Walnut Valley Quantum

Hydromechs

Technical Report

Diamond Bar High/ Walnut High

Orange County, California, U.S.A.

2017 Team Organization

Johnathan Chiu: Chief Executive Officer, Class of 2018

Kimberly Sung: Chief Operation Officer, Class of 2018

Tiffany Wu: Chief Finance Officer, Class of 2018

Ashley To: Engineering Design Lead, Class of 2018

Colby Chang: Programming Lead, Class of 2019

Salvador Rodriguez: Mechanical, Class of 2020

Evelyn Pan: Mechanical, Class of 2019

Sean Chang: Software, Class of 2020

Renny Gong: Mechanical, Class of 2019

Peter Hsueh: Software, Class of 2020

Daniel Paz: Engineering Design, Class of 2018

William Loo: Founder/Mentor Class of 2017

Pakshal Shah: Mentor, Class of 2017

Mentors

Mr. Bill Chiu

Mr. Richard Loo

Mr. William Shih

Mr. Matt Sandt

Abstract

The popularity of the sunny Port of Long Beach continues to grow as the commerce and entertainment industries prosper. As Californians, the Walnut Valley Quantum Hydromechs team takes great pride in maintaining the beauty and productivity of the port. Composed of 13 dedicated high school students, the team uses the principles of physics, math, and engineering to create Cetacea, a Remotely Operated Vehicle (ROV). Cetacea's design meets all the needs of maintaining Long Beach's entertainment equipment and collecting contaminated samples for the safety of tourists, workers, and the environment. Our underwater robot features shrouded, bright orange propellers for safety and a stainless-steel frame to ensure durability. The busy Port of Long Beach is home to commerce and industry and it is the company's dedication to construct an ROV that can accomplish all the client's requests for proposals.


[1]

Bottom row from left to right: Ashley To, Renny Gong, Kimberly Sung Johnathan Chiu, Tiffany Wu, Colby Chang
Top row from left to right: Evelyn Pan, Daniel Paz, Salvador Rodriguez, William Loo, Pakshal Shah, Sean Chang
Missing: Peter Hsueh

[1] Photo by Shing Lin

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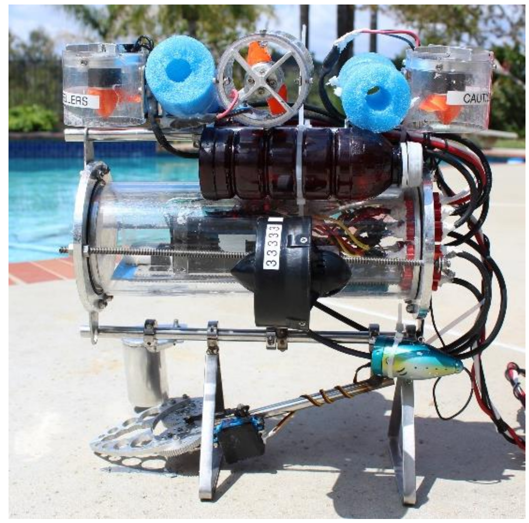
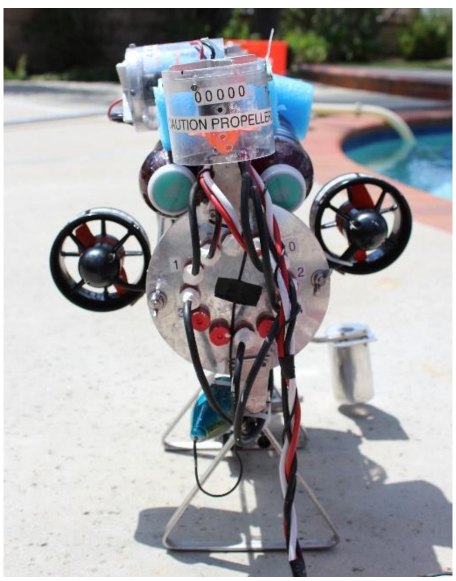
[2]Completed ROV

Front View

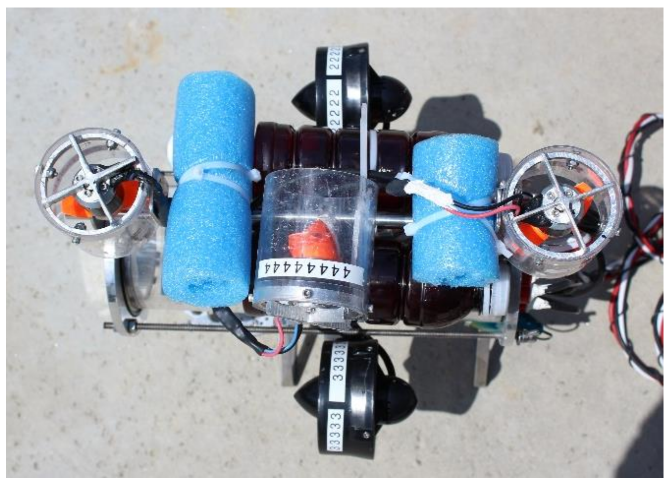
Side View



Side View

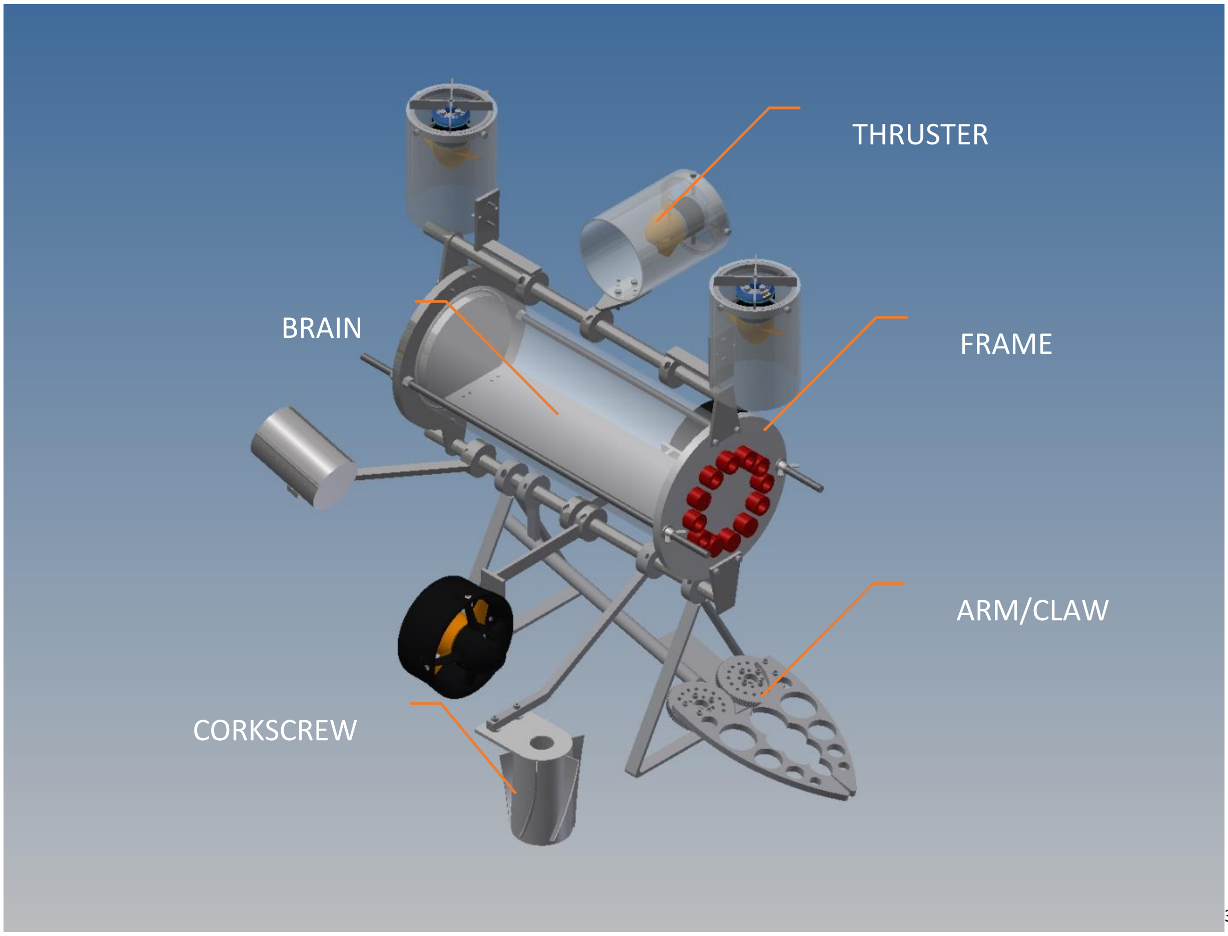


Back View



Top View

[2] Photos by Kimberly Sung



[3]

"Cetacea glides smooth, just like the rest of its family."

Design Rationale

Versatility is very important to us. Last year, we were often faced with the challenge of changing our design throughout the season. This year, our goal was to create a ROV that would utilize modular construction. We achieved this by clamping shaft collars, which held components like our thrusters, arm, and agar collector, to the stainless steel tubing built into the main chassis of Cetacea. As we developed and added system components this season, we were able to move the components around easily to accommodate new additions, allowing us to even empirically determine an optimal use of our ROV dimensions by experimentally moving components back

[3] CAD by Ashley To

and forth. To further streamline mission performance in these conditions, the company developed an efficient task order to minimize the number of trips to the surface.

Frame and Tether

The frame is constructed out of stainless steel to maximize the strength and durability of the ROV through all the tasks it must complete. Other benefits to using stainless steel include its corrosion resistance and chemical resistance. The frame was built to accommodate a variety of possible designs and elements that could be altered at any time, such as the claw, thrusters, and camera. By simply welding the elements to a split collar and attaching the split collar to the rod, we were able to incorporate five thrusters, an arm, and a camera. Our rod-screw closure ensures that our electronics rack is safe from leakage and allows the robot to be easily disassembled and assembled.

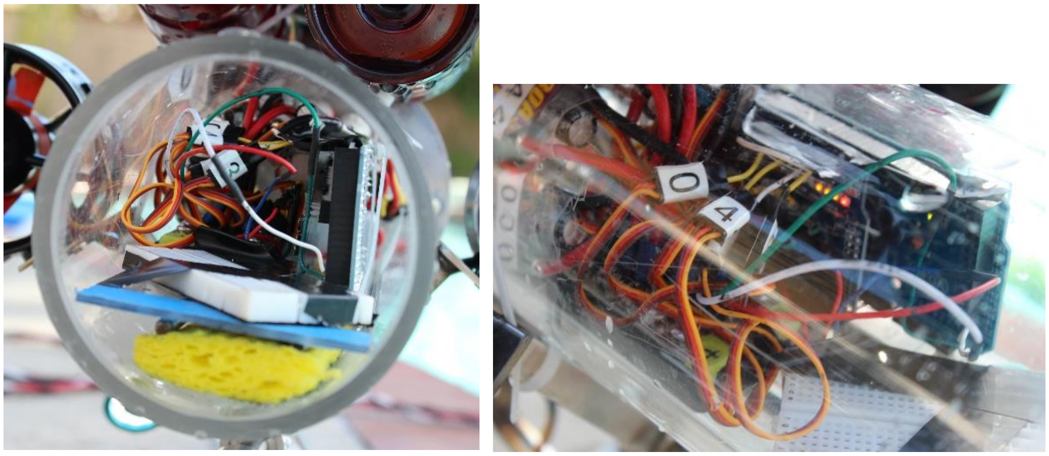
The tether consists of one Ethernet cable, two 12 gauge wires, and one camera cord. Since the tether is 15 meters long, it is braided to prevent tangling. Each wire connects back into the base of the robot through penetrators that have been epoxied to prevent leakage. To gain a firmer hold on the robot, the tether was zip-tied to the frame for strain relief.

Braided tether

Frame

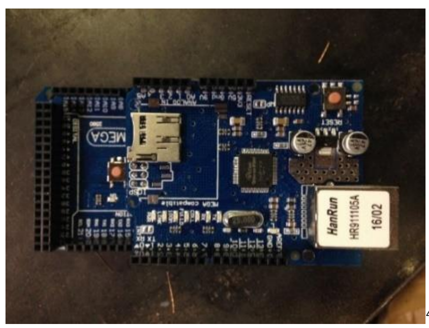
The Brain

The Brain is the control center of Cetacea and is composed of an Arduino MEGA 2560, a 12-volt terminal block, and ESCs (Electronic Speed Controllers). It receives Ethernet packets from the topside control computer running our customized Java control program and interprets the data into commands which activates motors and servos at variable speeds.



The Brain with all of its components connected. Front view and side view.

Command and Control Systems



[4]

Arduino Mega 2560 with Ethernet Daughter Board

The control system employs:

- A tether with an Ethernet cable
- Two programs that use Java and C++
- A Logitech video game controller
- The Joytokey application

The control system is designed to be accessible to any user. All parts of the robot can be controlled using a typical video game controller. All the movement and functions of the robot can be controlled using the two joysticks, the trigger buttons, and the “X” and “Y” buttons. Using the two joysticks, the user can move the robot forward and backward, turn the robot left or

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[4] Photo by Kimberly Sung

right, and make the robot strafe from right to left. Because the two joysticks each control their own individual motor, the robot's movement is very flexible and can move in any direction. Additionally, the robot's forward and backward controls have variable speed. We utilized an exponential function when interpreting the values inputted by the joysticks, meaning that a full press would give it greater speed, while an incomplete press results in a slower speed for more precise movement. The trigger buttons allow for the robot to ascend and descend by controlling the two vertical motors. Lastly, the claw is controlled by the "X" and "Y" buttons, which open and close the claw.

The system functions by initially opening a client from the computer (the java program) that the Arduino Mega and the computer both read. If a keypress, or frequency, of a specific key is found, the key is then displayed to the client. On the C++ side, or the Arduino Mega side, the program interprets the information that is being displayed by the client. If a certain key is displayed, the board will activate the relevant motors for movement or the servo for the arm. All of the keys are inputted from the game controller. The entire process is facilitated by the tether and Ethernet cable connected from the computer to the Arduino Mega.

Thrusters and Thruster Placements

Instead of using factory made thrusters, we chose to use custom ones. Unlike premade thrusters, the custom thrusters are able to accommodate size limitations. Also, we could easily disassemble whenever there is an issue with the motor. The ROV consists of 5 thrusters: two for front and back movement, two for up and down, and one for side by side. Each thruster is built with a brushless motor. The two, horizontal thrusters provide over 5 pounds of thrust and a rotational speed of 300-4200 revolutions per minute. The other three thrusters are built on the same motor with 3-D printed propellers. All of the thrusters are controlled with ESCs. Two horizontal thrusters are placed on either side and attached to the bottom rod of the frame to turn the ROV and to balance the weight. The two thrusters placed on the top are upside down to maximize space for other elements like the camera and the claw. They control how the ROV travels up and down. Lastly, the thruster on the top controls its left and right movement.

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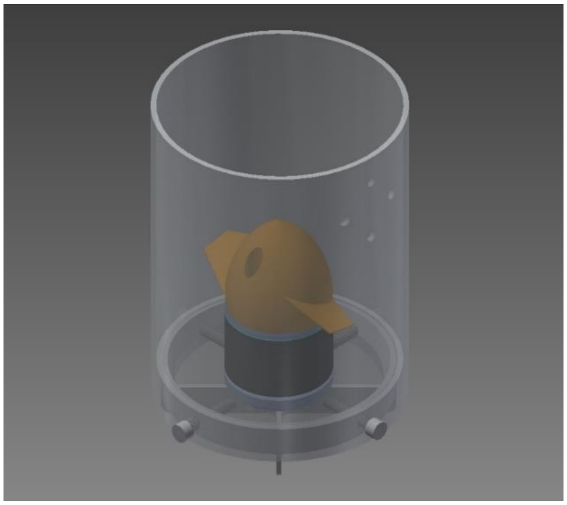

Motor for the vertical and side by side directions.

6

Motor for the front and back directions.

Arm and Claw Design

The arm is designed to perform a multitude of tasks. It is constructed out of stainless steel and aluminum for durability and reduced weight. The arm is mounted on stainless steel tubing and welded to one side of a two-piece split collar, which is attached to the main frame of the bot. We chose the two-piece split collar in order to make the arm easily detachable and modifiable, so we could continue improving and testing it quickly. Mounted in the center of the robot, the claw is attached to the center frame, at the lowest part of the robot, so that we can easily pick things up. On the other side, we welded the tubing to a stainless-steel plate, with drilled holes for bolts, to attach two swivels. One side of the swivel is attached to the plate and the other is attached to a gear so that it can rotate freely. The claws are attached to two gears that are set against each other. The claws are pulled by a single stainless-steel rod attached to the gear with a swivel bearing. The other end of the rod is connected to a hub arm on the servomotor. The stainless-steel piece where the swivels are mounted and the claw pieces were hand-crafted by our team. The claw pieces were designed with rough inside edges in order to maximize grip and with holes drilled into the center to reduce the weight of the claw.

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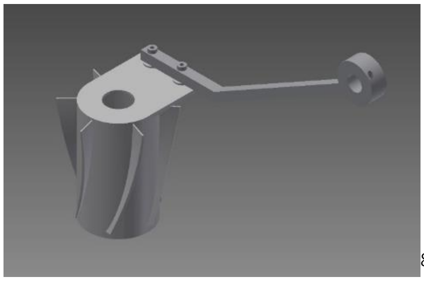
[5] CAD by Ashley To
[6] CAD by Ashley To


[7]

The CAD of the claw design.

Corkscrew

The corkscrew is designed solely for the task of picking up contaminants. It is made of a 5-centimeter aluminum tubing welded to an aluminum plate with a hole drilled through it. A piece of acetate is fixed on top of it loosely enough so that air can escape, but not so loose that the agar escapes as well. The volume of the agar pushes out the air through the acetate flap. When extracted from the cup of agar, the acetate flap seals shut from the force of the displaced air pulling against it. This creates a vacuum that keeps the agar safe inside the container. The outside is sheathed in an acetate cylinder connected to strips of acetate that are glued on with hot glue. The cylinder is present because hot glue doesn’t stick to metal; however, it adheres very well to acetate. The function of the acetate strips is to break the vacuum that holds the agar to the outside of the aluminum tubing.


[8]

The CAD of the “Corkscrew” design used to pick up the agar in task 3.

[7] CAD by Ashley To
[8] CAD by Ashley To

Camera


[9]

Innobay underwater fishing camera. 7 inch Color LCD HD Monitor 800×480 TFT 1000tvl 30M Cable length. waterproof (IP 68) Mfg Part# i-UV70 SY-7001

Since the "Innobay Professional Fish Finder Underwater Fishing Video Camera" we used last year worked so well, we decided to repurpose it for this year's ROV as well. The camera provides an 800x480 pixel view of what is in front of the robot and comes with a 12- piece LED light that can illuminate whatever the camera is looking at. We placed the camera at the bottom of Cetacea with a downward angle in order for the driver to see the claw, the corkscrew, and the task the ROV is performing. To maximize perspective, we placed the camera as far back as we could without obscuring the view. We used zip ties were used to attach the camera onto the ROV to take advantage of their functionality in case further repositioning was required.

Buoyancy

Achieving a variable ballast system is a very important part of a having a well-controlled submersible. After we constructed the entire ROV, we put our full attention into making sure it would remain buoyant when it was underwater. We zip tied hard plastic beverage bottles onto the sides of Cetacea, which worked to some degree. Last year, the plastic bottles did the job perfectly because our frame was made out of PVC. However, we chose to use stainless steel for the frame this year, causing the ROV to be weighed down significantly. Although we had control of how buoyant we wanted Cetacea to be, the extra weight of the metal forced us to take an extra measure. We decided to attach pool noodles onto the top of the frame to make it more buoyant. The pool noodles were easily acquirable and efficient to use. Whenever we changed the design of the frame, we could simply cut and alter the shape of the foam noodle. The robot became more controllable to prevent tilting and sinking when driving.

[9] Photo provided by Innobay's website.

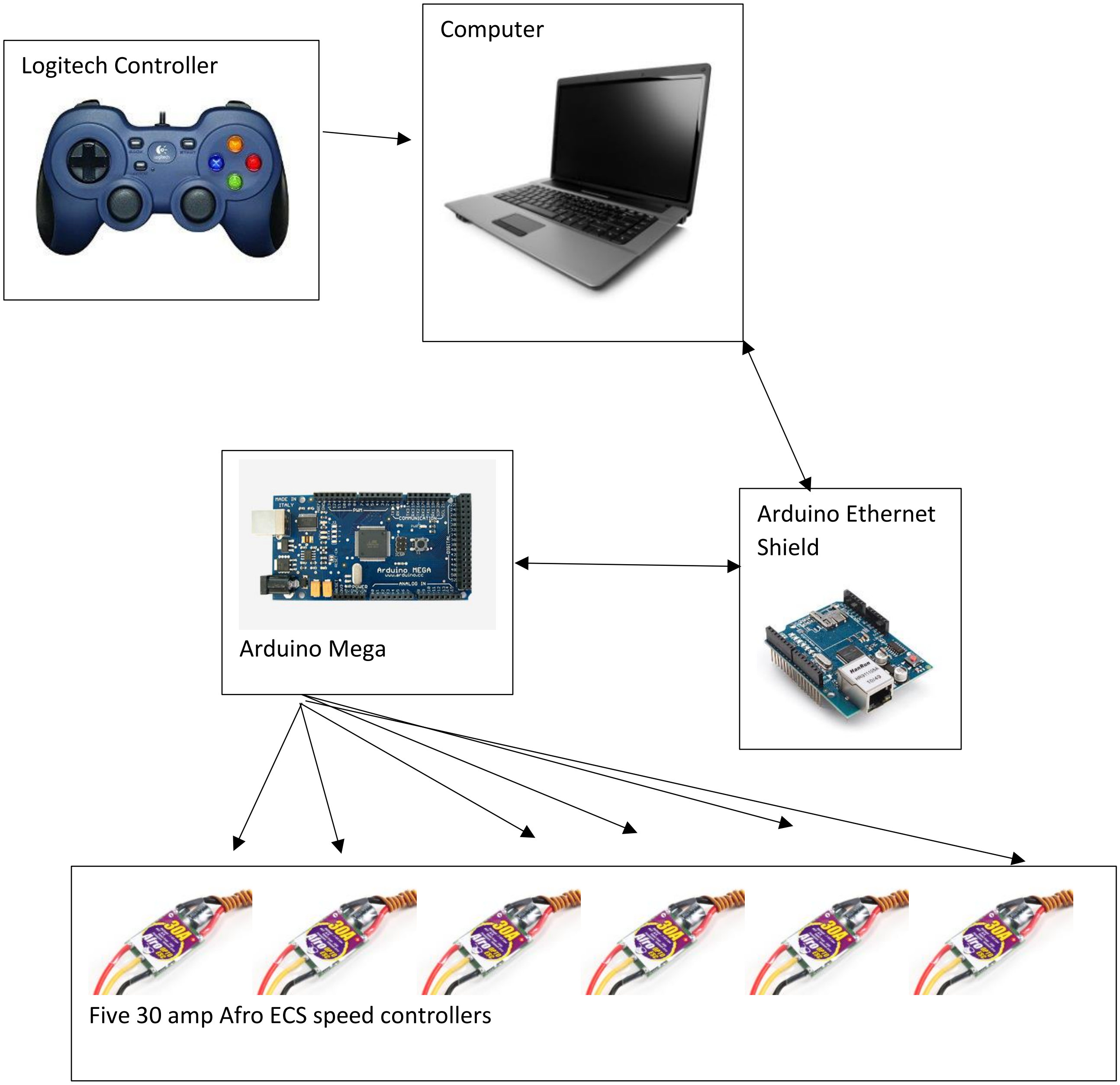
Mission Strategy

Name of Task	Task #/set	Number of Points	Difficulty (1-5)
Rebar	1	5 x 2	2
Frame	1	20	2
Pin	1	5	3
Hose	1	10	2
Beacons	1	5 x 3	1
Remove Power Cable	2	5	1
Turning Valve OFF	2	10	5
Switch OFF	2	5	2
Remove Fountain	2	5	1
Replace Fountain	2	5	1
Switch ON	2	5	2
Turning Valve OFF	2	10	5
Reconnect Power Cable	2	10	5
Raman Spectrometer (LED)	3	5	2
Collecting Clams	3	5 x 2	1
Collect Agar	3	30	2
Cap	3	15	1
Find 4 Containers	4	5	1
Insert Sensors	4	5 x 4	1
Use RFID High Risk	4	5 x 4	2
Attach Buoy to High Risk	4	10	4
Determine Container Distance	4	5 x 3	5
Distance and Direction Survey Map	4	10	5

System Architecture

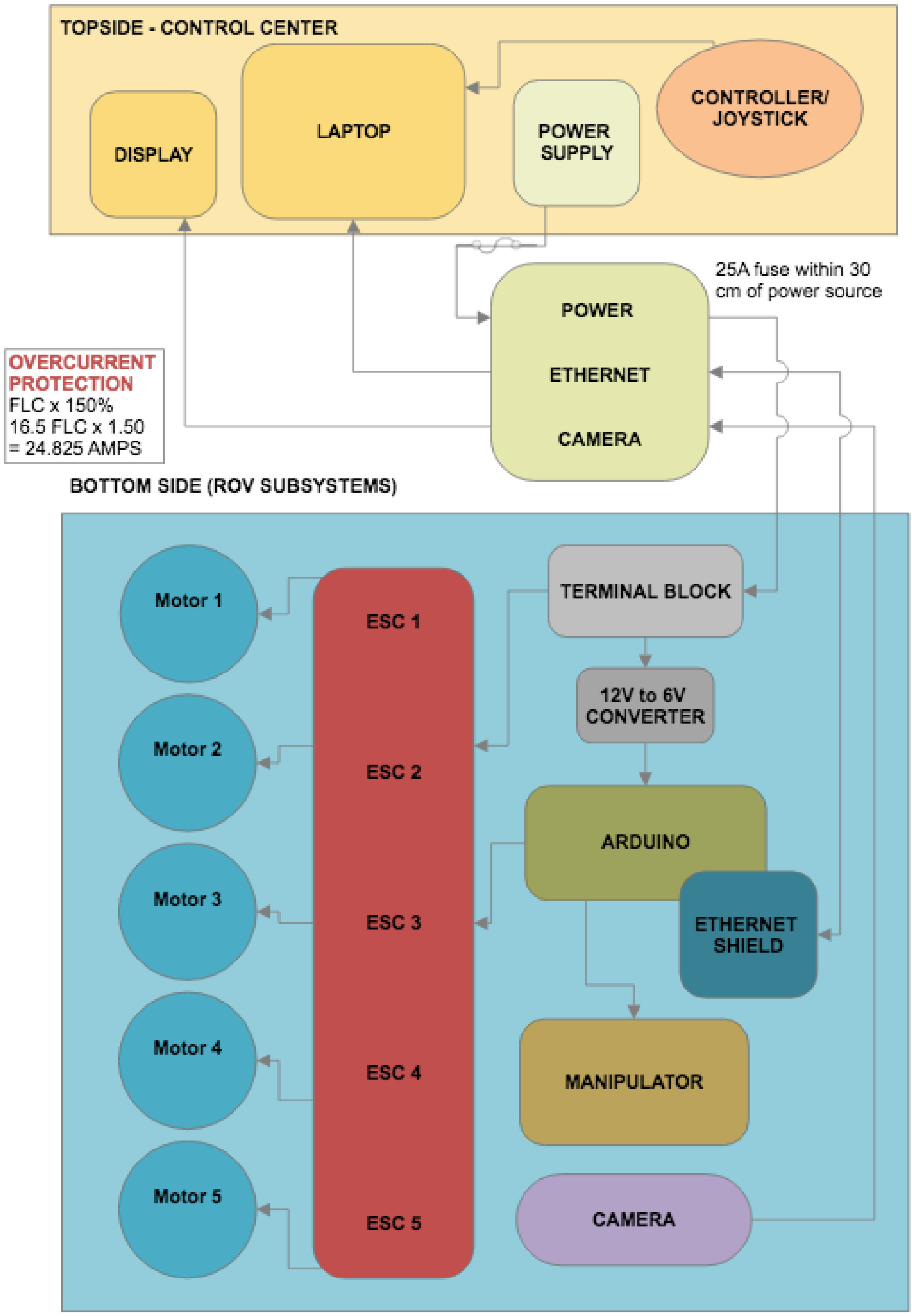
Block Diagram

[10]*The following guide is a general map of the major system components and how they are connected.*



[10] Block Diagram by Peter Hsueh

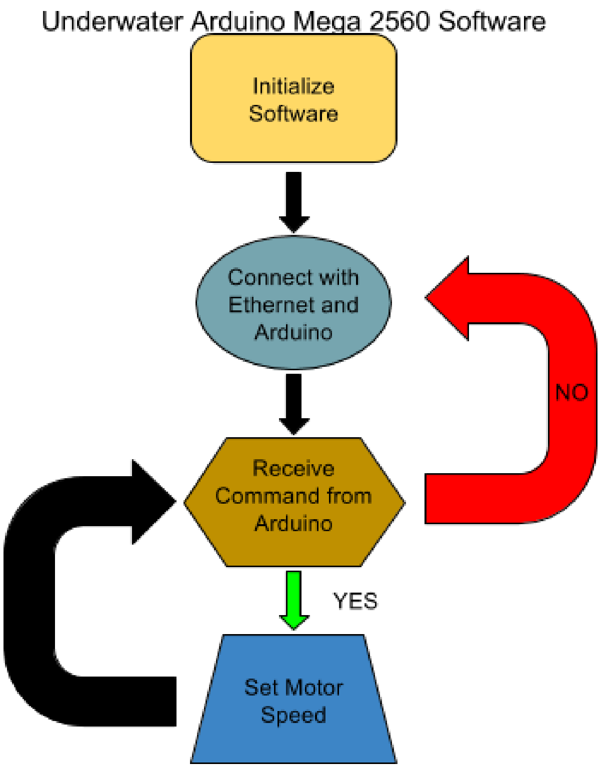
System Interconnection Diagram (SID)



The SID diagram maps the electrical components and how they interface to each other. It shows how the operator commands are translated to vehicle controls.[11]

[11] SID by Johnathan Chiu

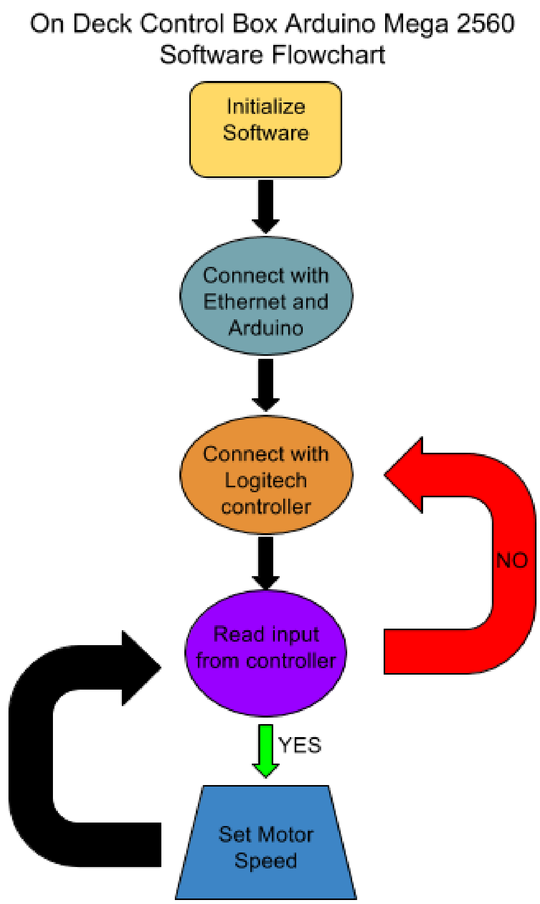
Software Flow Check



[12]

The diagram above depicts the basic flow of the major software steps that occur when Cetacea is underwater.

[13]



The diagram above is a basic flow chart of the major system processes that happen when Cetacea is on deck. Mainly when members are uploading new code or checking for errors.

[12] Flow Check Chart by Colby Chang
[13] Flow Check Chart by Colby Chang

Build of Materials

ITEM[14]	QUANTITY	UNIT PRICE	TOTAL
ROV Costs			
2-IN X 10-FT SCH40 PIPE	1	$7.70	$7.70
1/2-IN X 10-FT 315 PSI PR	1	$1.99	$1.99
5/16-IN X 2-1/2-IN X 5-IN	2	$1.37	$2.74
BHK #100 10-FT OBLG HBY D	2	$6.97	$13.94
2-IN SCH40 TEE 401020	8	$2.48	$19.84
5/32-IN X 38-FT DIMND POLY BR	1	$3.47	$3.47
2-IN SCH40 BUSHING 438247	2	$1.97	$3.94
1/2-IN SCH40 ADAPTER 4360	4	$0.26	$1.04
1-1/4-IN SCH40 BSHNG 4381	3	$1.08	$3.24
1-IN X 1/2-IN BUSHING 437	3	$0.54	$1.62
1-IN SCH40 COUPLING 42901	3	$0.46	$1.38
1/2-IN SCH40 TEE 401005	4	$0.34	$1.36
1-1/4-IN SCH40 COUP 42901	3	$0.63	$1.89
1-IN SCH40 ELBOW 406010	2	$0.98	$1.96
1/2-IN SCH40 ELBOW 406005	2	$0.40	$0.80
1-IN SCH40 CROSS 420010	1	$2.78	$2.78
1/2-IN SCH40 SIDE OUT ELB	5	$0.98	$4.90
1/2" PVC EL 90D SXS	6	$0.35	$2.10
1/2" PVC TEE SXSXS 10 PACK	2	$2.84	$5.68
THRUSTER CABLE	1	$14.00	$14.00
BASIC 30A ESC	3	$25.00	$75.00
TRAXXAS 2056 HIGH-TORQUE WATERPROOF SERVO	2	$24.02	$48.04

[14] Chart made by Tiffany Wu

T100 THRUSTER	1	$119.00	$119.00
Miscellaneous			
#700 TAPE 1 UNIT 3M	1	$1.99	$1.99
LOCTITE MARINE EPOXY	1	$6.00	$6.00
SILICONE GREASE	1	$3.38	$3.38
OATEY 8-OZ PVC CEMENT	1	$5.38	$5.38
LEAK SEAL WHITE 15-OZ	1	$12.98	$12.98
Tax/Shipping			
TAX	1	$7.47	$7.47
TAX	1	$0.68	$0.68
SHIPPING	1	$4.00	$4.00
TAX	1	$1.23	$1.23
SHIPPING	1	$6.00	$6.00
TAX	1	$6.56	$6.56
TAX	1	$4.20	$4.20
SHIPPING	1	$14.00	$14.00
TAX	1	$10.94	$10.94
TAX	1	$1.14	$1.14
TOTAL COST (Cost from this year and parts used from last year)	$2000		

A list of all the materials bought this year with total budget adding up to $2,000 last year's salvaged parts included.

Safety

[15]Here at Hydromechs, the safety of our members, advisors, and supervisors is of the utmost importance. According to the strict company policies, members must obtain their own pair of safety glasses and working gloves before attending any work meetings. General safety guidelines include wearing closed-toed shoes (toes and burning solder do not bode well) and tying up hair to avoid injury with power tools and soldering irons. In the case that an injury does occur, a supervisor will always be present to handle the situation. Members are to report any injuries so that that there will be a proper follow-up to treat the injury.

Figure 2: Member wears safety goggles to protect eyes from plastic that may fly off while drilling.

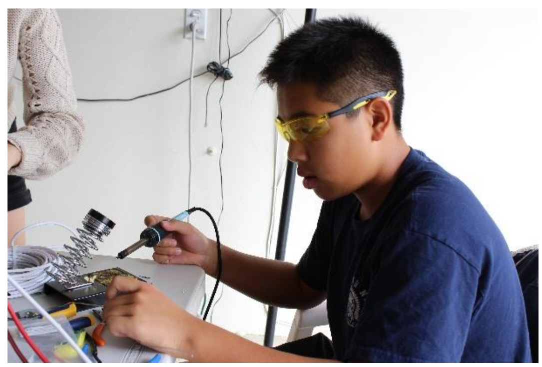


Figure 1: Member wears safety goggles while soldering in case hot solder starts to splatter.

Checklist

Safety:

- Members are wearing closed-toed shoes
- Long hair is tied back to avoid accidents involving power tools or soldering irons
- Long, dangling jewelry is removed
- Safety glasses are worn when on deck or during the use of any tools
- Gloves are worn during power tool use
- All electrical connections are secure—no exposed wires

[15] Photos by Kimberly Sung

- Double-check all connections to make sure they are plugged in properly

Pre-Run:

- Double check that electrical power connections are plugged in and operational
- Make sure the camera is running
- Check waterproof seals
- Check that electronics boards are safely enclosed in the center capsule
- Dry-run the thrusters to check if they are functioning properly
- Actuate the arm to check if it is functioning properly

On Deck:

- Follow Tether protocol
- Unplug battery before uploading new files of code to prevent short circuiting
- Check all electrical connections to make sure they are plugged in correctly
- Power up the ROV
- Double check functionality of the thrusters and arm
- Deck Crew gives a "Ready" signal

Post-Run:

- Follow Tether protocol
- Disconnect the power, then the tether from the laptop
- Disconnect all electrical connections, such as those for the thrusters and arm
- Dry the ROV in case of any leaks while running

Tether Protocol:

- After unrolling tether, plug one end into the laptop's Ethernet port and the other into the Ethernet shield of the ROV
- Position laptop and ROV carefully so that tether will not be in the way and laptop is secured on land
- Watch tether when the ROV is driving underwater so that it will not be tangled
- After use, unplug both ends of the tether and roll up the tether neatly to prevent tangling

Power Troubleshooting

Throughout the year, there were multiple failures that required troubleshooting. A large issue with our ROV failures was due to faulty soldering. Many times, we couldn't get the motors to work. In one instance, when we removed the electrical tape on the bullet connector joints, we found that the bullet connector came off with it. We solved these issues by re-soldering the joints and applying less pressure on them by shortening the overall wire length so the joints wouldn't bend and twist as we plugged the connectors into our ESCs. Also, we found issues with the communication from our laptop to our ROV. We realized that this was due to a bad connection in the Ethernet cable itself. To solve this issue, we used a new Ethernet cable to establish a sustainable connection with the ROV while on dry land. The new Ethernet cable worked perfectly, so we began to question why our original Ethernet cable failed. It turned out to be a loose connection from the wire to plug-in on the Ethernet. We re-crimped the Ethernet connector on the ROV, solving the problem. Similar to last year, we had many issues with trying to keep the jumper wires in the Arduino ports. While underwater, the motor would sometimes stop working and we would need to bring the robot back to the surface to plug in the wires again. This issue was easily resolved by taping the wires into the ports with electrical tape.

Team Schedule

<table>
<tr><td>[16]</td><td colspan="10">MONTH</td></tr>
<tr><td>TASK</td><td>Aug</td><td>Sept</td><td>Oct</td><td>Nov</td><td>Dec</td><td>Jan</td><td>Feb</td><td>March</td><td>April</td><td>May</td></tr>
<tr><td>Preliminary design and analysis</td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
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<tr><td>Fabrication and buying parts</td><td></td><td></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td></td><td></td><td></td></tr>
<tr><td>Assembly</td><td></td><td></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td></td><td></td></tr>
<tr><td>System level testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td><td></td></tr>
<tr><td>Operation testing</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td style="background:#f8cbad"></td><td style="background:#f8cbad"></td></tr>
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[16] Gantt Chart be Kimberly Sung

The Gantt Chart above is a basic outline of the year's work schedule.

Reflection

As a second-year team, we had the drive and motivation to excel our work from last year. Learning from our mistakes from the last season, we were prepared to face all the challenges we came across and had trouble solving the previous year. With careful planning and better pacing, were able to solve previous and new problems that arose.

Challenges

Throughout the season, we faced countless challenges in brainstorming, designing, and building Cetacea. One of the major problems that our team encountered was a very common one that occurs in all fields of engineering regardless of the field-- leaking. Once we completed the main design of the ROV, we fully submerged our robot into the water and immediately noticed a slight leaking where the main wiring components are situated. About a quarter of a liter of water had leaked through an unknown aperture in our bot. To pinpoint the problem, we carefully tied tissue around each wire joint. Once we knew exactly where it leaked, we re-soldered and epoxied the wire joints again.

Another challenge that our team faced in developing our ROV was regarding the buoyancy of our robot. Calculating the buoyancy of our robot was very difficult because during field runs, it would either sink or float too much. This would result in us being unable to control the depth, rendering the robot useless during competition. To solve this issue, we zip tied two beverage bottles on either side of the robot so that we had the flexibility to control the buoyancy by adding or removing water from the bottles.

Lessons Learned

As this team is brand new and this is its second year, I think we have improved a lot. Last year, we had a lot of trouble sending commands to the Arduino inside the robot. There seemed to be a delay between signals and sometimes the motors didn't even work. This year, our motors are all working well and the robot is easy to control. Using JoytoKey, we were able to use a video game controller to move the robot. One big problem that we still have and can improve on is making our robot watertight. It is an important part in being successful because even a small gap could let water in. Our epoxy should be put on more carefully, and we should clean the O-rings from time to time as well as change them since we have so many in supply. We also need to work on wiring because sometimes the wiring loosens when we place the capsule around the electronics. As we progress, we can all start test driving earlier and give everyone a chance to perform the assigned tasks.

Future Improvements

To ensure that the ROV works at all times, we still have a lot of room to improve upon making our robot watertight. It is an important part in being efficient because even a slight leaking problem can cause disastrous results. We will make sure that our epoxy is added in a more meticulous routine, consisting of superglue *and then* the epoxy so that everything is guaranteed to be watertight. Something else we will definitely keep in mind is better wiring, because the wiring occasionally pops out when we place the capsule around the electronics. We hope that we can work with a camera company in the future as well, since we do want to have an underwater camera with a wider view. Instead of focusing only on community service, our goal for the company is to expand our list of potential clients to research universities and environmental companies.

Afterthoughts

In my introductory year to this team, I quickly learned the intricacies that are involved with building an ROV from scratch. Throughout the year, I learned many valuable skills about mechanical and electrical engineering. Being a part of the team has dramatically improved my knowledge on the usage of different mechanical and electrical tools, such as the drill press and soldering iron.

I also learned the importance of teamwork. At Walnut Valley Quantum, every member is an integral part that works relentlessly to benefit the team as a whole. Working together with a team has allowed me to learn new ideas from others. This entire season has proved to be rewarding in both an intellectual and social way. —Renny Gong

Acknowledgements

We owe special thanks to all of these wonderful people for their support and advice throughout the entire building season.

- Mr. Matt Sandt for letting the team use his garage and his special utilities.
- Mr. William Shih for helping us with our programming.
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