Skunk Works ROV Team Technical Report

ROV - *Cinderella*

Lompoc, CA

www.SkunkWorksROV.com

Team Members

Brian Dunaetz - Team Leader / Pilot / Engineer
Mattison Boothe – Co-Pilot / Engineer
Rebecca Hansel – Document Control / Engineer
Juan Elenes – Tether Management / Engineer

Mentors:

Michael Dunaetz
Teresa Dunaetz

INTRODUCTION

What is a Skunk Works?

"As a generic term, it dates from the 1960s: A small group of experts who drop out of the mainstream of a company's operations in order to develop some experimental technology or new application in secrecy or at speed, unhampered by bureaucracy or the strict application of regulations (Kelly Johnson formulated 14 visionary rules for running such an operation, which are still regarded as valid even now). It is also sometimes used for a similar group that operates without top-level official knowledge or support, though usually with the tacit approval of immediate management." (http://www.quinion.com/words/qa/qa-sku1.htm)

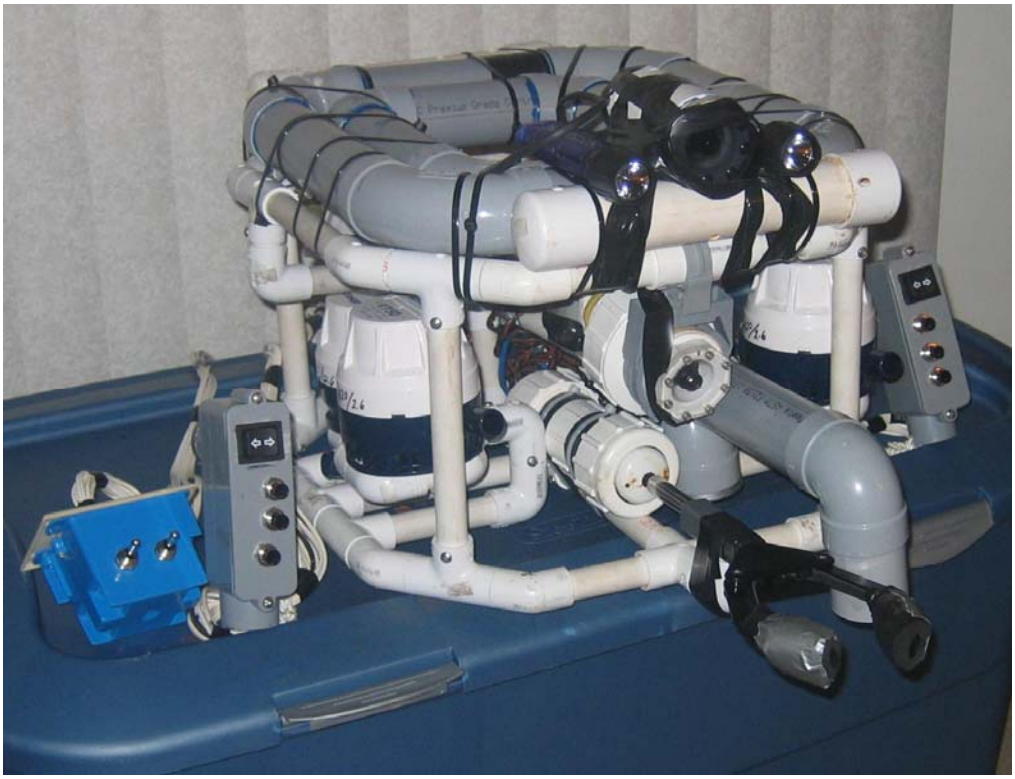
ABSTRACT

This technical report outlines the building process of a Remote Operated Vehicle (ROV) by four high school students known as the Skunk Works ROV Team. We are a small independent group of students with a common desire to build and fly submersible ROV's. We began this project as a hobby and we hoped to gain enough knowledge to participate in the 2005 MATE Center/MTS National ROV Competition.

We found our way to the 2004 National ROV Competition by placing First in the Ranger Class at the 2004 Monterey Bay Regional ROV Contest. The ROV has been design to accomplish the 7 tasks as outlined in the "Competition Challenges and Design & Building Specifications" with speed and efficiency. From our humble beginnings on January 10, 2004, with nothing more than a bag full of fittings and some pipe, we have come a long way. What follows is the story of the ROV *Cinderella.*

The total cost to reproduce this flight ready ROV is $615.00

Cinderella is ready to fly!



The ROV is flanked by the two Pilot controls and the blue box in the bottom left is the Co-Pilot control

SKUNK WORKS ROV TEAM
EXPENSE REPORT

	Materials	Price per unit	Total Price
	DRIVE COMPONENTS		
18	Attwood V500 bilge pumps	$11.00	$198.00
1	Attwood V650 bilge pumps	$20.00	$20.00
12	Attwood V750 bilge pumps	$25.00	$300.00
3	Attwood Bait pumps	$25.00	$75.00
80	Props	$1.00	$80.00
	VIDEO CAMERA		
4	CCD Cameras	$22.50	$90.00
	Misc. PVC Fittings	$20.00	$20.00
	Plexiglass	$10.00	$10.00
2	Sunglass lenses	$10.00	$20.00
1	A/B Switch	$20.00	$20.00
180	Cat-5E Cable	$0.12	$21.60
	ARM		
4	6 Volt Drill	$10.00	$40.00
2	Trash Grabber	$20.00	$40.00
2	PVC Housing	$10.00	$20.00
1	Deep Sockets & Fittings	$4.00	$4.00
	FRAME		
3	20' 1/2" PVC Pipe	$4.00	$12.00
32	45-degree Elbows	$0.34	$10.88
40	Tees	$0.33	$13.20
40	90-degree Elbows	$0.34	$13.60
	BUOYANCY		
2	7' - 2" Gray Vacuum tubing	$7.00	$14.00
16	2" 90-degree swoops	$1.00	$16.00
	BALLAST		
8	2' Pipe caps	$0.50	$4.00
2	2' - 2" PVC pipe	$1.00	$2.00
	CONTROLS		
4	Momentary Toggle switches	$7.50	$30.00
20	Momentary push buttons	$5.00	$100.00
2	Rocker switches	$5.00	$10.00
4	Control handles	$5.50	$22.00
3	Outlet Box & Cover	$2.00	$6.00
	TETHER		
55	Feet T2 FT1 Cable	$0.12	$6.60
300	Feet 18 gauge zip cord	$0.15	$45.00
3	Strain Reliefs	$1.00	$3.00
1	1/8" Cord for strain relief	$3.00	$3.00
	MISCELLANEOUS		
1	5" black and white TV monitor	$60.00	$60.00
1	Marine Battery	$80.00	$80.00
4	8' Stick of Pipe Insulation	$6.00	$24.00
2	Mag-Light Flashlight	$6.00	$12.00
3	Boxes of Stainless Steel Screws	$5.00	$15.00

MISCELLANEOUS (CONT.)

3	Box of Wire Nuts	$4.00	$12.00
2	Tube Silicon Grease	$4.00	$8.00
2	Tube Silicon Caulk	$7.00	$14.00
5	Velcro Straps for the Tether	$1.00	$5.00
3	Voltage Control Regulators	$10.00	$30.00
1	Audio Video Cables	$20.00	$20.00
1	Misc. Nuts and Bolts	$20.00	$20.00
1	Dremel Tool	$70.00	$70.00
1	Dremel Bits	$15.00	$15.00
1	Drill Bits	$20.00	$20.00
1	Safety Goggles	$5.00	$5.00
30	Electrical Tape	$0.50	$15.00
2	Waterproof fusing tape	$5.00	$10.00
	Office and Printing Supplies	$200.00	$200.00
1	In-line fuse	$5.00	$5.00
2	Liquid Electrical Tape	$6.00	$12.00
8	Film and Photo Processing	$10.00	$80.00
2	Dive lights	$25.00	$50.00
	Misc. Materials	$100.00	$100.00

PARTS SUB TOTAL	**$2,151.88**

TRAVEL & ACCOMMODATIONS

Monterey Regional Competition	$455.00
Santa Barbara National Competition	$784.50
Santa Barbara National Competition	$270.00

GRAND TOTAL	**$3,661.38**

DONATIONS

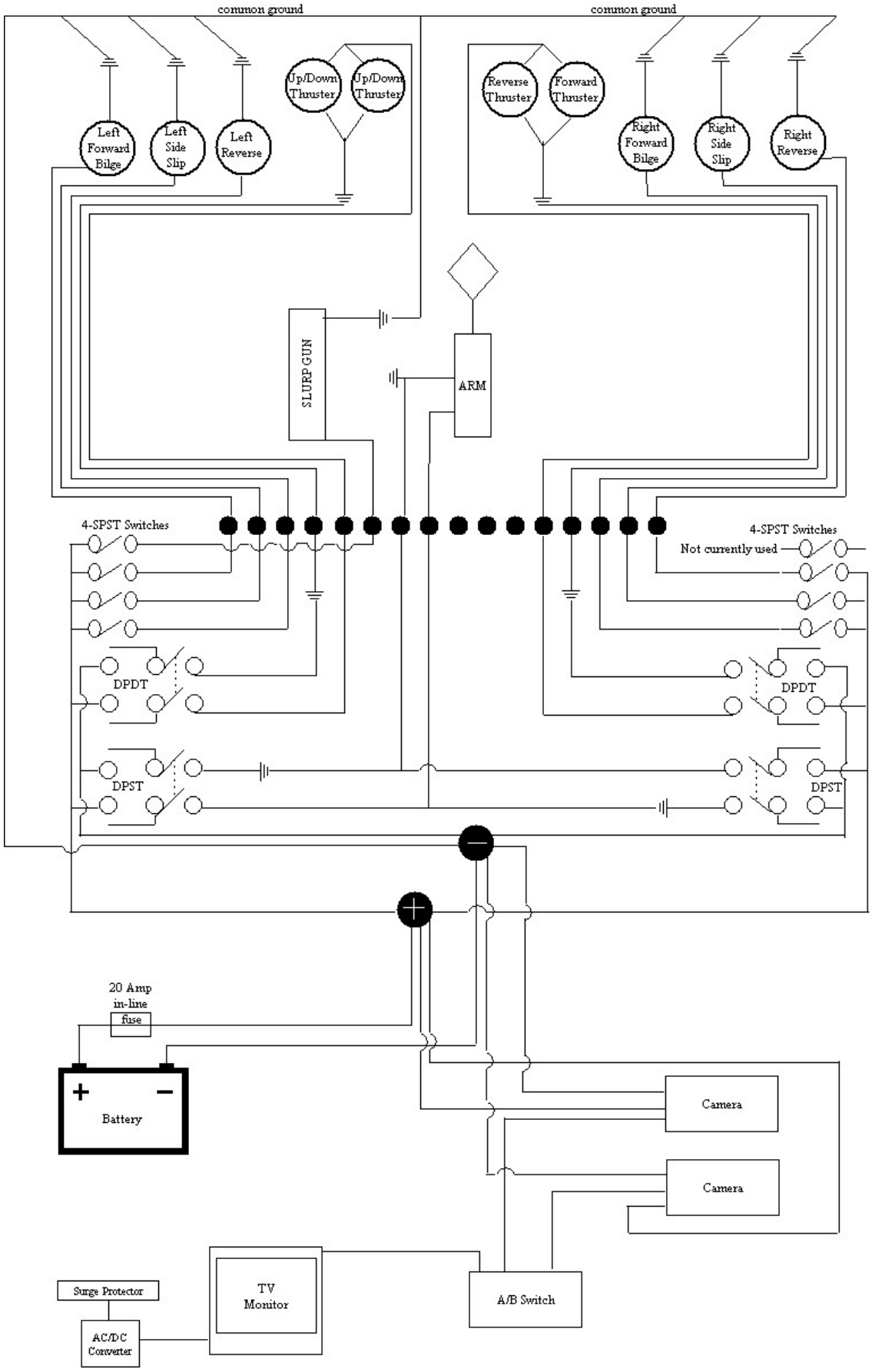
CASH DONATIONS

Marine Advance Technology Education (MATE)	$100.00
California Chrysler Jeep Dodge-Lompoc	$50.00
David Ewen & Jacquelyn Tanner	$50.00
Dennis Crosgrove	$100.00
Ben & Janice Ross	$20.00
Michael & Teresa Dunaetz	$1,120.68
	$1,440.68

MATERIAL DONATIONS

Marine Advance Technology Education (MATE)-National Accommodations	$784.50
Marine Advance Technology Education (MATE)-Regional Accommodations	$455.00
Attwood Corporation	$494.00
Tanks A Lot Dive Shop	$50.00
Home Depot	$100.00
Thoregren Tool and Molding	$50.00
Doug & Sarah Boothe	$60.00
Advanced Air International	$10.00
Cabrillo High School Aquarium	$117.20
Michael & Teresa Dunaetz	$100.00
	$2,220.70

GRAND TOTAL OF ALL DONATIONS	**$3,661.38**



MATE National ROV Competition 2004 - Santa Barbara, California - June 25th to June 27th

SkunkWorks ROV Team Electrical Schematic for ROV *Cinderella*

Shop Notes & Drawings By Brian Dunaetz

Cad Drawing by Brian Dunaetz and Mentor Teresa Dunaetz

DESIGN RATIONALE

- **ROV Dimensions in Metric**
  35 cm Tall
  41 cm Wide
  51 cm Long (71 cm Long - including the Arm)
  Weight 10.1 kilograms

- **Frame**
  We designed the frame to be a stable platform much like a tug boat. We did this so it was capable of accomplishing the multitude of tasks that was going to be required of it. We used ½" schedule 40 Poly Vinyl Chloride (PVC) pipe and fittings to construct the frame. To hold the pieces together we used ¾" size 8 stainless steel screws. We used screws instead of glue to easily manipulate the design of the ROV. This minimized wasted material during R&D (research and development).

- **Control system**
  Our control system was designed for maneuverability and hand comfort. The Pilot's hand controls each have 4 SPST momentary pushbutton switches; the right hand control switches are for the right side motors and the left control switches are for the left side motors. One button on the right controller operates the slurp gun. There are 2 DPDT momentary rocker switches which open and close the arm. The right rocker switch closes the jaws and the left rocker switch opens the jaws. The Co-Pilot's hand control has 2 DPDT on/off/on momentary toggle switches. On this controller the right toggle switch controls the forward/reverse propellers. The left toggle switch controls the up/down propellers.


Pilot hand controls


Co-Pilot hand controls

- **Electrical Connections (Junctions)**
  Every connection was soldered and waterproofed with 4 coats of liquid electrical tape.

- **Power**
  We use a 12 volt Eveready Deep Cycle Marine battery. This is a Group 27 battery with 120 amp hours of capacity.

- **Power Distribution**
  Our electronics will not be damaged if polarity is reversed. The motors will run in the reverse direction and the cameras will not function; but once the polarity is corrected everything functions normally.

- **Tether**
  There are three components to our tether. The primary tether has 26 strands of 24 gauge shielded wire and is 52' long. For each of our bilge pumps we combined two 24 gauge wires which give us the equivalent to one strand of 18 gauge wire. We combined 4 of the 24 gauge wires for a common ground for the bilge pump motors. This gave us the equivalent of one 12 gauge common ground wire.

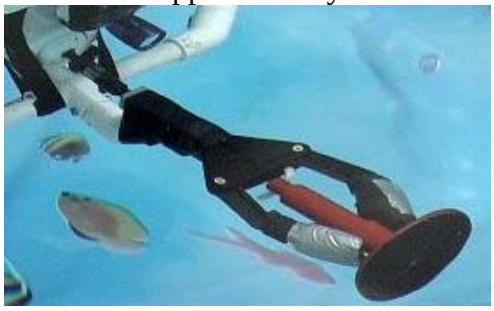
  We connected our tether to a junction box using 18 gauge zip cord which then added 12.5' of additional tether length. This was done to extend the length of the tether available in the water. The connections within the junction box are soldered and then waterproofed with 4 coats of liquid electrical tape.

  The two additional tether cables are used for each camera. Each camera is connected to one 90' length of Cat-5E cable. We used 90' length of cable so our ROV would be able to use the cameras and cables for future ROV construction. The excess cable is coiled up and stowed approximately 8' from the hand controls.

  The 12 volt power supply is protected by one 20 amp fuse located approximately one foot from the battery terminal. This single power line feeds all motors and cameras on the ROV. The 20 amp fuse was used so it would blow prior to exceeding the 25 amp limit.

- **Retrieval mechanism**
  The arm is made out of the jaws of a trash grabber. We added foam pipe insulation to the jaw pads so we would have more control over the grip pressure. The actuator is a Black & Decker alkaline screwdriver. It runs on a piece of allthread and as you spin the nut clockwise it closes the jaws. When you reverse the direction the jaws open.

  The forward compartment of the housing is sealed from the rear compartment where the motor is located. In the forward compartment we drilled two holes which we use to inject silicon grease to maintain a water tight seal around the drive mechanism of the screwdriver. Our injection device is a standard syringe used for dispensing medications to babies in a measured amount and we attached a metal ink tube from a ball point pen as the needle. The front compartment holds approximately 18 ml of silicon grease.



- **Video Cameras and Monitor**
  We have 2 Monochrome low light CCD 3.6 mm board lens video cameras. They are installed in separate home made water proof PVC housings. One camera is used to view the arm at a down angle and allows us to look down and out when we are near the surface. The second camera is to scan our surroundings. This camera points straight ahead and we rotate the ROV to view our surroundings. We are able to view each camera on a single black and white 5" TV. The cameras are connected to a pushbutton A/B switch which allows us to switch from one camera to the other very quickly.

  The cameras are extremely light sensitive and subject to whiteout on bright days. Installing a sunglass lens over the lens of the cameras solved this problem.

- **Buoyancy**
  The buoyancy is made of 6' of 2" central vacuum tubing and 8-90 degree elbows. We built two square doughnuts, one fits inside the other. This made us positively buoyant. We added one 12" piece of 1 1/4" thin-wall PVC with end caps to the front and rear of the ROV. These were placed horizontally and at the top of the ROV so we would have easy access to them to adjust our ballast. We have a variety 11" long weights that we utilize in the front or rear to change the buoyancy or adjust the attitude of the ROV front to rear.

  Although we do not have a method of adjusting our buoyancy in flight, we found our ROV doesn't need this capability to accomplish the mission tasks. Adding this would have increased design cost and complexity without significant improvement in mission capability. The large size of our ROV makes it less susceptible to minor weight differences.

- **Thrusters**
  The ROV uses V500 and V750 Attwood Marine bilge pumps as motors. Six of the bilge pumps use water jets for propulsion. Four of these are model V750 and two are V500 bilge pumps.

  Additionally we used two V500 and two V750 Attwood bilge pumps that are modified to accept propellers. Two of these control our up / down thrust by reserving the polarity to the motors. The other two are used as Turbo power for forward and reverse.

- **Slurp Gun**

  We have designed a slurp gun to pick the authigenic carbonate pieces. It is made out of an Attwood Tsunami T-1200 aerator pump and 2" central vacuum tubing. The carbonate pieces are sucked up and dropped into a small collection basin.

- **Propeller Thrust Measuring Device**

  We designed a device that allowed us to measure the thrust of different propellers. The interesting thing about the data we collected is; the propellers with the least pounds of thrust in testing actually propelled the ROV better in real life situations. We have not had time to thoroughly understand this and look forward to more research. At the same time we do this we are able to measure amperage load.

Challenges

One of the challenges we faced was our cameras are designed for low light situations. When we first started flying with our cameras it was late in the day and/or foggy. After a number of flights the sun came out and there was to much light in the pool which caused a condition known as white out. We couldn't see anything. In order to solve this problem we attached 1 sunglass lens to the outside of each of the camera housings in front of the camera.

Additionally, we are an independent team who worked in a garage of one of our team members. Even though we were independent, we did have a number of sponsors. After winning the Regional Competition, one of our sponsors wanted more credit than they were due. They wanted to take control over the Team and ownership of the ROV we built to give their organization more publicity. Because the sponsor had such a close tie to the team, this put us in a very difficult position. There were only two ways to handle this situation:{1} give full ownership and control to the organization, which would mean the team had to follow all the new plans the sponsor had for us and forget about where we started and what was important to us, or {2} Have the organization give up their sponsorship to the team and compete with the other sponsors we already had. Both were valid choices but also had there downsides. The 1st choice made us give up all control over the project, and the 2nd forced us to deal with the fact we could possibly loose the opportunity to compete in the National Competition because the organization had such an impact in the community.

We had a silent vote individually then tallied as a team. The outcome was: 4 to 0-we were going to take the second option, and loose the sponsorship of the organization. We could only hope that it wouldn't affect our ability to participate in the National Competition and/or affect our future but we knew it was the right thing to do.

Trouble Shooting Techniques

The motor for the arm was to powerful. It had the ability to crush the gripping mechanism. It was designed to run with 4 AA batteries for a total of 6 volts. We tested voltages down to 1.5 and found the speed of the rotation was reduced but the motor maintained about the same amount of torque.

Lessons Learned and Skills Gained

Brian
I learned many different things about electrical applications and was able to apply them to the ROV construction. I also refined my ability to focus on a future goal and not let anything get in my way.

Mattison
The project gave me good work habits; taught me how to deal with a boss, about taking orders and getting work done efficiently and on time.

Rebecca
Even though this is a technical hands-on project, I think the most valuable thing I learned was to listen, express opinions and accept ideas from all three of the other team members. This is definitely a skill I can use in any career I chose.

Juan
This experience taught me how to get along with people.

The Team
We all learned how to overcome our differences, and use them to our advantage. Each member must work up to their ability and use their strengths to teach others.

Discussion of Future Improvements

If we were to do this project again we would test different shapes and designs; we would do this because, there is always a new shape or way to improve the ROV. Along with the ROV improvements we would begin planning for the competition much sooner. We did not know we were going to compete in the Monterey Bay Regional until the beginning of February.

The Thunder Bay National Marine Sanctuary and Underwater Preserve

The Thunder Bay National Marine Sanctuary and Underwater Preserve tested a wireless network to develop a mobile, low cost, live web cast to promote public awareness of the rich cultural history lying on the floor of Lake Huron. It is suspected that over a hundred wrecks lie within the boundaries of the sanctuary in waters ranging from 20 to 200 ft. These wrecks sometimes represent a paradise for divers, but can be a very big mystery to the public.

(http://www.nurp.noaa.gov/Spotlight%20Articles/underwaterweb.html)

A Remote Operated Vehicle (ROV) from the NURP (NOAA's Undersea Research Program) center was launched at the Great Lakes Environmental Research Laboratory (GLERL) off of *R/V Shenehon* which was anchored over the wreck of the "Montana", lying 60 feet below and 9 ½ feet offshore.

Two divers explored the lake bottom as the ROV followed them as they conducted a full exploration of the lake bottom. Within the short time, the divers documented the distribution of two invasive species – the Zebra Mussels and Round Gobies.

As part of the COS project; Student Jason Williams uses a live Webcast to teach science to students from around the country. He is on the *R/V Connecticut*.
(http://www.oar.noaa.gov/spotlite/archive/spot_cos.html)

An ROV operator controlled the vehicle from a system on board the ship using a joystick, camera, and video monitor, the operator followed the divers while sending video signals to the surface cameras on the ship, and then transmitted over the wireless network to shore. From the shore the video was also sent to sever at the University of Connecticut and from there to the American School for the Deaf. This broadcast is part of the COS (Classroom of the Sea). The COS project is funded by the NSF (National Science Foundation) and is run by National Underseas Research Center in collaboration with

several other institutions. There are three main participants working under the NSF; American School for the Deaf, the University of Connecticut and the National Technical Institute for the Deaf at Rochester Institute of Technology. (http://www.rit.edu/~comets/pages/cos/coscommaccess.html)

Acknowledgements:
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- Michael & Teresa Dunaetz
- Doug & Sarah Boothe
- Steven C. Shinn
- Dennis Crosgrove
- Ben & Janice Ross
- David Ewen & Jacquelyn Tanner
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- Cabrillo High School Aquarium
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- Shirley Pillus