERMOCOUPLE
CONTROLLER
RS-232 TO SURFACE
CONTROL SIGNALS
RS-232 TO TITLER
VIDEO
CAT5 VIDEO TO SURFACE
FRONT CAMERA
SAMPLE CAMERA
GRIPPER CAMERA
REAR CAMERA
BOTTOM CAMERA
48V LED POWER
VIDEO & 12V

EAGLE 4.0 - LIBRARY | NAME: ROVVideo1 | DATE: 6/11/2004 04:34:32p | SHEET: 1/1
Devices | ROV Surface Video



Design rationale

SAMPLING

Bryan Bischoff

The Viking Explorer's sampling system relies on the vacuum pressure within 2 Lexan bottles. Each bottle is capped with a 3-way solenoid valve to control the flow of fluid into it. The two bottles are connected in series by a clear plastic tube. A rubber plug with a hollow brass pipe in the center serves as the contact point for sampling. When 24Volts is applied to the second solenoid in the system, fluid will flow from the brass pipe to the plastic tubing, through the first solenoid, bypassing the first bottle, on through the second solenoid and into the second bottle. The purpose of doing this is to purge the system of any air or water, insuring a pure sample for the first bottle. Once the sampling camera shows a solid color of fluid flowing to bottle #2, the first solenoid can be activated to switch the flow to the first bottle. Once the sampling camera shows that the fluid has reached the 500ML mark, the solenoid will be turned off and the ROV can return to the surface with the pure sample.

Both bottles are 1 liter and made of Lexan. The plastic lids have 3-way manual valves with 1/8th inch threading on top where the solenoid is attached. The two unused ports are in the closed position and sealed with epoxy. The 3-way solenoids are also sealed in epoxy to prevent leaks or problems with the electrical connections. Forms were made from wrapping paper rolls and cardboard. Epoxy was poured into the forms to seal the solenoids. A brass barb fitting connects the tubing to the solenoids. This way the tubing can easily be removed and cleaned or replaced if needed.

At the point of penetration a rubber plug was made with a steep taper to guide the sampling pipe into the leaking source and plug the hole to prevent ambient fluid from mixing with the fluid to be sampled. The plug is made of RTV-11 and the tip is coated in red tool handle coating making it easier to see when guiding into the source.

Distance Measuring.

Michael Golebiewski

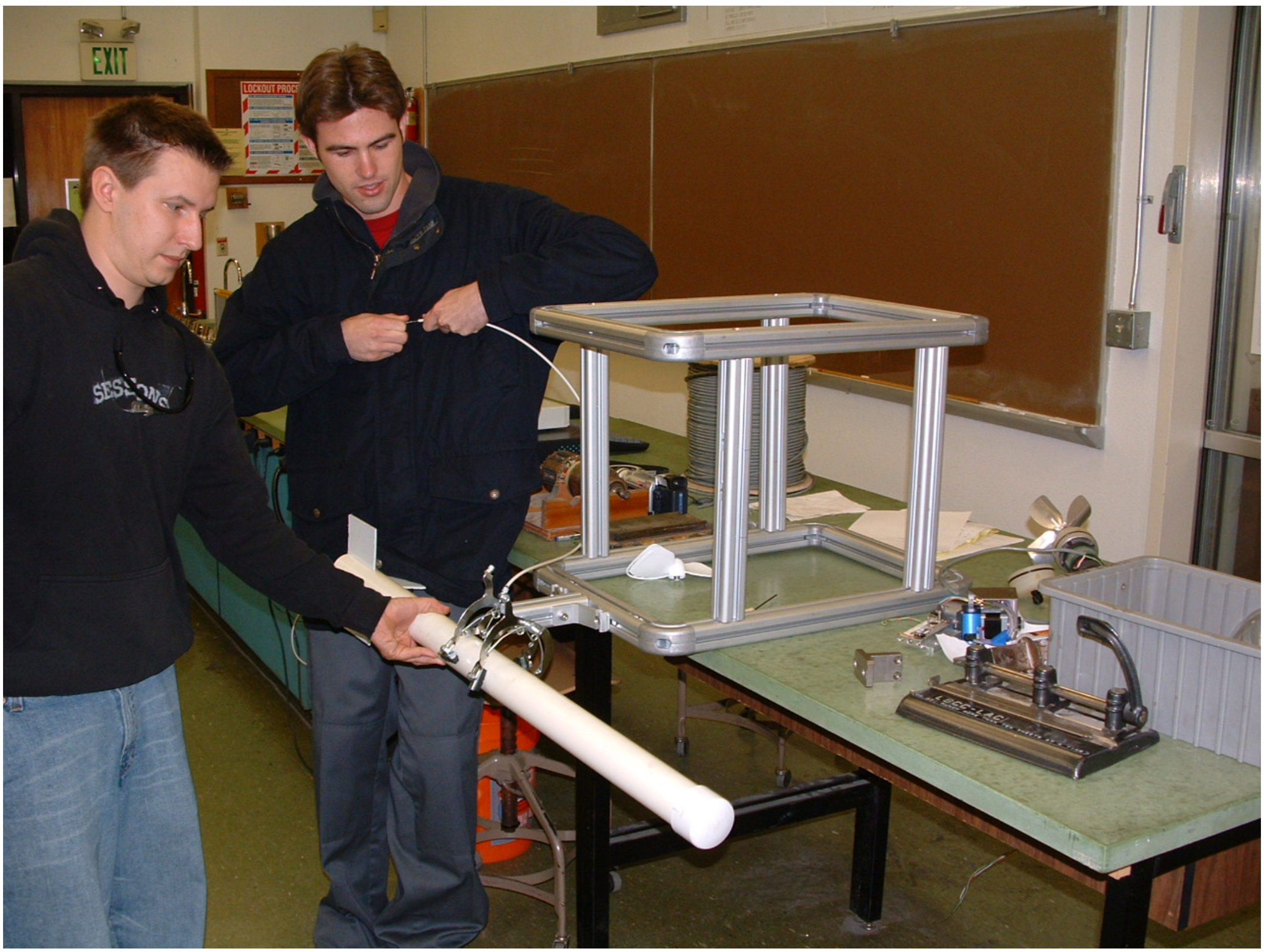
Our team designed two different distance measuring assemblies. First design was using a measuring tape with a specially fabricated brake assembly. The brake assembly for first design contained a solenoid that was attached to plunger with an arm and stop button. We were unable to create enough braking power to hold the tape firm and also had trouble with creating a good water resistant seal for the system. The team decided to drop this design and work on a new measuring device.

The second design is based on concept of a motorized tape measure. It contains an aluminum frame 15 cm by 12 cm. The frame holds a sealed stepper motor similar to the gripper motor. It is a single shaft 12 VDC stepping motor connected to Bi-polar Drive Circuit that provides for very precise movement of the measuring tape. The shaft of the motor holds a spool of measuring tape wheel loaded with 6 meters of tape. The tape measure assembly is mounted on the back bottom frame bracket behind main control box. The control box contains a video camera facing down and reads the tape scale. The front end of the tape has special attachment made of PVC "T" shape piece 1" x 1" x ¾". The "T" piece is placed in gripper. The gripper then places the "T" piece at starting point of measurement. The ROV then starts to reverse drawing out measure tape to the end point. The measurement is read from camera placed in main control box when it is determined that the measurement location has been reached.

ROV Gripper

Michael Golebiewski

The gripper design started with our team learning what kind of tasks it would have to perform, so we could make the correct size, power, and strength. After discussion of many different choices the team decided to go with double bicycle brakes design. The brakes in our design work as finger grippers, able to fully close enabling the pick-up of very small objects. It also opens up to 10 cm and that allows us to grab bigger items such as a tow fish. The mechanism used to open and close grippers contains: 12 VDC stepper motor VEXTA model # PH 266, mount bracket (upright bracket) 8cm by 7 cm, slider 17 cm, slider brackets 8 cm, and two cables 18 cm each. The heart of the mechanism is 2-Phase stepping motor with single shaft mounted on upright bracket positioned on the front top frame bracket of ROV. Shaft of the motor connected is to screw slider with slider bracket. Slider bracket secures one end of the cables to the slider and the opposite end attaches to grippers. Smooth and very precise movement of the gripper was reached by using eight step input sequence delivered by Bi-polar Drive Circuit. Protecting the motor from water is done by specially fabricated aluminum cube 7.5 by 8 cm with waterproof seal for the shaft opening and water resistant connector for electrical cables. The cube is oil filled for additional pressure equalization.



Hand Tests of Gripper Operation

Thruster Design

Francisco Canul

In our ROV, there are two types of thrusters: shrouded and unshrouded. The shrouded ones are mounted on the outside of the ROV. The shroud also acts as a safety shield for the propellers; for instance, when working around the thrusters with the propellers turning one can get fingers, arms, or any other body part in contact with the rotating props; or when operating the ROV and get too close to an object under water, it helps to save the props and the object. The unshrouded thrusters are mounted in the inside of the ROV frame, so there is no need for a shield. These were originally designed to be completely unshrouded, but the ROV floatation device was fabricated and it provides a level of shrouding for the thrusters.

The outer housing of the thrusters is made out of aluminum tubing with plastic end caps, our main concern was having a watertight seal to keep the motor dry. There is a Viton quad seal on each of the end caps. On the shaft side there are three Viton shaft seals to keep water from entering the motor housing. The shaft seal housing is made out of pneumatic end cap with two extra shaft seals and one more bronze bushing for added shaft support. The outside of the seal housing has an external o-ring to seal against the plastic end cap. The reason for the extra seals is that we were going to use the thruster dry; we needed the seals for the differential in pressure.

Our very first thruster design was going to be a magnetically coupled motor; with the windings enclosed in a sealed housing and the magnets, shaft and bearings in the outside, but the thrust generated was not enough to drive the magnet assembly; so it was dropped.

Then we got some donated DC servo motors with enough torque to drive the propellers; we had a couple of sessions designing housing and shaft seals, we opted for using some of the donated PVC tubing for the housing and Nylon for the end caps; well the concept worked but we had a cooling problem.

The shaft seals put pressure on the shaft, as the load increased more heat was generated by the motor, the PVC housing acted as an insulator and trapped all the heat inside, we were testing the first thruster with different prop configurations to find the one that give us the most thrust. Everything was going fine, we ran the motor with the lowest voltage then increased the voltage until we got to full voltage 48VDC.. Though the course of the testing, we switched props and continued until after a few hours of testing, the test motor would not operate, we checked all electrical connections everything was fine, but the motor did not turn, we decided to open the motor and take a look inside. We found that the motor was too hot to touch and it smelled like it was fully cooked. Once the motor cooled down we found that the armature was completely burnt. The PVC tubing did not provide any mechanism for the transfer of heat out of the motor enclosure.

Back to drawing board, this time we decided to go with aluminum for the housing since it offers good thermal transfer; also made brass heat sink that wraps around the motor and is in constant contact with the housing, this was an improvement over the previous design; and we were not overheating as much, but the temperature was still too high. We did not want to take any chances, on loosing another motor. We installed a temperature sensor to the body of the motor so that we could monitor the temperature during the testing. We observed temperatures up to 65C. This seemed to be too hot, too soon. We also notice a large thermal lag between the time we shut down the motor and the temperature stopped rising. We looked at the construction of the motor and realized that being a permanent magnet motor, all the heat is generated inside the motor on the armature. The only path for the heat to escape is down the armature shaft, out the bearings and finally to the housing. This explained the large lag in temperature. We decided to fill the housing with oil to help transfer the heat. This worked quite well. The highest temperature seen in testing was 50C. The oil caused another problem. The motor started acting up when put on horizontal, we opened the motor again and found that the oil that seeped inside the motor was getting trapped inside and the carbon from the brushes was contaminating the oil. We drilled some holes on the bearing housing of the motor itself to help circulate the oil in and out of the motor and now the oil flowed freely and the temperatures were well below danger levels. Finally, success!

The thruster operation is simple; rotate the propeller in the direction needed. The seals and the oil work together to keep the water out of the motor, the temperature sensor monitors the motor heat making sure is within range of motor, since the thruster is oil filled there is no need for the extra seals, but since they are pressed in permanently they would be hard to remove.

Photos of Thruster Assembly

ROV Electronics and Controls

Kevin McKee

The electronics for the LBCC ROV there are seven circuit boards total. First there are four H-Bridge circuit boards, one for control of each thruster. There are two video boards, one for the ROV, and one for the surface control unit. The last board is the main controller which is the interface between the surface and the ROV. The six circuit boards on the ROV are mounted inside an aluminum box (33.02cm x 15.545cm). The box was welded together and has a removable clear Lexan 3/8 inch (9.5mm) cover mounted at the bottom of the ROV on center. The cover is held in place with 44 screws and is sealed with a specially made rubber seal. There are 20 connectors mounted on the topside of the box which are designed to withstand five atmospheres. The boards are all 10.16 cm square and designed to mount end-to-end with three on one side and three on the other. The tether comes down into one large connector which has 6 cables total. Four of the cables are 12 gauge speaker wires for power and the other two cables are CAT-5. All six cables in the tether are enclosed in one sleeve of vinyl tubing which is sealed and filled with air for buoyancy.

Assembly of Electronics Boards

The four H-Bridge boards are identical and are designed to provide the control for the four thrusters. These boards can be either ran in remote or local mode. In local mode the boards are controlled by a DIP switch and two adjustable potentiometers, mounted directly to the board. In remote mode the boards are controlled by an RS-485 interface to the main controller board. The main component of these boards is the 5 Volt Pic Processor

(PIC18F254). The PIC Processor controls the FET driver IC which is designed to drive a medium voltage brush motor. The FET driver controls the four MOSFETS whose outputs drive each thruster.

The controller board is the heart and soul of the ROV, it also has a PIC18F254. This is the device that sends and receives information to and from the surface. It has the power supply which takes the 48V from the supply, monitors the 48V and converts it to regulated 24V, 12V, and 5V. It controls the valves for the water sampling system. There are inputs for temperature of the control box, temperature for all four thrusters, two water temperature sensors, and a pressure sensor.

The on-board video board has 5 inputs for the 5 cameras on the ROV. It also has 6 audio inputs that can be selected one at a time. The output is sent to an audio monitoring circuit to measure the amplitude of audio signals and to the surface video board.   Currently only the main microphone is monitored.

Camera 1 is a black-and-white camera that faces forward and has a text overlay provided by a text chip. The text overlay contains information for temperature, pressure, and depth. The other four cameras are all color and do not have text overlay. The 5 video inputs from the cameras all go through differential drivers and then sent to the surface video board.

The surface video board receives the signals and routes them through common mode chokes for impedance matching and then to differential receivers which convert it into a single ended video signal. Video 1 and Video 2 signals go in to monitor 1 and out to the video switching unit. Video 4 (Valve Cam) and Video 5 (Measuring Cam) are routed through an A/B switch and out with Video 3 into Monitor 2, and then out to the video switching unit. From the video switching unit are two outputs, one for the pilot (controller), and one through a VCR to the Big Television.

ROV Video System
Van Yean

On the ROV that Long Beach City College robotics team engineered has five cameras. The five cameras on the ROV will provide the pilot with five different locations on the vehicle that will need to be monitored precisely. The cams that were chosen to be used for the ROV are mini cams, each measures 20mm x 20mm, with a mini circuit board built into the back. Four of the five cameras are in color and one in black and white. The purpose of the black and white camera is that it can operate under low light and usually has better resolutions opposed to color cameras.

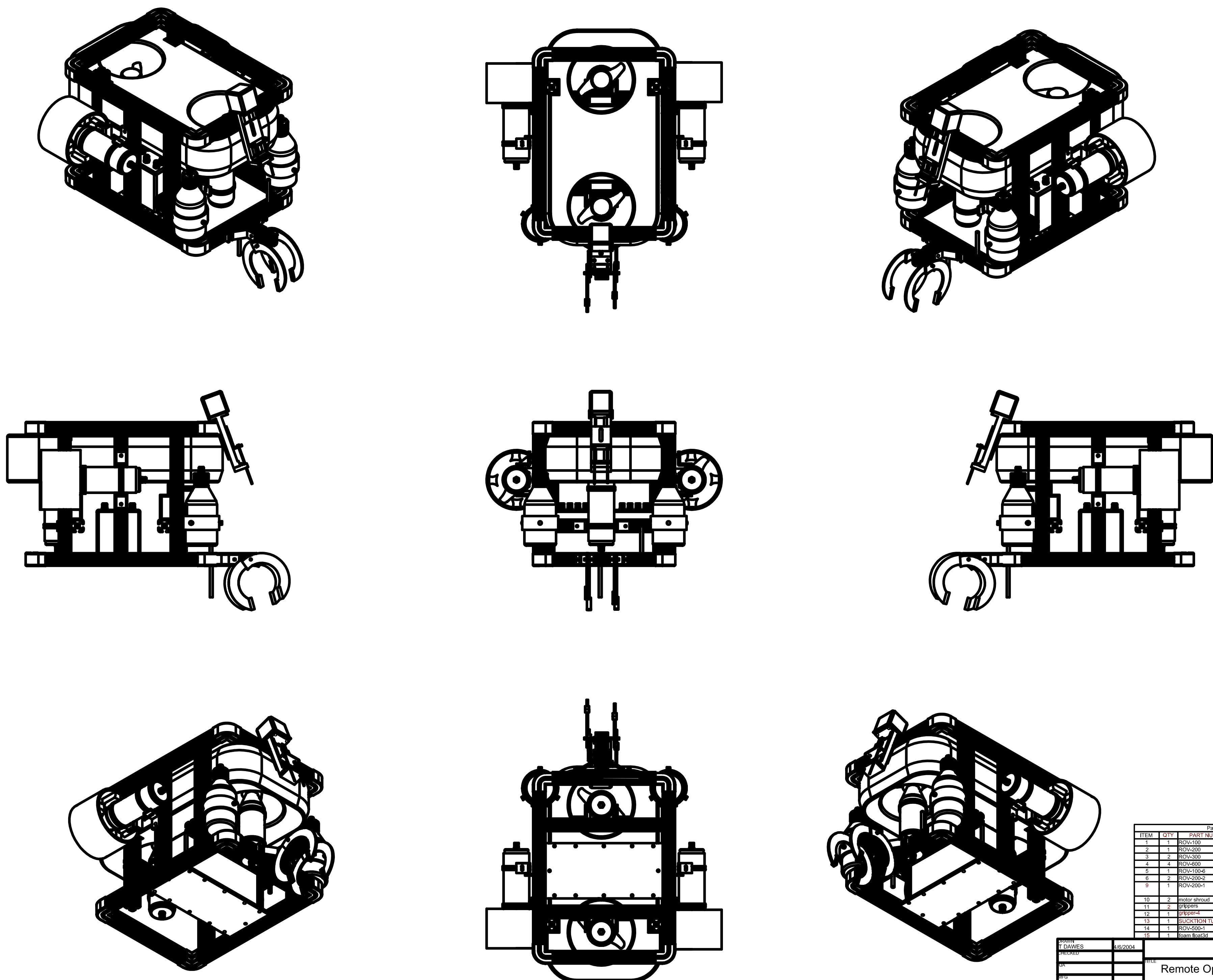
The location of the cameras will be mounted on the vehicle in a location where it is most needed. The black and white cam will be located on the front of the ROV as the main cam. This cam will provide the operator with directions and has an overlay screen with info such as depth, water temp etc. One of the color cams will be located underneath the robot viewing the gripper and the sample pipe, the pipe leads into the sampling bottles. The second color cam will be mounted on the inner side of the ROV looking at the amount of liquid the bottle will be sampling. This cam will let the pilot know when to disable the sampling device. The next cam will be looking down at the measuring system that is built to sit in the electronic control box. The final cam will be sitting on the back of the ROV providing the operator with a path that’s been traveled, including anything the pilot has overlooked.

One challenge that we faced was waterproofing the camera system. Epoxy glue was used to waterproofing the camera along with the LED’s which provided light for the camera. Clear plastics, glass, and epoxy alone went into discussion into sealing the camera. The LED’s that were used for the light source are white. There were aluminum disks about 6cm in diameter used to frame the LED's and the camera lens. The disks were individually punched to fit twelve LED's around the camera.

One of our first ideas of waterproofing the cameras was to set it in small candle jars. The first problem was the jars it self, the glass would not provide us with the clarity that was needed. We were concerned about clarity through the bottom of the glass and the possibility of the glass breaking. Our second option was cutting a piece of clear Plexiglas that was the same diameter as the paper cup which was used as a mold. With this procedure, when the glue hardens the glue itself will keep the water coming in contact with the camera. The next problem was the glue, we used five minute epoxy, when epoxy glue is mixing the two chemical compound come in contact with one another and creates heat. The glue was very hot as we poured it into the mold that it had fried the camera and cracked the lens. The next set of cameras used Enviro-Tex Lite which is a 24 hour cure epoxy so it will not interfere with the camera. After trial and error our mistakes will lead The LBCC Viking Explorers into top rank.

A CCD camera stands for charged couple device. A CCD captures light and changes it into data; the data is presented as pixels.

Sealed Camera with LED Spotlight being tested



Parts List

ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	ROV-100	
2	1	ROV-200	
3	2	ROV-300	
4	4	ROV-600	
5	1	ROV-100-6	
6	2	ROV-200-2	
9	1	ROV-200-1	GRIPPER MOTOR MOUNT
10	2	motor shroud	
11	2	grippers	
12	1	gripper-4	
13	1	SUCKTION TUBE	
14	1	ROV-500-1	
15	1	foam float3d	

DRAWN T DAWES	4/6/2004
CHECKED	
QA	
MFG	
APPROVED	

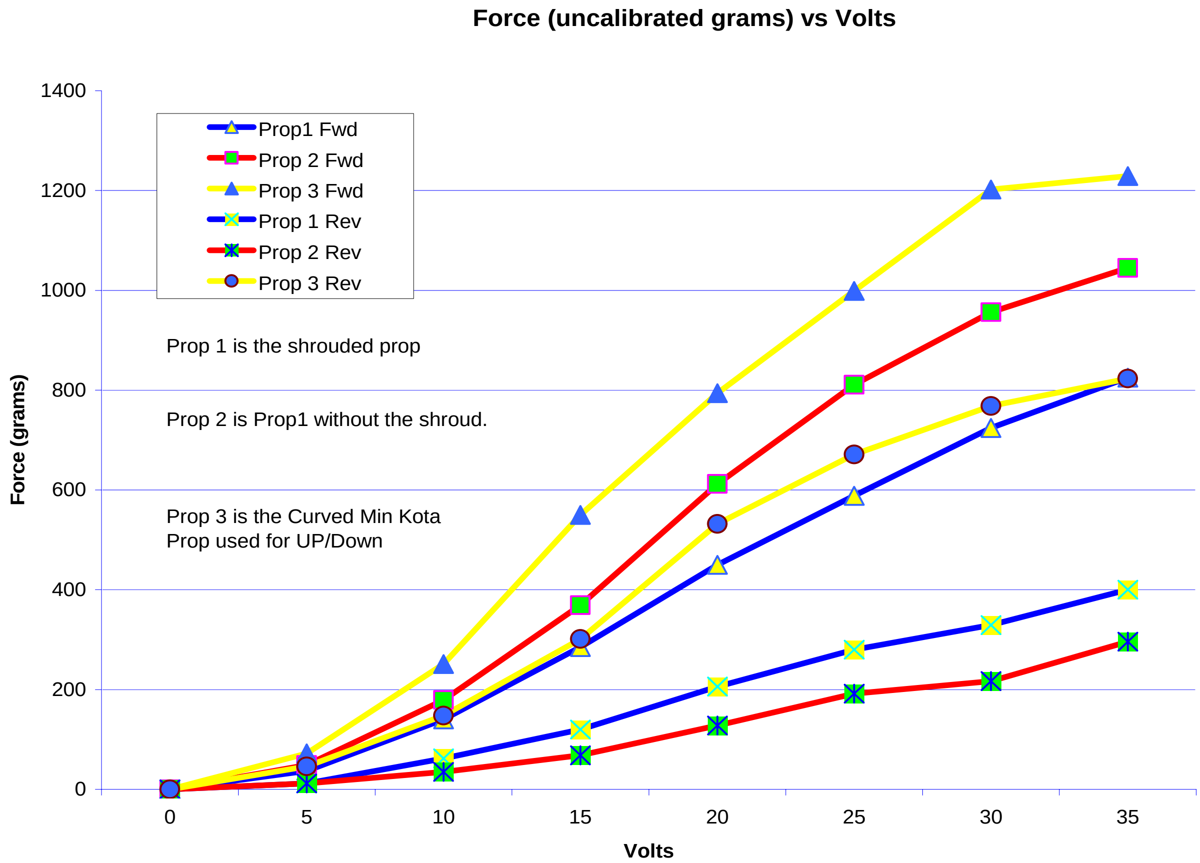
TITLE
Remote Operated Vehicle

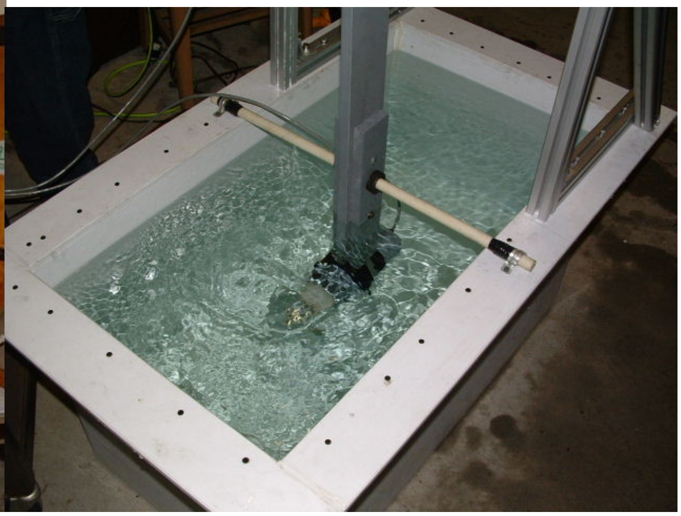
ROV

SIZE E | DWG NO ROV | REV

SCALE | SHEET 1 OF 1

Propeller Test Results





Propeller Test Tank

Buoyancy Calculations

ROV DISPLACEMENT FORMULA

Weight of ROV	**43.400 Kg**			
Water Volume Equivalent				
Fresh Water	**43.400 Liters**		**Displacement Needed**	**43.400 Liters**
Salt Water	**42.259 Liters**		**Displacement Needed**	**42.259 Liters**
			Ballast for Salt Water	**1.141 kg**

Float	**In**	**CM**	**Liters**	
Length	30	76.2	51.619	
Width	14	35.56		
Thickness	7.5	19.05		
Box				
Length	13.25	33.66	7.762	
Width	5.5	13.97		
Thickness	6.5	16.51		
Holes				
Diameter	7.5	285	-10.859	
Thickness	7.5	19.05		
Curving of Sides		3.228	-3.228	
	Total Displacement		45.295	**Liters**
	Extra Displacement		1.895	**Liters**

Curving Calculations

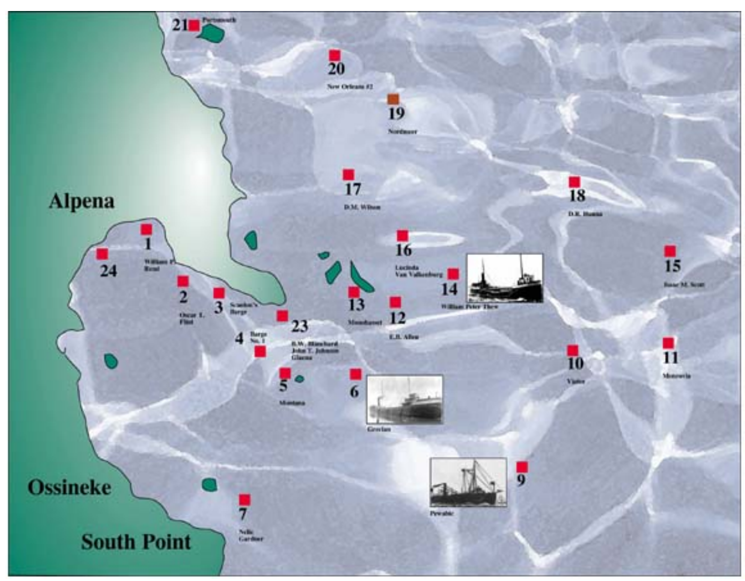
3.8	cm
3.8	cm
7.22	
1100.3	Length cm
513.5	Width cm
1613.8	Total per side
3227.6	Top & Bottom cc
3.2	Liters

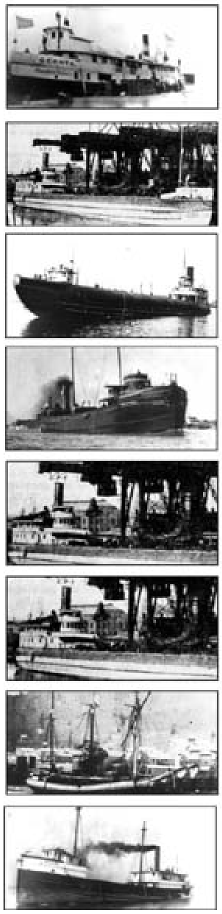
ROV's in Thunder Bay

Kevin McKee

Underwater ROV's are playing a major role in exploring Thunder Bay National Marine Sanctuary and Underwater Preserve. Thunder Bay is located on the east side of Lake Huron, next to Michigan, and is home to over 100 reported shipwrecks. The ships which lie in the appropriately named "Shipwreck Alley" are anywhere from 20 to 200 feet deep from the surface, which is accessible for many types of ROV's. Two of the major ROV's used to explore some of the sunken ships are *Little Hercules* and *Argus* (shown on left). Thunder Bay is the newest National Marine Sanctuary and can provide an amazing history of the ships traveling through the great lakes between the 18th and 19th centuries. Many of the ships in the deep parts of the bay have yet to be explored but are the most alluring because they are probably are mostly intact since they are in cold water and too far for divers to scavenge. The sanctuary has been devoted to preserving the shipwrecks for all divers and ROV's to explore. They can provide us with valuable links to our maritime history. Many of the shipwrecks have not been mapped for fear of being stolen from if the coordinates were given to the public.

On one of the expeditions to record the downed ship the *Montana*, a small ROV named the Phantom III followed divers down to the wreck to capture pictures of the vessel. The wreck was approximately 60 feet deep, and about 9 miles of shore. During the mission, the ROV was able to document zebra mussels and round gobies. The video was sent to through a tether to the surface of a ship, and then transmitted to the coast in Michigan. This type of ROV is commercially available and is very similar to the designs used in the MATE competition in Santa Barbara, California. In addition, ECHO, a sidescan sonar towfish has been used to map the area in and around Thunder Bay to find sunken ships and the sea floor landscape.





	Ship	Year Built	Year Lost
1.	Willam P. Rend	1888	1917
2.	Oscar T. Flint	1889	1909
3.	Scanlon s Barge		
4.	Barge No. 1	1895	1918
5.	Montana	1872	1914
6.	Grecian	1891	1906
7.	Nelie Gardner	1873	1883
9.	Pewabic	1863	1865
10.	Viator	1904	1935
11.	Monrovia	1943	1959
12.	E.B. Allen	1864	1871
13.	Monohasset	1872	1907
14.	William Peter Thew	1884	1909
15.	Isaac M. Scott	1909	1913
16.	Lucinda Van Valkenburg	1862	1887
17.	D.M. Wilson	1873	1875
18.	D.R. Hanna	1906	1919
19.	Nordmeer	1954	1966.
20.	New Orleans #2	1844	1849
21.	Portsmouth	1853	1867
23.	B.W. Blanchard	1870	1904
23A.	Galena	1857	1872
23B.	John T. Johnson	1873	1904
24.	Schooner Barge		
All locations are approximate			
Ships not located on map			
Camela B. Windiate		1873	1875
Kate Bruce		1872	1877
James Davidson		1874	1883
Norman		1860	1895
New Orleans #1		1885	1906
Vienna		1871	1906
William A. Young		1863	1911
W.H. Gilbert		1892	1914
Barge No. 83		1920	1941
John J. Audubon		1854	1854
Cheboygan			
Defiance			
Carbide Barge			
Unknown schooner barge			

These types of advances for ROV's will further our exploration in uncharted wrecks and will enable us to complete missions that cannot be completed by divers alone. By using this type of technology it allows us to monitor and study these shipwrecks in Thunder Bay, and to preserve them for many generations ahead.

References:

National Ocean and Atmospheric Administration
http://thunderbay.noaa.gov/

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National Marine Sanctuary Foundation
http://www.nmsfocean.org/evening_with_ballard.html

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