ENGINEERING REPORT

Monterey Peninsula College Robotics Team
Monterey, California 93940

PERFORMED BY:
ROV ADVANCED TECHNOLOGIES, INC
MONTEREY, CALIFORNIA 93940
https://www.facebook.com/pages/getting_started?page_id=367903543267698#!/pages/ROV-Advanced-Technologies-Inc/367903543267698

QUALITY DESIGN & TESTING OF REMOTELY OPERATED VEHICLES AND THEIR USES IN RELATION TO SHIPWRECK SITE EVALUATION AND RECOVERY TASKS

PROJECT: FL621

POCs: Ross Williams, President; Chris Pilland, CEO; Rachel Gaines, CFO; Lisa Rike, CIO; Thomas Smith, Design Engineer
Mentor: Jeremy Hertzberg

MATE CENTER May 22, 2012

Monterey Peninsula College
980 Fremont Street
Monterey, California 93940

Re: Quality design & testing of ROVs and their uses in relation to shipwreck site evaluation and recovery tasks

Attention: Matthew Gardner,

Enclosed is the engineering report detailing the project that we recently completed at the Monterey Peninsula College Robotics Team, Monterey, California, 93940. ROV Advanced Technologies, Inc. (RAT) is a full service independent testing company and appreciates the opportunity to provide you system design, inspection, quality testing and engineering support services.

Our mission is to provide an independent technical service to enhance the safety, reliability and efficiency of underwater robotics in relation to shipwreck recovery.

Thank you for the opportunity to provide this service. Please contact us if you have any questions or wish to know more about our services.

Respectfully Submitted,

Thomas Smith
Design Engineer

CC: Mr. Ross Williams, RAT President
CC: Ms. Jill Zande, ROV Competition Coordinator
CC: Mr. Jeremy Hertzbert, MPC Robotics Team Mentor

TEAM MEMBERS

Ross Williams – President/Tether Manager

With five years experience building ROVs at MPC, Ross is a task-oriented leader with schedule efficiency as his top priority. Proficient with electronics, he created the detailed, tidy electronics systems for the entire ROV. He is currently studying Marine Science Technology at MPC.

Chris Piland – CEO/Missions Commander

Chris has participated as a member of MPC's ROV team for three years. He has played a leading role in the design of the ROV systems all three years. Chris is studying to become an Aeronautical Engineer.

Rachel Gaines – CFO/Mission Specialist

Rachel joined the ROV club last year to learn specific and technical knowledge of ROVs as she works towards a marine based career. She has spent the last few years doing wild land firefighting. She has learned a fair amount from the ROV club thus far and looks forward to participating in the competition!

Lisa Rike – CIO

Lisa is a Mathematics student and a mentor for a high school (MAOS) robotics team. She has been either a team member or mentor in robotics for nearly seven years. Lisa has spearheaded the technical report and poster for MPC Robotics for the last three years, placing third at the 2011 International MATE ROV Competition for her spectacular poster design.

Thomas Smith, – Design Engineer/Pilot

This is Thom's second year on MPCs ROV team; although he has competed before in Ranger level competitions. He has aided in both the design and the construction of the ROV. He joined the team because he hopes to one day work and pilot ROVs. Meanwhile, he is finishing up his Marine Science degree at MPC

ACKNOWLEDGEMENTS

Entering into the MATE Centers International ROV competition, we realized from the beginning that the road wasn't going to be cheap, and definitely not easy. We took it upon ourselves to reach out into the community, and see who would be willing to lend a helping hand, receiving more than a few large donations, and many smaller ones. We would also like to thank our mentor, Jeremy Hertzberg, for all of his help and time in assisting us in our endeavor. We would also like to send an additional thank you to Dr. Kevin Raskoff for acting as our assistant mentor.

The Associated Students of Monterey Peninsula College for funding all of the various side projects that has allowed our ROV, *Barreleye*, to take flight. $1,000

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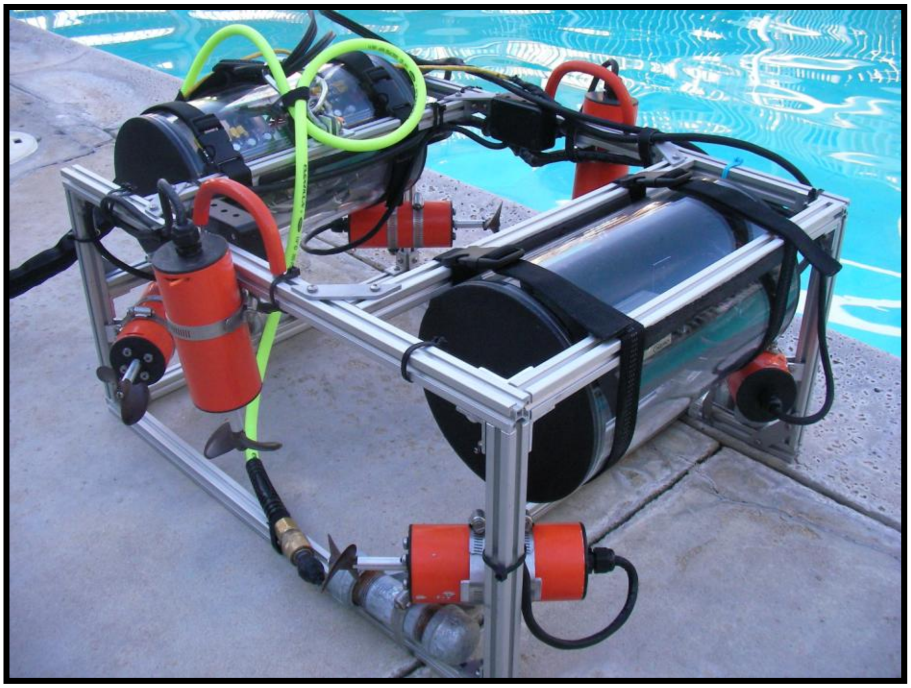

Figure 1: Photo of ROV *Barreleye*

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SECTION 1 - ABSTRACT

SCOPE:
On December 15, 2011, Marine Advanced Technology Education (MATE) Center issued a challenge for teams to build an ROV for the 2012 international competition. The theme highlights the role ROVs played in the evaluation of World War II shipwrecks and the potentially hazardous material the they may still contain. Assessing the condition of these shipwrecks and determining what to do with any hazardous materials on board is a very real world challenge and this year's competition has the toughest mission requirement seen in the last eleven years.

RAT, Inc. will be providing the ROV to assist MATE with their mission requirements. Detailed notes and observations were documented during the execution of this project and are contained in the support data, test data, and recommendation section of this engineering report. This summary contains data for the completed systems.

PURPOSE:
The pupose of this design is to provide assistance relative to the evaluation and recovery of shipwreck debris located in Orlando, Florida. This report is intended to assist you in planning for future systems by providing innovative electrical systems, showing the safety of underwater power systems through inspections and provide recommendations for future equipment usage at other shipwreck sites. It is not intended to imply that other equipment issues or recommendations not covered in this scope may or may not exist at the time of the recommendation.

PROCEDURE:
All designs and recommendations are performed in accordance the MATE's Design & Building Specifications and Competition Rules.

INSPECTIONS:
The ROV equipment associated with MPC Robotics team was inspected before, during, and after all design updates and implementations according to the RAT, Inc. practices, appropriate sizing, and cleanliness. Equipment inspections include the grounding system and requirements for additional fuses to be embedded in the electrical system for safety.

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SECTION 2 – SYSTEMS DATA

ROV FRAME:

The main structural components of MPC's ROV, *Barreleye,* were made up of 80/20 20 SERIES 20mm x 20mm T-SLOTTED ALUMINUM EXTRUSION. This is strong, adjustable, modular framing material that can be assembled with simple hand tools. This is a perfect solution for customer machine frames like an ROV, giving it a professional look while still being useful. Vilfredo Pareto (1843 - 1923), an Italian economist, said that 80% of your results come from 20% of your efforts. That is how 80/20 aluminum framing works. Pretty much all of the tools are easily attached to this slotted aluminum frame.

Figure 2: Cross view of T-Slotted Aluminum Extrusion

Figure 4: ROV Frame braces

As you can see by Figure 3, the pieces are easily screwed together by placing a square nut in the slot of the aluminum framing and screwing a screw through that nut. Each corner is reinforced with both a hand-tooled L-Shaped brace and a hand-tooled flat, angular brace. The size of *Barreleye* is 60cm x 50cm x 30cm. This size was chosen to allow for sufficient spacing for any additional payload tools. By attaching several cross pieces, we were also able to create a cradle for the electronics housings which will be discussed later in this report. For the safety of the crew members that will be taking the ROV in and out of the water, two handles were also bolted into the frame.

Figure 3: ROV Handles

HOUSINGS/CAMERA:

In an effort to reduce the size of our tether, we chose to place a large portion of our electronics underwater. To do this, we had to design a waterproof housing to keep those electronics dry while keeping it within a certain size to prevent throwing off our buoyancy. We needed a housing that wasn't going to be an enormous weight or an enormous float on our

ROV. With an 18cm diameter acrylic tube that was provided to us from Monterey Bay Aquarium Research Institute (MBARI), we calculated that we needed two 30cm long canisters to use as our "watertight cylinders."

The front cylinder houses a GoPro HD Helmet Hero camera modified to work with a Universal Serial Bus (USB) charging cable through a Resistor Capacitor (RC) Battery Elimination Circuit (BEC), running at 5V. The camera was removed from its waterproof housing to allow for more clearance inside the watertight cylinder. A software update was loaded into the camera to allow for live feed during the operation of the ROV. The camera is attached with Velcro to a black piece of high density polyethylene board, to allow for easy removal and troubleshooting. The viewing angle for the camera is 170º, industry's widest angle, which allows for a very well developed view of where the ROV is going and whatever tool it may be using at any given time. A standard sized Servo is attached to the back side of this board and is used to rotate the camera. Its 360º rotation allows us to alleviate the need for multiple cameras. To run the Servo, we are using Lynxmotion SSC-32 Serial Servo Controller and a 6V RC BEC. We chose this controller for the motion control that allows either an immediate response, speed controlled timed motion, or a combination. This controller allows for some extremely smooth moves in the water.

Figure 5: GoPro Camera

Figure 6: SSC-32 Servo Controller

The rear cylinder houses three Sabertooth 2x50 High Voltage (HV) Dual Motor Speed Controllers. Each of these controllers will be used to power two Anaheim Automation Motors. These controllers are suitable for up to 120lb robots and can supply two Direct Current (DC) brush motors with up to 50A each and has a voltage range of 12-48V. The rear cylinder also houses a Castle Creations BEC Pro Voltage Regulator. This allows us to drop the higher voltage for the motors to a voltage level that is suitable for receivers and servos. A power cable runs from the back canister to the front canister via ten pin SubConn connectors. This will be used to power the tool sled and the SSC-32 Servo Controller.

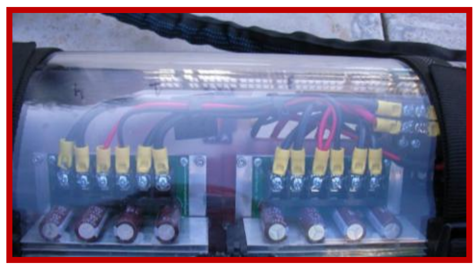


Figure 7: Dual Motor Speed Controllers

Figure 8: DC Motor

THRUSTERS:

Figure 9: Completed thruster

For thrusters, we chose six Brush DC motors from Anaheim Automation, Inc. These can run from 10.0 to 30.0 VDC with a shaft speed of 5450rmp. The cylindrical body is 8.5cm long and has a diameter of 5.2cm. By borrowing equipment at a local business, we were able to design watertight housing for these motors. O-rings are used to seal each connection. Octura Propellers are attached via our hand-tooled connectors. Each thruster is then anchored into position by using metal straps to hook into hand-tooled L-Shaped connectors that slide right into our modular frame.

TETHER:

Figure 10: Tether

To keep our tether from tangling, we store it in a RubberMaid plastic bin. The tether consists of two separate 30m cables encased in 2" tubular webbing. One cable is Quabbin DataMax 6e 600mhz Enhanced Patch Cord. It has a temperature rating of 75^{o}C and a voltage rating of 300V. This cable is used for connecting our computer on dry land to our two servo control boards located in the underwater cylinders. The second cable is Cerrowire 12-Gauge 2-Conductor Low Voltage Landscape Wire. This wire is rated up to 150V and has a jacket made of Polyvinyl Chloride (PVC) and is suitable for temperatures between -20^{o}C and 60^{o}C. This cord is for operating the main power of our vehicle by connecting it to a 48 nominal power supply. Between this cable and the MATE provided power supply is a hand built fuse box with an emergency kill switch. Inside this nifty box is a large diode to prevent electronics from frying due to reversed polarity. The power is also wired into a shunt to allow us to check overall current draw of the vehicle. This system will be used as a preventative measure; keeping the safety of all area personnel in mind.

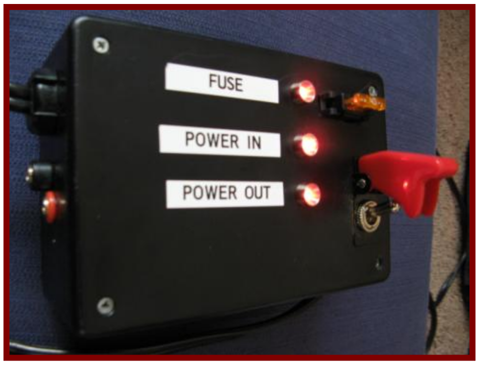


Figure 11: Emergency Shut-off Switch

LIGHTS:

Figure 12: L&M Sunray Light System

The sonar system will be simulated using two Light and Motion Sunray 2000x Video Light Systems. This is a light system designed for underwater photography/videography. These video lights are bright, rugged lights. The 2000 lumen system puts out an 85^{o} flood pattern and operates at 6000-6500 Color temperature (Kelvin). We have modified the wiring of this light system by removing the battery pack and soldering the lights into a SubConn Connector. This connector is then attached to the bulkhead in the front cylinder. The lights are attached to the top, front sections of the ROV. Testing of these lights have proven them to be amazing, especially in low-light underwater conditions.

Quality Design & Testing of ROVs in Relation to Shipwreck Site Evaluation and Recovery Tasks

SECTION 3 – DESIGN DATA

TASK 1 – SURVEY THE SHIPWRECK:

There are several steps involved in surveying the shipwreck. First, the length of the wreck must be measured. A tape measure is attached to *Barreleye* for measuring the length of the ship. An over the door hook is connected at the start of the tape measure to latch onto the starting edge of the ship. This hook is attached with an offset calculated to allow for accurate measuring in spite of sag in the measuring device in the water. Once we measure the length of the wreck, we must determine the orientation of the ship on the seafloor. A waterproof digital compass is attached to *Barreleye's* frame for easy viewing. All the ROV has to do is hover facing the direction of measurement and take a reading from this compass. After the orientation of the ship is determined, a map must be created of the wreck site. Our trusty assistant driver will be watching the monitor and communicating with the pilot to ensure accurate information is recorded. After the map is created, we must determine if the debris piles are metal or non-metal. A magnet hanging from a flexible hose will be dangling from the ROV. As the pilot drives over each piece of debris, his assistant will note whether there is movement of the magnet towards the debris or not. Movement denotes ferrous metal while lack of movement will mean non-metallic debris is present. Finally, we must scan the shipwreck with sonar. While hovering in position, a modified Light and Motion Sunray Video Light System will be flashed on to simulate sonar. See Lights on page 11 for more details on this system. All these methods have been tested and timed to ensure accuracy and efficiency and their simplicity allows for less likelihood of system breakdowns.

Figure 13: Metric Tape Measure with hook

Figure 14: Digital Compass

Figure 15: Light for Simulated Sonar

TASK 2 – REMOVE FUEL OIL FROM THE SHIPWRECK:

The steps involved in the task of removing fuel oil from the shipwreck involve transporting and attaching a lift bag to a fallen mast. To grab the mast, *Barreleye* will use its swinging claw to secure the mast to the ROV for safe transportation up and out of the grid area. Once we have attached the lift bag, it must be inflated so the mast can be removed from the worksite. *Barreleye* is equipped with two 1.5 liter tubes held vertically in the center of *Barreleye's* frame. Each tube has the same dimensions and the same construction. The bottoms of the tubes are left open while the top are sealed with an outlet pipe (or air release pipe) connecting both tops together and being vented in the center by one valve (see figure 16). The tubes are filled with air through the side by one air line branching off at a "Y" joint to each tube. Two smaller inflatable ballast tanks were chosen instead of one large ballast tank to prevent the air from being pushed to one side causing instability in the ROV. This system works in the same way as the baffles in a car's gas tank that prevents the gas from sloshing around while driving. The claw will first clamp down on the mast and then be allowed to swing/hang from the bottom of the ROV. The ballast tubes will then be inflated with the vent valve at the top shut (with an actuator) until the entire system is positively buoyant. At this point Barreleye will use its four horizontal thrusters to position the mast and the ROV outside of the grid. Once this is achieved the ballast tubes will be vented, the system will become negatively buoyant, and *Barreleye* will release the mast once it has safely made contact with the bottom of the pool.

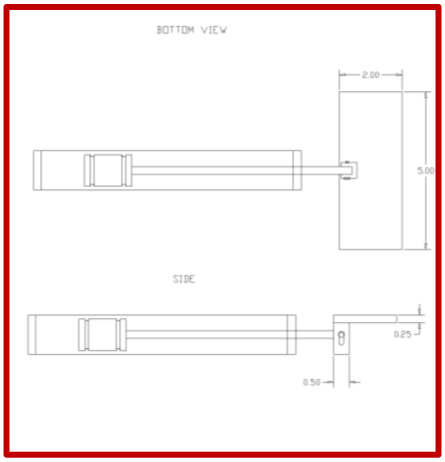


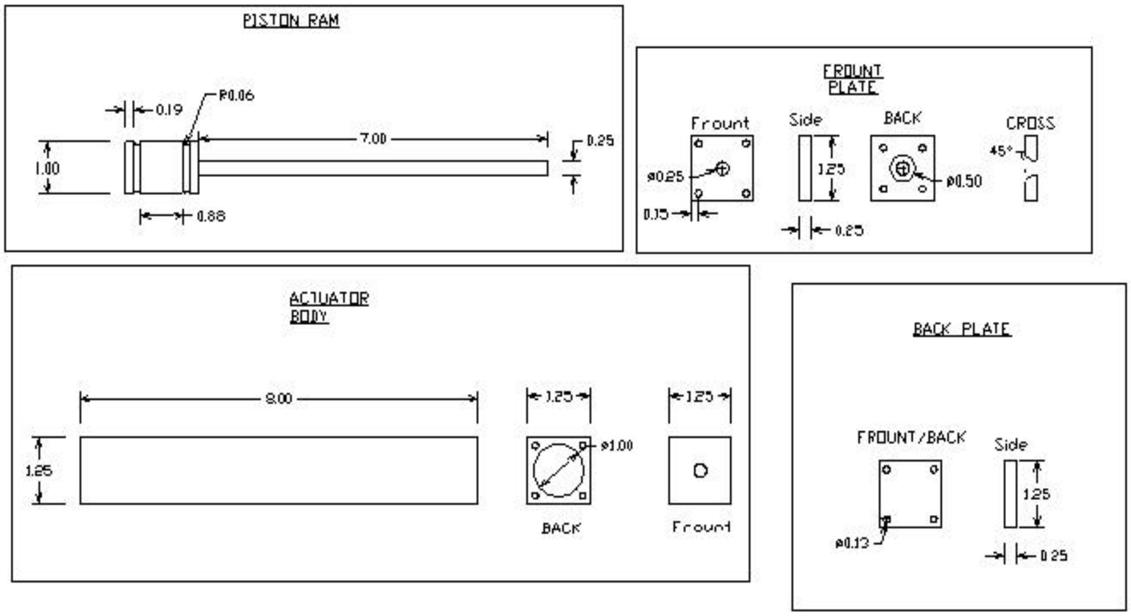
Figure 16: Drawing of Air Release Valve

Once the mast is cleared from the work site, endangered encrusting coral must be removed from the ship's hull and transplanted to a safe zone. We will be using our claw for this taks, as well. The claw consists of an actuated pincer at the end and a 360° pivot point connecting the rear of the claws arm to the ROV. The pivot point is pneumatically actuated and controls what orientation the entire arm is facing. The pivot is also located directly underneath the inflatable ballast in the center of the ROV.

Once the coral is removed, two sensors will be used to determine if fuel oil remiains inside the fuel tank. The sensor will be constructed as a two centimeter by two centimeter cube of ABS plastic. Connecting the sensor to the ROV will be a stiff spring roughly eight centimeters long. The spring will allow the ROV to be slightly askew while still allowing the sensor to make perfect contact with the target object.

If it is determined that there is fuel oil in the hull, we will drill two holes into the hull and underlying fuel tank and remove the fuel oil from within the tank and replace it with seawater. A plastic container on *Barreleye*'s tool sled will be ¾ full of simulated salt water. A tube will be coming from the bottom end going towards the oil extraction device inflow. A Pneumatic piston will push the sea water out while pulling in or extracting the oil from the fuel tank. There will be excess sea water in order to ensure all of the oil is captured during this task.

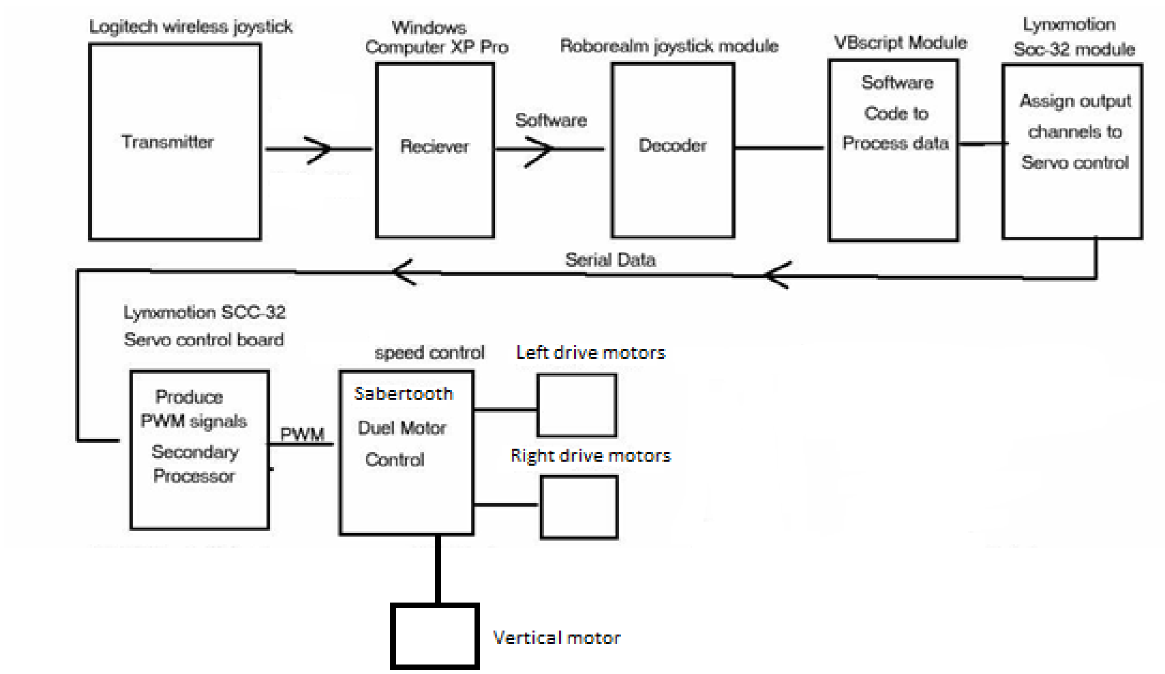
DRAWINGS:



SOFTWARE:

To control our ROV, we used RoboRealm software. RoboRealm is primarily designed for video analysis; however, we liked how it communicated with our Servo boards, such as the Lynxmotion SSC-32 that we use with our vehicle. For programming, we used a Visual Basic Script plug-in that is within the RoboRealm software. The programming was simple in that only one line of code was used to control each motor. Each line receives an input from multiple joystick axes and then combines them into a single servo signal that is sent from the SSC-32 to the motor controller. There is also a speed reducer variable that is in each line that works by dividing each joystick axis input by a number. When a "boost" button is pushed, the number of that variable drops significantly, creating a greater input and therefore a higher motor speed. This allows for slow movements and adjustments, while still keeping the power and speed of the ROV. To keep the program from sending too large of a signal to the motors, we used the RoboRealm software to create maximum and minimum limits that the board can send out. These were all set to where the output equals 24V in each direction, which is the max rated voltage of our motors.

FLOWCHART:



Logitech wireless joystick
Transmitter
Windows
Computer XP Pro
Reciever
Software
Roborealm joystick module
Decoder
VBscript Module
Software
Code to
Process data
Lynxmotion
Ssc-32 module
Assign output
channels to
Servo control
Serial Data
Lynxmotion SCC-32
Servo control board
Produce
PWM signals
Secondary
Processor
PWM
speed control
Sabertooth
Duel Motor
Control
Left drive motors
Right drive motors
Vertical motor

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SECTION 4 – SUPPORTING DATA

SHIPWRECKS:

Thousands of World War II shipwrecks pose oil spill threats. After decades of corrosion and wave action underwater, these ships could begin leaking oil. Many oil spills over the past several years were a mystery. Dozens throughout the 1990s had killed more than 50,000 seabirds and several sea otters just off the coast of California (Marshall).

Finally, in 2002, Lisa Symons and her team from Damage Assessment and Resource Protection at the National Oceanic and Atmospheric Association (NOAA) were able to pinpoint the culprit. The SS Jacob Luckenback, a freighter headed to Korea filled with supplies for the Korean War effort. This ship sank off the California coast in the summer of 1953. After spending decades resting on the ocean floor, the ship began leaking oil through corroded ventilation pipes.

Over 8,500 potentially polluting shipwrecks sit on the bottom the the sea. More than 6,300 of these are from World War II (Marshall). Now, after years of corrosion and battering currents, some may not hold their toxic cargo for much longer. Dagmar Ektin of Environmental Research Consulting in Cortland Manor, NY created an assessment in 2005 stating that "the amount of oil contained in these ships could be anywhere from 757 million to 6 billion gallons."

Cleaning up these wrecks involve tapping the compartments and pumping the oil out. Unfortunately, it can be difficult to know which compartments hold the oil after so many decades. Also, depending on the location and orientation of the wreck, it can be hard to get at them. The problems are not limited to oil. Researchers noted that some ships noxious cargo like chemicals or unexploded ordnance (Woodward). Because these ships are underwater, they tend to be out of the sight and mind of people's attention. It is important for future generations that a plan to take care of these contaminating shipwrecks is made now. This way we can ensure the continuing survival of not just marine life, but the wildlife on land affected by the cantaminants leaking out of these old ships and into our oceans.

TROUBLESHOOTING TECHNIQUES:

The most troublesome issue with this system was when the ROV functioned perfectly through dry land testing but continued to fail when in the water. In the water, the motors would all come on at one time at what appeared to be full power and the cmera would flicker and shut off when operating the vertical propellers. Since the power from the camera and the power for the propellers were being provided from different cylinders, it was difficult to find a realation between the two problems. First, we checked all wiring for possible water damage. None was found so it was resealed with heatshrink wrap. Next, the motor wiring was checked and a small amount of moisture was found in one of the motors. For this reason, all motors were opened, cleaned, resoldered, and podded with a more appropriate podding compound. Believing this was the problem and it was solved, however, before the in water test could be completed the Sidewinder died and needed to be replaced. It is now believed a failing Sidewinder could have been the initial problem. Reguardless, all motors are fully functional and leak free.

FUTURE IMPROVEMENTS:

Money is always an issue when starting out the MPC Robotics Club each year. Even though we were able to procure many donations in equipment, there was still a great need for more funding since the team wanted to step their ROV up to a higher level, this year. Now that we have a year of fundraising attempts under our belts, we feel that we have a better chance next year to get a head start on fundraising. A list has already been created of major events we can sell food items at as this was one of our best ways to bring in money quickly with minimal effort.

CHALLENGES/LESSONS LEARNED:

When upping the level and quality of robotics systems, it is even more important to study all the data sheets for purchased items. So much more time and care is needed in the research of products before making intended or desired modifications. We were often soldering and resoldering wire connections and improving waterproof techniques as we worked our way through the process of finding a strong, functional, technical solution for all of our systems.

Having all team members for this year come from last year's team really created a more cohesive group. Although there were many heated discussions on how things worked, we discovered that our discussions allowed us to troubleshoot possible issues before we even built the ROV. We learned that communication was the key to improving our systems and were pleasantly surprised when it all came together just as we engineered it. It is now the method we use when creating any changes to our ROV. Everyone discusses all possible failures and systems are put in place to prevent these failures before they even become an issue.

REFLECTIONS:

As a small unit, the MPC ROV team really learned how to be a cohesive group. The learning curve this year for each and every member was phenominal. Rachel and Lisa set up an initial timeline for getting the ROV completed that was aggressive but obtainable. With the inspiration of Thom and Chris and the motivation of Ross, progress kept moving forward. Numerous late nights where team members worked to find solutions to a system that wasn't quite ready to call perfect led to a strong knowledge in the mechanics, electronics and waterproofing processes. All members agree that each one could walk away and rebuild the whole ROV on their own with little assistance. There is no doubt this year was the most impressive year the MPC team has had in a long time.

BUDGET:

Frame / Tool Sled

item	quantity	description	mfg p/n	source	cost	total
80/20 T-slot extruded aluminum 20 series	4 at 122x2.0x2.0cm	20mm X 20mm T-slot extruded aluminum	N/A	amazon.com	$ 9.63	$ 38.50
aluminum L-brackets	92x2.54x2.54x0.32cm	aluminum 90° angle stock	N/A	home depot	$ 9.97	$ 9.97
aluminum support braces	122x2.0x0.32cm	aluminum flat stock	N/A	home depot	$ 5.72	$ 5.72
stainless steel machine screw	100	#8-32 stainless steel machine screw	N/A	Fastenal	$ 0.07	$ 6.50
stainless steel square nuts	100	#8-32 stainless steel square nuts	N/A	Fastenal	$ 0.32	$ 31.57
80/20 T-slot extruded aluminum 20 series	2 at 244x2.0x2.0cm	20mm X 20mm T-slot extruded aluminum	N/A	amazon.com	$ 17.32	$ 34.64
						$ 126.90

Water tight cylinder						
item	quantity	description	mfg p/n	source	cost	total
Water tight cylinder material	2	16.5cm ID x 17.45cm OD x 30cm clear acrylic tubing	N/A	MBARI	unknown	unknown
Water tight cylinder end-caps	60x60x1.905cm	black high density polyethylene	N/A	granger	$ 55.45	$ 55.45
stainless steel threaded rod	0.635x91.44cm	stainless steel threaded rod 0.635x91.44cm with 7.87 threads per cm	N/A	home depot	$ 5.24	$ 5.24
						$ 60.69

motors and motor housing						
item	quantity	description	mfg p/n	source	cost	total
motors	8	24v brushed DC motors	BDS-52-85-24.0V-5451	Anaheim Automation	$ 39.99	$ 319.92
motor housing cylinder	300 x 5.08cm	5.08 schedule 40 pvc pipe	N/A	home depot	$ 6.36	$ 6.36
motor housing end-caps	60x60x1.27cm	black high density polyethylene	N/A	granger	$ 36.85	$ 36.85
stainless steel machine screw	50	5mm stainless steel machine screw	N/A	Fastenal	$ 0.17	$ 8.50
o-rings	1 pack of 100	4.0x2.0mm o-rings	N/A	Fastenal	$ 10.86	$ 10.86
o-rings	4 packs of 4	#125 o-rings	N/A	Fastenal	$ 5.40	$ 21.60
locking string	12 meters	2.4mm orange universal trimmer line	N/A	home depot	$ 2.98	$ 2.98
motor housing clamps	12	#026 stainless steel hose clamps	N/A	home depot	$ 1.29	$ 15.48
shaft seals	12	6.35x12.7mm rubber u-cup o-rings	N/A	CSC of Salinas	$ 1.79	$ 21.48
propellers	8	Octora 1470 modal boat propellers	N/A	http://www.funrcboats.com	$ 2.89	$ 23.12
stainless steel set screws	6 packs of 2	#6-32 stainless steel set screws	N/A	home depot	$ 0.69	$ 4.14
IP68 cable glands with strain relief	20	PG9 IP68 cable glands with strain relief	N/A		$ 0.80	$ 16.00
o-rings for cable glands	1 pack of 100	14x2.0mmm o-rings	N/A	Fastenal	$ 10.78	$ 10.78
						$ 498.07

Tether						
item	quantity	description	mfg p/n	source	cost	total
tether cover	30 meters	black 5.08cm tubular webbing		rei.com	$ 50.00	$ 50.00
air hose	30 meters	Flexzilla Pro Air Hose 30 meters by 6.35mm	HFZP14100YW2-D	Orchard Supply Hardware	$ 60.00	$ 60.00
communication line	30 meters	cat 6 stranded 4 twisted pairs of 24 AWG	N/A	from previous years and donated by MATE	$ -	$ -
power line	30 meters	2-Gauge 2-Conductor Low Voltage Landscape Wire	N/A	home depot and from previous years	$ 30.00	$ 30.00
video line	30 meters	3-RCA Component Video Cable	N/A	amazon.com	$ 22.60	$ 22.60
						$ 162.60

item	quantity	description	mfg p/n	source	cost	total
Sabertooth 2x50HV	2	dual 50A motor speed controller	Sabertooth 2x50HV	www.dimensionengineering.com	$ 250.00	$ 500.00
Sabertooth 2x50HV	1	dual 50A motor speed controller	Sabertooth 2x50HV	www.dimensionengineering.com	$ 200.00	$ 200.00
Castle Creations BEC Pro	2	programmable voltage regulator	CC BEC Pro	www.castlecreations.com	$ 45.00	$ 90.00
Battleswitch	1	relay switch that can be toggled by servo signals	Battleswitch	www.dimensionengineering.com	$ 25.00	$ 25.00
Lynxmotion SSC-32 Servo Controller	2	serial 32 channels servo controller	SSC-32	http://www.lynxmotion.com	$ 40.00	$ 80.00
5V 5A Switching BEC	1	steps power down to 5V for camera	DYS 5V 5A Switching BEC	http://www.robotmarketplace.com	$ 13.00	$ 13.00
standard servo for camera rotation	1	Parallax (Futaba) Standard Servo modified to continuous rotation	900-00005	http://www.parallax.com	$ 13.00	$ 13.00
camera	1	GoPro HD Hero	GoPro HD Hero	one of our team members	$ 200.00	$ 200.00
lights	1set	Light and Motion Sunray 2000x underwater lighting system	Sunray 2000x	Light and Motion	$ 3,800.00	$3,800.00
camera power cable	1	micro USB charging cable	micro USB charging cable	target	$ 15.00	$ 15.00
2.5mm 4C Right Angle Plug with 30cm Cable	2	2.5mm Right Angle Plug four conductor cable	2.5mm 4C Right Angle Plug	amazon.com	$ 4.50	$ 9.00
vacuum test port	2	automotive tire valve	NTH 90226	Napa auto parts	$ 4.99	$ 9.98
						$4,954.98

total donated	$3,830.00	total recycled	$932.84	total purchased	$1,866.00	GRAND TOTAL	$6,718.84

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