Technical Report for:
The RoboLobster

robolancers

CENTRAL HIGH ROBOTICS OF PHILADELPHIA, PA

Ranger Class

Members

Chief Executive Officer:	Gabriela Alfaro-Angulo
Chief Financial Officer:	Bianca Rivera
Chief Operating Officer:	Alexandra Thompkins-Johns
Chief Programmer:	Kevin Mai
Chief Electrical Engineer:	Jonathan Zhu
Chief of Documentation:	Mary Conrad
Chief of Communication:	Margaret March
-Marketing Team:	Linda Babu
	Jocelyn Mar
	Rose Manjarres
Chief Mechanical Engineer:	Kyle Fragassi
-Head of Propulsion:	Craig Talis
Propulsion Team:	Quahmir Martin
-Head of Structure:	Jordan Ramos
Structure Team:	Kevin Scott
-Head of Manipulation:	Alexandra Thompkins-Johns
Manipulator Team:	Melvin Brown
	Joshua Lynch
	Michael Manson
Chief Driver:	Jonathan Zhu

Instructor

Daniel Ueda

MATE

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Abstract

Central High School's robotics class, the RoboLancers, is composed of 18 members and is in its second year of applying our engineering process to design robots for underwater applications. Our engineering process is a continuous cycle that is made up of five key parts: (1) recognize design constraints, (2) design, (3) test, (4) build, and (5) test.

This year, the task for our robot is based around the tragic Deep Horizon oil spill that started in April 2010. Our underwater ROV for this particular task is called the RoboLobster. It is designed to accomplish four main tasks: (1) remove a damaged riser pipe, (2) cap an oil well, (3) collect and interpret water sample data, and (4) collect biological samples.

This report will describe how we used our engineering process to develop the RoboLobster and how our design decisions affect the underwater robot and its performance.

Mission Summary

The mission for this particular MATE competition is related to the Deep Horizon Oil Spill, which occurred in the Gulf of Mexico starting in April 2010 with the damage of an oil pipe belonging to BP. There are four main tasks that each ROV must accomplish in a specific order. These tasks are: (1) remove the damaged riser pipe, (2) cap the oil well, (3) collect and interpret water samples, and (4) collect biological samples. There are 15 minutes total for all tasks to be accomplished.

The first and second tasks are closely related. In order for an ROV to successfully complete tasks one and two, the ROV must remove the hose line from the top kill manifold, insert the hose in the wellhead, turn the valve wheel clockwise approximately three rotations (1,080 degrees) to stop the flow of water, and install the cap onto the wellhead.

The third task is to collect water samples at different depths and to determine whether or not there is oil present in the water sample. In order to correctly complete this task, the ROV must interpret a graph to determine the correct depth at which to collect a sample, measure the depth at the sample site, collect a water sample and bring it to the surface.

The fourth task is to collect biological samples. In order to successfully complete task four, the ROV must collect one sample of a sea cucumber, glass sponge, and Chaceon crab and return these samples to the surface.

Connections to the Deep Horizon Oil Spill

In December 1998, the Deepwater Horizon oil rig construction began in Ulsan, South Korea. In February 2001, the oil rig was delivered to its location and valued at 560 million dollars. On April 20, 2010, there was an explosion on the BP run oil rig. Eleven people were reported missing and seventeen were injured in the explosion. On April 24, oil was found leaking from the well. On April 25, remote underwater cameras reported that the well was leaking 1,000 barrels of crude oil per day. The number of barrels of crude oil leaking into the water kept increasing as time went on. By May 6, the number climbed to 5,000 barrels of oil per day. By May 20, at a Congressional hearing, it was testified that anywhere from 20,000 to 100,000 barrels of oil were leaking into the environment per day. [4]

While BP and their engineers tried to figure out a way to stop the oil flow, many methods of containing the oil were used. Those methods included wiping marsh grass clean with pads that attract oil but do not absorb water, blocking oil with a boom, burning small slicks of oil, using dispersant to break up oil slicks, skimming the oil from the surface, and cleaning up beaches. [1, 3]

On May 2, 2010, BP began to drill a relief well to permanently seal the leaking well. On May 8, BP suspended its efforts to place a containment dome over the leak because hydrates began to build up. On May 16, the drilling of a second relief well began. A riser insertion tube tool became operational and captured an estimated 3,000 barrels of oil per day. On May 29, the "top kill" method, a method in which heavy drilling fluid was injected into the well, was deemed unsuccessful. On June 4, the Discoverer Enterprise began to receive oil and gas as a result of the "lower marine riser package" containment cap being placed on the leak. On June 12, a sealing cap to increase the containment and potentially shut off the flow of oil in the well was put into place. On July 15, oil finally stopped flowing into the Gulf of Mexico. On August 9, the Macondo well cement operation was considered successful after pressure tests are conducted. On September 16, the relief well intercepted the Macondo well. Finally, on September 19, 2010, the U.S. Coast Guard deemed the well kill operations complete. [1]

None of this would have been possible without the use of underwater robots, known from now on as ROVs. These ROVs were both the eyes and hands in the BP operation because the well was beyond a depth humans could go. They did everything. They tightened bolts, closed valves and put in riser pipes. They overcame the harsh conditions from the leaking oil that no human could ever go near. [2] These underwater robots fixed the problems that their human designers caused.

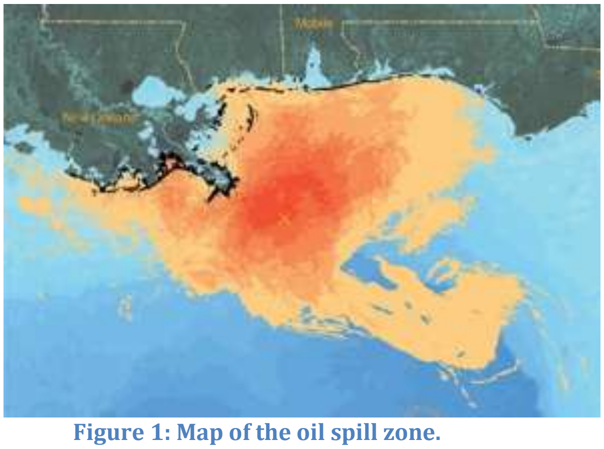


Figure 1: Map of the oil spill zone.

Citations

1. Ernst & Young, BP. "Containing the Leak." BP. BP. 13 May 2011 <http://www.bp.com/sectiongenericarticle800.do?categoryId=9036583&contentId=7067603>.

2. Ernst & Young, BP. "Remotely Operated Vehicles." BP. BP. 13 May 2011 <http://www.bp.com/sectiongenericarticle800.do?categoryId=9036600&contentId=7067604>.

3. Reports, Sources: Staff. "Cleaning up the BP Spill." The Washington Post: National, World & D.C. Area News and Headlines - The Washington Post. Web. 11 May 2011. <http://www.washingtonpost.com/wp-dyn/content/graphic/2010/06/07/GR2010060705117.html>.

4. Research, Guardian. "BP oil spill timeline | Environment | guardian.co.uk." Latest news, comment and reviews from the Guardian | guardian.co.uk. 12 May 2011 <http://www.guardian.co.uk/environment/2010/jun/29/bp-oil-spill-timeline-deepwater-horizon>.

ROV Overview

Name: The RoboLobster

Length: .6731 m

Width: .4572 m

Height: .1905 m

Weight: 4.76271 kg

Propulsion System: The propulsion system on the RoboLobster consists of four bilge pump motors. Two of these motors control forward and backward movement and two control up and down movement.

Flotation: Specially molded polyurethane foam provides the flotation for the RoboLobster.

Structure: 3/4" PVC backbone with supports and wings (as opposed to a full frame of PVC) creates the structure of the RoboLobster.

Safety Features: Wires zip tied to the structure of the RoboLobster prevent entanglement. A shut off switch on the control board allows for the entire ROV to be shut off at once. Also, well placed foam flotation prevents the ROV from flipping over.

Special Features: Multi-functioning claw both opens and closes and rotates. A sample collection tank allows for the collection of water from different depths.

Total Creation Cost: $1,986.42

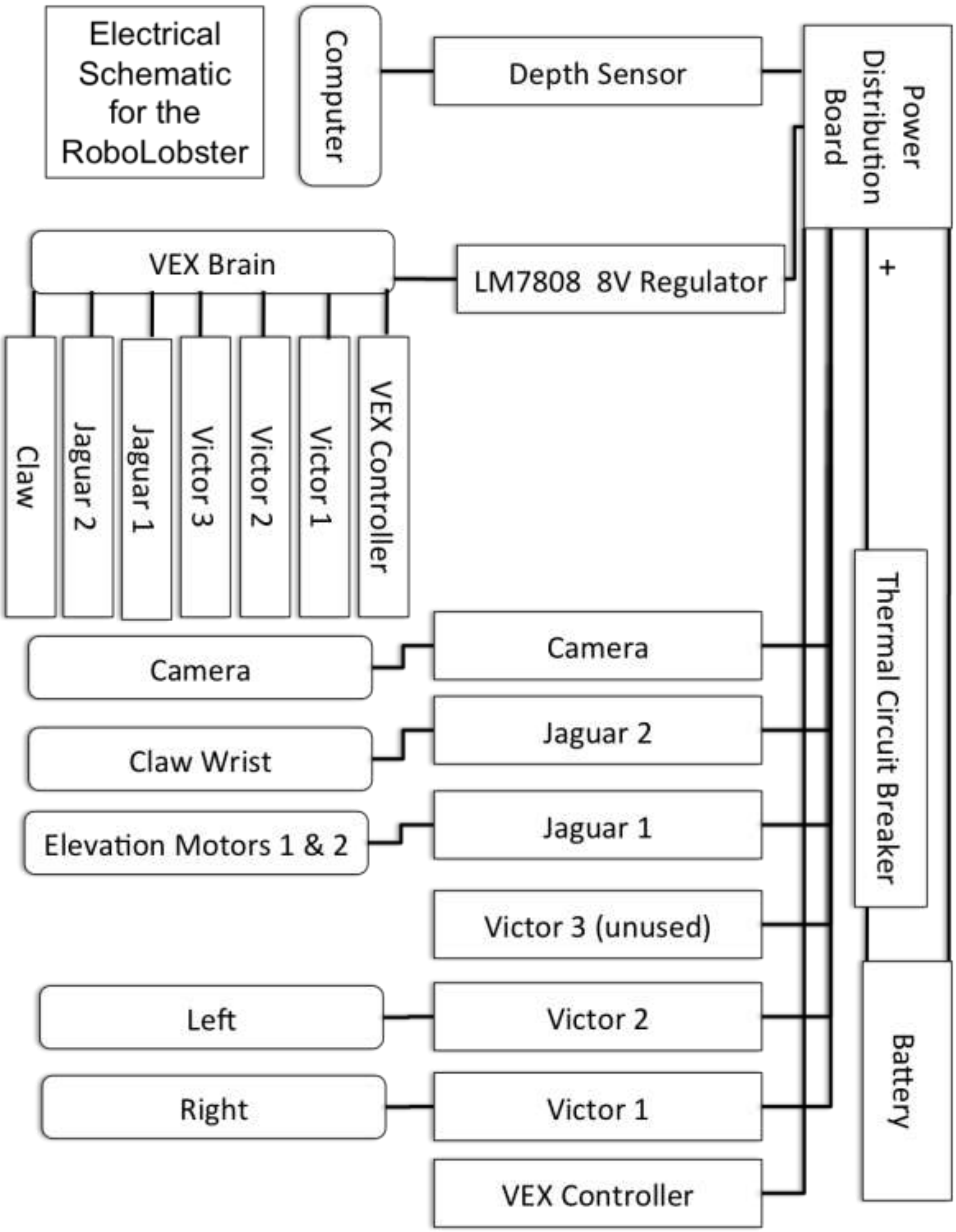
Figure 2: The RoboLobster.

Budget and Expense Sheet

Budget and Expense Sheet
Central High School - Central RoboLancers

Item	Quantity	Price Per Unit	Total Price	Source
Power Distribution Board	1	$189.00	$189.00	FIRST Robotics Component
Victors	3	$90.00	$270.00	FIRST Robotics Component
Jaguars	2	$153.00	$306.00	FIRST Robotics Component
Vex Brain	1	$149.99	$149.99	VEX
VEX Extension	5	$3.00	$15.00	VEX
VEX 75 MHz Transmitter and Receiver	1	$129.99	$129.99	VEX
480-1927-ND Sensor Amp 100 PSI Gau .5-4.5 out	1	$64.05	$64.05	Digi-Key
Enclosure for Pressure Sensor	1	$2.49	$2.49	Radio Shack
Silicone	1	$17.79	$17.79	Radio Shack
LM7805 Regulator	1	$2.00	$2.00	Digi-Key
Kill Switch	1	$20.00	$20.00	FIRST Robotics Component
Navroute Titan Underwater Drop Camera and Video System	1	$270.00	$270.00	Regy Imports
Big Motor	1	$54.50	$54.50	FIRST Robotics Component
Small Motor	1	$13.00	$13.00	FIRST Robotics Component
Transmitter	1	$139.00	$139.00	FIRST Robotics Component
Continuous Flex Multi Connector Cable (18 gauge)	1	$85.00	$85.00	McMaster Carr
Regulator	1	$0.77	$0.77	Digi-Key
3/4" PVC 90 degree Elbow	12	$0.44	$5.28	McMaster Carr
3/4" PVC Tees	6	$8.66	$51.96	McMaster Carr
Zip Ties - Multipack	1	$7.44	$7.44	Home Depot
VEX Advanced Gear Kit	1	$19.99	$19.99	VEX
AeroMarine #4 Density Foam	1	$47.24	$47.24	AeroMarine Products
12" X 12" X 1/4" Polycarbonate Sheeting	1	$13.12	$13.12	McMaster Carr
3/4" Four Way PVC Fitting	4	$0.94	$3.74	DP's Bargain Basement
Direct Drive Prop Adapter	4	$6.95	$27.80	Direct Drive
RCBP1816006_45 45 mm RCEP Boat Plastic Propeller	4	$1.07	$4.28	R2 Hobbies
28572 Marine Pump Cartridge for 500 GPH Motor	4	$18.25	$73.00	Johnson Pumps of America
Air Tubing	1	$3.99	$3.99	PETCO
Total Cost:			$1,986.42	

Electrical Schematic



Our Engineering Process

Central High School's RoboLancers used a five-step continuous engineering process to effectively build and design our ROV, the RoboLobster. The first step in our engineering process was to recognize design constraints. For us, the biggest constraint was the waterproofing aspect of the robot. We are a relatively new team to the MATE underwater competition; therefore, we have very little experience with waterproofing. However, we did not let that get in our way. We learned from last year and we did a lot of research and we now know how to effectively waterproof electronics. The next step in our engineering process was the design and document phase. This step lasted the longest of all of the steps because an effective design is the most important aspect of any engineering project. We split into groups, with each group responsible for a certain aspect of the design of the ROV, for example, manipulator, propulsion, structure, etc. On white boards, we drew out possible designs. Then, we regrouped and discussed these designs. Each group came up with a solid idea for their aspect of the ROV. Then, they moved onto the next step of the engineering process, the test phase. Each group was responsible for coming up with a working prototype of their aspect. If they were not satisfied with their prototype, they redesigned it and re-prototyped it until they were satisfied. Then, they went on to the next step of the engineering process, the building step. After they built their group's task, we regrouped and put the entire ROV together. We then tested the ROV to make sure all of the systems worked together correctly.

Figure 5: Whiteboard drawing used during brainstorming session.

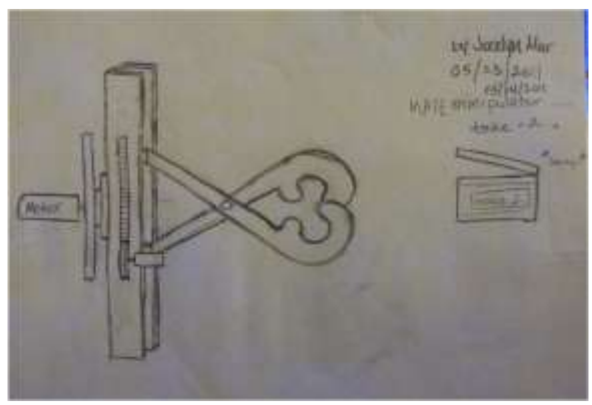


Figure 3: Proposed claw design.

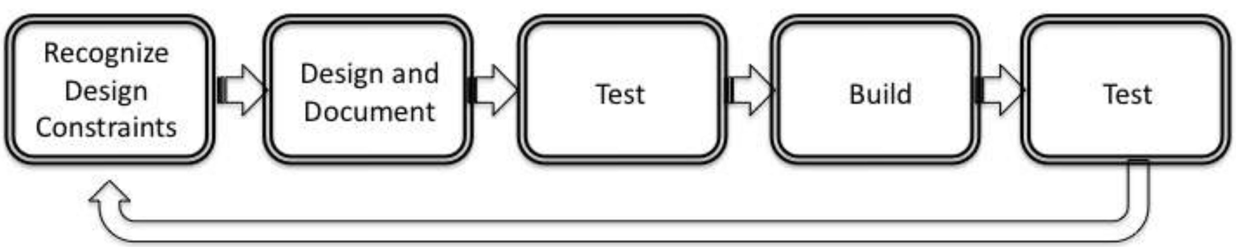


Figure 4: The Engineering process used by the Central High School RoboLancers.

Design Rationale

Structure

Figure 6: Structure of the ROV in process. As you can see, it does not have a full frame but rather a backbone, supports, and wings.

Our previous ROV had a full frame made from 1" PVC piping. This year, we wanted a lighter, more hydrodynamic ROV. We really liked the durability and properties of PVC but we wanted it to be lighter. We decided to use ¾" PVC pipe. We also decided that instead of having a full frame, we were going to have a backbone with supports and wings. We did this to remove other unnecessary weight from the PVC frame and create a more hydrodynamic ROV.

Propellers

We conducted a series of tests in order to decide which propeller and propeller configuration would be the best for our ROV. The results for the two tests are shown below.

Test 1

	Traxxas R	Traxxas Spartan
Total Force (N)	2.686	2.838
Weight (N)	0.926	0.926
Thrust (N)	1.760	1.912

Test 2

	Spartan	Cowling Spartan
Total Force (N)	2.306	1.726
Weight (N)	0.403	0.403
Thrust (N)	1.903	1.323

The two propellers that we decided to test were the Traxxas R and the Traxxas Spartan. The differences that occurred in the propellers are in their shape. The first propeller is called the Traxxas R. It has a more flowerlike shape but did not have much of a screw shape. The second propeller is called the Traxxas Spartan. It has a more helical screw shape that tapers out gradually.

Figure 7: Traxxas R Propeller

The first test we conducted was to determine which propeller propelled the water with more force. The first test showed that the Traxxas Spartan propelled the water with about 8.6% more force than the Traxxas R. Therefore, we decided to go with the Traxxas Spartan.

Figure 8: Traxxas Spartan Propeller

The second test that we conducted was to determine whether we wanted a cowling on the Traxxas Spartan propeller or not. The cowling used was just a PVC piece suspended by thin aluminum rod attached to the propeller. From our test, we concluded that the Spartan propeller was approximately 44% more powerful without the cowling. We decided not to use the cowling.

Camera

Figure 9: Navroute Titan Underwater Drop Camera Video System

The camera, which we decided to go with, is called the *Navroute Titan Underwater Drop Camera Video System*. We chose this camera because it already was waterproof. Some of the other features we like about this camera is its 7" monitor with color display and its ability for infrared night vision. We also chose this video system because it came with a rechargeable battery. The final reason we chose this camera was because of its price. It was only $270.00 at the time of its purchase, which was within our budget while having all of the features we needed in our camera video system.

Flotation System

The flotation system is comprised of polyurethane foam. The hardened, lighter than water substance, is made of equal parts of a hardener and a resin. We used this system because it does not crush under higher-pressure environments. We shaped the foam using cut out Arizona Iced Tea cans with PVC pipe hot glued in the center. When the foam dried, we cut the cans apart and took out the molded foam. They were then zip tied onto the PVC of the ROV structure itself.

Figure 10: Kyle and Bianca work on making the foam flotation.

Hardware Approach

Our robot takes a more hardware approach to accomplishing the given tasks. The reason for this was because we wanted our hardware to be as complete as possible before developing our software because software is easier to apply than hardware.

Safety

In order to protect our ROV's propellers from becoming entangled in the wires and being pulled out, we zip tied all wires to the frame of the robot. There are no loose wires. Also, the electronics board, which is in the control station, has a thermal circuit breaker, which is an on/off switch. If something goes wrong with the robot, the drivers are trained to hit the switch. The entire ROV will turn off. Carefully placed foam flotation allows for the ROV to stay right side up and prevents the ROV from flipping over.

The safety precautions we employ while using our ROV include making sure that when using tools near the ROV, goggles are worn and tools are correctly and safely operated. While testing the ROV and when the ROV is turned on, hands and clothing are to be a safe distance away from the propellers so they do not catch onto the propellers if they are turned on by accident. Other safety precautions are that before the ROV is put into the water, all electrical connections are checked to be sure they are all properly waterproofed so when the ROV is put into the water, it will not spark.

Final Design Selections for Vehicle Systems

Tether: The tether has sixteen strands of wires and a vinyl air tube. Two of the strands are video wires, six of the strands go to the thrust motors, five of the strands go to the claw, and three of the strands go to the depth sensor.
Thrusters: There are four thrusters on the RoboLobster. Two of the thrusters control up and down motion and two control forward and backward motion.
Camera: The camera we decided to go with is called the *Navroute Titan Underwater Drop Camera and Video System*. It has a rechargeable battery and a 7" full color monitor with infrared night vision.
Electronics Control Board: Our control box is made of lexan and wood. The lexan top opens and closes and is held shut with Velcro for easy access. It houses the electronics for the entire ROV. The electronics board houses victor motor controllers, jaguar motor controllers, the power distribution board containing 20 amp circuits, and the vex controller.
Frame: The frame of our ROV is ¾" PVC. The shape of the frame of the robot is more hydrodynamic than our 2010 ROV. We do not have a full frame. It consists of a backbone, supports in between the backbone and bottom of the ROV, and wings.
Buoyancy: Our flotation system for our ROV consists of polyurethane foam around the PVC frame of the ROV.

Challenges

Our main challenge was to design a manipulator that was versatile and could easily be adjusted to do all of the tasks that we needed. It had to be able to remove a damaged riser pipe, turn a valve to stop the flow of water, collect water samples, and collect sea creatures. The main challenge was figuring out whether we wanted one manipulator to rotate and one to be stationary and just open and close or whether we wanted to make a more complicated manipulator that could open and close while rotating. After we decided we wanted to make one multi-functioning manipulator, we needed to figure out how we wanted it to work and what mechanisms we wanted to use so it could rotate and open and close. Our original idea was to use a gearing system for rotary motion and an additional motor controlling linear open and close motion. However, we discovered that our original idea did not have enough torque and could not hold onto what we would have it try to pick up. So, we refined our initial idea a little bit by replacing the set of gears with a rack and pinion and having one of the claws stationary. This allowed for the claw to have enough grip. In order to pick up things from the floor, we also decided to add end effectors to the claw.

Payload Description

Payload Description

The wellhead base is a 40 cm in diameter, 10 cm tall oil pan filled with cement. A 2” PVC connector is embedded in the cement.

The wellhead is constructed of ½”, ¾”, 1 ½”, and 2” PVC pipe. The port opening for the hose line is 5.2 cm. The valve wheel is constructed of ½” PVC pipe and must be turned approximately 1080 degrees clockwise to stop the flow of water. The top of the wellhead is constructed of a ¾” PVC coupling. A 10.5 cm by .3 cm length of Velcro is wrapped around the wellhead.

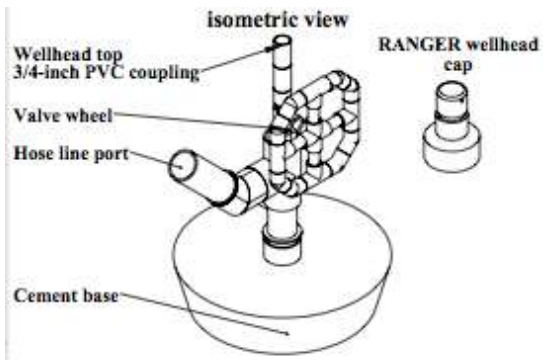


Figure 11: Ranger Class Wellhead, Wellhead base, Wellhead top, and Wellhead cap isometric CAD drawing.

The wellhead cap in made from a 3” to 1 ½” flexible drain coupling and 1 ½” PVC pipe. The cap is 15 cm tall and 8.8 cm in diameter. The wellhead cap is attached to a 30 cm long polypropylene and nylon-braided rope, which serves as a handle.

The top kill manifold is constructed from 1.5-inch PVC surrounded by .5-inch PVC framework. The holder for the hose line connector sits at a 45-degree angle in the top kill manifold.

The hose line connector is constructed of .5-inch PVC tube.

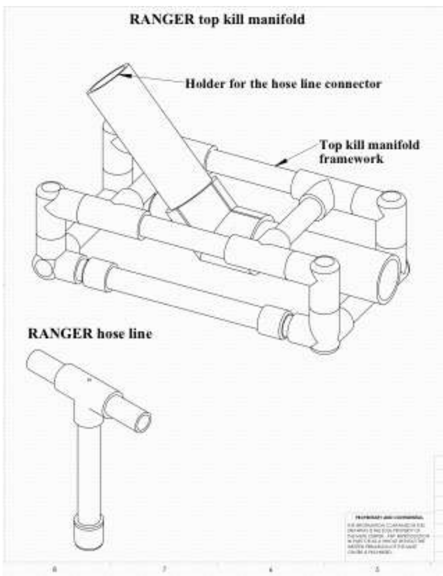


Figure 12: Ranger Class Top kill manifold and Hose line isometric CAD drawing.

The riser pipe is constructed of ¾” class 200 PVC. It has a U-bolt extruding from the top part of it. The U-bolt is 3/8” x 3 ½” x 3 5/8” and is 8.8 cm wide and extends 8.5 cm above the PVC pipe. The cut area is constructed of a ¾” PVC coupling. An 8.5 cm length of ½” PVC descends below the coupling and 10.5 x .3 cm piece of Velcro encircles the cut area.

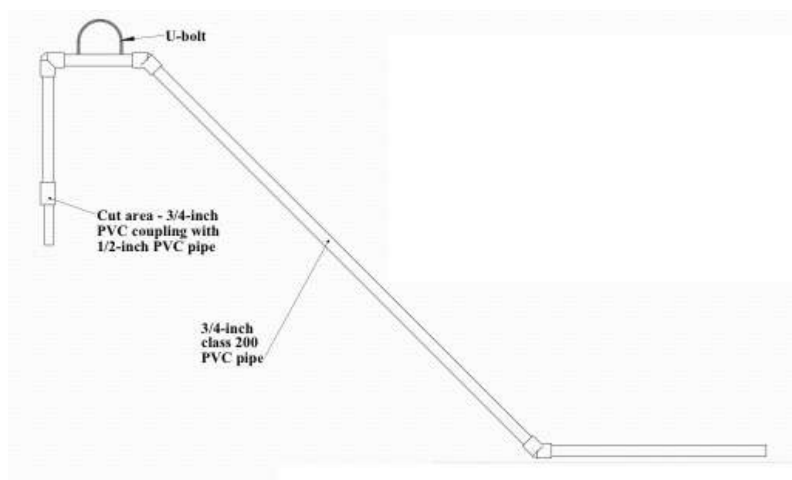


Figure 13: Ranger Class Riser pipe CAD drawing.

Payload Tools and Alternatives

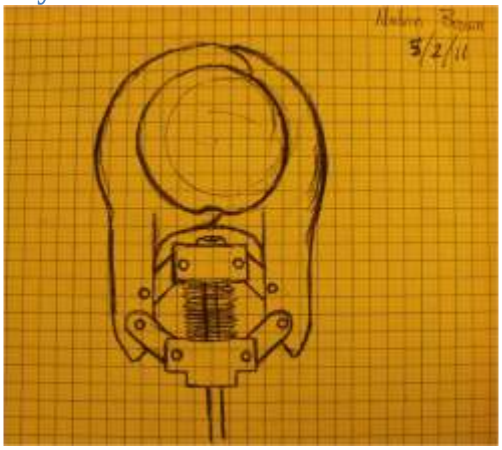


Figure 14: One of the designs for the claw.

The ideas for the payload tools we had were numerous. Some of the ideas included a manipulator which just rotated to turn the valve wheel, a fish net manipulator to capture biological samples, a claw that just opens and closes, and a claw which rotates and opens and closes at the same time.

The idea we ended up going with is the claw that opens and closes and can rotate at the same time. It uses a rack and pinion for the linear open and close motion. The rotary motion is controlled using a motor attached to the manipulator using machined ABS plastic and a setscrew. The claw itself is made from ¼" thick lexan that was cut with a jigsaw and the edges were rounded down with the sanding bit on a Dremel.

Troubleshooting

When we were testing the ROV on land, we had a problem with something on the electronics control board. When we turned on the electronics, something began to smoke. We did not know where the smoke was coming from and whether or not it was a bad wire or a bad electronics component. So, we quickly turned on the electronics board again and saw the general area that the smoke was coming from. We switched the board off. Then, we began to test individual components of the electronics board. We finally came across what was wrong. A victor controlling one of the propellers was broken and it caused the smoke that we saw. We replaced the victor and everything worked fine.

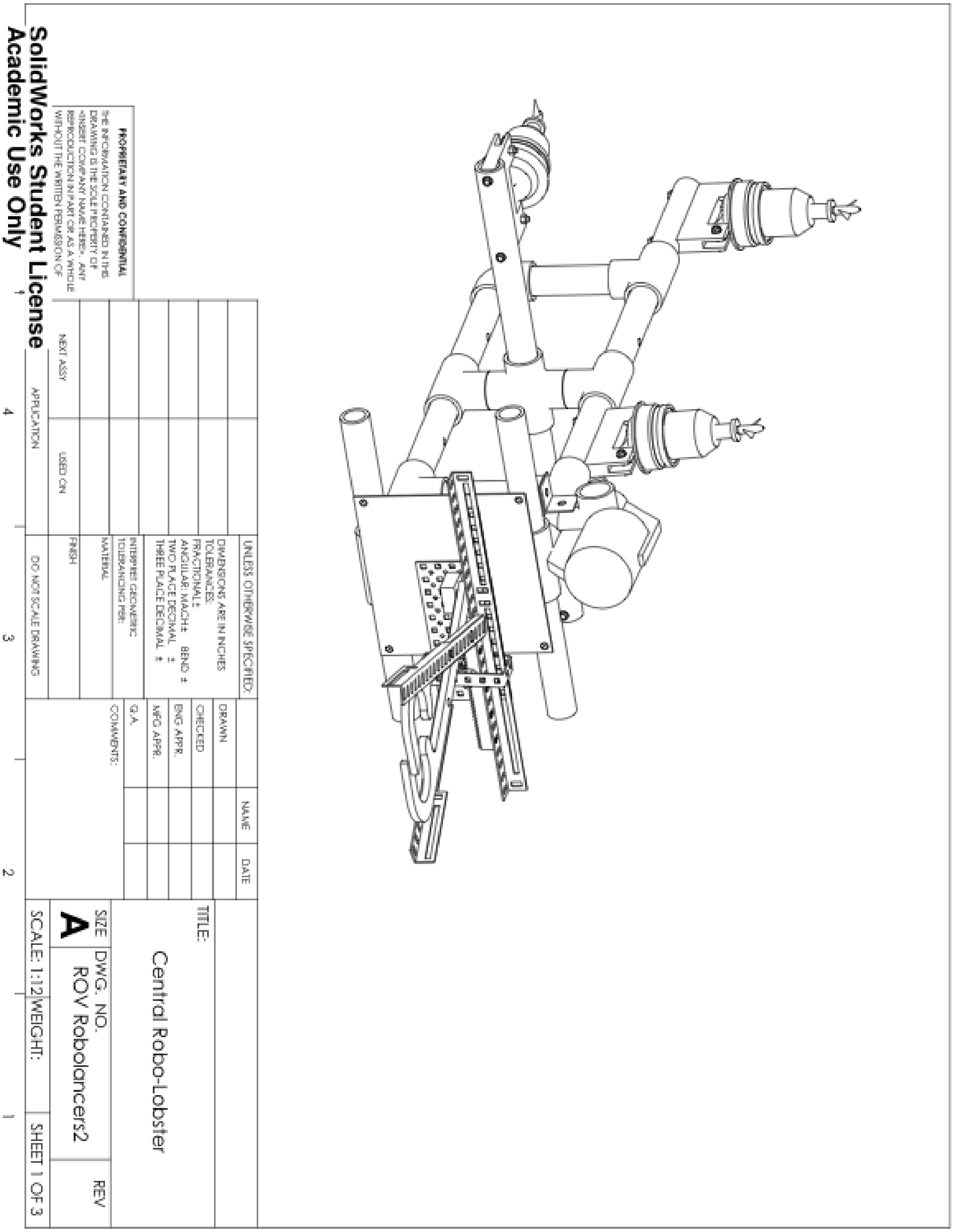
Future Improvement

After we tested the ROV in the water, we noticed a few things wrong with the placement of the motors that caused some minor complications. The motor's placement was far from the center of mass of the entire ROV. This allowed for more torque when the motors are turned on, making the movement difficult to control. We would move the motors so that they would be closer to the center of mass of the ROV.

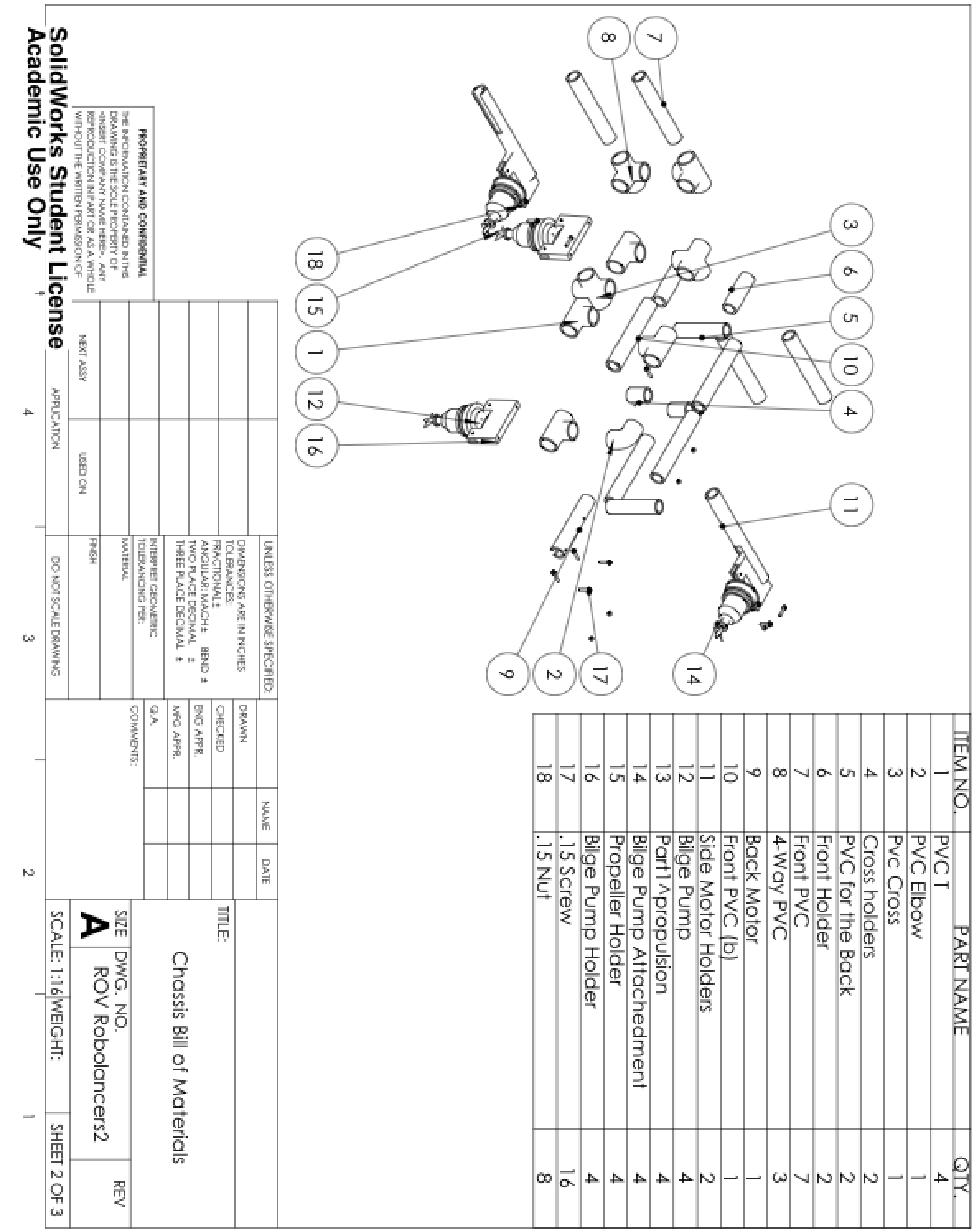
Lessons Learned

The lessons that the RoboLancers learned from this years MATE competition are many and to list them in one small section would be almost impossible. However, most of the lessons learned had to deal with communication skills. We learned it is extremely important to properly document design ideas and constraints. We had one particular instance in which the lack of communication caused design errors. When the manipulator team was conducting its design process, it failed to go over the constraints that were designated. The dimensions on the claw were wrong, which wasted time and materials. From then on, everything was in writing and double-checked.

RoboLobster CAD Assembly

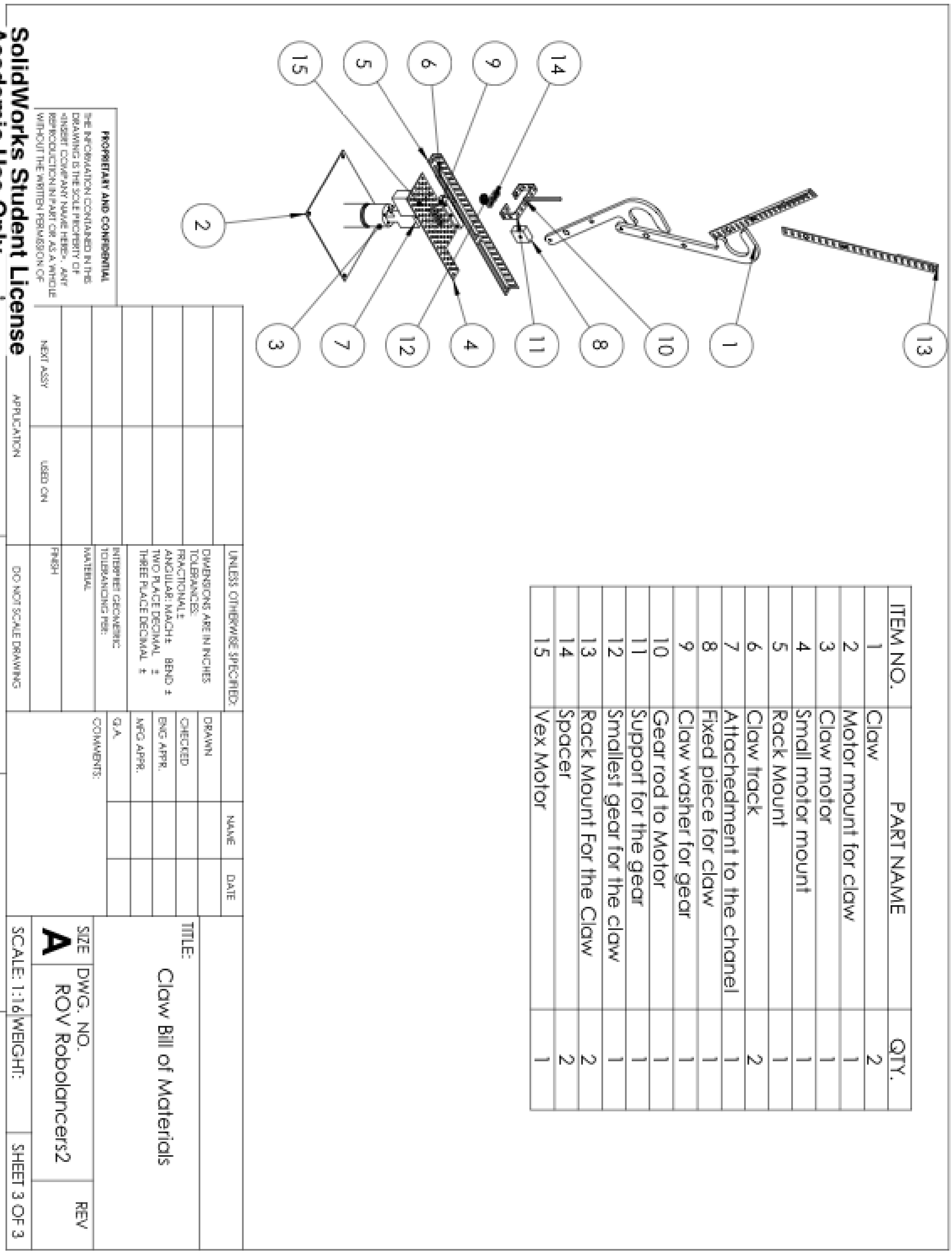


Chassis Exploded CAD Drawing with Bill of Materials



ITEM NO.	PART NAME	QTY.
1	PVC T	4
2	PVC Elbow	1
3	Pvc Cross	1
4	Cross holders	2
5	PVC for the Back	2
6	Front Holder	2
7	Front PVC	7
8	4-Way PVC	3
9	Back Motor	1
10	Front PVC (b)	1
11	Side Motor Holders	2
12	Bilge Pump	4
13	Part1 Apropulsion	4
14	Bilge Pump Attachedment	4
15	Propeller Holder	4
16	Bilge Pump Holder	4
17	.15 Screw	16
18	.15 Nut	8

Claw Exploded CAD Drawing with Bill of Materials



ITEM NO.	PART NAME	QTY.
1	Claw	2
2	Motor mount for claw	1
3	Claw motor	1
4	Small motor mount	1
5	Rack Mount	1
6	Claw track	2
7	Attachedment to the chanel	1
8	Fixed piece for claw	1
9	Claw washer for gear	1
10	Gear rod to Motor	1
11	Support for the gear	1
12	Smallest gear for the claw	1
13	Rack Mount For the Claw	2
14	Spacer	2
15	Vex Motor	1

Reflections

"*MATE has taught me how important documentation is in any engineering process. It has taught me that teamwork relies on keeping accurate record of designs and that engineers communicate through drawings and models. MATE also taught me that the building step in the engineering process is not the most important step, but rather the designing step is because without a solid design, building really means nothing.*"
Mary Conrad, Grade 12
Chief of Documentation
Career Goal: Mechanical Engineer

"*MATE has taught me how to effectively waterproof things. MATE has also taught me how to deal with laminar flow, which could help me build radiator systems for automotive engineering.*"
Kyle Fragassi, Grade 12
Chief Mechanical Engineer
Career Goal: Automotive Engineer

"*By taking part in the MATE competition, I learned how to properly utilize SolidWorks. We designed some of the claw in SolidWorks and realized there was a serious problem. We saved tons of time designing in SolidWorks first because it helped us to realize potential problems before they occurred.*"
Craig Talis, Grade 11
Head of Propulsion
Career Goal: Engineering

"*The oil spill crisis was a real and current problem that affected all of us. By participating in MATE, my eyes were opened to the situation and the competition allowed me to use practical skills to try to find a solution.*"
Kevin Scott
Structure Team Member
Career Goal: Computer Programmer

"*MATE has been an interesting experience for me, I have never worked on an underwater robot before. MATE taught me time management, problem-solving skills, and to always be open minded about your design. These skills are skills that will be very useful in my pursuit of becoming a biomedical engineer.*"
Alexandra Thompkins-Johns
Chief Operating Officer
Career Goal: Biomedical Engineer

About Us

The Central High School RoboLancers are a unique group of people. The name "RoboLancers," actually encompasses two separate, yet very closely-knit groups of people. At Central High School, there is a class and a club. The club has been around for 11 years and partakes in the FIRST and BEST Robotics Competitions. The class has been around for 4 years. Only last year did the Robotics class begin to enter into a robotics competition. There are 18 members of the class and their roles are listed on the title page. This is the second year for the Central High School RoboLancers to be in the MATE Competition. The class solely completes the MATE Competition, although many of the members of the club are in the class. Before the MATE Competition, the class learns about the engineering process, mechanical advantage, buoyancy, simple machines, safety training, and tool training.

Each day, we have approximately 55 minutes of class. As the MATE Competition's deadlines approached, a vast majority of dedicated class members stayed after school until at least 5 o'clock every night, sometimes later, to get the work that needed to be done finished.

In order to help offset some of the costs associated with entering into a competition, the RoboLancers held several bake sales. They also joined with the RoboLancers Club and hosted the first annual Philly Robotics Expo, which was a huge success. This event showcased the work that high schools, colleges, and companies are doing in the field of robotics.

Figure 15: RoboLancers (left to right)(back) Micheal Manson, Alexandra Thompkins-Johns, Melvin Brown, Joshua Lynch, Kyle Fragassi, Mr. Daniel Ueda, Kevin Scott,(middle) Mary Conrad, Bianca Rivera, Jonathan Zhu, Craig Talis, Linda Babu, Magaret March, (front)Kevin Mai (Not present) Gabriela Alfaro-Angulo, Rose Manjarres, Quahmir Martin, and Jocelyn Mar

Acknowledgements

We would like to thank:

-MATE Rover for allowing us to participate in this competition.

-Joan and Bernard Spain for generously refurbishing our robotics lab and providing a safer, cleaner, more modern area for us to work in.

-The Widener School for allowing us to use their pool for testing.

-The Alumni Association of Central High School for providing funding, which made it possible for us to go to the International Competition.

-Our teacher/coach and mentor Mr. Ueda for spending so much time both in class and after school imparting his knowledge on us and guiding us through the engineering process.

-Our Philly Robotics Expo sponsors, who generously donated funds towards the advancement of the robotics programs in our school:

SolidWorks
Society of Women Engineers
Drexel University
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igus
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The School District of Philadelphia

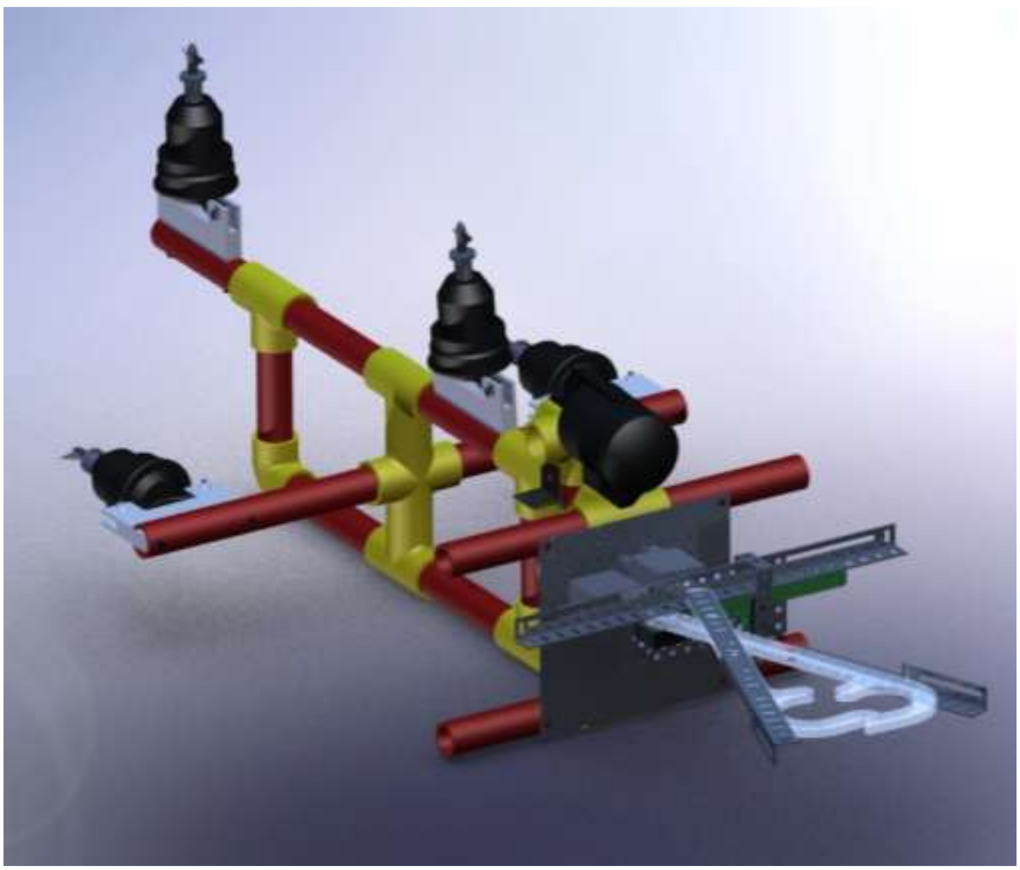

Figure 16: CAD Final Rendering of the RoboLobster.