2011

Pearl City High/Highlands Intermediate School Pearl City, HI

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Kaimana Enterprises

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Abstract

During the Deepwater Horizon oil spill, engineers removed the damaged riser pipe from the well, placed a cap on the well to prevent oil from escaping, collected water samples to analyze the movement of the spill, and collected water samples to observe effects on marine life in the Louisiana gulf. Similarly in the 2011 MATE competition, our ROV must remove the riser pipe, cap the oil spill, collect water samples, and collect biological samples.

Figure 1: Photo of our ROV (top view)

Kaimana is Hawaiian for "power of the ocean," which describes the strength of our ROV. Our company, a team of eleven students of various ages, six from Highlands Intermediate School and five from Pearl City High School, constructed the ROV in a short but intense month and a half of preparations for the MATE competition.

This technical report illustrates the electrical and structural design of our ROV, the challenges we faced, the lessons we learned, and the financial report for our company. We have also included background information on the Deepwater Horizon oil spill, and photographs of our steps to success.

Vehicle Systems

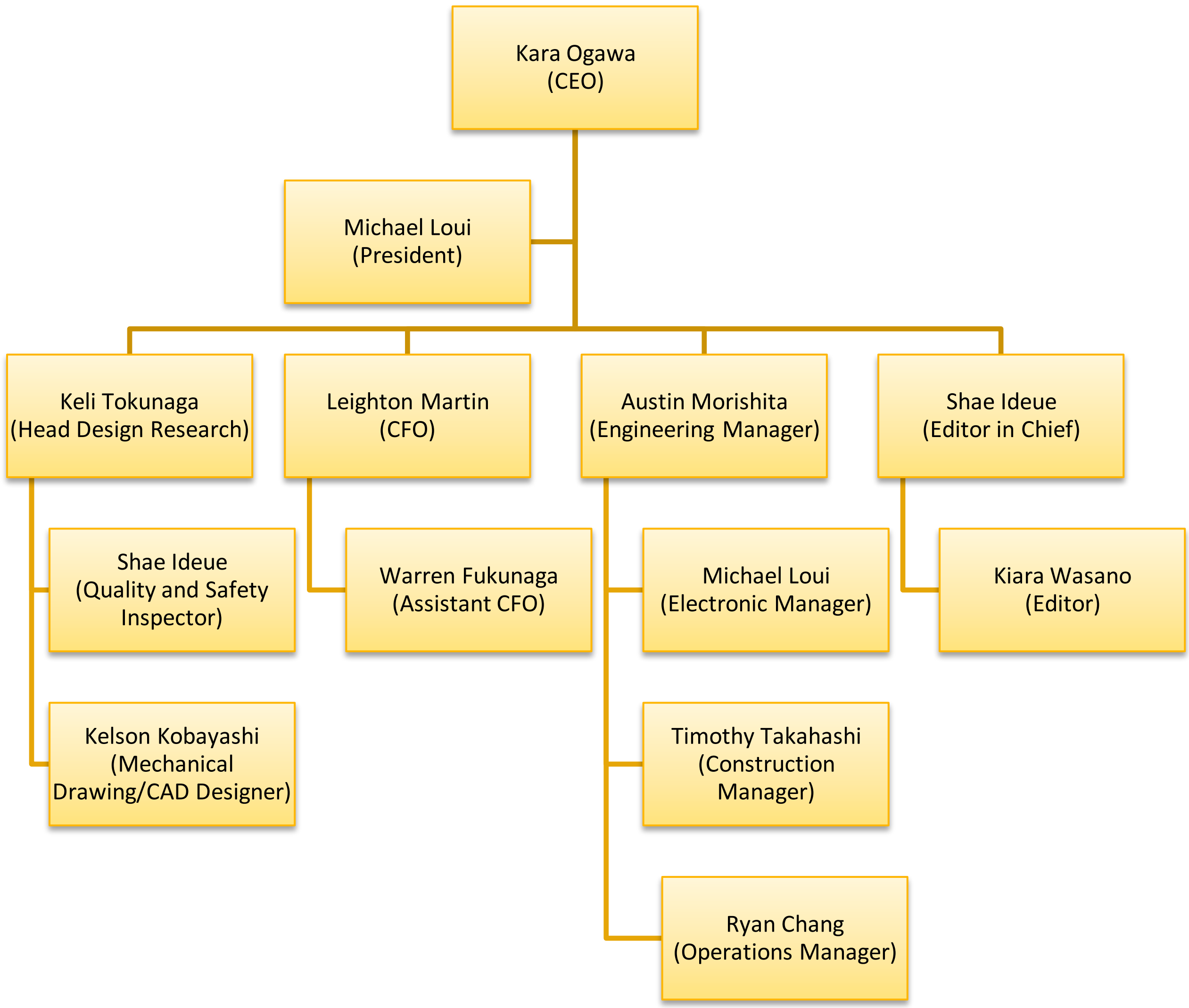
The frame of the ROV is constructed with PVC pipes and ABS pipes to create neutral buoyancy. The ROV is composed of a left and a right motor for lateral movement, an additional motor with two propellers for vertical movements, one car door actuator to operate the grabber, and a power window motor to control the rotating arm. We used three cameras to guide our ROV as well as to provide visibility for the grabber and rotating arm to accomplish the missions.

The tether consists of two CAT-5s, one air line, three camera wires held together by cable ties, and capped ABS pipes to achieve neutral buoyancy.

Our company has taken the hardware system approach for our electronics system, which our Engineering Manager was familiar with from last year. We are using six momentary switches encased in a plastic control box. We added fuses in the electrical system for safety.

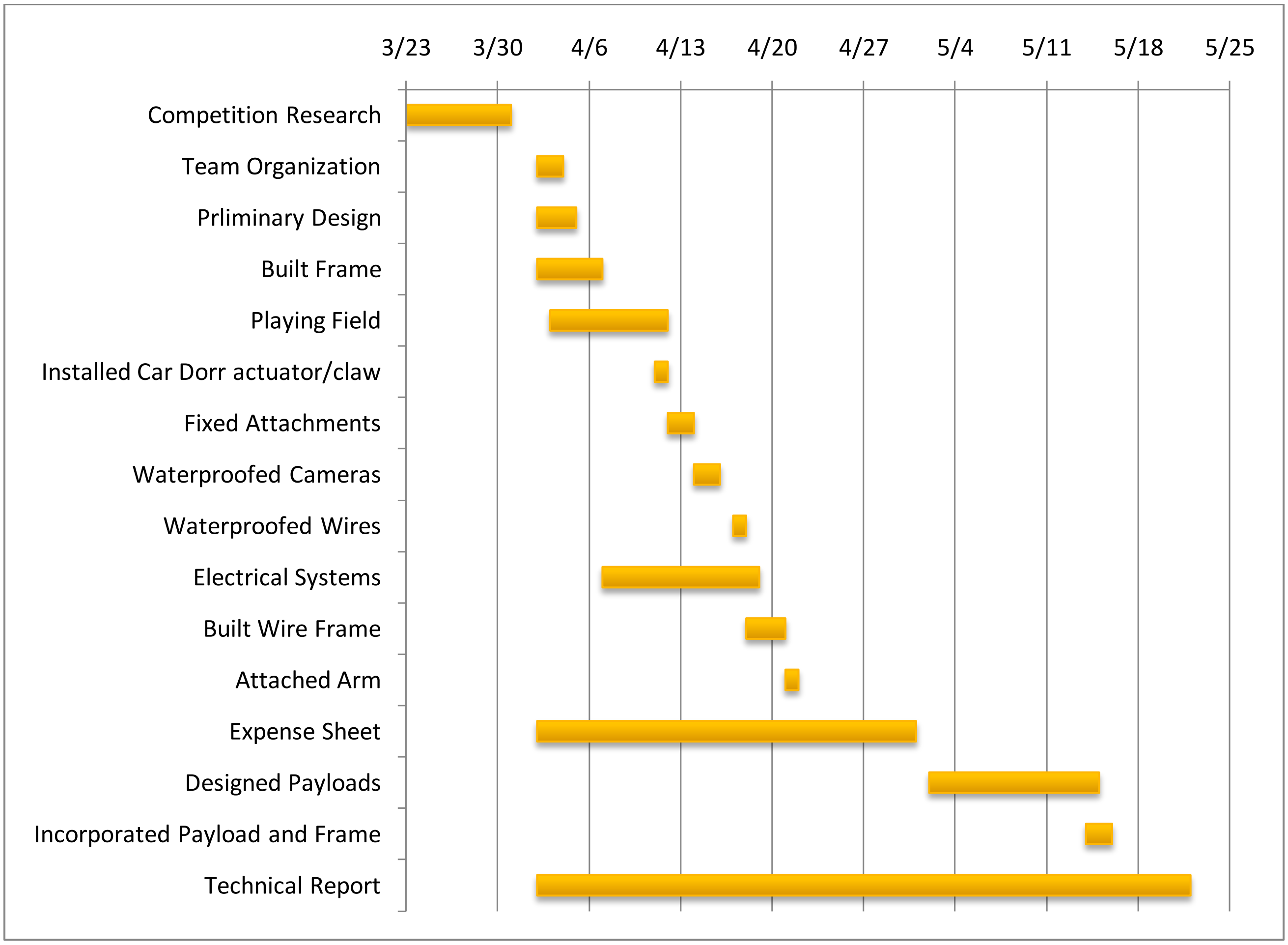
Team Organization

Chart 1: Company Roles



Timeline

Table 1: Building Timeline



Information about the Deepwater Horizon oil spill

On April 22, 2010, the Deepwater Horizon drilling unit in the Gulf of Mexico on Louisiana exploded. The most probable cause of the Deepwater Horizon Oil Spill is methane, an explosive gas found within oil reservoirs. A bubble of methane under the pressure of the ocean released up into the drill column and expanded as it traveled up into areas of lower pressure. The expansion of the bubble of methane forced through safeguards and barriers and when the methane reached the engines of the oil rig, a small spark or an open flame set the methane on fire. The explosion then opened a pipe designed to transport oil up from the bottom of the ocean to the platform and the oil began to escape through the pipe, releasing up to an estimated 52,700 to 62,200 barrels per day. ROVs were sent to cap the oil spill (Fig 2).

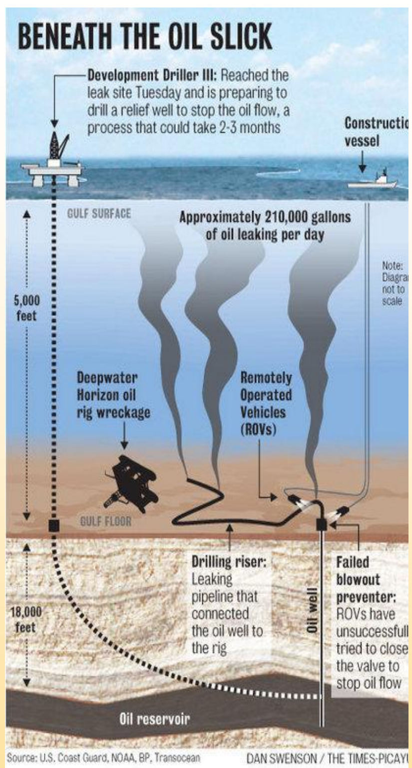


Figure 2: Depiction of oil spill

Capping the Deepwater Horizon oil spill

At the end of May, BP decided to cap the oil spill by removing the broken riser pipe and capping the remainder of the riser pipe. Oil would be siphoned to the surface through other pipes. However, after cutting the riser pipe, 20 percent more oil would rush into the Gulf. Still, a temporary cap was installed on the well during the middle of July and on September 17th, a relief oil well was drilled and concrete was pumped into the well, finally killing the well.

Much of the oil evaporated and dissipated due to chemicals delivered from helicopters on the spill.

Effects of the Deepwater Horizon oil spill

The bird and marine wildlife including the wildlife in the Gulf and on the Chandeleur Islands were contaminated with oil. Consumers were deeply affected. Oyster farms closed, crabs became scarce, and seafood businesses took a plunge. Tourism in Florida decreased.

The oil may plague the Gulf's ecosystem for years, settling at the bottom of the ocean or dispersing into the ocean.

Design Rationale

Frame

Our company decided to use ½ inch polyvinyl chloride (PVC) pipes for the frame. These pipes are light and durable.

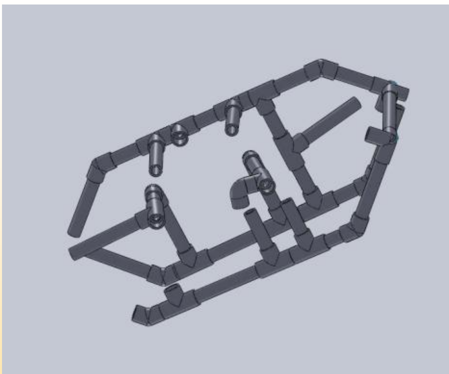


Figure 3: Frame cut-away

The frame of the ROV (Fig. 3) is designed for maneuverability. A rectangular frame is bulky, so our company sought to increase mobility by creating a hexagonal frame. Our frame measures 64cm by 30cm with a height of 24cm. On the left and right sides, a 42cm pipe is connected to a 15cm pipe that extends a 45 degree angle to a point 12cm from the base. This creates the hexagonal frame on both sides. The sides are held together by a pipe in the front that extends across the middle to the other side. This middle attachment also makes attaching the claw easier.

A final structure sits on top of the ROV for the payload attachment to rotate the wellhead.

We screwed together the ROV to make sure the PVC would not break apart in the water. We are still able to rearrange parts of the ROV because screws are not as permanent as PVC glue.

Our ROV is a "wet" ROV. We drilled ballast holes to allow water to enter in the PVC pipes so we would not have to close and waterproof the PVC pipes.

Propulsion

The next attachments we added onto the frame were the motors. We are using three motors that came with the kit provided by the Big Island ROV kit. One motor with two propellers is attached downward in the center of the ROV, allowing the ROV to move vertically and the other motors allow the ROV to move left and right. All motors are attached to PVC piping and are held in place by 1.27cm diameter hose clamps.

The special design, a t-shape, of the PVC structures for the left and right motors allows PVC of the left and right motors to

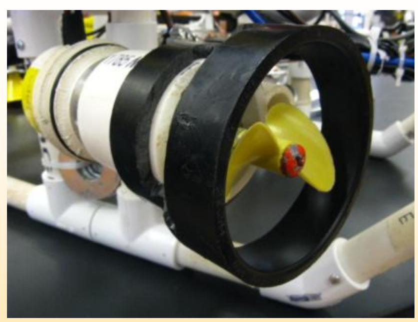


Figure 4: A propeller painted yellow in the shroud

rotate and allows the driver to face the motors in the direction he or she wants.

We installed a "shroud" over the propellers made of 5.98cm ABS reducer (Fig. 4).

Safety

We thought about ways to protect divers and the pool's delicate coating from the blades of the propeller and developed a protocol (Table 2).

The propellers are painted yellow on the ROV to distinguish it from the rest of the vehicle. Also, the propellers are housed in a special case, consisting of a 5.08cm ABS reducer. We cut out three sections in this "shroud" to allow water to pass through.

We have spray painted yellow diagonal stripes on the black ABS pipes. This alerts divers of moving propellers and also indicates where our ROV is located in the water.

Table 2: Safety protocol

1	Wear shoes
2	Bring goggles to use in working area
3	Check safety shrouds on each motor
4	Drivers decide which mission to complete
5	Two designated divers

Waterproofing

Before testing for buoyancy and going into water, we realized we had to waterproof the ROV. We waterproofed the cameras using 30-minute resin. The first step to waterproofing a camera is to focus the camera. We connected each camera to a television and focused on an item 4-6 inches away from the lens. To remove dust and moisture, pressurized air was blown on the lens and the lens cap was placed back on the lens. Next, we placed the camera in a clear container and filled the area in the container with resin. The cameras dried overnight.

To waterproof the tether, the wires, the car door actuator, and power window motor, we used a combination of plastic spray and electrical tape.

Visibility

We added the cameras to the frame next. Our team is using 3 Anaconda Indoor/ Outdoor Color Video Cameras chosen for its small size and light weight, allowing for greater maneuverability.

One camera is mounted above the ROV to see the claw/rotating arm (Fig. 5). Another camera is mounted in the middle bottom and aimed toward the front of the ROV to see the front of the ROV and to make sure the crustaceans are collected in Task 4. The final camera is mounted on the sheath over the rotating arm to focus on the rotating arm on the ROV for Task 2.

Figure 5: Camera to see claw/rotating arm

Tether

We worked on the tether next, since we were done wiring the ROV with the CAT-5s and the camera wires. The tether consists of two insulated CAT-5 wires that control the motors, the claw, and the rotating arm from the control box. Along with the CAT-5 wires, the tether includes a 0.3 cm air line used for Task 3, collecting a water sample, and three lines for cameras (Fig. 6). These five lines are held together in a sheath of 100 feet of polypropylene hollow braid rope.

The rope is positively buoyant to counteract the negative buoyancy of the cables.

Figure 6: Tether covered with hollow braid rope for buoyancy

Buoyancy

We tested buoyancy next in the water. The ROV achieved buoyancy using capped ABS pipes filled with air (Fig. 7). We wished to achieve neutral buoyancy, when an object does not float or sink in a body of liquid, or to achieve slightly negative buoyancy so the ROV would descend faster. In order to find the volume of air required to achieve neutral buoyancy, a system of five 500 mL empty plastic bottles was attached to the center of the ROV and removed one at a time until the ROV became neutrally buoyant. To calculate the exact dimensions of ABS pipes, we used the total volume of air required to compensate for the ROV, 2,000 mL, and plugged in the different sizes of ABS pipes, 3” and 2”, into the formula

Figure 7: ABS capped pipe

$V = \pi r^2 d$ to find the different length of ABS pipe needed. We chose the 2” radius pipes over the 3” pipes because the 2” by 2’ ABS pipes was the length of the ROV. The ABS pipe is capped and sealed with waterproof coating and PVC caps and attached to the top of the ROV.

Electronics System

Finally, we soldered and created our control box of six momentary switches in a plastic casing (Fig. 8). The left and right switches control direction respectively, and the bottom switch controls vertical movement. The top switch controls the rotation of the car door actuator connected to the claw. The top right switch on the box controls the rotating claw during Task 2.

For safety, the control box runs on a 20A fuse. The three cameras run on 3A fuses.

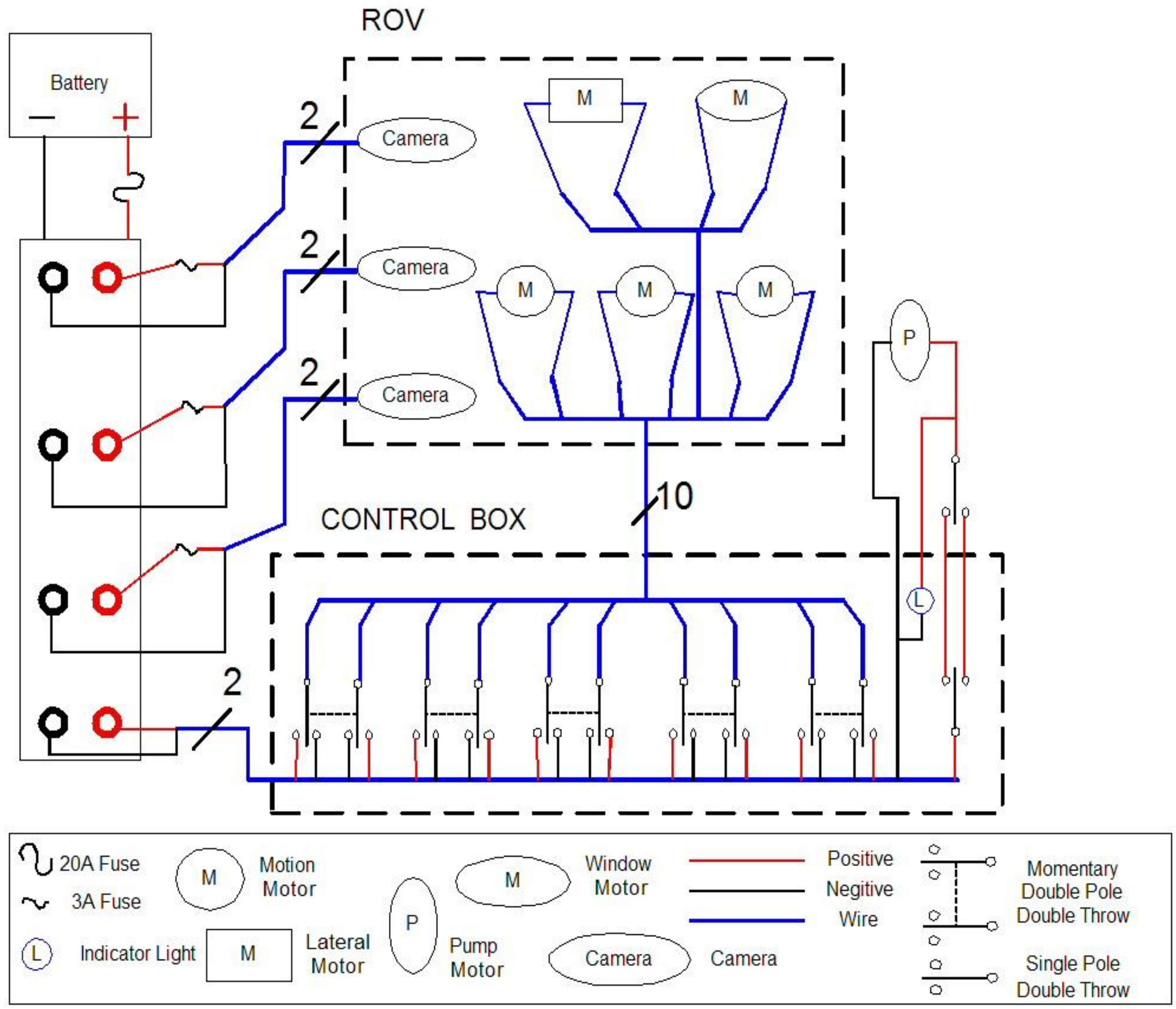
The battery and control box are connected through the power box.

We decided against a software approach (such as the NXT Mindstorms from First Lego League) because we thought we would have more control with the hardware approach. A hardware control system allows the driver to have greater manipulation of the vehicle in the case of a system failure or an environmental change.

Figure 8: Control box (outside)

Electrical Schematic

Figure 9: Electrical Schematic



Payload Description/Mission Tasks

Task 1: *Remove the damaged riser pipe*

The damaged riser pipe was removed during the Deepwater Horizon oil spill in order to cap the oil spill. This task consists of three steps: attaching a line to the U-bolt on the pipe, removing the Velcro strip on the pipe, and removing the riser pipe.

We created a clip to attach to the U-bolt (Fig. 10). The front of this clip is a PVC Tee which guides the attachment through the U-bolt. The clip is constructed using two hinges of PVC held together by a 10-24 threaded rod on another PVC pipe. Two elastic bands and a spring allow the clip to push through the opening in the U-bolt and to open and lock in place once through the U-bolt. A line attached to the coupling on the long PVC pipe is mounted onto the ROV over the claw using a special PVC mount. Once the clip locks in place on the U-bolt, the driver will reverse the ROV, causing the PVC pipe to detach and to remain in place on the U-bolt. A company member on deck holds the line taut.

Figure 10: Clip for the U-bolt (top view)

The next step is to remove the Velcro using the claw (Fig. 11). The claw was originally from a garden grabber our company purchased from Home Depot. After dismantling the grabber, our company created a three gear grip system for our ROV. One gear connects to each side of the claw and the other two gears attaches to a car door actuator. Running the motor causes the gear to open and close the claw.

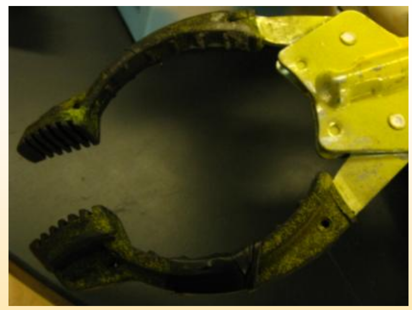


Figure 11: The claw (powered by a car door actuator)

The driver maneuvers the arm of the claw into the PVC attachment on the Velcro and drives around the riser pipe to remove the Velcro. Once the Velcro is removed, the company member on deck pulls up on the line, removing the riser pipe and placing it on the side.

Task 2: *Cap the oil well*

During the oil spill, a cap rested on the oil well to stop the flow of oil. This task consists of four steps: retrieving the hose line, inserting the hose line into the wellhead, stopping the flow of water from the wellhead by turning the wheel, and placing the cap on the wellhead.

The claw attachment is used in this task to pick up and insert the hose line into the wellhead. Once this is completed, a two-pronged arm of PVC pipe turns the wheel (Fig. 12).

The driver drives the two-pronged arm of PVC pipe into the wheel, and the power window motor rotates the arm in a counterclockwise motion, rotating the wheel. When the wheel has been rotated 1080 degrees, the driver backs out of the wheel, having successfully shut off the well.

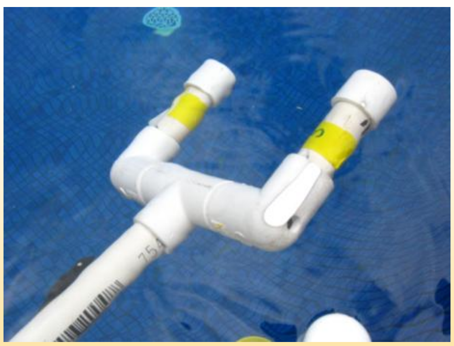


Figure 12: The two-pronged rotating arm

Task 3: *Collect a water sample*

Scientists during the oil spill examined the contaminated water for oil. This task consists of three steps: interpreting the graph to find the correct depth to sample, measuring the correct depth, and collecting a water sample from the depth.

Our team practiced deciphering the graph by finding the correct depth at the correct value on practice graphs. Our strategy for finding the correct depth is to designate a company member to interpret the graph while the driver completes Task 1 and Task 2.

Figure 13: Barometer

To determine depth in the water, we attached the barometer as a payload on our ROV (Fig. 13). The barometer consists of a deflated soda bottle with a clear tube inserted into the cap. We attached this upside-down to the ROV with cable ties and placed weights at the bottom of the test tube to ensure that the barometer stays perpendicular to the bottom of the pool. As the ROV drives into the pool, the water pressure increases and causes the water level to rise at the bottom of the straw up toward the plastic bottle. We calibrated and marked off different depths and placed a small Styrofoam ball in the clear tube to help us quickly determine the marker.

After the depth of the ROV is determined and matches the depth we interpreted using the graph, the driver inserts the copper air line end of the water sample collector into the well (Fig. 15). This consists of an upside-down funnel and weights strung onto a hollow copper rod (Fig. 14). Electrical tape at the bottom of the rod holds the funnel to the rod. The structure is held in place on the ROV with a sample collector holder made of PVC (Fig. 15) that extends into the plastic air line to the water sample container pump on deck. The rod keeps the line stiff and the funnel decreases time by allowing a larger guessing area for the driver to drive the rod into the water sample container.

The other end of the water sample collector on the air line tubing consists of the water sample collector pump which is a car window washer pump (Fig. 16). The air line

Figure 16: Water sample collector (pump end)

on one end pulls water into the pump and the pump pushes this water out of the pump on the other end. A company member on deck turns the collector on, running the pump, to push water through the pump back into the pool, until the desired sample water runs through the air line. At this time, the team member places a designated water sample collector container under the pump and proceeds to collect the sample water.

Figure 14: Sample collector (metal tube end)

Figure 15: Sample collector holder on ROV

Task 4: *Collect biological samples*

Collecting biological samples is critical to analyze the impact of the oil spill on biological samples on the ocean floor. This task requires the collection of three biological samples from the floor: a sea cucumber, a glass sponge, and a Chaceon crab. These biological samples will be collected from the floor and will be returned to the surface.

We created a scooper made of tine affixed to a flat metal rod and attached this to the bottom of our ROV using screws (Fig. 17). This payload runs along the bottom of the pool in front of the ROV. The driver drives the scooper under the crustaceans, trying to corner these against the pool wall. When the ROV is ready to return to the surface, the ROV ascends, with the tine holding the crustaceans in place.

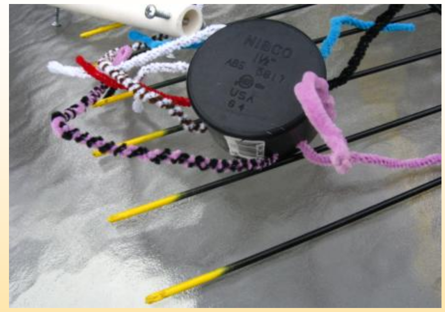


Figure 17: The scooper to collect the crustaceans

Challenges

Our biggest challenge this year was finding and commuting to a pool so our team could test our ROV. A teacher graciously volunteered his pool in Kailua when we were in need of a pool, but the drive from Pearl City to Kailua is a long drive of one hour. Our team has only had about 27 hours of pool practice, and lost precious time when we forgot materials at the school. By the last month, our team planned well in advance by creating a checklist of needed parts, packed all materials, and managed our time wisely through writing a running list of tasks needed to be completed.

Troubleshooting Techniques

While we were wiring our system, our fuse broke. To fix the problem, we went over with a voltmeter and found that the broken fuse was in the control box. We replaced the fuse and the system worked again.

The original sweeper arm for the ROV consisted of PVC with a motor attached to the side. Before we attached it however, we realized the motor would rotate 360 degrees, not 90 degrees and that the arm would hit the motor upon rotation. Thus, we decided to design a scooper instead.

We also had trouble with the resin when we waterproofed our cameras. One week after the cameras were waterproofed, the resin had not set in two cameras. We suspected the resin and hardener were not mixed in equal parts. We removed the gummy layer of resin from the top of the camera and placed fresh 5-minute resin in the cameras.

We are using three motors, two for lateral movement and one for vertical movement. Yet with our many payload items, we realized we would more vertical power. Therefore, we added an extra propeller to the vertical motor and extra ABS pipe for buoyancy. The extra propeller added power to the ROV and the extra pipe made the ROV more buoyant so less force needed to be exerted vertically to move the ROV.

Future Improvement

Our team would like to use an extra motor for vertical movement and an extra camera for extra visibility. Next year, we would also like to cut back on the amount of payload items to make our ROV lighter. We can dedicate more thought into the mission tasks to make one payload serve multiple functions.

Furthermore, we would like to make our frame smaller and lighter. Our frame was designed to be more maneuverable but turned out bulky. A smaller squarer frame may be the better choice.

Lessons Learned

This year, one specific technical skill we learned was how to effectively achieve neutral buoyancy. Last year, our company used hot water insulation for buoyancy but we realized insulation compression increased with depth and our ROV had a hard time returning to the surface. This year, we strived to keep buoyancy constant at any depth, which required using an uncompressible item to hold in air. Our team came up with the ABS pipe which is capped on both ends with PVC capping and sealed with PVC glue and waterproofing spray. We calculated the correct amount of piping we would need by attaching empty water bottles to the ROV and then converting the amount of air needed to ABS piping.

An interpersonal challenge we faced was working together as a team. Our team has two high school juniors, one sophomore, two freshman, two eighth graders, and four seventh graders. The high school members learned how to be patient with the intermediate school students and the intermediate school students learned how to cooperate with the high school members. In the end, all team members learned to cooperate and all contributed to running the ROV.

Reflections

Some students joined our MATE ROV team because they were interested in ocean engineering. Only our Engineering Manager, CFO, and Head of Design and Research had worked with the MATE competition last year. The water environment had many variables. Buoyancy and waterproofing were challenges. During testing in the pool, our car door actuator appeared to have short circuited, so we dried it out and re-waterproofed it with more electrical tape and liquid tape.

Furthermore, we realized why engineers took so long to cap the oil spill in the Gulf of Mexico. We had sided with the outraged public last year, angry at engineers who failed many times to cap the well. However, our company now realizes the adversity they faced- water and electricity just don't mix. Through the MATE program a few of our team members have become interested in ocean engineering, and perhaps we will be the engineers capping the next oil spill. Our personal accomplishments included understanding and working with the water environment during the month and a half we worked on the vehicle.

Financial Report
Table 3: Mission Props

Item	Quantity	Unit Cost	Subtotal
1/2" PVC EL 45 Degree	13	$0.54	$7.02
1 1/2" PVC EL 45 Degree	6	$1.99	$11.94
2" PVC EL 45 Degree	4	$2.69	$10.76
1/2" PVC TEE	10	$0.69	$6.90
1 1/2" PVC TEE	2	$1.73	$3.46
2" PVC TEE	5	$2.89	$14.45
2" PVC TEE	1	$2.44	$2.44
1/2" PVC Cross	1	$1.49	$1.49
1 1/2" Cupling	7	$0.99	$6.93
3/4" Cupling	1	$2.99	$2.99
1/2" Cupling	1	$2.19	$2.19
PVC Bushing	3	$0.98	$2.94
PVC Bushing	1	$0.64	$0.64
PVC Bushing	1	$0.93	$0.93
PVC Bushing	1	$1.62	$1.62
PVC Bushing	1	$0.65	$0.65
Plastic Bags	3	$1.18	$3.54
Plastic Bags	2	$1.18	$2.36
Braid cord	1	$3.92	$3.92
Flex CPLG	1	$7.50	$7.50
Electrical tape	4	$0.99	$3.96
Asst. Cable Tie 500pc	1	$0.99	$9.99
Combo Pk	1	$2.70	$2.70
Screws	1	$4.41	$4.41
U-Bolt	1	$2.58	$2.58
3/4 Gate VLV	1	$10.15	$10.15
DWV Pipe	1	$4.33	$4.33
PVC 40 Pipe	1	$1.85	$1.85
1 1/2" Cupling	3	$0.72	$2.16
1/2" F Adapt	1	$0.47	$0.47
PVC M Adapt	1	$1.80	$1.80
ABS Cap	1	$2.81	$2.81
Tote Box 30G	1	$18.49	$18.49
PVC 40 Pipe 1/2"x10"	2	$1.54	$3.18
L 1/2 PVC	2	$3.29	$6.58
		Total:	**$171.13**

Table 4: ROV expenses

Description	Quantity	Unit cost	Subtotal
.5 inch PVC	14 ft.	$0.99	$14.00
Chicken wire	24in. By 10ft.	$10.00	$10.00
Motors and Propellers	6 motors and 7 propellers	$66.67	$400.00
Underwater Camera	3	$50.00	$150.00
Insulation	4 pack	$1.00	$4.00
.5inch PVC couplings	5	$1.00	$5.00
Car Door Actuator	1	$20.00	$20.00
Car Window Motor	1	$40.00	$40.00
Claw	1	$20.00	$20.00
2 containers of 500 zip ties	2	$10.00	$20.00
.5 inch 45 degree elbows	12	$0.44	$6.48
. 5 inch 90 degree elbows	7	$1.00	$7.00
.5 inch tee's	15	$1.00	$15.00
.5 inch End caps	2	$0.29	$0.58
.5 inch crosses	2	$1.49	$2.98
.5 inch 3 way elbows	4	$3.00	$12.00
.5 inch Female pressure adapter	4	$1.00	$4.00
.5 inch PVC coupling	1	$1.00	$1.00
Electric Tape	4	$1.00	$4.00
Solder	1.5 ounces	$4.19	$4.19
Hacksaw	2	$8.12	$16.24
sheet metal	1	$2.69	$2.69
PVC cement	2	$4.13	$8.26
		Total:	**767.42**

Table 5: Donations/Borrowed Item

Description	Donor	Quantity	Subtotal
Pool	Mumaw Family	1	N/A
Drill	Highlands Intermediate	1	$60.00
Television Monitors	Sam's Electronic Service, LLC	1	$350.00
Screw Drivers	Loui Family	all sizes	$30.00
		Total:	**$440.00**

Acknowledgements

Mrs. Kathy Lin, Highlands Intermediate School Science Club Coach- For coaching our team, providing a classroom, transporting supplies to the pool, and giving up her time on weekends and afterschool.

Mr. Robert Loui- For mentoring our team, helping with the electrical schematic, providing supervision for our team, and teaching us technical details to complete our ROV.

The Loui Family- For allowing our team to work in their home while we didn't have access to our coach's classroom.

The Mumaw Family, Highlands Intermediate School- For allowing us to use their pool and supervising our team.

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Mr. William Swider, Auto Parts Sales LLC- For assisting us with wiring and technical details we needed to complete the ROV and props.

Mr. Mark Rognstad, University of Hawaii Researcher- For assisting us with waterproofing the cameras.

Highlands Intermediate School- For providing us with a classroom.

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