MATE ROV: The Reaper

Taipei American School

Taipei American School-Tigersharks and the Reaper

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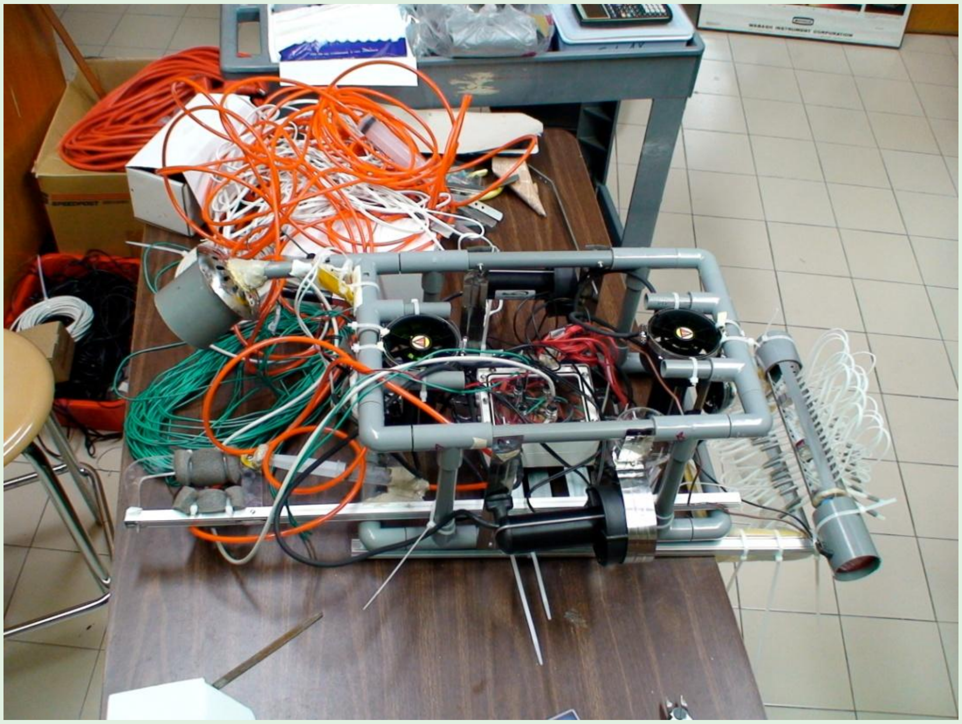
Abstract

Stepping into the crowded room on the first floor of Taipei American School, all members felt a sudden pride: we did it. The 2010 Marine Advanced Technology Education ROV competition models after scientists' attempts in exploring the Loihi Volcano, including four different tasks that required intense planning. With nine dedicated individuals, the team spent innumerable hours in the work room planning and manufacturing the ROV. In addition, the team balanced original ideas from all members and pragmatism to produce our first and, speaking with certainty, well-designed ROV.

With four tasks in mind, and simulating the work of a team of marine biologists and geologists, this team has designed, built, tested, and completed a ROV. The ROV can deploy secondary scientific instruments, use sonar to locate sound source, enter a simulated cave to collect samples with a sweeper, utilize a probe to measure temperature, and employ a suction device to obtain a simulated bacterial sample.

The following technical report deals with the specific details of the entire process, from the drawing table to the school pool. More specifically, the report contains a specific explanation of the design rationale behind all specifically designed tools and the general principles behind the various systems, a through explanation of all components of the ROV, a succinct budget sheet, planned future improvements, a lesson(s) learned, trouble shooting techniques, reflection, challenges the team faced, and finally acknowledgement to those individuals who gave their valuable time in assisting this first-time team in completing its ROV production.

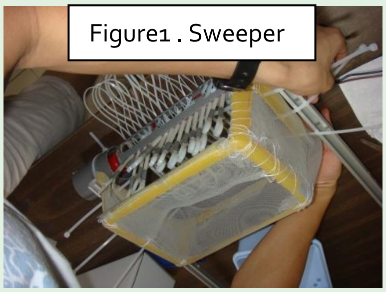


The Reaper

Design Rationale

Tigersharks' main goals were: compact and control. These two goals were to ensure that the ROV could maneuver easily and that we have fine control over the ROV. Achieving these two goals was not an easy task; our ROV team had implemented numerous designs and revisions until the final design was reached. The trial-and-error process was a regular part of the design process. Below is a list of design rationales of the numerous components of the ROV and of course, the main ROV itself.

Figure1 . Sweeper



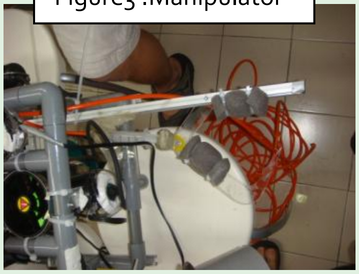
Sweeper (Crab collector for Mission 3): The sweeper is essentially a bilge pump motor that rotates an axis of 3 leaves of brushes that spins on an axis fixed in front of a container (some may say it looks like a duster or a broom). The rationale is that when placed in front of the ROV frame, the motor would power the 3 leaves of brushes, and would brush objects on the pool floor into the container. Each leaf was made with zip ties. It is both lightweight and cheap. The design process of the sweeper is not complicated; there are only so many ways to design a sweeper. The individual leaves have three different lengths, so that just in case one length cannot sweep, the other lengths can. The sweeper was to save time by collecting the crabs more quickly. (See Figure 1)

Temperature Sensor: At first, our ROV team was excited about making our own temperature sensor with bought components, but we decided it was too much of a hassle after we did brief researching. Thus, we used our school's Vernier's temperature sensor connected to a laptop. We chose Vernier because the software it provided can let us graph the temperatures – a great tool that will enable us to get more precise data when tackling the "measuring water vent temperature" task.

Figure2 .The old and new thrusters (left to right)

Thruster: From the beginning, our team decided that because of the cost and the novelty, we should build our own thruster. We took apart a Rule Bilge Pump (1100GPH), attached 5M propeller shafts from Hobby Shack, fitted propellers from Cornwall Modelboats, and then created a PVC pipe cowling. After testing this design of thruster, we found out it didn't meet our expectation because the PVC pipe limited the amount of water for the bilge pump to displace, thus losing efficiency and thrust. Then, we tried the thrusters without the cowling. However, the lines often got tangled in the propellers and the thrust was not strong enough for the agar mission. Furthermore, it was hard to mount our thrusters and they were often crooked.In the end, our team decided to buy thruster from Seabotix directly. (See Figure 2)

Figure3 .Manipulator



Manipulator: Basically the manipulator is built using a self-made acrylic claw, two syringes, and an aluminum bar to connect to the ROV frame. One syringe is situated snugly on the manipulator while the other syringe is on deck controlled by a team member. The contracting and/or expanding motion of the syringe is thus the driving force of the claw; when the syringe on deck contracts, the syringe on the ROV contracts, and thus the claw opens. Vice versa, when the syringe expands, it pushes out the syringe on the ROV, and the claw closes its grip. The foam section of the manipulator is intended to gain more grips over smaller and harder-to-grapple objects. The air hose connecting the syringes is also filled with water because water is less compressible than air and also prevents another possible random source of buoyancy.(See Figure 3)

Sonar Sensor: The buzzing is a sound, and its source can be detected easily underwater. Thus, we turned to using a microphone with an almost parabolic cone surrounding it. We then connected the microphone to a computer using the line-in plug, and launched the open-source software Audacity. Through Audacity, our team is able to detect the proximity of the buzzing, thus when the ROV is underwater, it can steer towards the three options, and detect which one has the loudest buzz. Our team figured that a small plastic container for second waterproofing (which contains mineral oil) would be more secure and decrease the chances of ruining the microphone. Mineral oil will allow sound to travel better (it is denser than air, and because it is hydrophobic and doesn't conduct electricity). The rest of the waterproofing is sealed with acetoxy sealant.

Agar sucker (Agar mat sampler): Our team calculated the volume of agar needed for the mission, and handpicked a 5cm diameter PVC tube. We started our first version of Agar Sucker with just a PVC tube and a rubber flap on the top. The sucker worked fine as long as it is in water as the suction and closed-flap prevented the agar from slipping out. However, we encountered two problems: it was hard to pull the sucker out of the bucket and the agar slipped out once we lifted it out of the water. Thus, we added sharp Nestea razors to cut up surrounding agar when the sucker is inserted. In addition, removable zip ties were added so that they held the agar in, but also were removable so the agar can be taken out when we are on deck. (See Figure 4)

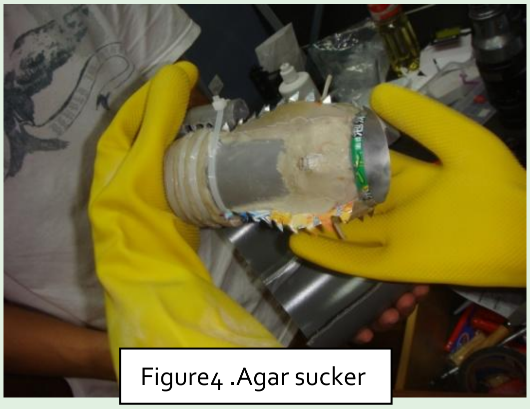


Figure4 .Agar sucker

Frame: Probably the most important component of the entire ROV, copious amount of time was spent designing the frame to make it lightweight and integrated with other components. Initially, our team chose to used thick PVC pipes and glued them together into an aesthetically pleasing trapezoid shape. We thought that this shape would be easy to work with, as components would theoretically attach to them with ease (especially when the main bilge pump was situated in the middle top part of the trapezoid frame). There was a Lucite board installed on the bottom of the frame (with holes in it) so as to have an interchangeable part for different missions (that we could install and uninstall on demand during the breaks between missions). This idea was later on disapproved, however, because the design was too bulky and the thick pipes created much water resistance. In January, the team had the opportunity to meet with Mr. Shu of ITRI Creativity Lab. After that meeting, the team settled on a design that centers on a waterproofed central box. Our new goal was to make as compact of a frame as possible with the box in the middle of the ROV. The box is waterproofed, and more importantly, it houses many of the connectors and wires while adding buoyancy to the ROV. For the final design, we used Seabotix thruster, and we used thinner PVC pipes for the frame. We reduced the use of zip ties because the zip ties shifted easily and looked messy. We also wanted the ROV to be symmetrical and balanced. We drilled holes in the frame to reduce the buoyancy of the frame and allow water to flow in; the holes also enable us to screw components on the main frame. For example we can now screw detachable hose clamp for fitting the thrusters. We wanted to be able to take off and replace everything which glue would not allow. The whole frame is now shaped like a rectangular box. Also, we have "legs" for the ROV to rest on. The ROV frame is also on symmetrical on both sides, which allowed us to operate with either side as the "head". This two-headed design allowed us to do the cave mission with the "sweeper head", then completed the other missions with the "manipulator head". (See Figure 5)

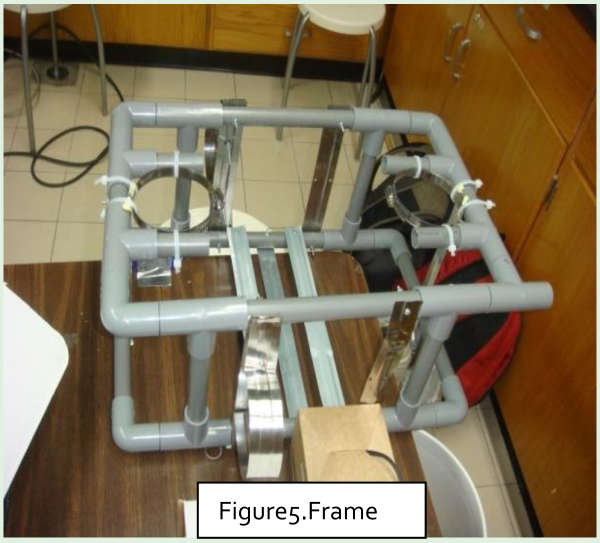


Figure5.Frame

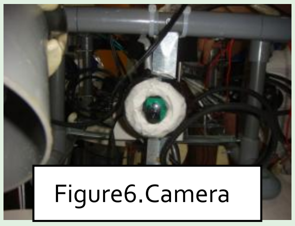


Figure6.Camera

Camera: We had a total of 3 design revisions as we learned through the design process. For the 1st version, our ROV team just used big security cameras, installed them into big PVC pipes, and sealed them shut with Lucite lens with PVC glue and epoxy. However, this design was bulky, heavy, and the building process took too much time. In addition, the glue was not secure enough, thus there were small leaks in the camera. For the 2nd version, the camera size was significantly reduced (radius-wise), however, the length was still a problem; it was too long due to the connectors and cables situated within. For the 3rd and final design, our team decided that we should solder the connectors so we could get rid of the bulky and inflexible connectors. After getting rid of the bulky components and using much smaller cams that were taken apart from security cams, the camera case was significantly reduced in size (the size of the previous camera increased the ROV's buoyancy, which caused many other complications as well). The improved camera design was able to fit in a small, clear plastic dome. We have one camera for front and one behind, one for the manipulator, and one servo cam for the agar and the sweeper. This servo-controlled camera is underneath the ROV so it can turn 180 degrees and look at the agar sucker or the sweeper basket. This way, the camera would cover almost every angle so we could maneuver more easily. (See Figure 6&7)


Figure7. From the primary camera to the final camera. (right to left)

Tether: The tether is a bundle of different wires going down to the electric box on the ROV. Initially, the team utilized four cameras and four bilge pump motors that require two wires for each. This made the tether extremely bulky, and would hamper the movement of the ROV. However, the team solved the problem with a simple solution using an Ethernet cable for the camera signals while all the 12V power comes from one pair of cable that is distributed in the electronic box for the cameras and the thrusters. The tether ultimately consists of one pair cable for sound signal, one cable for temperature probe, one cable for signal from the RC controller, two cables (one ground and one power) for 12 V power, one Ethernet for camera signal, and the air hose for the manipulator.

Buoyancy: Our goal was to make the center of buoyancy above the center of mass. The buoyancy design is like an inverted triangle, with two points of buoyancy on each side of the top and one point of center of mass on the bottom so the ROV doesn't tip over. We used a mix of water bottles and Styrofoam to create buoyancy

Electronics and Controls: Initially we simply started with rheostats and parallel circuit to control all of the cameras and thrusters. However, the weakness was that the tether is simply too thick, and the multiple lines made the tether unorganized and bulky. The rheostat and the double flip switches were also too big for one man to control and too messy for rearrangement and reprogram. We decided to use a RC controller as the solution. The 9 channel 9XII controller was chosen for its ability to program hybrid. Then the 7 channel receiver was selected, for there were 6 channels planned to be used and 1 more just to be safe. We knew that the radio wave would be disrupted underwater, thus we merely attached a cable from the transmitter to the receiver. Because the receiver doesn't generate DC voltage to the thrusters and we want the thruster to be able to be variable, we bought reversible RC car Electronic Speed Controller (ESC) to convert the signal from receiver into variable DC voltage for the thrusters. We added a capacitor to absorb the thrusters' resistance toward sudden total voltage reversal for safety reasons (According to Lenz's law, a coil would try to resist a change in magnetic field by inducing a magnetic field opposing the change. Thus, when the voltage polarity is switched, the thruster would induce a current opposing the change and damage the ESC.). The capacitor would buffer the opposing current by storing it and releasing it when the thrusters' magnetic field has been completely altered. (See Figure 8.)

The circuits, ESC, and receiver were fitted into a waterproof box provided by Mr. Chen. This box comes undrilled, has an o-ring, and an acrylic cover. In addition, there were Valves with o-rings for us to fit the wires through. We had to drill the holes in the box ourselves to fit the valves and arrange it to our liking. Then, we would fit the valves on the wires and waterproof them with Acetoxy sealant. A thermometer is also put in the box to monitor the temperature inside the box to prevent overheating of the cables.

Figure8.The old and new controllers and the electric box (left to right)

Loihi and ROV

Loihi is an underwater volcano located on the southeast coast of the big island of Hawaii rising 3km above the sea floor and is now just 969m beneath the ocean's surface. Loihi is also the newest volcano on the Emperor Seamount Chain. Originally thought to be one of many submerged seamounts that surround the Hawaiian Islands, it is now know that Loihi is an active volcano, and will one day become the newest of the Hawaiian Islands. Loihi and the rest of the Hawaiian Islands were formed as the Pacific tectonic plate moved northwest over a geologic "hot spot" which melted the crust above it as the plate passed over it. Loihi's location off the southeast coast of Hawaii (thus falling along the line created by the Hawaiian island chain) is actually used as part of the supporting evidence for the Theory of Plate Tectonics. (See Figures 9 & 10)

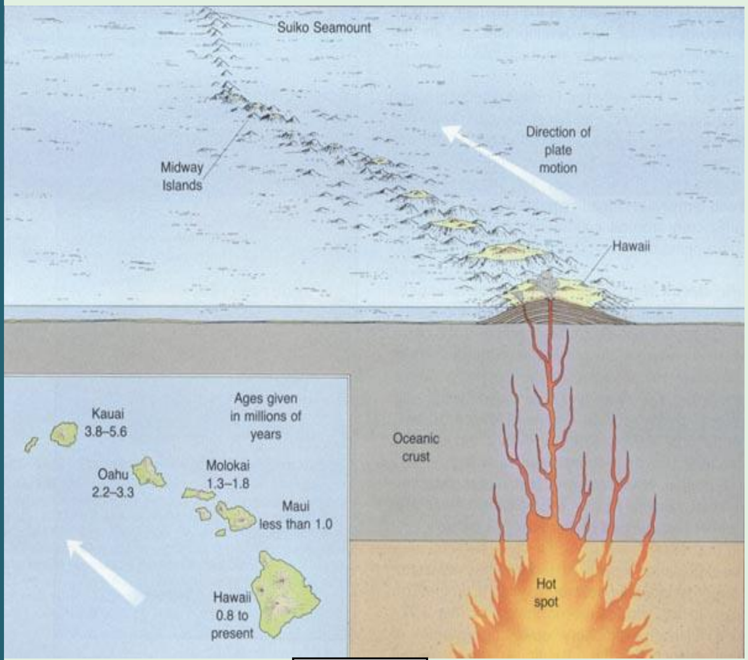


Figure9.

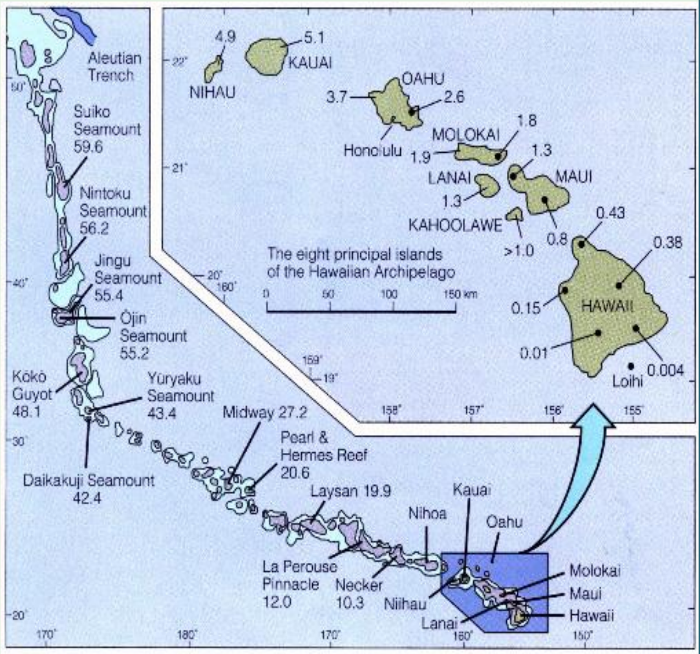


Figure10.

Loihi's importance to science is not limited to Plate Tectonics. As an undersea volcano Loihi is now a site for research on hydrothermal vent ecosystems. First discovered off the Galapagos Islands, hydrothermal vent ecosystems are based on a process of "chemosynthesis" as contrasted with the "photosynthesis" found in most terrestrial ecosystems. Sometimes called "black smokers" most of these ecosystems are located at tectonic plate boundaries, with a consequence being that these ecosystems tend to move laterally across the seafloor along the path of the movement of these plates. Loihi is somewhat unique in that it is growing vertically. Eventually Loihi should move into the "photic zone" ending the exclusive prominence of the chemosynthetic bacteria that are the foundation of the current hydrothermal ecosystem. (See Figure 11)

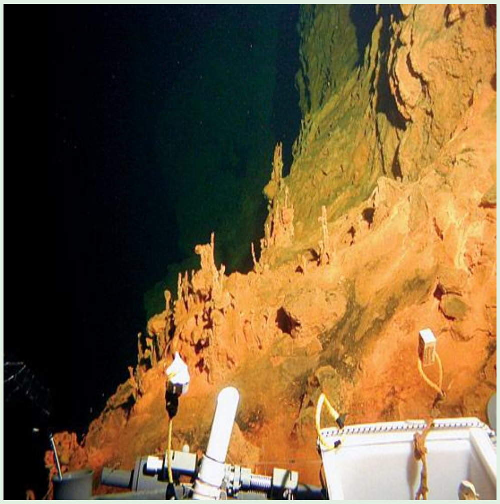


Figure11.

Loihi has been explored using both manned and unmanned (ROV) vehicles starting in the 1970's. It has been explored by organizations such as the USGS (United States Geologic Service), NOAA (National Oceanographic and Atmospheric Agency), and the University of Hawaii. Its depth and extreme conditions make it an excellent candidate for the use of ROV's for those wishing to investigate its unique geology and ecosystems. (See Figure 12)

Figure12.

Looking into the future, the exploration of Loihi will help us perfect both the technology and techniques needed for a new generation of autonomous ROV (AV's) submersibles. These vehicles will be used to explore objects such as Europa, one of the larger moons of Jupiter. NASA is designing and testing a "hydrobot" to explore Europa. It is believed that Europa has hydrothermal vents, and could be the genesis of life that has evolved outside of Earth. It will be this generation of AV type submersibles that students such as ourselves will likely design and build in our future.

Trouble Shooting Technique

The team's main trouble shooting technique came down to water testing, performance analysis, and redesigning of the ROV components. The team feels that this is not the same as trial and error. This method is not as reckless or unorganized as trial and error. Though the general idea is similar in the testing then redesign process, the similarity between the two methods ends here. We think the important difference is that our approach is more systematic and less random compare to trial and error. Often times, before a water test, we suspected of many potential problems. Instead of trying to fix what may or may not be a problem, we systematically conducted water tests while being aware of those possible flaws. If there was indeed a problem, then we fixed it.

In a normal trial and error situation, a group may encounter one problem and immediately pull up the ROV to solve that particular problem. However, in this team's technique, we always test everything whenever there is a water test. Though some may argue this is rather time consuming, this method is actually the most time saving. Since the ROV is delicate machinery in which all parts have some form of influences upon other, to have a full inspection during every water test allows the engineers to have a full evaluation of the entire ROV as of that test. (See Figure 13) Through this measure, this team's engineers can locate structural and fundamental flaws within the ROV instead of realizing these potential flaws several trial and errors later. One such example of the success of this method in saving time can been seen in our first ROV and second ROV. The first ROV embodies a more typical design of a frame with attached tools and add-on electrical components. However, the second version of the ROV abandoned the frame concept and centered the entire machine on the electronic box that holds all the electric components of the ROV, where all tools and other parts of the ROV is built around this central box. The drastic shift came after several water tests that prove the frame structure is not the best plan to pursue as it wastes space and makes the ROV bulky, a structural flaw that could have took dozens if not more water tests under a traditional trial and error method.

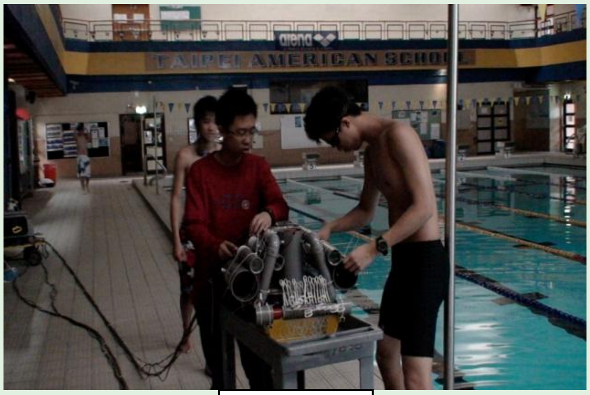


Figure13.

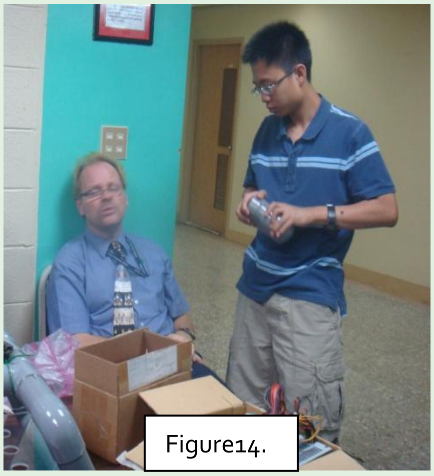
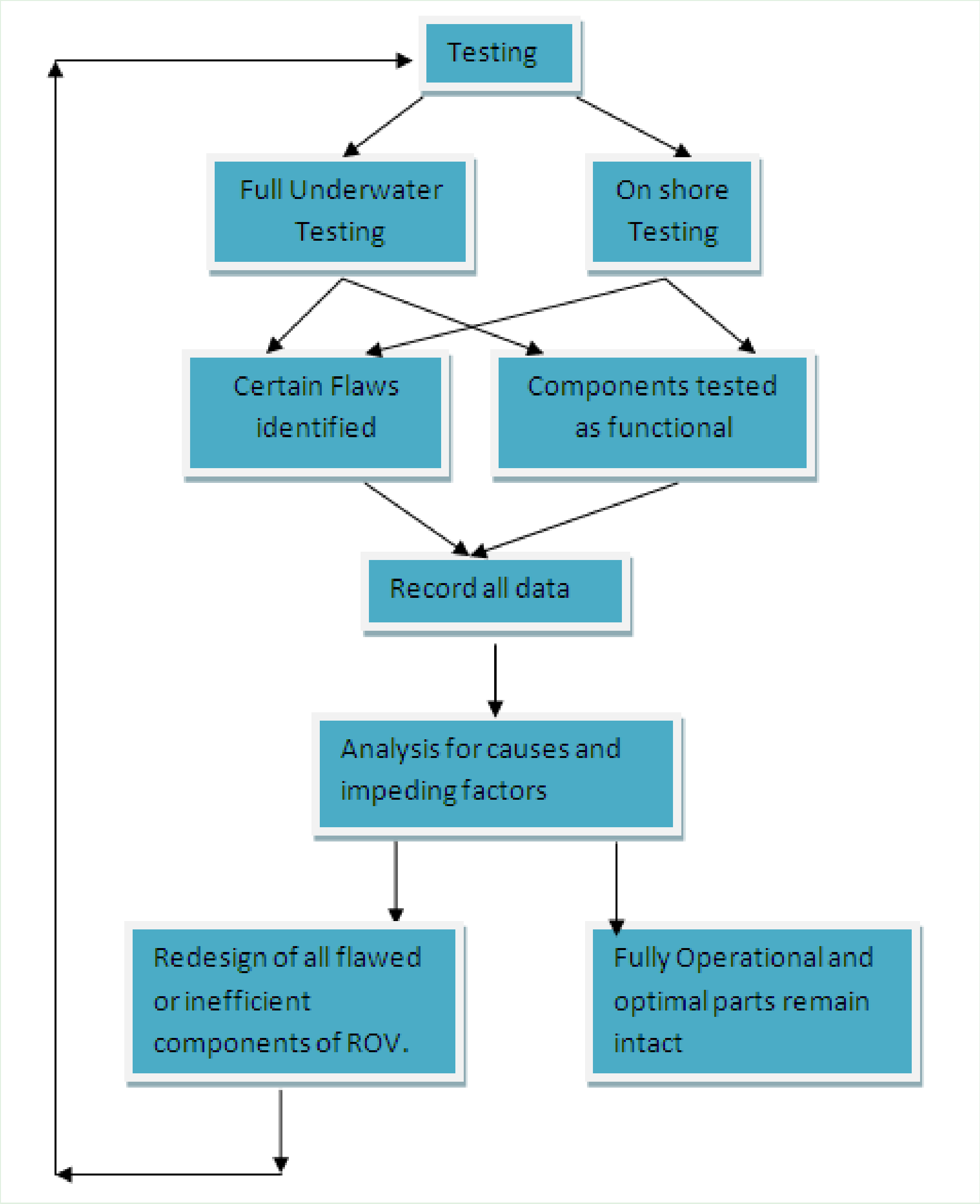


Figure14.

Another difference of this team's method and the usual trial and error method was the analysis of the results. Instead of simple tinkering or the shifting of attachments on the ROV to solve some minor problems, this team's method pursued a much more comprehensive and in depth analysis of the problem. In the longer but more detailed water test, each problem was repeated, recorded, and kept for future analysis. After the water test session, the team would confer with each other and seek to find out the problems exposed by the test (thus, more closely resembling the entire scientific method). Also involved in this step was the gathering of information from professionals. The team consulted with two individuals, our sponsor Mr. Nelson and our advisor Mr. Shu, in order to validate the feasibility of abstract thoughts, initial hypothesis of potential problems, and other questions before the actual build. (See Figure 14) Both adults had experienced with underwater technology and were able to give valuable information that pointed to possible solutions to certain challenges. This team would see the problem, record the problem, and finally discuss and analyze the fundamental cause(s) of the problem.

The last but the most vital in this process was the solution to any problems identified. Rather than focus on small scale tinkering, the team employed a strategy of the complete fix. Whether it be producing new underwater cameras or abandoning the entire frame; the team used the abundant information gained from rigorous testing and through analysis to decide on a solution.



Trouble Shooting Procedure

Challenges

As a team, we faced many challenges from the beginning. The challenges came from all different aspects, such as team establishment, organization, purchasing materials, technical difficulties and so on. Led by our team leader, our team was newly made for this year's ROV competition. Since there has not been a club related to robotics or remote controlled vehicles, our team's needs were very new to our school. It took a significant amount of time and effort to get approved as a school club and get sponsored by our school. As a new team, we did not have many experts or students who had experience to advise and help us with basic information. All the work was done and organized by us, which took a large time in the beginning of the project. We had built and ran many tests with our first model, Mark 1. This took almost all of our time from August till January. This was almost like competing or working as a rookie. However, we gained an amazing amount of information and we have been able to create a much more sensible and powerful ROV with our current model: The Reaper.

Working in our region was also challenging. In our region of Taiwan, it is very uncommon for local companies to sponsor student-run clubs, especially under college level. Thus, at first when we were planning the budget, it was very difficult to find a way to raise money for our project unless we ourselves would do fund raising. Unfortunately, our school only allows fund raising for charity purposes. However, luckily, our school decided to support our project financially and our problem was solved. Considering that robotics-related projects are not prosperous in our region, it was also very hard to find shops that had the necessary materials. Often, local shops did not have sufficient variety of products and we had to look up shops in the US or Amazon. Yet, only a few shops in the states were willing to sell and send their products, such as thruster, bilge pump and propellers to our region. Even though there were shops that were willing to send us the materials, it often took weeks for the products to arrive. This, consequently, led us experience significant delays in early development of our ROV as well as heavier financial costs due to shipping fee.

For building our vehicle frame, it was not easy to find suitable components in Taiwan. For example, corner joints, which were essential in building our vehicle in the shape we wanted, were not available in Taiwan. Thus, we had to use L and T joints to make build the corners of the ROV, which took more space by making the ROV longer. Even though we wanted to make our ROV more compact, we couldn't because of our region's lack of supplies. Furthermore, propeller matching was very challenging. Apparently, Taiwan has only a few of propeller supplies that we could choose from, so it was hard to find the propeller shafts and propellers that matched with our bilge pump motor. Therefore, there was a lack of source of components for propeller, which prevented us from testing out a variety of options to find the most suitable and the most powerful combination of the propeller, the propeller shafts and the bilge pump.

As they are called "challenges," we had hard times solving the challenges. It took a significant amount of time. Nevertheless, we learned a lot through the problems, whether they were related to organization or technology, and we felt proud by overcoming these challenges.

Lessons Learned and Skills Gained

We learned a lot in this whole experience, especially through the design and building process of the ROV. Nothing will be perfect in the first try; this is a very important lesson. We had about 4 or 5 water tests, and some of the water tests even ruined one of our cameras. Even though the damage was pretty major, our team did not give up, and still proceed to test out other components. We learned not to be disheartened, because we now know, trial and errors are the essential process in engineering. Also through trial and error, our team learned a lot about materials and their uses. For example, we tried using silicone glue to piece our ROV together, but it wasn't good enough. Thus, we ended up using epoxy glue, and it worked wonders. However, it made our frame permanently attached, which caused us to switch to nuts and bolts. However, the nuts kept falling off, so we attached rubbery flaps between the bolts and nuts.

There are numerous skills that we as a whole ROV team learned, be it cooperation or other important life skills. These life skills are most essential in the future when every one of us enter the work force, or even broader, life. The skills learned here would be applicable to future situations as well.

In the Science/Engineering Aspect:

Of the many skills we have learned, the engineering aspects were the most in amount. These include using the Dremel and cutting hardware materials. In addition, we have learned a lot about electronics and how thrusters work. We have also learned about hydrodynamics or fluid motion. Understanding the effect of buoyancy has also been very important. This is evident as we purposely put the buoyant bottles on the top and keep the mass to low-center.

Of the less theoretical area, we have also improved our skills in cutting, drill and other hands-on work. (See Figure 15) We learnt new skills too such as soldering wires together through the members themselves. The most important skill that we have learnt together with these two is how to synthesize different areas of knowledge and skills in order to solve problems creatively with available materials.

Figure15.

As for waterproofing techniques, we learnt how to utilize Epoxy glue and silicone glue to successfully waterproof the cameras. This includes research on previous models and even researching on design of watches. Soldering made it possible for us to shrink the size of the cameras. Throughout the construction of the camera case, we learnt how to cut perfect circles of Lucite, further honing our skills in cutting and shaping wood/Lucite.

Figure16.

We learned the fundamentals of electronics from this project: Ohm's law, and what logistically "clean" electronics components ought to be like. We also learned some more in depth electronic things like Pulse-Width Modulation, Analog vs. binary/digital, oscillating crystal, Coil drain, etc. With these we are sure that we can continue on with other advance topics like Arduino or a wireless controlled vehicle.

Through the construction of the agar sucker, we also learned a lot about suction, surface area and how rigidity affects how much we can pick up without the agar falling out. (See Figure 16)

Lastly, we learned how to use a wide variety of tools from wire strippers to heavy cutting machinery in order to create finely tuned devices for the missions.

Figure17.

Cooperation: The ROV competition is the largest project us as students have ever encountered. The massive project size means that teamwork and cooperation are two very, very important factors in ensuring the success of the ROV. In our case, even though each individual member had own specialties, we always worked as a whole team helping each other. (See Figure 17)

Organization: Such big project also requires superb organization skills too. Procrastination is a big thing to avoid, so all of the team members strive to follow schedules and appointments. With superb organization from our team leader, the team members are able to follow the progress that is determined. This ensures fast and efficient execution of the numerous parts of the building process.

School Topics: At school, the knowledge we learned are through lectures, and if lucky, some occasional labs. However, the concepts introduced in those classes were not deeply ingrained in our mind, because we didn't have the chance to apply our knowledge. This ROV competition was like an excellent chance to apply those knowledge, and really learn them (that is, learn the concepts for the sake of learning, not for high grades on tests). Concepts such as forces, thrusts, momentum, power, electricity, all those concepts introduced in classes were applied and expanded during this project. This is truly a rewarding and educational experience.

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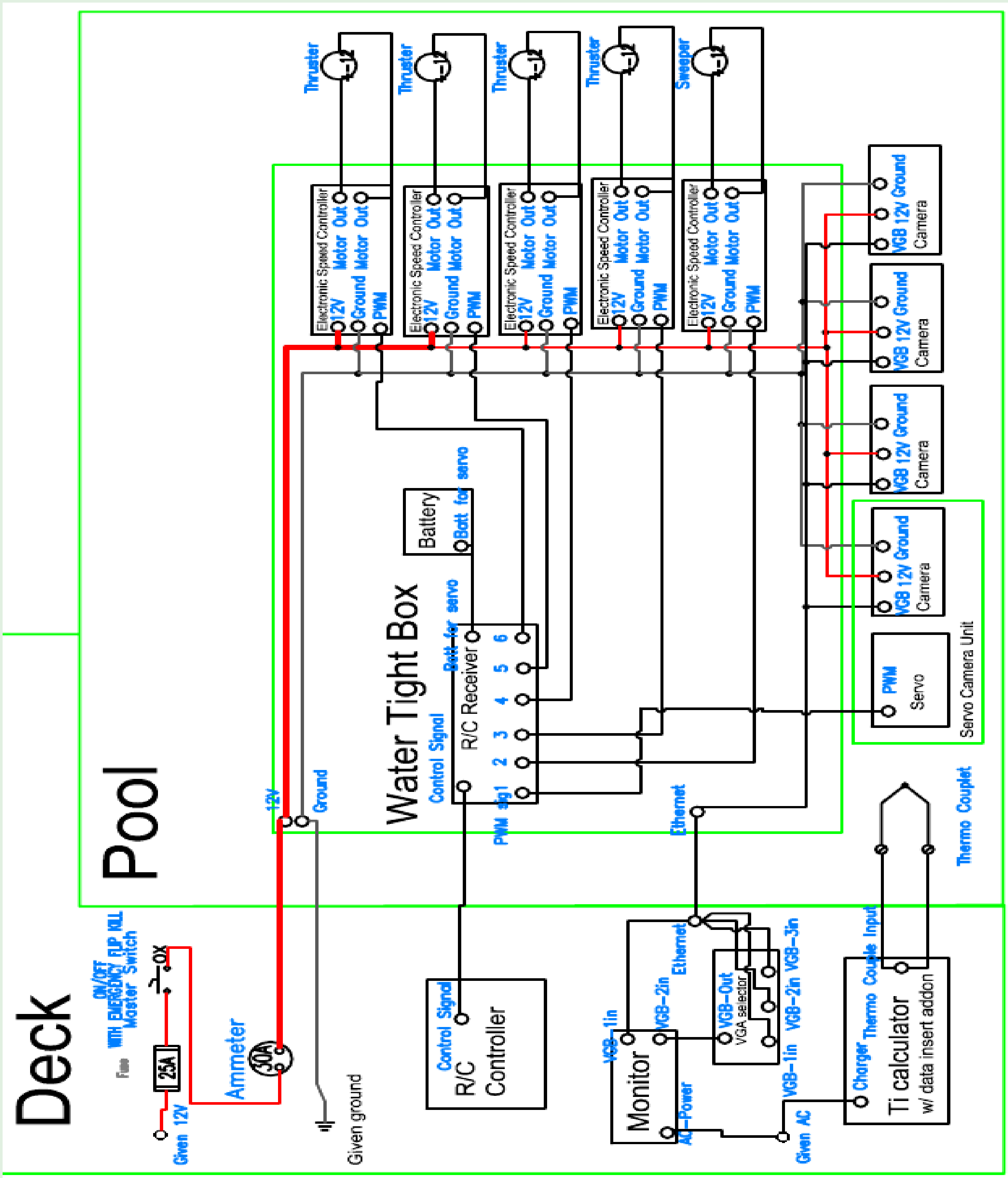
Reflections on the Experience

This ROV competition sponsored by MATE is perhaps the most unique and rewarding experience each of our team member has ever encountered. We have never participated in such an extensive project that requires months of coordination and hard work, thus this experience really teaches us a lot of things.

In particular within the professional accomplishment side, this ROV competition allows our team to experience real-life situations that we are going to inevitably encounter when we all graduate and go to work. How do we cooperate? How do we track and keep progress? How do we coordinate all the resources and advices from faculty and outside professionals? These are all important problems we encountered during the quest of what is the ROV. Thankfully, our team was able to face those problems and solve them with what we have learned during the process. We gained experience when we solved those problems, and the process and rationale of that problem solving would be very much applicable in the future. In short, it is the hands on learning of this competition that enables to learn so much.

The most important aspect that developed out of this competition is character development. During the process, we encountered many problems as outlined in the previous paragraph. As we start solving them and attacking them, we really grew as a person; we started to gain patience and endurance. The problems would not just solve themselves; we had to be patient until we can come up with a solution. We also learned that teamwork is a key part of this process. Without teamwork, this ROV team is doomed to fail. Throughout water tests, our sponsor constantly reminded us not to be down and give up. We learned to be persistent and not panic during moments of despair.

Electrical Schematic



Future Improvements

Throughout this year long process, the team made improvements in its organization, management, designs, and production, but several problems still remain. One overarching problem that persisted through the entire process is keeping the ROV workstations clean. The team began with an unclear division of labor, where all members do bits and pieces without specialization. But as the year progresses, each member became more specialized in certain task(s), leading to an increase in efficiency. For next year, this team hopes to employ the division at the very beginning of the entire process to save as much time as possible. Another measure the team plans to implement is a cleaner workroom. This year, being the first year, the team did not take massive amount of time to ensure a clean working room, leading to a rather chaotic work environment. So next year, the team plans to clean the room on regular basis and put all tools/items back in order. On the more technical side, the team aims at improving five unsatisfying phenomenon: more specialized frame for our manipulator's pipe, less burdensome tether, make the ROV more symmetrical, more attention to the center of mass, and more shifting of computers and electronic components on to the ROV. The team plans to simplify the tether line by shifting more electrical and control components onto the ROV itself, as the last problem suggests, resulting in multiple benefits. Lastly, the team plans to produce a more symmetric ROV by paying more attention to the center of mass, which can help with the ROV's stability in water and prevent it from tipping over or inability to run in a straight line.

Acknowledgements

Firstly, we would like to thank our principle, Dr. Hartzell, for finding the fund we need for the project and getting us the connection to experts like Mr. Shu and Mr. Chen so that we can still be successful in our first year in the competition. His help with funding eased our financial concerns and allowed us to only concentrate on the ROV.

We would like to also thank Mr. Agostine for his support and professional advice on making precise and accurate cuts with the correct tools. His space and equipment have been invaluable to the team and there was no way we could have completed the project without the generous contribution of his woodshop room.

Next, we would like to thank Mr. Tsao as well for sharing his knowledge and connections to local Taiwanese hardware and materials stores so we were able to quickly buy materials for the ROV.

Lastly, but definitely not least, we would like to thank Mr. Nelson, our inspirational, passionate, dedicated, and AWESOME sponsor. Mr.Nelson always gives great advice and points us in the right direction, however, he never tells us what we must do and allows us to make and learn from our mistakes. His passion for marine science and excitement about the project always fuel and inspire us to not give up and continue working hard. His simple and practical way of explaining intricate concepts have helped us learn much more quickly and more fun! Thanks!

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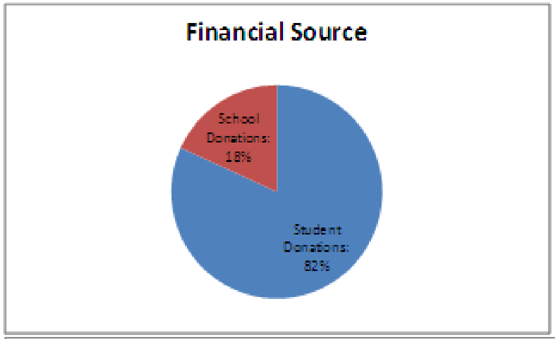
Photos

Budget Sheet

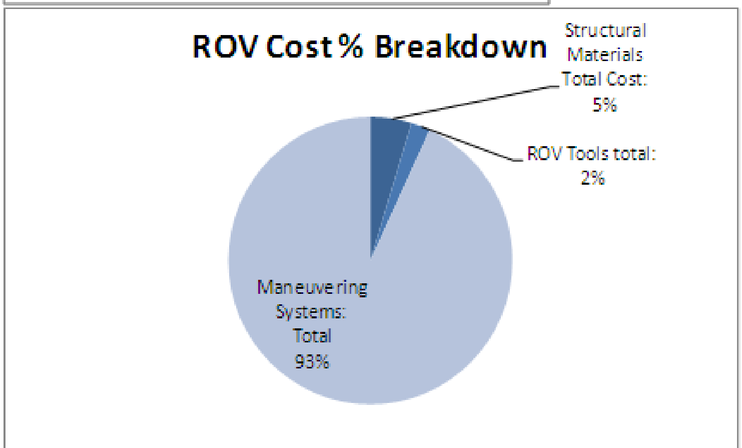
The currency of 31 NTD to $1 USD was applied.

Total Value of ROV:	121,864 NTD	3,931.10 USD
Student Donations:	135,000	4354.83 USD
School Donations:	30,000	967.74 USD
% used	90.27%	90.27%



Structural Materials Total Cost:	5658 NTD	182.52 USD
Specific	Individual Cost	Cost in USD
PVC pipes	4634	149.48
Zip Ties	165	5.32
Others	625	20.16
Screws	234	7.55

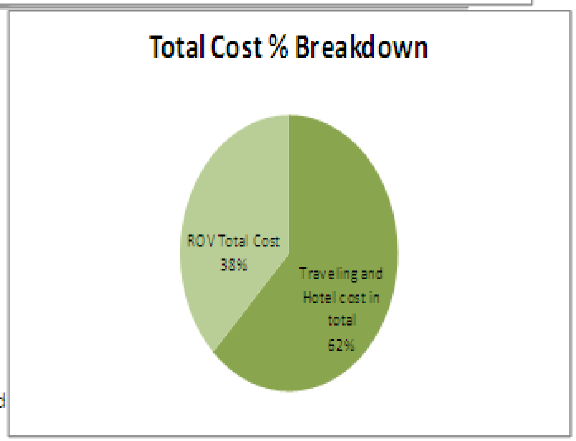
ROV Tools total:	2659 NTD	85.77 USD
Specific	Individual Cost	Cost in USD
Manipulator	120	3.87
Sweeper	1032	33.29
Alger Sucker	0 (PVC pipes and recycled)	0
Temperature Sensor	1287	41.52
Sonar Sensor	220	7.10



Maneuvering Systems:	Component	Cost (NTD)	Cost (USD)
Propulsion System:	6 Seabotix Thrusters	98,803	3187.19
Camera System:	5 cameras	750	24.19
Tether outreach:	internet cables and various cables	1,994	64.32
Control system: Lent	RC Controller, onboard electronic center	12,000	387.10
	Total	113,547	3662.81

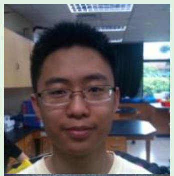
Traveling and Hotel cost in total*	201,200 NTD	6490.32 USD
ROV Total Cost	121,864 NTD	3,931.10 USD
Total Cost	323,064 NTD	10,421.42 USD

*The above fees are all paid by the parents due extension of the ROV project itself, so is counted the budget. Two members planned to go to USA during the summer, so the cost is not included.



*The especially high travelling cost is due to the fact that the team is traveling across the Pacific Ocean during the peak time of traveling season as massive amount of tourists and visitors book flights to USA every summer. The heavy cost posed as an obstacle to all of the traveling members, as their passion and diligence to the competition pushed them to pay that heavy cost. Yet, the team believes all the financial burden will be worth it as the team joins other teams all over the world in the MATE ROV Competition.

As seen in the multiple component of the budget sheet, the team has minimized the cost of the actual ROV to as minimal as possible. However, being the first year team, the most expensive components, such as thrusters, needed to be bought, resulting in the higher price.



Lawrence Chang: It has been an amazing experience to work with the team on building an Underwater ROV. I had not realized something that seems so advance and complicated could be constructed by high school students mainly using PVC pipes and R/C controllers. I've also learned a lot about hydrodynamics and it has become a field of interest I may choose to continue to pursue in high school and college.

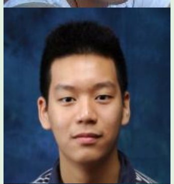
Alex Chen: Before this project, my only knowledge on electronics was power is needed and Ohm's Law. Now, I learned about rheostats, Pulse Width Modulation, and much more. I will definitely attend this competition again; Solving engineering problem, get to go to other countries representing one's school and country, how much better can this get?

Markus Granstrom: The ROV experience has taught me how to work very well with a team, while working independently on separate projects to eventually combine into the whole ROV itself. Also, I learned a lot about soldering, wiring and waterproofing which i did not know beforehand. Because I mainly focused on the agar sucker, i also learned a lot about suction, surface area and how rigidity affects how much we can pick up without the agar falling out. Lastly, I learned how to use a wide variety of tools from wire strippers to heavy cutting machinery in order to create finely tuned devices for the missions.

GaHyun Kim: Even though it has been very challenging to start up a new team, it has also been a lot of fun and interesting! I learned how to work with other team members and, of course, gained much knowledge related to ROV. Participating in ROV competition has been very meaningful.

Justin Lin: During this year, I had a lot of fun while gained a lot of experience. This project required lots of teamwork, which I believed our team demonstrated it well. I learned how to design water proof frames and gained experience in building underwater frames. ROV was defiantly one of the most memorable experiences in my high school.

Kevin Lin: I learn several things: cooperation, fusion of knowledge from diverse fields; and on a more specific skill. Within a number of students with different ideas and different backgrounds, I believe ROV has given me an invaluable chance to learn new skills ranging from collaboration/decision-making to researching because this activity has challenged us with all sorts of problems. These problems include communication, division of work, etc.



Derek Meng: Through the ROV experience, I have a much clearer image of what it means to be an engineer and the possible future for me. The team work, cooperation, dedication, creativity, and problem-solving skills involved strike me like a hammer and exposed my current inadequacy. Through this, my strengths and weaknesses are fully revealed, and allow me to work on them in preparation for the future.

JaeHeung Surh: I think I learned to work as a team the most, like how to discuss and troubleshoot in a more efficient manner. The ROV competition also made me use everything I knew to come up with designs and solutions.

HanPin Tai: Participating in the MATE ROV competition is perhaps the most meaningful activity I have pursued for quite a while. Even though the workload was not an easily manageable task, it was enjoyable; and that's all that matters. I am excited to participate in the competition!

Mr. Nelson: What has most impressed me about these students is that at the start of this effort they wanted to be told what the "right answer" is. Now I get to work with young scientist/engineers who have an ethic of "Build it, Test it, Improve it." I could not be prouder of a first year effort.