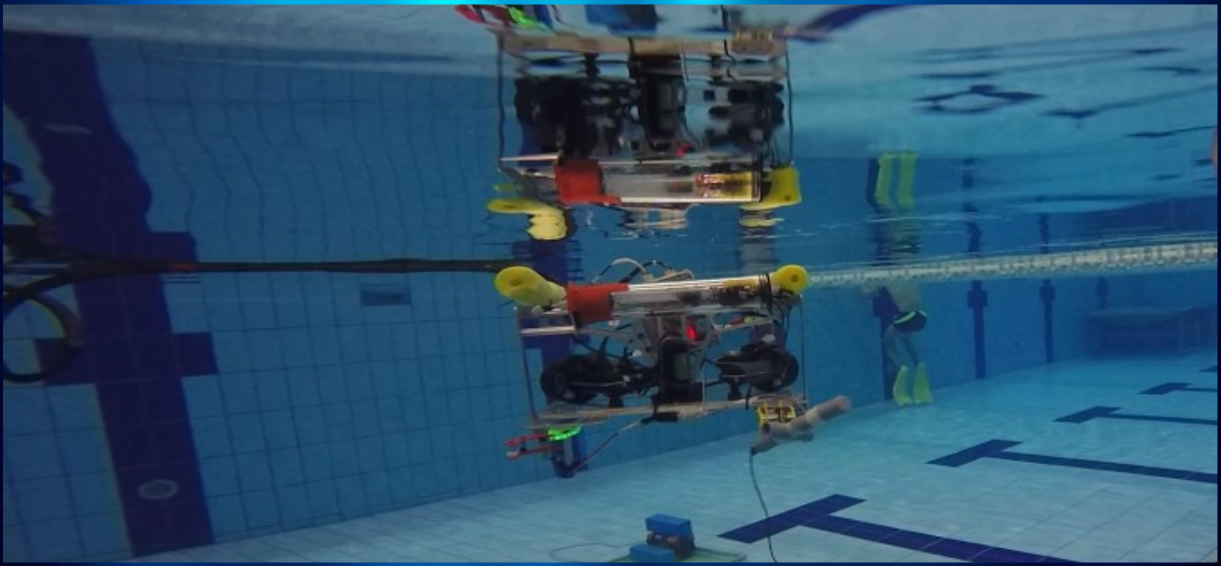
2016 MATE International
ROV Competition
Technical Report



tigersharks co.

Taipei American School
Taipei, Taiwan

Company Information

Tisha Sinha'16: CEO
Jonathan Wu'17: CEO
Ray Ku '18: COO, Pilot
Tiffany Chen'18, CFO
Thomas Yuan '16: Programmer
Joseph Chuang '16, Programmer
Mina Kim'16: Documentation Specialist
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Julian Wu'19: Mechanical Engineer
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Table of Contents

I. Introduction

A. Abstract

After six years of experience, TigerSharks Co. is ready to attend the 2016 MATE ROV competition. This year, our *Mark VII* vehicle will navigate simulations of harsh environments from Jupiter's moon Europa to the deep oceans in the Gulf of Mexico. The *Mark VII* is the product of countless hours of planning, designing, prototyping, and troubleshooting, containing many mission-specific adaptations:

Improvement to the master & slave arm system with a massive 6-servo arm with 3 degrees or rotation. Combined with a small claw, our actuators are fully capable of retrieving and moving objects underwater for tasks 2, 3, and 5.

The X drive configuration was conserved based on the great results seen in previous years, allowing us to reuse thrusters to save money. The new ROV is significantly smaller than all previous versions, allowing for high maneuverability when passing through waypoints for task 1 and getting good angles for photos for task 4. The frame also contains significant weight-relief to maintain neutral buoyancy and beams for structural support.

New control boards were designed to connect the onshore serial and I2C connections to the ROV, housed in a waterproofed control box. Additional safety features were added in the form of stress relief and new connectors were added to the tether, and the signal quality across the tether was improved with the addition of video baluns. The improvement to video quality was important for identifying mission-critical serial numbers for task 2 and taking high-quality pictures of coral for task 4.

B. CEO's Remarks

The 2016 competition marks TigerSharks Co.'s seventh year participating in MATE ROV. As CEOs this year, we are incredibly proud of what our team has accomplished, especially given that most of our team were new to ROV. Our team bases itself on cooperation and mutual guidance, both of which have helped strengthen the efficiency and quality of our company.

Our Mark VII vehicle is capable of navigating the challenges that space exploration poses. Because of our company's passion about what the future holds for the existence of life beyond Earth, we are proud to be a part of paving this bold, untraveled path. Tigersharks Co. strongly believes in STEM's potential for creating technology that allows for interstellar travel, but science is a continuous process. Our faith is that the vehicle we have created will help take humanity's understanding of space a step forward.

It is an incredible honor to have the MATE organization and NASA as our clients. We have worked very hard to create our product – our hope is that you enjoy our product demonstration and technical report and approve of its standards.

Trisha Sinha & Jonathan Wu

C. Founder's Remarks

C. Founder’s Remarks

Back in 2009, I founded the Tigersharks Company with a passion for marine exploration and a vision of creating efficient and affordable underwater ROV for the world. The company faced many obstacles in its first year - we lacked funding and the technological know-how in many aspects of the ROV. I was very fortunate to have Alex, Kevin, Justin, Derek, Gaga, and Hanpin in helping me to steer the company through its fledgling first year. It feels unreal to see how much the company has grown in the past 5 years. With sufficient funding and innovative recruits, the company has become an industry leader in design and manufacture of underwater ROV. I am glad to see that the current CEOs, Trisha Sinha and Jonathan Wu, have taken the company in the right direction towards success and continual improvement. I believe that my vision will continue to be fulfilled by those who share my passion, and I am very grateful for the tremendous amount of effort that everyone has put in for the company and the underwater ROV industry.

Lawrence Chang

D. Mission Theme

The National Aeronautics and Space Administration (NASA) has been observing both the oceans and space for decades. Watching from space, oceanographic satellites go on survey missions to collect data on ocean surface topography, currents, waves, winds, phytoplankton content, sea-ice extent, rainfall, sunlight, and sea surface temperature. All this is crucial in being able to predict certain global and regional events, cycles, patterns that occur in the ocean.
Now, vehicles that can endure extremely harsh conditions in both space and the Earth’s oceans are needed. In constructing our dual purpose and single launch Remotely Operated Vehicle, we aimed to create an efficient vehicle that could perform various tasks in harsh environments such as in Jupiter’s moon Europa and underwater in the oil mats in the Gulf of Mexico. ROVs can do much of the hard work in maneuvering around coarse environments collecting data with less danger. In creating this ROV we hope to contribute to a better understanding of the operations in space and the oceans.

II. Design Rationale

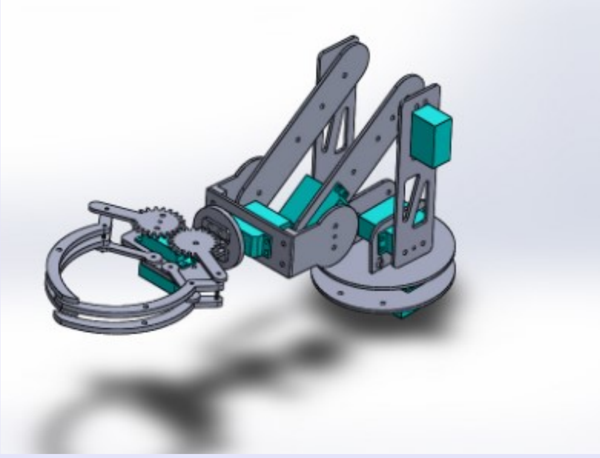
A.Claw and Arm (Manipulators)

This year’s arm design both conserves innovations made in previous years and contains many new features developed this year. The most important conserved feature is the master & slave system used to accurately manipulate the arm and keep track of its position at all times. The new arm was modeled after the human arm and contains 6 waterproof for 3 degrees of mobility. Although having such a complicated arm introduced many new challenges with wiring and controlling the servos, it was deemed necessary for this year’s missions. In previous years, the less-flexible arms meant that at times the entire ROV had to move to allow the arm greater reach. The huge number of arm-requiring missions this year made it necessary to increase the arm’s range and flexibility to increase efficiency. The new arm is also much more sensitive than all previous arms with a fine-control toggle built into the code. Now, instead of moving the ROV to make up for the arm, we can simply pilot the ROV to the test site and let the arm do all the work.

The arm’s long reach was important to allow the claw access to the sea floor. Combined with the horizontal and vertical rotation capabilities of the arm’s base, the long reach made the arm very effective at grabbing, rotating, and flipping the CubeSats for the mission-critical equipment recovery task, retrieving oil samples for the forensic finger-

The arm's long reach was important to allow the claw access to the sea floor. Combined with the horizontal and vertical rotation capabilities of the arm's base, the long reach made the arm very effective at grabbing, rotating, and flipping the CubeSats for the mission-critical equipment recovery task, retrieving oil samples for the forensic fingerprinting task, and accurately handling bolts for the rigs to reefs task. In addition to the arm, a small, single-servo claw was attached to the front of the ROV to carry objects and perform simple tasks. The small claw was particularly important in the Europa mission when it was used to open the door of the communications hub while the claw held the ESP. This saved a great deal of time and effort that would have been spent dropping the ESP, opening the door, then picking the ESP back up with the arm. Using the claw for the simple task of opening the door enabled us to use the arm for the complicated task of positioning the ESP and placing it inside the communications hub, making the most out of the arm's large range of motion.

A final design decision was to use brightly-colored acrylic and 3D printed parts to make the ROV easily visible underwater. This not only allowed non-diving employees to help troubleshoot the ROV from the shore, but also made the ROV look very flashy!



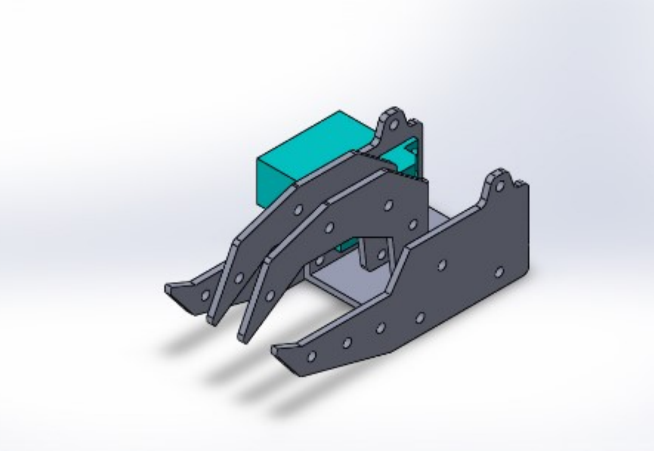


Figure 3: Solidworks CAD file of the arm Figure 4: SolidWorks CAD file of the claw

B. Structure (base)

The ROV's base design stresses functionality without sacrificing structural integrity or maneuverability. Although the base features large amounts of weight relief to help the ROV maneuver, it remains structurally secure with strong welds and multiple supporting beams. The weight relief also means that the ROV requires little assistance in terms of buoyancy - during tests, two small sections of pool noodle were sufficient to maintain neutral buoyancy. In case collisions occur, the ROV has rounded skids on the bottom side to make impacts with the floor less damaging.

The mounting surfaces for this year's claw and arms is modular, allowing for quick and easy adjustments of payloads and payload positions. The top surface of the MK-VII contains standard-diameter holes spaced out in even increments so universal mounting solutions can be created. With this feature on the all-aluminum base, sensors, actuators, and control boxes can be placed on the ROV in multiple combinations and in the optimal positions without making any major changes to the base. This means that ROV's equipment can be adapted to allow the ROV to operate effectively in multiple environments and for multiple purposes.

As with previous years, this year's ROV has four horizontal thrusters in an X-shaped holonomic configufor multiple purposes.

As with previous years, this year's ROV has four horizontal thrusters in an X-shaped holonomic configuration. This setup maneuverability by allowing us to strafe from side to side, rotate, and move backwards and forwards with ease. In addition to controlling the depth of the ROV, the two two vertical thrusters attached to either side of the control box balance the robot as it moves horizontally. Having a versatile thruster configuration is a basic requirement for any ROV, but was particularly important for this year's Europa mission when travelling through waypoints.

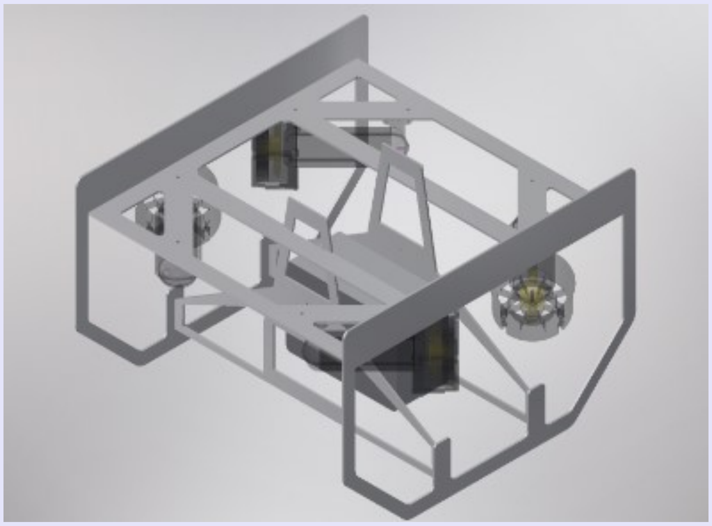


Figure 5: SolidWorks Cad file of the base with horizontal thrusters and main control

C. Control System (Electronics)

The electrical system for this year's ROV is designed to maximize space efficiency without limiting its range of capabilities. As in previous years, we designed our own board schematics and printed the final boards in-house with an Othermill board cutter. We also sourced and soldered all electrical components on the PCBs ourselves.

The ROV originally ran on a 3.3V Arduino Teensy, which was attractive for its small size and affordability. During troubleshooting, however, we encountered many problems with powering the Teensy on our 5V board, even after we added a level converter to give the Teensy 3.3V. Thus, a 5V Arduino Micro was used in the final board for better compatibility with the rest of the board while still saving space and money. This greatly simplified the board as the level converter was no longer necessary and components such as the brushless electronic speed controllers (ESCs) could be directly connected to the main power supply.

The motor controllers and cameras made up the bulk of the electronics. The thrusters used this year were 600HF Hi-Flow thrusters from CrustCrawler. Considering their high cost and strong reliability, these thrusters were salvaged off of last year's vehicle. Two HobbyKing Brushless motor controllers were used to provides the powerful vertical thrusters with the necessary power. Since these motor controllers can take a maximum current of 30 Amps, much higher than our fuse allows, there was next to no chance of over-supplying the thrusters and burning them out. Two sensors, one for temperature and one for pressure, were included to make measurements for the Europa mission. Six servos were also used in the claw. Since one Arduino Micro cannot handle that many peripherals, a second Micro was used, attached to a second control board. The two boards and Micros combined gave us a total of 12 analog pins: 6 for the arm, 2 for the vertical thrusters, 2 for sensors and 2 for miscellaneous usage just in case.

Based on experience, it is very difficult to locate problems on the board without visual feedback from the board itself. To aid troubleshooting, six LEDs were placed on the two main boards. Two LED was placed on each board to signal that the 5V power line and the Arduino Micro were operational. The two other LEDs were connected to the two sensors to help us determine whether they were receiving sufficient power from the board.

When prototyping of our vehicle, we used a linear voltage regulator but soon found out that it drew too much current and could not power the entire ROV on its own. To solve this issue, a switching voltage regulator with a higher maximum current allowance was used, ensuring all components of the vehicle were operating at full power. Using a switching voltage regulator had the additional benefit of reducing the amount of heat dissipated through the wires, adding to the safety of the vehicle. With a small fan and a small piece of metal to serve as a heat sink, our board cooled itself so well that heat was never an issue when operating the ROV for extended periods of time.

The new ROV utilizes new, higher quality, wider angled cameras to increase its range of vision. In previous years, the video feed suffered from excess amounts of static and lag. This year, the video feed was ran through a pair of baluns to filter out the noise. Before the camera camera travels across the tether, a balun on the ROV converts the signal into a balanced signal, removing noise and allowing it to travel through the tether without losing data. The signal is then reconverted to an unbalanced signal by a second balun on the onshore control system and is displayed on the video monitor. This method resulted in crisp, steady footage that was especially helpful for getting clear images of coral colonies for the coral study task and identifying serial numbers on CubeSats for the mission-critical equipment recovery task.

Another new feature to the cameras is modular connectors to make wiring easier. When wiring the electronics for the prototype ROV, much time was spent matching wires from the onshore control system through the tether to the on-bot control box. This was a very messy process and was only made worse by the fact that the wires had to be soldered directly then covered with shrink tubing and electrical tape. Mismatching a single wire often resulted in hours of troubleshooting as we had to first remove the insulation to find which wires were connected improperly, only to re-solder and re-apply insulation after isolating the problem. The new camera system fixes this issue by using sets of connectors instead of individual wires. Each side of the tether, onshore and offshore, has its own set of connectors that are connected in bulk through the tether. Thus if the wires are mismatched, all we need to do is rearrange the connectors on either the ROV or the onshore control system, not sort through each wire individually from onshore through the tether to the vehicle.

Electronics Components Box:

Although last year’s ROV utilized a cylindrical control box with great results, this year’s ROV uses a rectangular control box instead. This introduced new problems with waterproofing, which was fairly straightforward with the cylindrical control box, but was necessary to fit all the electrical boards on the much smaller ROV. The rectangular shape of this year’s box matches the shape of the boards, allowing us to save space by simply stacking the boards. Combined with the LEDs on the board, the clear lid also aids in the troubleshooting process when checking for power failures or leaks. We considered using two boxes early on in the prototyping phase, but ultimately housed all the electronics in one box to reduce the amount of waterproofing required. Once all the boards were finalized, they were also coated with a thin layer of epoxy to protect from condensation.

D. Troubleshooting, Testing Techniques, and Waterproofing

The main control box was bought at a local hobby store. Although it was advertised as a waterproof container, we had to put in a great deal of effort to increase its reliability, especially after holes were drilled in the sides to accommodate cable connections.

The first attempt prior to drilling holes was simply screwing the box shut and submerging it in a small bucket. Water was able to enter almost immediately, proving that more waterproofing was necessary. After watching the box closely for air bubbles, we isolated the leak to the space between the box and the lid and the screw holes. Our second attempt therefore included a rubber O-ring to serve as a gasket between the box and the lid and teflon tape around the screws. At this point, we also drilled several large holes to insert waterproof cable connectors, though in hindsight it would have been better to drill holes only after the box itself was verified to be 100% waterproof. In our second attempt, water trickled in at a slower but still significant rate. Using the bubble method again, we were able to identify two specific connectors as the sources of leaks. Our next attempt involved using silicone to cover the connectors completely. This waterproofing method protected against all leaks for up to ten minutes and only allowed a tiny, non-harmful amount of water to enter after ten minutes, proving that our system of waterproofing is effective.

One final test to identify the least secure part of the control box involved drilling an additional hole to attach a pneumatic tube. After pumping air in through the tube, small bubbles began to emerge from the waterproof connectors. Future waterproofing designs should seek to strengthen the connectors or remove them entirely as they are clearly the components most prone to fail and let water enter the box.

Silicone was used instead of epoxy during the testing phase because silicone is easier to apply and remove, making it better for testing. The final control box is waterproofed with epoxy which is more able to seep into small cracks and thus provides a stronger seal, lasting indefinitely so far in our tests.

Figure

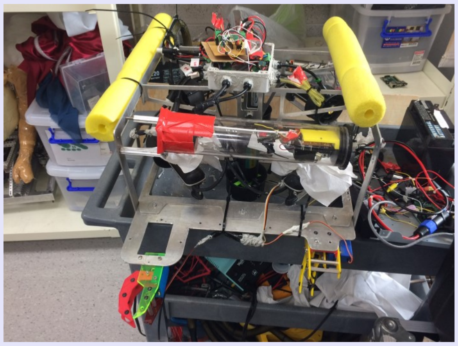
III. Safety

A. Vehicle Safety Features

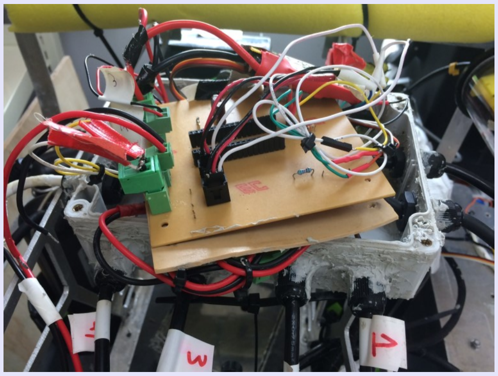
Our newest vehicle, the MK-VII, includes several innate safety features. The sides of the vehicle are all filed down in order to eliminate any sharp edges that can cause injury when moving the robot. In addition, all thrusters are positioned inwards and covered with a cap or mesh to prevent the rotor blades from hurting anyone. All thrusters are also identified with warning labels that clearly communicate the dangers posed by their powerful, high-speed blades. Every year, each thruster is first tested for functionality, then fully treated with special lithium grease to both waterproof its internal electronics and ensure it can run without stalling or overheating.

through waterproof wires, kept away from the thrusters to prevent snagging. A portion of the tether is also zip-tied to the side of the vehicle to prevent excess strain on the wires as the vehicle maneuvers. Finally, to prevent the vehicle from overheating due to current

The electronic components of the vehicle are housed in a waterproof box covered with silicone, epoxy, and rubber gaskets to prevent any leaks. The control box is connected to the tether through waterproof wires, kept away from the thrusters to prevent snagging. A portion of the tether is also zip-tied to the side of the vehicle to prevent excess strain on the wires as the vehicle maneuvers. Finally, to prevent the vehicle from overheating due to current overload, a 25-amp fuse is placed within 25 centimeters of the 12.6V battery. This prevents permanent damage to the vehicle's control systems, as well as ensures the safety of divers in the water while the ROV is operational.



Figure– Entire ROV with Smooth Edges



Figure– ROV Control Boards Safety

B. Water Test Safety

The ROV is a complex piece of machinery with many sensitive electrical components. As such, each component is individually water-tested in a small water inside the lab prior to testing in the pool. After the initial small-scale test, the ROV is assembled with all mounted components and a full-bot water test takes place in the school swimming pool. Aside from adding an extra level of security to our water tests, this two-step process also makes it easier to identify sources of leaks and fix them immediately. During water tests, an adult faculty mentor and a fully certified lifeguard are present to ensure the safety of employees in the pool. Since the swimming pool is always booked ahead of time, if other swimmers happen to be in the pool during water tests, we can simply use lap lanes to keep ourselves apart. We also make sure that our diver employees are fully capable swimmers and and stay at least 5 meters away from the vehicle once it is powered on.

C. Operation of Heavy Equipment

As a company that regularly uses heavy machinery such as the waterjet cutter, bandsaw, and lathe, we require that all employees demonstrate proficiency with the equipment and respect for safety guidelines. Less-experienced members are taught by more experienced employees, then supervised until they demonstrate proficiency in using the equipment. This training and supervising process allows older employees to pass on their knowledge and helps new members learn skills necessary in the lab, always keeping in mind that safety is the number one priority. Our lab safety protocol also requires all employees wear goggles to protect against projectiles, gloves when working with heat or chemicals, and face masks when toxic fumes or strong odours will be emitted. As a final precaution, our safety policy requires that a fully trained adult supervisor is in the room when any heavy machinery is being used, regardless of how experienced the operator is.

D. Gases, Fumes, and Chemicals

When undergoing tasks such as soldering, sawing PVC, or applying epoxy, windows are kept open to allow the ventilation of fumes and airborne particles. When using the laser cutter, which is ventilated to the outside, windows are closed to prevent the carcinogenic fumes from re-entering the lab. When dealing with fumes or dust particles that are particularly harmful when inhaled, such as aluminum dust produced in the process of filing, we require our employees to wear face masks. Gloves are also required when handling chemicals such as silicone sealant, motor lubricant, acetone, and epoxy. In the event that volatile chemicals are required for the construction of the ROV, production is conducted inside the fume hoods provided by our school's scientific research labs to provide additional safety.

IV. Logistics

A.Scheduled Project Management

Due to the fact that TigerSharks Co. submits a qualifying video as opposed to participating in a regional event, our work schedule was based around the crucial video deadline. The process of qualifying began in December when the team reviewed the competition guidelines and missions details as a group. From the very beginning, members were given a clear view of the overall ROV as well as their specific tasks. Thus, in addition to attending meetings every Tuesday and Thursday, members often put in time individually during lunch or free periods to run through potential designs.

From January to April, creating a new ROV constituting a new frame, new electronics, and mission-specific payloads was prioritized. Although we also developed new, mission-specific components during this period, the main goal was creating a functional ROV for the qualification video. After qualifying, the final months before the competition were centered around fine tuning the ROV's design and practicing missions in the pool. Throughout the year, members often worked on their own assigned parts or collaborated in a team effort to accomplish more challenging tasks like waterproofing the control box and connecting the onshore control system to the ROV's electronics. In the event of overdue deadlines, team members working on non-critical tasks were pulled in to help, preventing further delays.

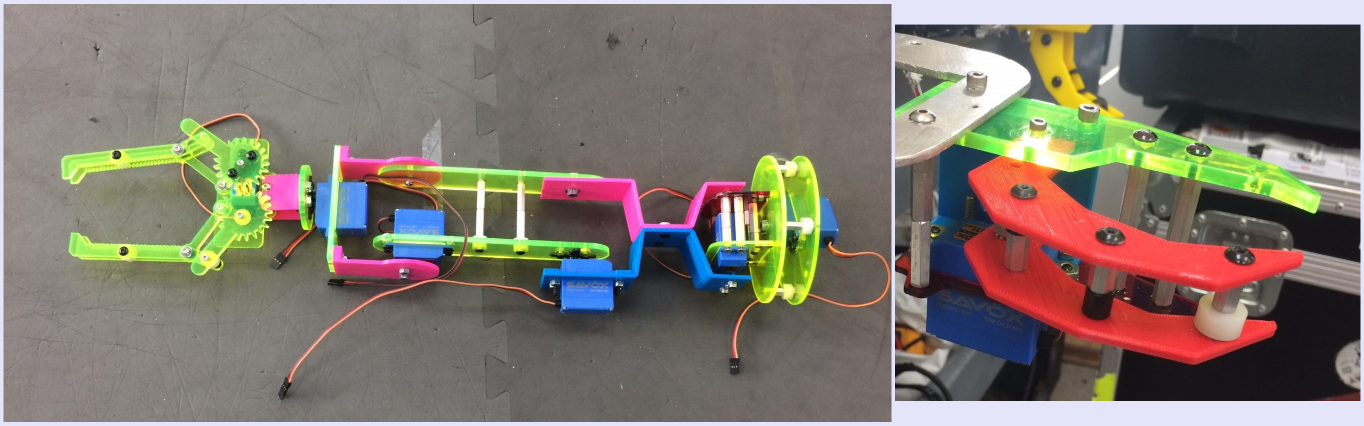
B. File Sharing and Communication

Communication was achieved through a Facebook group and email chains. These mediums quickly conveyed messages regarding meetings times, problems to solve, and job assignments to all the members and adult supervisors.

Source code management was especially important to the coders, who had to work on the same file without interfering with each other's work. Code was shared mainly on Github, which allowed easy collaboration through its repository, pull request, and branch system. In addition, a Google Drive and Dropbox folder were created to share documents such as Eagle schematics, CAD designs, and work schedules. Our extensive file sharing allowed each member to stay up to date on the ROV's state, and made it possible to plan work sessions with specific short-term goals in mind.

C. Budget & Cost Projection

Tigersharks ROV operates on a budget of 150,000 NT (around 4,620 USD) allocated by the Taipei American School. In many cases old parts were reused, such as last year's frame to test out new components built this year. We also received several generous donations and benefited from student discounts when purchasing equipment. All expenditures, including receipts and reimbursements, are recorded in an Excel file. The budget report includes the total expenses this year and the total ROV cost with reused and donated parts, adding up to a total of 5190.71USD for a completely new vehicle. Please see Appendix B for our complete budget report (The airfare expense is listed separately from the ROV budget because members pay for their own airfare).



Figure– ROV Prototype Arm and Claw

V. Conclusion

A. Challenges

In TigerSharks Co., challenges are motivate us to create innovative engineering solutions. One challenge that we faced regularly was navigating between equipment in the metric system and the imperial system, as well as the lack of materials available in Taiwan. Since this is an issue we encountered last year, our members have learned to improvise and modify the props construction manual around our means. For example, we would determine which pieces were needed and scale the measurements to fit the metric system used in Taiwan. In some cases this required 3D printing our own joints was required to make props as these were not sold locally.

Scheduling regular meetings was also a challenge in TigerSharks Co., since most members had additional commitments after school such as sports, MUN, & community service. Although these conflicts delayed our production schedule, they also pushed members of the team to step in and take charge of areas outside of their comfort zone, causing our members to be well rounded in many different technical skills.

B. Future Improvements

Despite the success in overcoming our challenges this year, there are some improvements that should be kept in mind in order for our building process to be smoother in the future. Since one of our main challenges has consistently been the lack of materials available in Taiwan, we could preorder materials that we know we would need from the United States, such as PVC joints and fittings, for more accurate props. In terms of scheduling conflicts, we could have members trained to be well-rounded engineers, so members from all divisions could step in and help out with knowledge in different aspects. Since we often know our schedules of afterschool activities for the year, we can start planning our ROV process earlier and avoid scheduling many work sessions during the months where people have numerous other commitments. These small but helpful aspects would definitely benefit our entire process of creation, and we look forward to implementing these changes next year.

C. Lessons Learned & Skills Acquired

TigerSharks Co. faced many communication challenges early on during the manufacturing period. As many of our employees specialize in specific fields of engineering, a lack of communication and initial planning resulted in a situation where certain employees were unable to continue their designing due to lack of additional output from another field of design. To combat this problem, we created a fixed schedule to give our employees rough ideas of when what should be completed. Our company thus learned the importance and the need for more thorough planning and communication between the different specialized fields.

Designing and creating our ROV this year saw extensive use of CAD, involving applications in 3D printing, hardware design, and PCB milling. Many of our employees, after finishing their tasks for the day, would then learn from those more experienced how to operate these designing and manufacturing tools. Aside from our new members gaining new skills, our more senior members also learned valuable lessons in leadership. As communication and power supply between on shore and on bot electronics is critical to an operational ROV, numerous flaws in on shore to on bot communication caused repeated failures, demanding more efficient troubleshooting. Our team therefore utilized the multi-meter and other tools to identify the problems, such as rusted wires causing insufficient power-flow, or loosely connected ground pins resulting in communication failure. As seen from these obstacles, both new and senior members of Tigersharks Co. learned valuable lessons and gained critical skills in engineering, which will undoubtedly allow us to improve our ROV this year.

D. Senior Reflections

“My third and final year in ROV has been brilliant. Every year, TigerSharks Co. has come up with newer, more innovative and precise methods of addressing the given tasks, and it has been a pleasure to work with a team of such passionate and creative people. I started ROV as a sophomore who knew nothing about robotics; now, as a senior and CEO of the team, I know what is involved when making an ROV, from the design aspects to the logistical details. As someone who plans on studying the social sciences rather than STEM, ROV has been an incredible opportunity to not only experience something completely different but also to witness how interdisciplinary robotics can be.”
- Trisha Sinha

"I used to think that intelligence was mainly demonstrated through test scores and AP classes, but ROV has taught me that applying my knowledge is just as important as having knowledge in the first place. The first few work sessions were filled with unintelligible jargon, and it was hard for me to admit my ignorance and let others teach me. At this point I am by no means an expert at CAD or Eagle, and I still need a lot of practice soldering and lathing, but the entire learning process has been immeasurably rewarding, like slowly filling in a crossword and realizing how all the bits and pieces fit together. My teammates are some of the most talented and creative people I have ever met, and I owe them all so much for their guidance. I would not trade all the theoretical knowledge in the world for the small amount of practical knowledge that they have given me this year." - Tommy Yuan

"As a programmer, ROV provided quite an interesting experience. I must (temporarily) acquiesce that coding is not absolutely superior to mechanical, real world "practical" aspects of engineering, and that each has its place in this project that spans so many fields of science and technology. I have found renewed interest in electrical engineering, as Lee and I work our way through the control system." - Joseph Chuang

E. Acknowledgements

- Dr. Hennessy, our superintendent, and Dr. Hartzell, our principal, for their continuous support in TigerSharks Co. and their financial funding.
- Dr. Garcia, our mentor, for sacrificing his holidays and weekends to support us in the lab and during water tests. We would like to thank him for his dedication and guidance.
- Marine Advanced Technology Education Center, our competition organizers, who has challenged us to create better products and provided us with an opportunity to meet people around the world who share our passions
- The PTA, Friends of TAS, and donors of the Robotics Lab for providing us with high-tech equipment and a wonderful workspace
- Taipei American School for letting us use its facilities and enabling us to explore our passions

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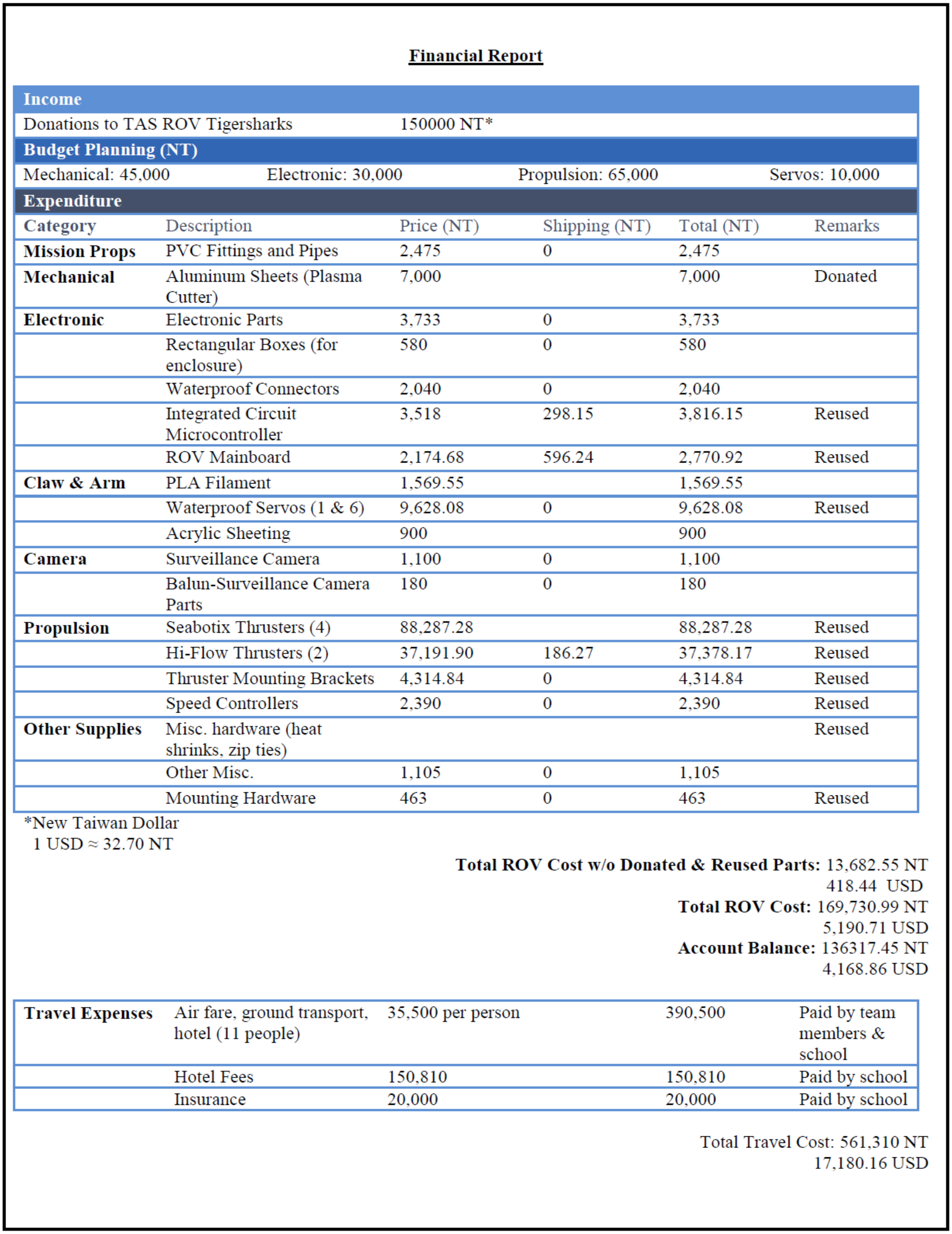
Appendix A: Budget Report



Financial Report

Income					
Donations to TAS ROV Tigersharks		150000 NT*			
Budget Planning (NT)					
Mechanical: 45,000	Electronic: 30,000		Propulsion: 65,000	Servos: 10,000	
Expenditure					
Category	Description	Price (NT)	Shipping (NT)	Total (NT)	Remarks
Mission Props	PVC Fittings and Pipes	2,475	0	2,475	
Mechanical	Aluminum Sheets (Plasma Cutter)	7,000		7,000	Donated
Electronic	Electronic Parts	3,733	0	3,733	
	Rectangular Boxes (for enclosure)	580	0	580	
	Waterproof Connectors	2,040	0	2,040	
	Integrated Circuit Microcontroller	3,518	298.15	3,816.15	Reused
	ROV Mainboard	2,174.68	596.24	2,770.92	Reused
Claw & Arm	PLA Filament	1,569.55		1,569.55	
	Waterproof Servos (1 & 6)	9,628.08	0	9,628.08	Reused
	Acrylic Sheeting	900		900	
Camera	Surveillance Camera	1,100	0	1,100	
	Balun-Surveillance Camera Parts	180	0	180	
Propulsion	Seabotix Thrusters (4)	88,287.28		88,287.28	Reused
	Hi-Flow Thrusters (2)	37,191.90	186.27	37,378.17	Reused
	Thruster Mounting Brackets	4,314.84	0	4,314.84	Reused
	Speed Controllers	2,390	0	2,390	Reused
Other Supplies	Misc. hardware (heat shrinks, zip ties)				Reused
	Other Misc.	1,105	0	1,105	
	Mounting Hardware	463	0	463	Reused

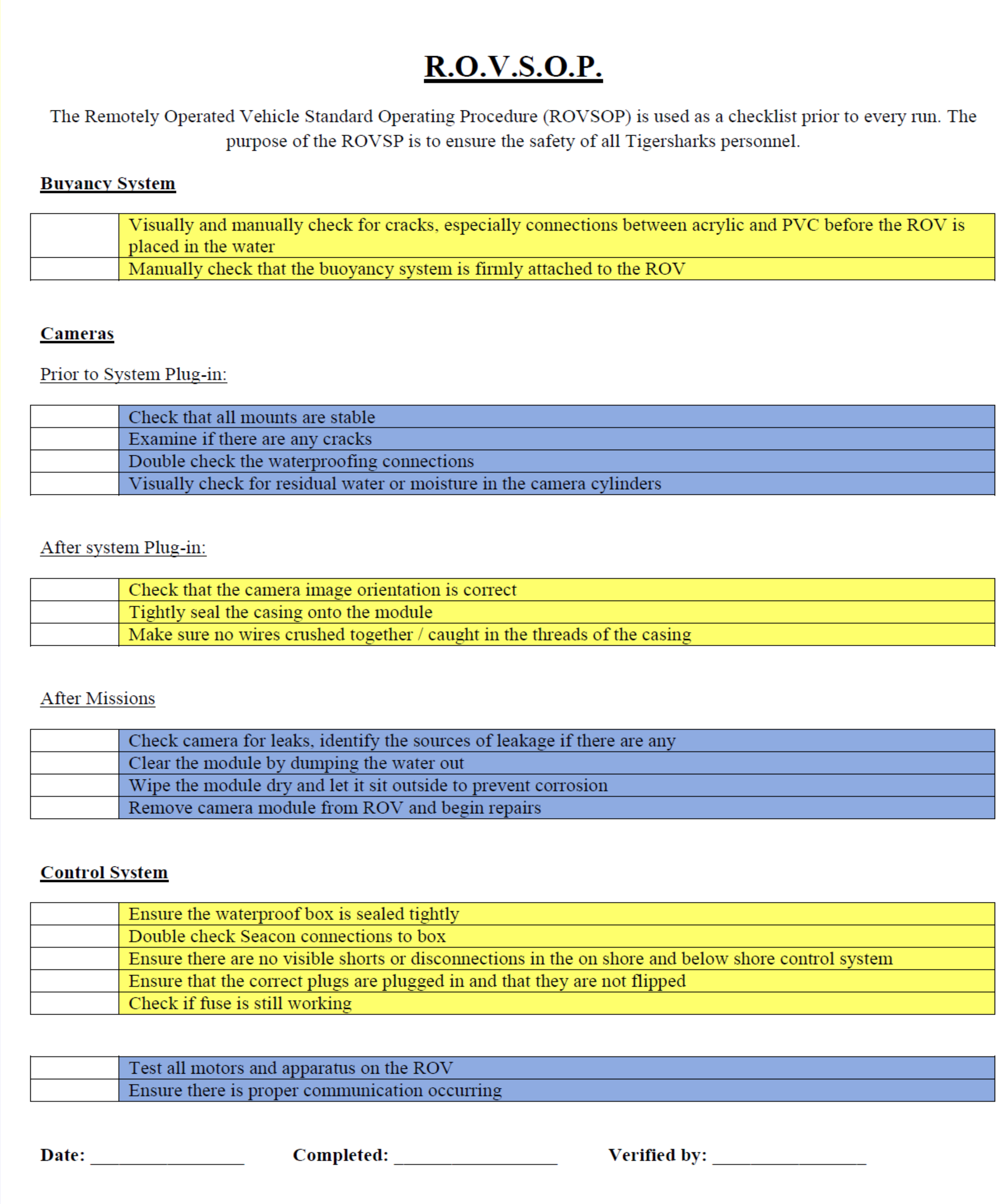
*New Taiwan Dollar
1 USD ≈ 32.70 NT

Total ROV Cost w/o Donated & Reused Parts: 13,682.55 NT
418.44 USD
Total ROV Cost: 169,730.99 NT
5,190.71 USD
Account Balance: 136317.45 NT
4,168.86 USD

Travel Expenses	Air fare, ground transport, hotel (11 people)	35,500 per person	390,500	Paid by team members & school
	Hotel Fees	150,810	150,810	Paid by school
	Insurance	20,000	20,000	Paid by school

Total Travel Cost: 561,310 NT
17,180.16 USD

Appendix B: Safety Checklist



R.O.V.S.O.P.

The Remotely Operated Vehicle Standard Operating Procedure (ROVSOP) is used as a checklist prior to every run. The purpose of the ROVSP is to ensure the safety of all Tigersharks personnel.

Buyancy System

	Visually and manually check for cracks, especially connections between acrylic and PVC before the ROV is placed in the water
	Manually check that the buoyancy system is firmly attached to the ROV

Cameras

Prior to System Plug-in:

	Check that all mounts are stable
	Examine if there are any cracks
	Double check the waterproofing connections
	Visually check for residual water or moisture in the camera cylinders

After system Plug-in:

	Check that the camera image orientation is correct
	Tightly seal the casing onto the module
	Make sure no wires crushed together / caught in the threads of the casing

After Missions

	Check camera for leaks, identify the sources of leakage if there are any
	Clear the module by dumping the water out
	Wipe the module dry and let it sit outside to prevent corrosion
	Remove camera module from ROV and begin repairs

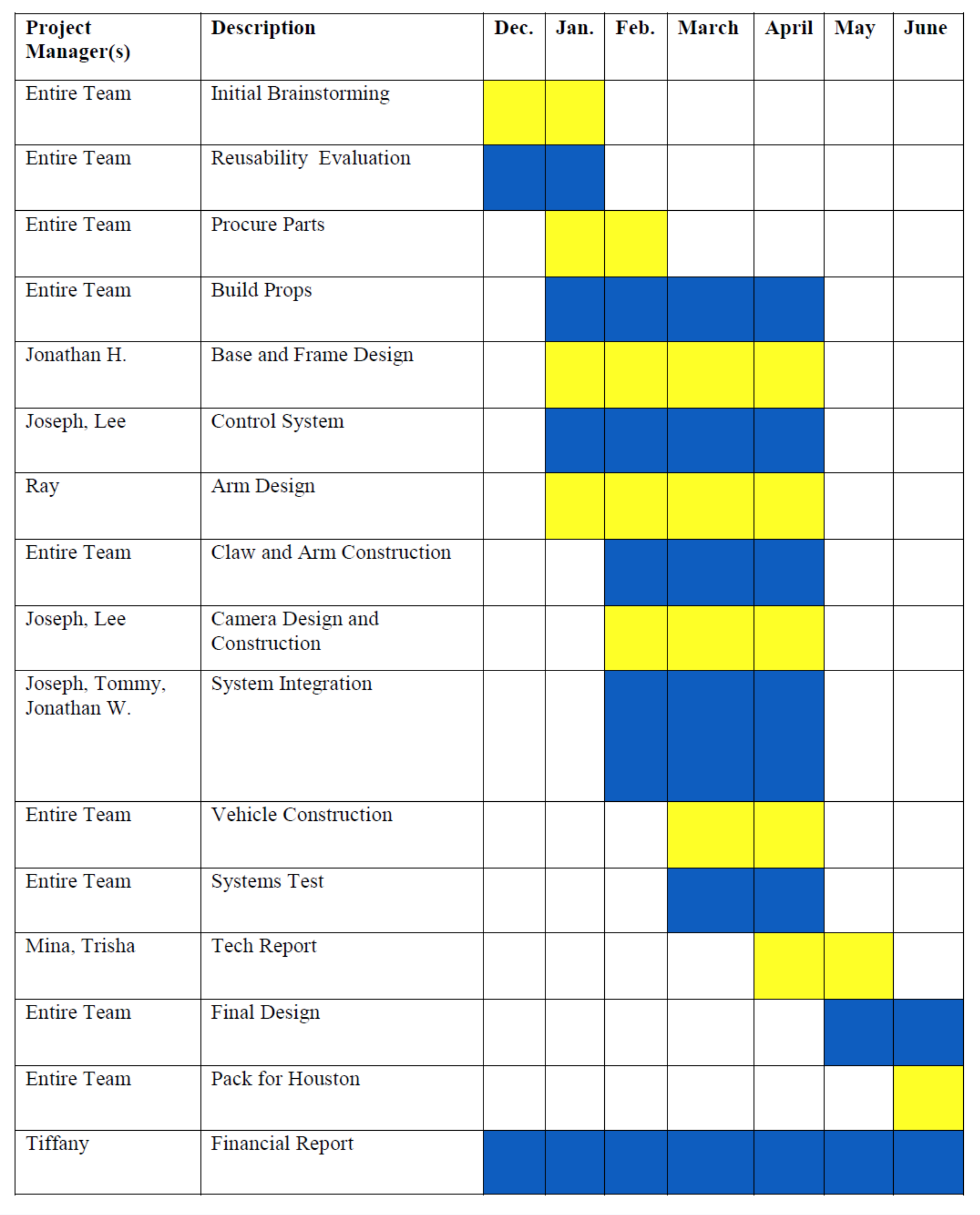
Control System

	Ensure the waterproof box is sealed tightly
	Double check Seacon connections to box
	Ensure there are no visible shorts or disconnections in the on shore and below shore control system
	Ensure that the correct plugs are plugged in and that they are not flipped
	Check if fuse is still working

	Test all motors and apparatus on the ROV
	Ensure there is proper communication occurring

Date: ________________ **Completed:** _________________ **Verified by:** ________________

Appendix C: Developmental Schedule



Project Manager(s)	**Description**	**Dec.**	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**
Entire Team	Initial Brainstorming	🟨	🟨					
Entire Team	Reusability Evaluation	🟦	🟦					
Entire Team	Procure Parts		🟨	🟨				
Entire Team	Build Props		🟦	🟦	🟦	🟦		
Jonathan H.	Base and Frame Design		🟨	🟨	🟨	🟨		
Joseph, Lee	Control System		🟦	🟦	🟦	🟦		
Ray	Arm Design		🟨	🟨	🟨	🟨		
Entire Team	Claw and Arm Construction			🟦	🟦	🟦		
Joseph, Lee	Camera Design and Construction			🟨	🟨	🟨		
Joseph, Tommy, Jonathan W.	System Integration			🟦	🟦	🟦		
Entire Team	Vehicle Construction				🟨	🟨		
Entire Team	Systems Test				🟦	🟦		
Mina, Trisha	Tech Report					🟨	🟨	
Entire Team	Final Design						🟦	🟦
Entire Team	Pack for Houston							🟨
Tiffany	Financial Report	🟦	🟦	🟦	🟦	🟦	🟦	🟦

Appendix D: Software Flowchart