Endeavor Enterprises

Sea-Tech 4-H Club

Skagit County 4-H Program – Washington State University Cooperative Extension Office
Mount Vernon, WA, USA

Matthew Atilano
CEO/CFO

Dean Jones
GRA/Pilot

Zachary Placzek
R&D/Sensor operator

Joshua Nelson
Design Engineer/Manipulator Operator

Jacob Hamiter
Tether Tender/Mission Commander

Team Mentors: Rick Hamitier
Joe Theiman

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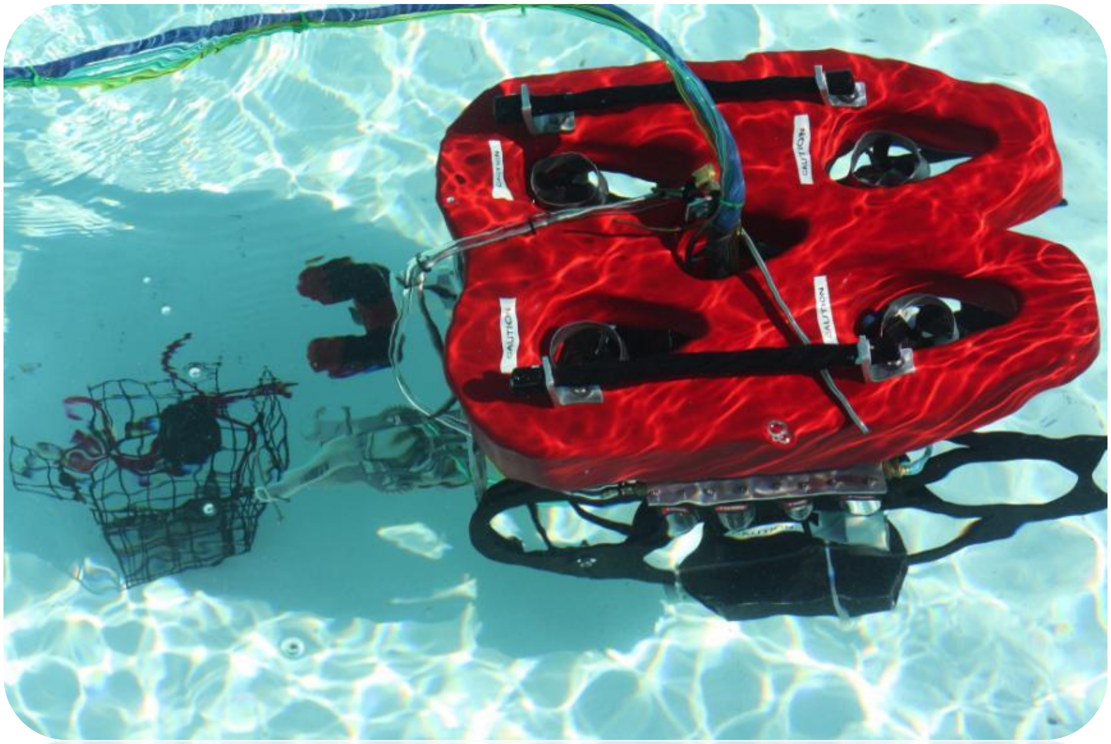
Abstract

Endeavor Enterprises is a provider of engineered services and products primarily to the offshore oil-drilling industry. Endeavor Enterprises is dedicated to providing efficient underwater inspection and servicing solutions. Their mission is to provide safe, cost-effective, and quality-based technical solutions satisfying customer's needs worldwide.

The Endeavor team designed their ROV (Remotely Operated Vehicle) using CAD (Computer Aided Design), and water-jetted the aluminum parts directly from these models. The simple, aluminum frame is designed to shield the core and function as the chassis. The team jigged the jetted plates for welding, and then anodized the weldment for corrosion resistance. The team also fashioned the hydrostatic-polyurethane foam float by hand.

One of the greatest strengths of this ROV is its simplicity. The PVC core assembly was wired and completely filled with potting materials. This approach eliminated the risk of water leaks at depth, which is one of the inherent hazards that must be considered in ROV design. Each system component, such as video cameras, thrusters, actuator, etc. can be easily removed for quick efficient testing and replacement. A small tether increases the ROV's overall maneuverability, enabling it to accomplish its missions quickly and efficiently.

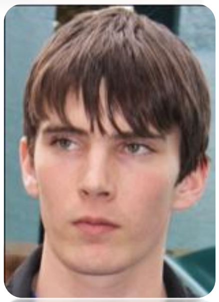
Team Endeavor is eager to perform your mission tasks, equipped with the engineering and teamwork skills they have worked hard to develop.



1. Meet Team Endeavor

Matthew Atilano
Company Role: Chief Financial Officer, Chief Executive Officer
Competition Role: Captain/CEO

Matthew is 16 years old and home-educated. He enjoys cinematography, and his Canon Rebel XT camera. This is Matthew's third year of Sea-Tech. One day, he hopes to be a mechanical engineer or independent film maker.



Joshua Nelson
Company Role: Design engineer
Competition Role: Manipulator operator

Joshua has participated in Sea-Tech for 2 years now. He enjoys learning new skills and working on his family farm. He was one of the main designers for the ROV on CAD. Joshua is 15, and has been home-educated for his entire academic career. Following high school, he plans to pursue a degree in either engineering or computer science.

Dean Jones
Company Role: Electrical Engineer, Government Regulatory Affairs
Competition Role: Pilot

Electronics are definitely up Dean's alley. He's pursued them ever since he began Sea-Tech, four years ago. At age 16, Dean is taking college classes at the Skagit Valley College in Mount Vernon, WA. He enjoys any kind of shooting sports. His career goal is to be in Law Enforcement. A clear eye and a steady hand are ideal characteristics to have in a pilot.

Jacob Hamiter
Company Role: Mission Specialist
Competition Role: Tether Tender

Jacob, 18, has been working with ROVs for 4 years now. He enjoys outdoor sports and mechanics, and is currently taking classes at Skagit Valley College. He is very fortunate to have his dad (a mechanic) as one of the team's mentors.

Zachary Placzek
Company Role: Research and Development, Public Relations
Competition Role: Sensor Operator

Zachary is enjoying his first year in Sea-Tech. Recently, he participated in a Christian Speech and Debate League. Being 15, and the 2nd eldest of 9 home educated kids, he has learned to enjoy hard work. He hopes to serve God and protect his country in law enforcement.

2. Design Rationale

2.1 Mission Compatible

Endeavor is an adept ROV (Remotely Operated Vehicle) used by the company to complete a series of training exercises published by the Marine Advanced Technology Education (MATE) organization for the 2011 ROV Competition. The Endeavor corporation ingeniously fashioned each mission related instrument to efficiently complete the tasks. The tooling includes: an aluminum gripper for removing Velcro strip, collecting biological samples, and removing and inserting the “Top Kill Manifold” hose; a four-pronged, PVC, rotating claw for closing the valve wheel, a sensor to measure depth and sample the water; a pair of cameras for navigation; and a carabiner to connect and remove damaged riser pipe.

Fig. 1.1 Completing pool missions

2.2 CAD Modeling

The design team decided first model ROV Endeavor, using CAD (Computer Aided Design) because the CAD modeler can foresee any size or design related problems. This decreases the amount of time to build and develop the ROV. However, this ambition required Endeavors design team to first learn the basic functions of CAD. The company designed the aluminum side plates and the camera mounts in 2D, and then extruded them to 3D to the desired thickness. They also used CAD to determine on the volume of float needed to support the ROV. Most of the other parts used were standardized by Sea-Tech 4-H and the models stored in a digital CAD library.

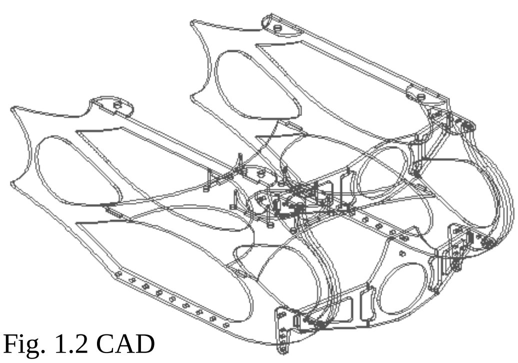


Fig. 1.2 CAD Model of aluminum framing

2.3 Mechanical Structure

The ROV that the company built last year had a series of leaks in the junction box. They were accustomed to using PVC in the past years, and thus assembled the core out of 1 1/2” PVC and fill the interior with potting compound. This core supports the frame of the ROV and serves as a mounting block to the machines 10 thrusters.

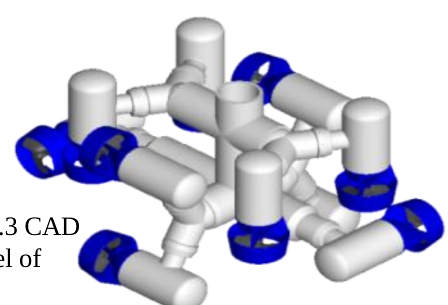


Fig 1.3 CAD Model of Core Assembly

To protect the core assembly, the company designed two identical side plates that frame the port and starboard sides. The plates were modeled in CAD by the Endeavor design team; water jetted from ¾' aluminum; welded to the rest of the frame; and anodized. (The water jetting, welding and anodizing services were kindly donated by Janicki Industries because the skills required for such tasks extended beyond the scope of training of Endeavor team members.) Two rotating cameras maximize Endeavor's field of view. Also, the manipulators are mounted to the rotating cameras assembly. The camera mount was also modeled on CAD and water jetted out of 3/16" aluminum. Then it was break formed to give it the necessary angles. The company created a stable machine by installing an over buoyant float and large weights. These were located on the bottom of the aluminum side plates to create an even-riding moment (where the float and the weight stabilize each other).

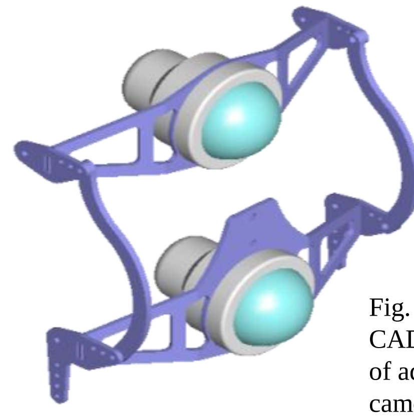


Fig. 1.4 CAD Model of adjustable camera mounts and cameras

2.4 Tooling

In order to open the valve wheel on the simulated well head, Team Endeavor made a four-pronged PVC rotating claw. This was powered by a bilge pump with 8:1 gear reduction with the intention of giving it ample torque and reducing the speed to a reasonable amount. Next, they experimented with a manipulator which was run off a bilge pump with a screw drive gear. This design had too many flaws and was scrapped because of its jamming problems. For the sake of simplicity, the company used 2 hooks to replace the flawed manipulator. After winning the regional contest, the company decided that a more reliable solution was needed. But because of time restraints, an aluminum gripper was loaned to Endeavor from last years team *Eclipse*. This gripper was intended for hydraulics, but the company not wanting to use hydraulics, modified it to meet the pneumatic requirements of 40 psi (Pounds per Square Inch). The gripper is compiled of aluminum fingers with gears and a pancake actuator with a gear for opening and closing fingers.

Fig 1.5 Rotating Claw

To measure the depth and sample the water, a Pneumo-fathometer was made using a 12" stainless steel rod connected to an air hose. This in turn, goes up the tether and connects to a depth gauge which then leads to an air pump. A Pneumo-fathometer is a way to measure depth. The operator of this sensor will flow air past the gauge, through the air hose, and down beneath the ROV until air bubbles out. Once this condition is achieved, the air pressure trapped in the hose will give a constant reading of the ROV's depth. The Pneumo-fathometer will also be used for sampling the water. Once it has finished measuring depth, its rod located on the ROV, will be inserted into the water sample site. The air flow will be reversed, sucking the water sample from its aquatic home.

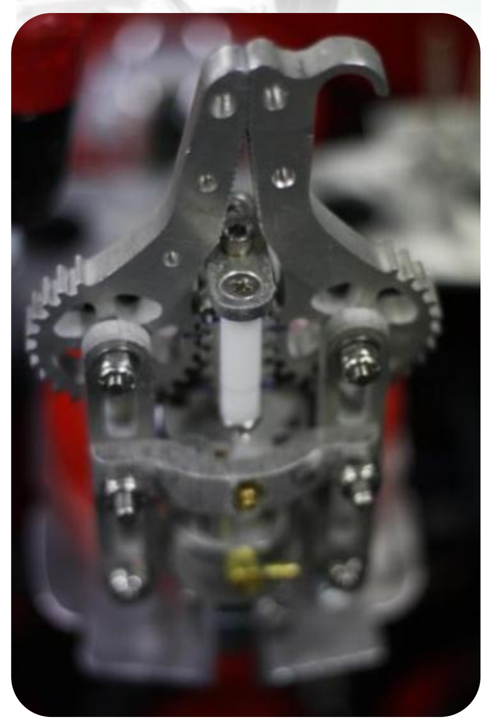


Fig. 1.6 Pneumatic gripper

Fig. 1.7 Vials for holding concentrated water sample

The Concentrated water sample will be held inside vials mounted to the ROV until a team member retrieves them. For collecting the biological samples, a cage will be transported to the pool floor. The pilot will pick up the organisms with the aluminum gripper and deposit them inside the cage for retrieval.

2.5 Propulsion Systems

Last year, the company used 8 thrusters and liked the maneuverability the ROV had. This year, they decided to take an extra step by adding another set of thrusters to its design. This caused amazing results in maneuverability. There are 4 starboard and port thrusters used to create fore and aft movement. In addition, they also added 4 vertical thrusters for up and down motion. The 2 new thrusters that were added this year were a set of side thrusters enabling the ROV to shift from side to side with ease. These have been a club standard for over 6 years. They are created from bilge pumps and protected with PVC pipe and shrouds. These were casted by the club. Each thruster unit produces 1.7 pounds of thrust at 2.5 amps of current.

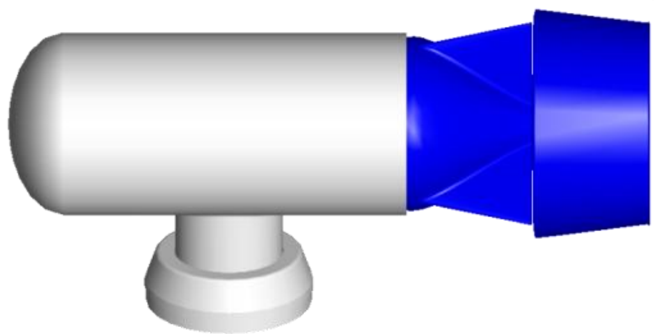


Fig. 1.8 CAD Model of modified bilge pump thruster

2.6 Cameras

In previous years, the company has had the disadvantage of having their cameras locked in one position, giving them limited options for different angles. With that in mind, two adjustable camera mounts were added. The company chose to use one Sony 120° wide angle color camera and one Sony 90° color camera. The cameras were installed inside PVC and covered by a 3" clear acrylic dome. The cameras were inserted from the back of the dome and potted to create a water tight seal. These completed camera domes were then inserted into a PVC camera housing and sealed by an O-ring. The cameras were connected to a coax cable run through the tether and powered by the 12 volts DC auxiliary power conductors in the tether. Dual cameras help with better depth perception, thus giving the company optional views of the payload tools.

Fig. 1.9 Camera behind clear acrylic dome.

2.7 Control Systems

After many leaks in last year's onboard junction box, much care was taken to prevent this from happening again. Endeavor's electrical connections and controls are not onboard the ROV, but are separately wired to a control box located on deck. The control box is a pelican case that was won by the company last year (3rd place prize).

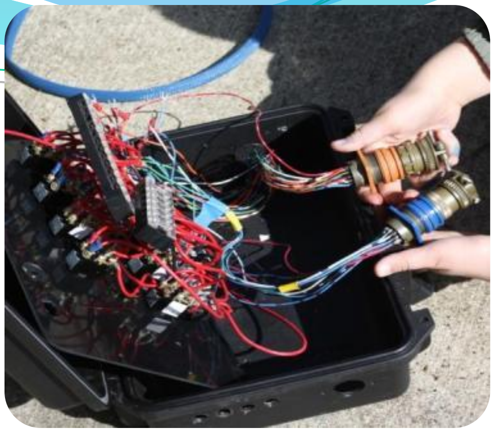


Fig. 2.1 Assembling control box

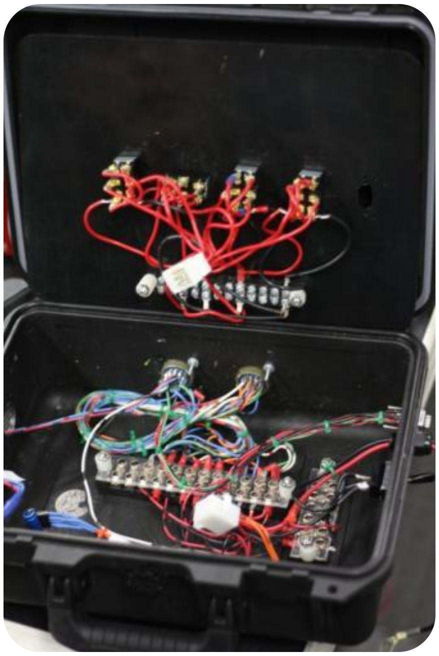
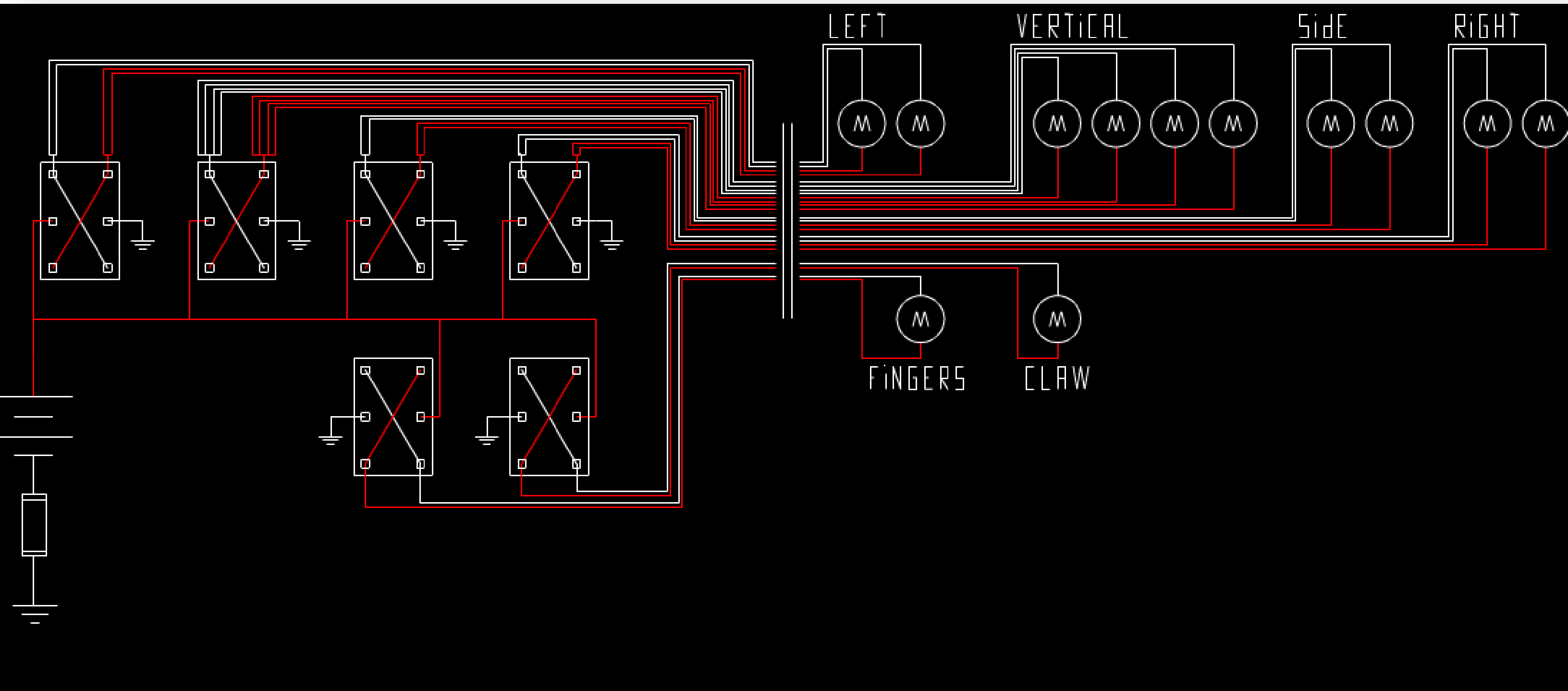


Fig. 2.2 Final Product

The control box contains a set of 3-position, double pole, double throw toggle switches that perform directional control of each thruster group: one to control the four fore-aft thrusters; one to control four up-down thrusters for vertical depth; and one to control the two lateral thrusters for side shift. These switches are connected to the thruster groups via 18 gauge power wires in the tether. The tether wiring has been configured to enable a future expansion to individually control each thruster via a programmable logic controller.

Electrical Schematic



2.8 Tether

On the company's previous ROV, a large bulky tether hindered the company's performance. This year the tether contains only twenty-six 18 gauge power wire conductors, a coax cable for cameras, three pneumatic air lines, and is shrouded in an expandable vinyl sheathing. The tether is 15 meters long and is connected to the control box via military grade 17-pin circular connector. The end of the tether connected to the ROV is inserted into the PVC core assembly and potted and sealed.

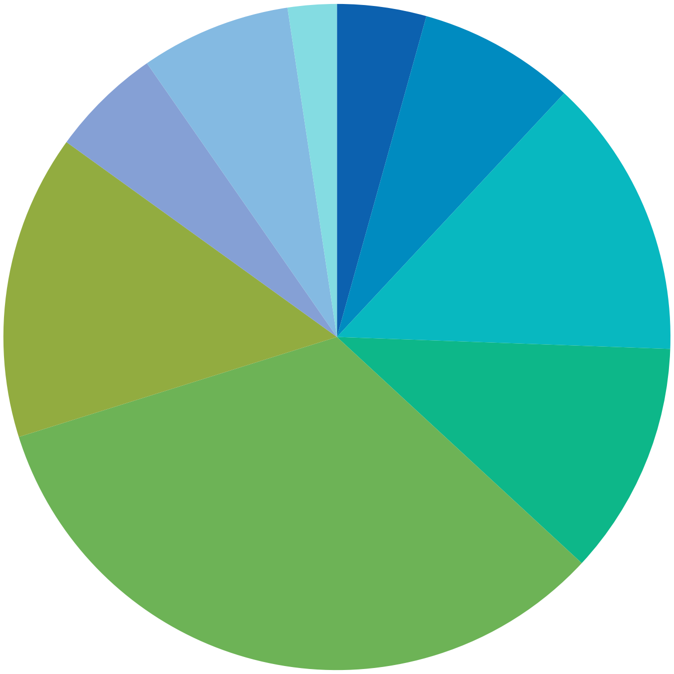
Fig 2.3 Tether without pneumatic air lines

2.9 Safety Features

Safety being important, several creative functions, designs, and labels were added; all thrusters are protected by guards and ducts, warning labels are placed near any moving parts, a safety protocol is always followed during testing of the electronics and the ROV design was made to protect thrusters from damage or doing damage to others by putting them inside of the aluminum side plates.

3. Expenditure Summary

This is a short summary of the expenses.
A more detailed expense sheet is located in the Appendix A.



Category	Purchased/Donated/ Reused/ Shared/ Made	Total
Core Assembly	Purchased/Made	$104
Camera Assembly	Purchased/Made	$183
Tether	Purchased/Reused	$328
Bouyancy	Donated	$272
Frame Assembly	Donated	$800
Propulsion	Reused/ Made	$356
Control System	Purchased/Made	$130
Mission Tools	Purchased/Reused	$175
Misc	Purchased/Made	$57
Total Cost:		$2,405

4. Deepwater Horizon Oil Disaster

At approximately 2145 hours CDT on 20 April 2010, the Deepwater Horizon drilling rig was rocked with an explosion and fire. High pressure methane gas shot up the drill column and exploded, killing 11 workers. The inferno raged for about 36 hours, at which time the crippled rig sank to the bottom of the ocean floor.

Fig. 2.4 Fighting flames aboard the Deepwater enterprise (bp.com)

Soon after the rig sank, both BP and the United States Coast Guard declared that they did not suspect that the damaged wellhead was leaking. However, on April 24, Coast Guard Rear Admiral Mary Landry stated that the wellhead was in fact leaking.

This precipitated a three-month scramble led by the best engineers and scientists in the world. They worked day and night to find a solution to cap the well, as the oil continued gushing into the ocean at an estimated rate of 53,000 barrels a day. To further complicate the situation, all the work had to be done nearly a mile below the surface of the sea. Since human divers would be crushed at this depth, engineers turned to the workhorse of the deep sea environment: Remotely Operated Vehicles (ROV).

Fig. 2.5 Bringing the blowout preventer back to New Orleans (uscoastguard.com)

In the first attempt to cap the oil well, ROV's (remotely operated vehicles) endeavored to close blowout preventer valves on the well head. When this failed, the crew placed a 125 ton containment dome over the largest of the leaks and tried to pump the oil to a storage tank on the surface. This was not successful in the end, because the cold water mixed with the gas leaking from the pipe and created methane hydrate crystals which lodged in the opening at the top of the dome, blocking flow. A third attempt was made with the top kill manifold. The intent was to pump heavy drilling fluids into the blowout preventer to plug the oil well before sealing it permanently with cement.

Fig 2.6 Top Kill Manifold (bp.com)

Fig 2.7 Control room (bp.com)

Fig 2.8 Gas being flared aboard the Drillship Enterprise (bp.com)

Next, "a riser insertion tube tool (RITT) initially collected an estimated 2,000 barrels of oil a day. [Gas brought to the surface by the riser insertion tube is flared aboard the drillship Discoverer Enterprise.]" (BP, 2011) Approximately 924,000 barrels of oil were collected this way before the pipe was removed.

By June 3, 2010, BP removed the disabled riser pipe from the blowout preventer and put on a new cap and riser pipe, which BP said caught most of the oil. The well went through several other caps and revisions until it was finally sealed with the help of a second relief well. Throughout this whole ordeal, ROV's played a vital role, preforming such tasks as monitoring, moving, and cutting. In essence, ROV's were the very hands of the scientists, engineers, and pilots who successfully capped the oil well. ROV's will have an important role in the future as together we endeavor to face the complex challenges of our ever changing world.

Fig 2.9 Deepwater Horizon Rig (nationalgeographic.com)

Fig. 3.1 Pressure testing the cement plug

(bp.com)

Fig 3.2 Rigs burn off oil and methane gas (nationalgeographic.com)

References

Text and picture credit:

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5. Mission Approach

With much practice and research, Endeavor Enterprises chose this approach to the missions, determining it to be the most efficient way to accomplish the tasks with their mission package.

#	Description	Points
1	Interpret graph to determine the correct depth at which to take sample of water.	10 points
2	Descend toward damaged riser pipe and connect carabiner to U-bolt.	30 points
3	Cut riser pipe by removing Velcro strip with aluminum hook located on gripper.	20 points
4	Lift and remove damaged riser pipe via tether connected to carabiner.	20 points
5	Remove hose line from the “top kill manifold” using aluminum gripper.	20 points
6	Insert “top kill” hose into wellhead.	20 points
7	Turn valve wheel to stop flow with four pronged rotating fingers.	60 points
8	Ascend to surface and retrieve wellhead cap and install Pnuemo-fathometer on ROV.	
9	Descend and install wellhead cap onto wellhead.	20 points
10	Continue on to sample site and measure correct depth with the Pnuemo-fathometer.	20 points
11	Insert tube into sample site and draw concentrated fluid into containers located on ROV.	20 points
12	Collect biological samples with gripper and insert into ROV’s organism basket.	15 points
13	Ascend to surface with max amount of water sample and organisms.	10 points
14	Submit samples to judges.	35 points
	Total Points	300 points

7. Challenges & Troubleshooting Techniques

"Houston, we have a problem!" Just as Apollo13 had to work together to troubleshoot on the fly, Endeavor Enterprises has had to do the same. This section is for some of the problems that we came across and how the company worked together to deal with those hurdles. Troubleshooting is a process. Here is a brief troubleshooting guide that Endeavor Enterprises followed:

1.Diagnosis problem 2.List potential sources 3.Narrow down sources 4.Repair or replace 5.Test.

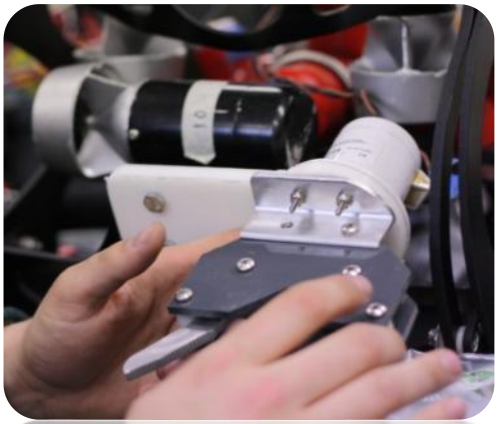


Fig. 3.3 Troubleshooting electrical gripper

***Claw failure*:** Initially, the company wanted to have an entirely electrical powered ROV. An electrical ROV, producing a smaller tether and produces a more maneuverable ROV. Thus the original manipulator used an electric claw out of a modified bilge pump motor with a screw drive. As we tested the gripper a complication arose. The claw would constantly jam whenever it was operated. To troubleshoot this problem and find a solution the company had to go through the process of elimination to determine the cause of failure. They knew from the beginning that bilge pump motors have a very high rpm speed but comparatively low torque so the corporation concluded that the motor spun so fast that it would jam whenever it opened, closed, or grabbed something. Since the motor lacked the torque to free itself, they tried to fix the problem by adding a capacitor which would give the motor a "boost" at startup. It helped somewhat, but not enough to make it fully reliable for use. The regional competition was fast approaching so we decided that Endeavor Enterprises would use the tool that got our company third at regionals last year: Hooks. They bent a couple pieces of threaded rod that we had in stock, and situated them so that they could fulfill their intended missions. At this point the company encountered another obstacle. The hooks could not pick up the biological organisms or mission props that were dropped.

Pneumatic Claw: In order to have a pneumatic claw we decided to run two more air hoses down the tether. We borrowed a spare claw from a previous Sea-Tech ROV. In doing so, we now have the ability to complete the missions with less chance of dropping something.

Sampler Vials: The corporation had to correct another design problem that came across at the regionals. Our two sample vials were not big enough to collect the entire water sample. They had collected about 50-65 milliliters (1/2) of the needed amount. (100 milliliters). Two more vials were made and another aluminum mounting bracket. Endeavor Enterprises now has a working manipulator, enough water samplers, and still maintains maneuverability.

6. Future Improvements

The ROV was designed so that, in the future, Endeavor Enterprises can adjust it for new mission packages. This enables the company to use the ROV year after year. The float was designed so that the machine was positively buoyant and weights were installed so that the buoyancy factor is adaptable for changes in payload tooling. An actuator can be installed in the camera assembly to rotate the cameras and claw vertically, as a single adhesive unit. Lastly, the company designed and wired the thrusters individually all the way up the tether and paired them in the control box. This enables Endeavor Enterprises to install a PLC (Programmer Logic Controller) into the control system. Then the ROV could "fly" through the water and give it the ability to pitch, roll yaw, etc.

7. Lessons Learned

One of the important lessons that Endeavor Enterprises learned was, do it once, do it right. In the process of compiling the control box the company overlooked possible safety hazards. Due to lack of time, we rushed through the process. This resulted in a precarious situation with unsecured terminal strips and wires with opposing polarity in close proximity, which caused a fuse to blow during pool practice. The company rewired the entire control box and secured all terminal strips and wires. Lesson learned: never overlook a seemingly simple safety issue- it might just mean missing the opportunity to compete.

Teamwork is necessary to accomplish any task. The company developed a bond, and solved problems as a group. When complications arose, they were resolved through patience and friendship. One such complication that occurred, was not communicating about certain tasks. This led to some co-workers of the corporation wondering if the member(s) was actually completing the assignment. This was resolved by extra communication and creating a company schedule.

8. Reflections

2010-2011 has been a good year. Endeavor Enterprises has enjoyed all of the experiences from competing in the 2011 MATE ROV competition. The company has been challenged in many skills such as CAD modeling, operating specialized sensors to measure depth and collect concentrated water samples. In addition, they have learned much more about the Deep Horizon Oil Spill, and how ROV's were used to contain its leak.

Through hard work, perseverance and long hours, Endeavor Enterprises has accomplished the challenge of designing, building and entering this year's international ROV competition. The company would like to thank the MATE organization for putting on this competition which has forced them to think outside the box, create new designs and tools to accomplish the mission tasks set before them.

9. Teamwork

This year Endeavor Enterprises is trying to function as much like a company as possible with members filling the roles of CEO, (Chief Executive Officer) CFO, (Chief Financial Officer) GRA (Government Regulatory and Affairs) and R&D. (Research and Development) All the company members have put in around eight hundred hours on the ROV, reports, posters, and modeling. The CEO delegated certain tasks to individuals whose area of expertise was involved. Dean Jones is in charge of the control box, electrical layout, and creating the wiring diagram. Matthew worked on the development schedule and was the main formatter of the poster layout. Joshua, Matthew and Zachary were the main formatters and writers of the technical report. The whole company reviewed and edited the report. Joshua, along with the companies input, designed the ROV on CAD before the actual ROV was built. Throughout this whole process, the entire team learned to delegate tasks and get the job done together and on time.

Fig. 3.4 Josh and Dean working on the ROV

10. Acknowledgements

The Company would like to thank the following people for their support in building this ROV.
Thank you to **Jesus Christ**- the Creator of all things, because of Him we endeavor.
Mr. Lee McNeil - We would like to specifically thank Mr. McNeil for all his advice, tools, garage and his support. Without him, the entire team would never had the chance to learn about the sciences. **Janicki Industries** - Janicki Industries donated the aluminum, water jetting, anodizing, and the float material. Thank you! **Mr. Rick Hamiter** - He was always encouraging and keeping us moving. **Mr. Joe Theiman** – Joe, a ten year Sea-Tech veteran, mentored our electrician, and showed us all new things. Thanks! **Mrs. McNeil** - For letting us take over her garage for the last 9 months. **Our Parents and families** - They allowed us to live and breathe Sea-Tech for the last year. They drove us around and were very supportive. We can't thank them enough. **MATE** - For hosting this competition in order to actively teach students engineering, by allowing them to put their knowledge to work. **Fullquiver Enterprises** – Thank you for your kind donation to the club! **Stanley Janicki-** He was always there ready to answer any of our questions whenever we needed help. **Jacque McNeil-** Thank you for proof reading our Technical Report and giving us tips how to write.

Appendix A

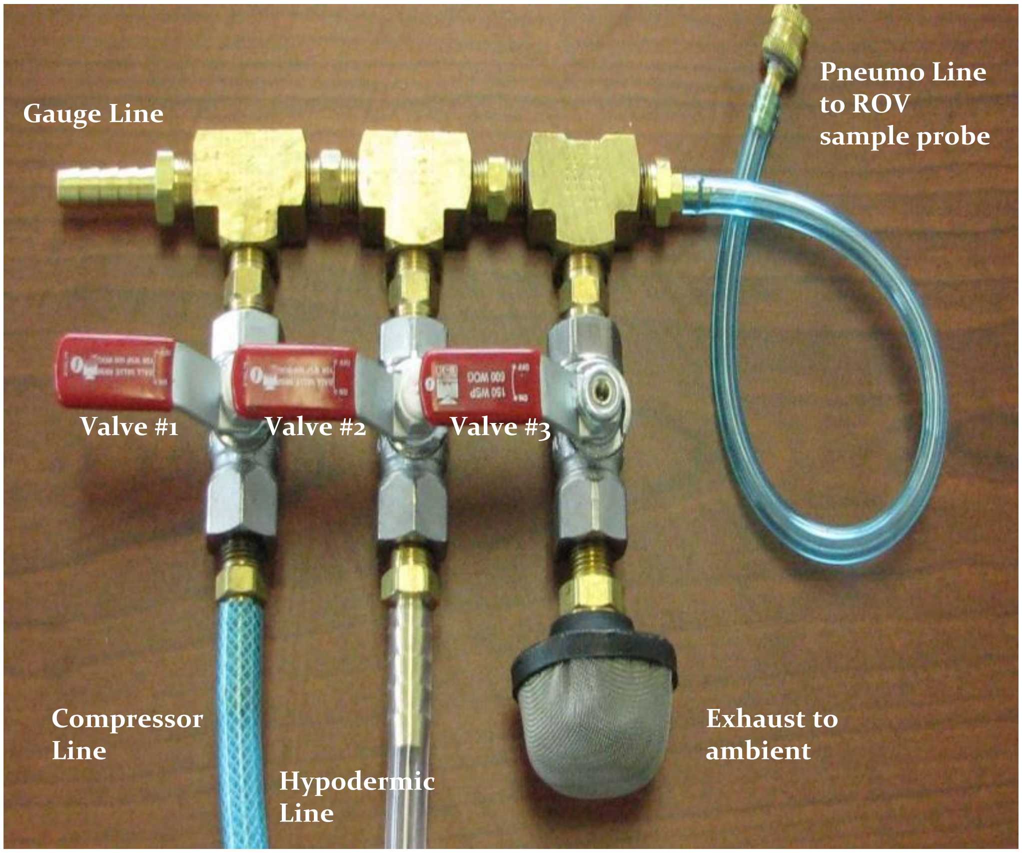
		Expenses Report	Year: 2011		
	Qty:	Item Description:	Source:	Cost:	Total:
Core Assembly					
	4	U-bolt: 8896T129	McMaster-Carr	$4.64	$18.56
	2	1.5" spigot x 1" slip true wye PVC fitting	Flex PVC.com	$6.37	$12.74
	2	1.5" slip x 1" slip true wye PVC fitting	Flex PVC.com	$7.78	$15.56
	1	1.5" slip 5-way side outlet tee PVC fitting	Flex PVC.com	$6.70	$6.70
	6	1.5" slip x 1" slip reducing bell PVC fitting	Flex PVC.com	$1.78	$10.68
	1	1.5" slip cross PVC fitting	Home Depot	$2.25	$2.25
	1	1.5" spigot x 3/4" FIPT reducer bushing PVC fitting	Lowes	$1.69	$1.69
	10	1" spigot x 1/2" slip reducer bushing PVC fitting	Home Depot	$0.39	$3.90
	10	1/2" slip o-ring union PVC fitting	Sea-Tech 4-H	$3.25	$32.50
				Total	$104.58
Aluminum Frame					
	1	Frame Side Plate: 3/16" alum	Janicki Industries		
	1	Frame Top Plates: 3/16" alum	Janicki Industries		
	1	Frame Seat Plate: 3/16" alum	Janicki Industries		
	1	Frame Saddles: 3/16 alum	Janicki Industries		
	1	Frame Cam UPR Plt: 3/16" alum	Janicki Industries		
	1	Frame Cam LWR Plt: 3/16" alum	Janicki Industries		
	1	Frame UPR C-Pivot: 3/16" alum	Janicki Industries		
	1	Frame LWR C-Pivot: 3/16" alum	Janicki Industries		
	1	Frame Camera Link: 1/4" alum	Janicki Industries		
	1	All Water-jetted parts	Janicki Industries	$700.00	$700.00
	1	Anodized Aluminum Finish	Production Plating	$100.00	$100.00
				Total	$800.00
Propulsion					
	1	Thruster: FWD RH UP	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: FWD RH DWN	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: FWD LH UP	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: FWD LH DWN	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: VERT RH FWD	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: VERT LH FWD	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: VERT RH AFT	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: VERT LH AFT	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: SIDE FWD	Sea-Tech 4-H	$30.00	$30.00
	1	Thruster: SIDE AFT	Sea-Tech 4-H	$30.00	$30.00
	10	Core: Thrust Connectors	Sea-Tech 4-H	$5.60	$56.00
				Total	$356.00
Forward Camera Assy					
	1	Aluminum mounting plate	Sea-Tech 4-H	$2.00	$2.00
	1	Sony 1/4" CCD color camera; 120° FOV	Super Circuits	$69.99	$69.99
	1	Sony 1/4" CCD color camera; 90° FOV	Super Circuits	$39.99	$39.99
	2	3" Acrylic Compass Dome Port	Ritche Navigation	$11.00	$22.00

	2	Back Ring: .25" PVC jetted plate	Tap Plastics	$1.00	$2.00
	2	Middle Ring: .25" PVC jetted plate	Tap Plastics	$1.00	$2.00
	2	Dome Ring: .25" PVC jetted plate	Tap Plastics	$1.00	$2.00
	2	3"- 2.5" PVC reducer bushing	Lasco	$3.25	$6.50
	2	2.5" PVC pipe sleeve	stock	$0.50	$1.00
	2	3 1/4" x 3 7/16" x 3/32" buna-N o-ring: AS568A-152 N70 ($8.33 / 50 pcs.)	McMaster-Carr	$0.17	$0.34
	2	Camera Plug: 3" dia x 2.38" Type I grey PVC bar ($18.64 / ln. ft.)	McMaster-Carr	$3.73	$7.46
	2	2-3/8" x 2-3/4" x 3/16" silicon o-ring: AS568A-332 S70 ($9.04 / 10 pcs.)	McMaster-Carr	$0.94	$1.88
	2	Plug Cap: 1/8" PVC jetted plate	Tap Plastics	$0.50	$1.00
	8	#2-56 x 1.0 18-8SS hex socket head cap screw: ($5.57 / 50 pcs.)	McMaster-Carr	$0.11	$0.88
	8	#2 Spacer .183 OD x .090" I.D. x .38 long black nylon: ($8.76 / 100 pcs.)	Grainger	$0.09	$0.70
	2	Coaxial BNC bulkhead connector: Amphenol 31-102	Allied Electronics	$6.09	$12.18
	2	Miniature Power Jack: Switchcraft #L722A	Allied Electronics	$4.38	$8.76
	2	Sea-Life Desicator capsule: Moisture Muncher	Diver's Supply	$0.95	$1.90
	1	1/8" NPT brass square head pipe plug	McMaster-Carr	$0.62	$0.62
				Total	$183.20
Tether					
	50	Tether sheathing	HeatShrink.com	$0.99	$49.50
	54	Wire conductors in tether	Sea-Tech 4-H	$2.99	$161.46
	1	Coax Cable in tether	Skagit Whatcom Electronics	$17.95	$17.95
	2	Tether Connectors	Janicki Industries	$50.00	$100.00
				Total	$328.91
Buoyancy					
	2	Stainless Steel Rods for weights	Online Metals	$24.00	$48.00
	4	Bolts and nuts for weights	Ace Hardware	$4.50	$18.00
	2	Aluminum Square Tubing for weights	Online Metals	$3.00	$6.00
	1	High Density Foam	Janicki Industries	$200.00	$200.00
				Total	$272.00
Rotating Claw					
	1	Bilge Pump	Ace Hardware	$15.49	$15.49
	1	Brass Bolt	Ace Hardware	$1.50	$1.50
	2	Brass Washers	Ace Hardware	$0.15	$0.30
	5	Brass Nuts	Ace Hardware	$0.35	$1.75
	2	1/4"-20UNC x 12" Threaded Rod	Lowe's	$1.00	$2.00
	1	1/4"-20UNC x 24" Threaded	Lowe's	$2.00	$2.00
	8	1/4"-20UNC hex nut	Lowe's	$0.10	$0.80
	2	Plastic Gears	Jameco	$3.99	$7.98
	4	1/2" PVC elbows	Lowe's	$0.49	$1.96
	1	1/2" PVC cross joint	Lowe's	$0.69	$0.69
	4	1/2" PVC end caps	Lowe's	$0.79	$3.16
	1	Hose Clamp	Lowe's	$1.29	$1.29
				Total	$38.92

Handles					
	4	Aluminum Handle Brackets	Sea-Tech 4-H	$1.00	$4.00
	4	1/4"-20UNC x 4" hex socket head cap screw SS	Ace Hardware	$3.50	$14.00
	8	1/4"-20UNC hex lock nut SS	Ace Hardware	$0.59	$4.72
	4	1/4" fender washer	Ace Hardware	$0.40	$1.60
	2	PVC Handles	Sea-Tech 4-H	$0.50	$1.00
	4	PVC end caps	Lowe's	$0.79	$3.16
				Total	$28.48
Pneumo-fathometer					
	1	0.25" OD x 12" Stainless Steel Tubing	Swagelok	$1.00	$1.00
	2	Pneumatic filter housing	Home Depot	$12.99	$25.98
	3	1/8"NPT x 1/4" hose barb	Ace Hardware	$1.79	$5.37
	1	1/8"NPT hex nipple	Ace Hardware	$2.99	$2.99
	1	1/8"NPT x 5-port manifold	Ace Hardware	$10.99	$10.99
	1	Marinating hypodermic needle	Resturante Wholesale	$15.99	$15.99
	1	1/8" NPT brass needle valve	Ace Hardware	$14.99	$14.99
	3	1/8" NPT SS ball valve	Ace Hardware	$9.99	$29.97
	1	1/4" OD x 1/8" ID x 54' urethane tubing	Airtronics	$19.95	$19.95
				Total	$127.23
Control System					
	6	double pole double throw toggle switches	Rick Hamiter	$7.99	$47.94
	1	Control Box: Pelican 1450NF Protector Case - OD Green - No Foam	Pelican	$79.03	$79.03
				Total	$126.97
Biological Sampler					
	1	Crab Bait Cage	Camano Marine	$10.67	$10.67
				Total	$10.67
Miscellaneous					
	5	Krylon paint	Ace Hardware	$4.59	$22.95
	1	4" Carabineer	Sportsman's Warehouse	$6.95	$6.95
				Total	$29.90
			Total Cost of ROV:	$2,406.86	
			Fair Market Value of Donated Parts	$1,000.00	
			Amount Bought	$849.90	
			Sea-Tech Stock	$556.96	

Appendix B

Pneumo-Sampler Instructions



At Poolside After Task:

1. To remove sample, place cup under sample probe and open ball valve #1 to collect red CDOM.
2. Close ball valve #1 when air comes out.
3. Remove vials and add trapped fluid to cup.

During Mission Task:

Before starting Task #3 open ball valve #1.
Position sample probe at correct location, and shut ball valve #1.
Record pressure gauge in inches of Mercury, (in.Hg), and hand to mission commander.
Insert sample probe into bucket with all valves closed.
Open ball valve #3 to ambient for 10 seconds.
Close ball valve #3 and open ball valve #2.
Draw hypodermic back all the way and close ball valve #2.

Mission commander will take recorded depth reading and subtract ambient reading then multiply by 0.3443523594

(________________________ - _________________________) x 0.3443523594 = ________________ meters of depth

(Record pressure in.Hg(60F) (Ambient pressure in.Hg(60F) **(Report value to judge in meters)**