2011-2012

Water Raptors Technical Report

Air Force Academy High School
Robotics Team
3630 S. Wells Street
Chicago, IL 60609

Water Raptors

Technical Report for MATE International Underwater Competition 2012

Air Force Academy High School

Position	Names
Chief Financial Officer (CFO)	Alicia Alvarez
Government & Regulatory Personnel	Dionte Collins London Westley
Research & Development (R&D) Personnel	Jessica Audina
System Engineer	George Onofre
Design Integration	Christopher Odor Jeffrey Bridges-Reed
Testing Specialists	Kevin Estrella Carlos Ortiz Christopher Odor
Operation Managers	Mario Rios Alicia Alvarez
Media Outreach Reporters	Jessica Audina Ayana Cochran
Engineers	Heidi Herrera Kity Lai JohnPaul Nelson Moshe Brown Louis Zarycki Isaiah Moore

Robotics Team 2011 - 2012
Chicago, Illinois

Abstract

To remedy the ill effects of oil and fuel contamination from a World War II shipwreck, the Water Raptors have designed a remotely operated vehicle (ROV) capable of minimizing the environmental damage. This vehicle has all of the capabilities necessary to survey the shipwreck site including measuring the length of the shipwreck, determining the orientation of the ship on the seafloor, creating a map of the shipwreck site, and determining the composition of debris piles in the vicinity of the ship. The ROV is also capable of safely relocating coral, measuring the thickness of the ship hull, and determining the content of the fuel oil tanks within the wreck.

Our ROV will non-intrusively perform this mission without negatively impacting marine wildlife and will preserve these precious World War II landmarks, as the final resting place for many, for future generations. Additionally, our vehicle will help make future decisions about managing fuel and oil waste. By caring for this natural landmark, we will also preserve this historic wreck site.

This ROV took a team of seventeen staff members, technicians, and engineers from Water Raptors Incorporated two months to build. We believe we have designed the perfect ROV. With our modular design, we can accommodate an array of different instruments and accomplish any mission tasks presented. At a cost of just over one thousand dollars per unit, this ROV will avert further unnecessary environmental damage, and, perhaps, prevent millions of dollars in potential economic damages to the coastal community.

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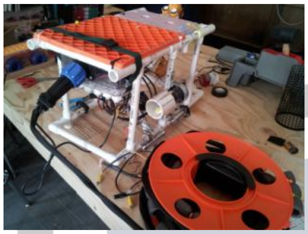
Photographs



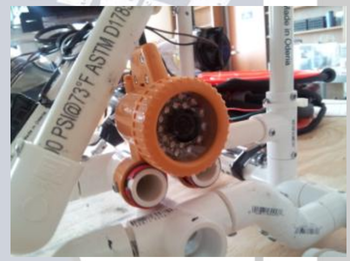
Back of the ROV

Front of ROV

Weights

Top of ROV

Downward Facing Camera



Forward Facing Driving Camera

Compass

Magnetic Detector

Otter Box

Sliding Motors

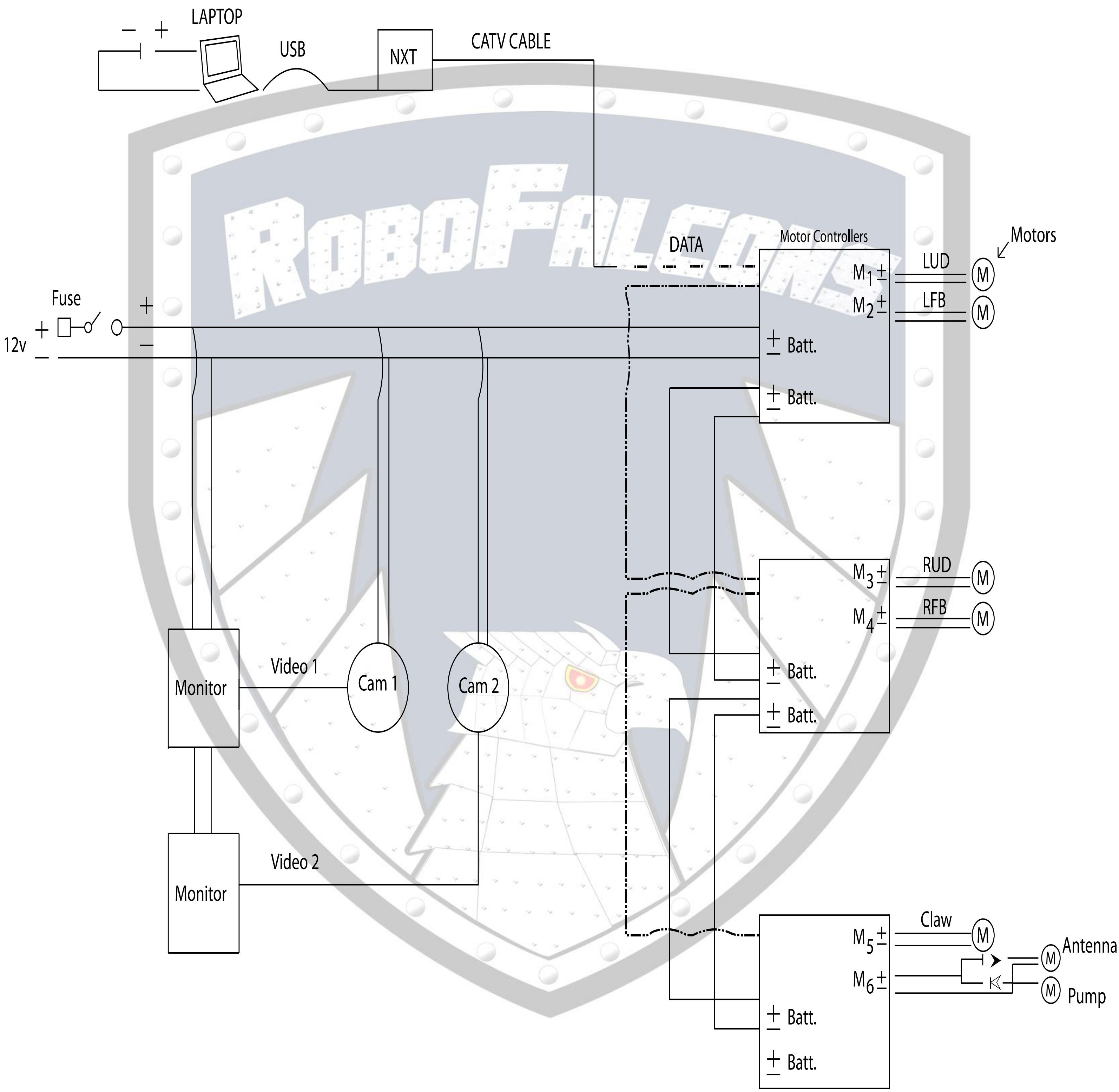
Left Front/Back Motor

Budget/Expense Sheet

Item	Item Type	Price per Unit	Quantity	Total Cost
Motors	500 pumps/hr	$23.63	2	$47.26
	1000 pumps/hr	$29.98	2	$59.96
Cameras	Underwater Fishing	$170.00	2	$340.00
Laser		$25.99	2	$51.98
Controllers		$35.27	2	$70.54
Compass		$3.79	1	$3.79
Propellers		$19.00	4	$76.00
Epoxy	Marine Epoxy	$4.99	4	$19.96
	Heavy Duty	$15.67	1	$15.67
	Super Glue	$4.87	2	$9.76
Ballast	Extruded Polystryene	$11.68	1	$11.68
Laptop	Lenovo ThinkPad	$1,000.00	1	$1,000.00
NXT		$275.00	1	$275.00
USB Cable		$5.00	1	$5.00
PVC	T-shaped	$0.51	20	$10.20
	10 x 1 Extension	$8.00	1	$8.00
	Elbow	$0.28	8	$2.24
	Male Adaptors	$0.32	14	$4.48
	Caps	$0.61	14	$8.54
	X-shaped	$0.98	5	$4.90
Claw		$20.00	1	$20.00
Vex 2 Wire Motor		$15.00	1	$15.00
Gears		$15.00	1	$15.00
Boring Bits		$40.00	1	$40.00
			Total*	**$2,114.26**

*The total cost of the ROV was calculated without tax.

Electrical Schematic



Design Rational

Structure and Form

Our primary objective in designing our ROV was to make it compact, modular, and maneuverable. The ROV was designed to be neutrally buoyant; therefore, the ballast and weights must be balanced. We designed a dual camera system so that the pilot would have a forward-looking view to make precision movements with the claw and a downward-looking view to the entire shipwreck site. The overall design of the vehicle maximizes the ability to perform precise maneuvers in tight situations. Ducting prevents entanglement.

Propulsion

Our motor setup was created to allow the ROV to glide effortlessly through the water and make hairpins turns. For vertical and sideways motion, we used two vectored thrusters placed at 45° angles to the vertical. We tested several types of bilge pump motors and propeller configurations. We came to the conclusion that two 1,000-gallon per hour motor pumps with plastic, two-bladed propellers were ideal for the vectored thrusters. We also concluded that two 500-hundred gallon per hour pumps were best for the forward, aft and pivot motors. Our 500-hundred pump motors are fitted with ducting to improve the efficiency of the motor by making it more directional. This improved the speed of the ROV forward and aft as well as in pivoting.

Controls

We piloted the vehicle with a gamepad controller connected through a USB cord to a laptop. The laptop interfaced with a Lego NXT brick controller through LabView 2010 software. Through the LabView program written by our software engineers, the NXT converted the gamepad signals into a data signal. The motor controllers used this data signal. The signal was delivered through a date cable within the ROV tether.

With our control layout, the pilot has the ability to control all four motors and two instruments through a single controller. The pilot can move vertically, horizontally, backwards, pivot left and right, to make precise adjustments when scanning the ship and operating close to the hull. The tether contained ten wires. Six were dedicated to NXT data: two for video and two for our main power. We placed these wires in a mesh cover to keep the tether thin and lightweight. Floats were added to make the tether neutrally buoyant.

We chose to use onboard motor controllers because our previous ROV models had significant voltage loss over the length of the tether. In order to fix this problem, we delivered all power to the ROV through two thick gauge wires capable of carrying a large current with lower resistance. Our ROV was designed to move swiftly and speedy. The motor controllers also allowed us to analog the controls for more precise maneuvers by our pilots.

Instruments

The magnetic compass was read through the downward looking camera to determine the orientation of the vehicle and shipwreck. The compass was placed away from the motors and the magnetic detector to minimize magnetic interference.

The dual ultrasonic thickness gauge and the neutron backscatter device were used to determine the thickness of the hull and to detect the presence of old debris and coral within the ship.

We also had a magnetic detector. It is a simple but elegant design to detect the debris. By pulling on the metal in the debris, the magnetic detector reveals an orange coded section. If the debris is non-mental, no orange is shown.

A linear gear slides ¼" tubing out in front of the vehicle to allow for fluid extraction from the shipwreck. A 5 liter per minute aquarium pump is used in conjunction with ¼" tubing and an inflatable bladder to extract the sample for surface recovery.

Our final instrument is a multipurpose robotic claw. Its default state is closed, but when a motor was powered, the claw opened. Located in front of the pilot camera, the claw is used for manipulating a variety of tools and objects including the lift bag, magnetic patches, and delicate sea life.

Description of Challenges

One challenge our company faced was coming up with a design for our ROV. It took us two weeks to come up with a basic design. In the end, we drastically altered our original design. We initially had difficulty communicating between the engineering, controls, and design. It started out as every team for themselves. If a person was assigned a task, it was all on them to complete it. Sometimes, individuals were blamed for a task was not being completed when it was a group failure. We fixed our communication issue by creating an online management blog at www.minigroup.com. On Minigroup, we assigned tasks to certain groups or individual people, we posted events, and made posts about the ROV. Minigroup also helped us meet the deadlines. We initially created deadlines which we failed to meet. Minigroup helped us stay on task and allowed all individuals access to the overall design and management of the team.

Troubleshooting

In order for the robotics team to check if the items that we used on our ROV were functional and waterproof, we used a large container of water. With this, the underwater cameras were checked if they worked properly. We also tested the motors to see which ones worked the best by designing a test rig. The test rig was made from a thin meter stick and attached to the thruster in the water container. When the motor was turned on, the meter stick deflected and we used the deflection to determine the thrust provided by various motors and propeller configurations.

We had major issues with our control box. We used a waterproof Otter Box to house the motor controllers onboard the ROV. We drilled holes in the Otter Box for the motor/ tool wires and tether. We initially used silicone around the wires outside and epoxy around the wires inside. PVC caps were also attached to the box. We believed the box was completely waterproof until we tested it in the water. There were leaks coming into the box from unknown places and our motor controllers got wet and shut down. To test to see where the leaks were, we put numerous paper towels in the caps, around the ridge of the box, and around the tether connector. We determined that there were leaks in the caps and coming from the tether connection. We replaced the silicon with marine epoxy in the caps and changed the metal washers on the tether connector to rubber ones. We soon found out that there was a leak around the ridge of the box. To solve this problem, we tightened a strap around the box to maintain constant pressure on the seal.

Another problem we encountered was that very time we tried to move the ROV upward/downward, we would have to stop every three seconds to move up/down again. After troubleshooting, we determined that the motor controllers were being overloaded and cutting out when they drew too much current. We lowered the voltage on the individual motors and swapped the configuration of the motors so that two 1000 gph motors were never running simultaneously on a single motor controller. This solved the problem.

Before competition we made many trips to the YMCA in order to check if the ballast was correct, and after several attempts we made the ROV neutrally buoyant. At the YMCA we also did troubleshooting to adjust the motors, cameras and position of motors with respect to mission props and cameras.

Lessons Learned or Skills Gained

STEM can help students if they are aiming for majors in engineering, which most members of our company are. In Robotics, our members can learn the basics of engineering. However, we all learn a variety of different things about engineering and about ourselves.

"I learned that our team tends to procrastinate, but can hand things in"
–Heidi Herrera, Engineer

"I have learned to be a little more optimistic, many things can be done if you just apply yourself. I have also learned a little of how college might feel like. With that I have learned to write more professionally and meet deadlines."
–Mario Rios, Operations Manager

"I learned that LabVIEW is one of the most difficult, complicated programs I've ever known"
–Ayana Cochran, Media Outreach Reporter

"I have learned many things that can help me with my future career such as engineering, computer skills, writing, and cooperating with your colleague."
–Jessica Audina, Media Outreach Reporter

Future Improvement

There are many improvements that we could do in the future to make us a better team. We need to work on our communication skills. We need to know what has been done, what has not been done, and what needs to be done. We also need to ensure that our team members stay more focused on their assigned tasks.

Our team needs to be more organized in our workshop. If our team is more organized, we would be able to finish more work, since we know where our tools are located. By utilizing organization skills, we would be able to spend more time on our ROV, instead of spending most of our time unfocused or looking for our tools.

Other improvements our team might need is that we have to be more responsible in completing our assigned tasks. We have to meet deadlines in order to accomplish the larger mission.

The most important improvement that we must make is to work on our ROV earlier and to work seriously before we have to rush into competition. If we improve on this, we would have more time to test our ROV, make improvements, and have a better product for our company to market and sell to prospective buyers.

Reflections on Experience

Throughout the process, we found many things to be challenging yet rewarding. "The most rewarding part of this experience was…

"...Bringing my ideas to life."

-George Onofre, System Engineer

"…Getting the knowledge in engineering and what I need to know for the future such as teamwork and taking care of responsibility."

-Jessica Audina, Media Outreach Reporter

"…Learning how to work as a group while not completely depending on other people"

-Louis Zarycki, Engineer

"…Taking on a leadership role so the new members of the Water Raptors were not so lost; helping my peers, who were new, learn how we work. This really makes me feel a sense of happiness. There is not much I would trade for that."

-Mario Rios, Operations Manager

Theme

Worldwide, more than 8,500 oil-bearing ships lie at the bottom of the ocean and, even, in bodies of water such as the Great Lakes. It is estimated that they contain between 0.5 to 4.3 billion gallons of oil and other hazardous cargo. More than 6,300 of these shipwrecks are from the World War II era. These shipwrecks contaminate the water and disrupt the existing oceanic ecosystems and, and thus negatively affect local economies including the fishing industry. Environmental and socioeconomic damages from these oil leaks have an untold cost. The shipwrecks also limit mobility of vessels through existing sea-lanes, as ships must navigate around them. The protection and the preservation of cultural and natural heritage is important, however. According to the Convention on the Protection of the Underwater Cultural Heritage, and the UNESCO treaty, it is our responsibility to preserve these World War II shipwrecks as historic sites. In the spirit of the UNESCO treaty, the Water Raptor Team will use our ROV to obtain “responsible non-intrusive access” to this historic vessel.

As a responsible and conscientious environmental company, we must survey the site and obtain a sample from the shipwreck without disturbing the environment or the integrity of this underwater heritage site. Only after this task is complete can we determine the environmental impact of this sacred site and determine if further preservation or environmental cleanup must be done to stabilize the shipwreck.

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