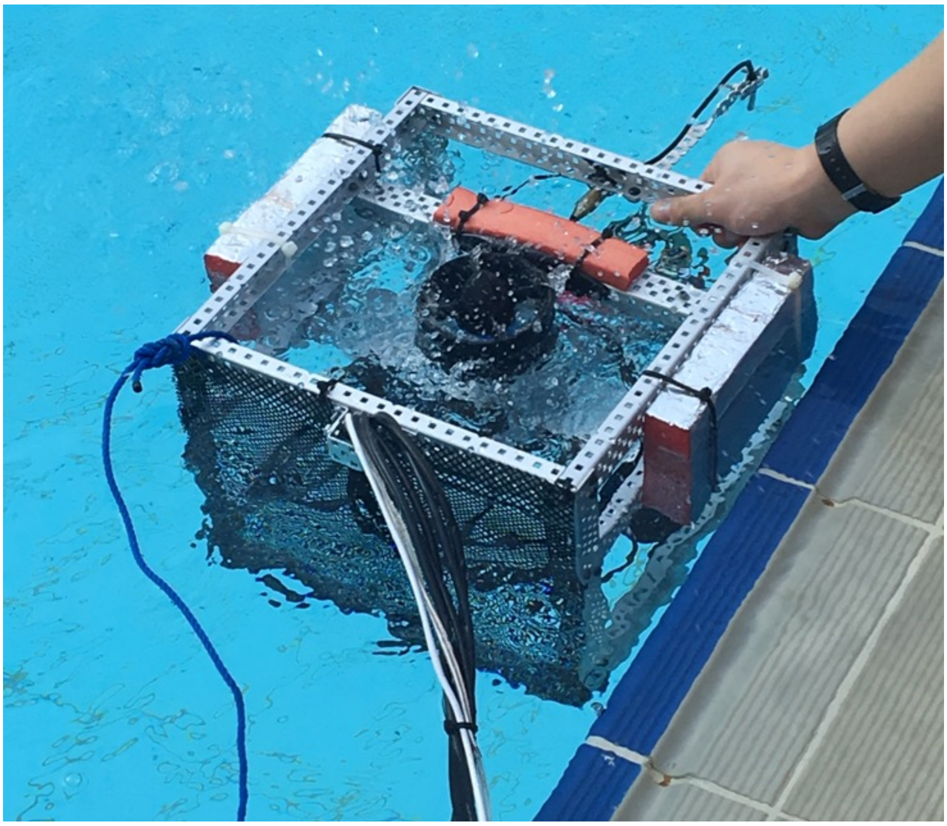
ONE DEGREE NORTH RED



Members:

Singapore American School
Singapore

Dalen Ward (G)
Company Role: Coder

Sae Jin Jang (Grade 12)
Company Role: Writer/Tether Manager

James Quek (Grade 12)
Company Role: CEO

Colin Clark (Grade 12)
Company Role: COO

Sohit Gatiganti (Grade 10)
Company Role: CTO/Writer

Aaron Cruz (Grade 10)
Company Role: Coder

Vijayendra Jagtap (Grade 12)
Company Role: Writer

Rohan Sahu (Grade 12)
Company role: - Engineer

Natalie Weinrauch (Grade 12)
Company role: Intern

Alyssa Garner (G)
Company Role: Intern

Mentors:
Mr. Barton Millar
Mrs. Meredith White

ABSTRACT

Initially, the lack of underwater robotics experience seemed to be a problem, so One Degree North Red decided to build a prototype with a basic frame that almost mirrored our final robot. We managed to get our prototype up and running in the water with simple mechanics. We felt that the building of the prototype highly contributed to the learning of effective techniques, tools, and design. With a similar model our final robot, Usain Boat, is the one the newest MATE robot created by One Degree North Red. With a complete new look from the previous robot, the Usain Boat is built with a robust base structure powered by efficient codes.

Before Usain Boat was made, the team consisted of most members with minimal experience to the MATE competition. Initially, we decided to start on a prototype in order to gain more experience to the competition. The construction of the prototype with working codes was fruitful because our members faced difficult challenges, made mistakes and corrections, and learned new methods and techniques. All these factors contributed to the growth of each and every member of the team in terms of coding, building, and even the relationship and morale of the team. The prototype also helped our members recognise our strengths and weaknesses in the field of robotics so that we could each give the most contribution to our robot in the appropriate role(s).

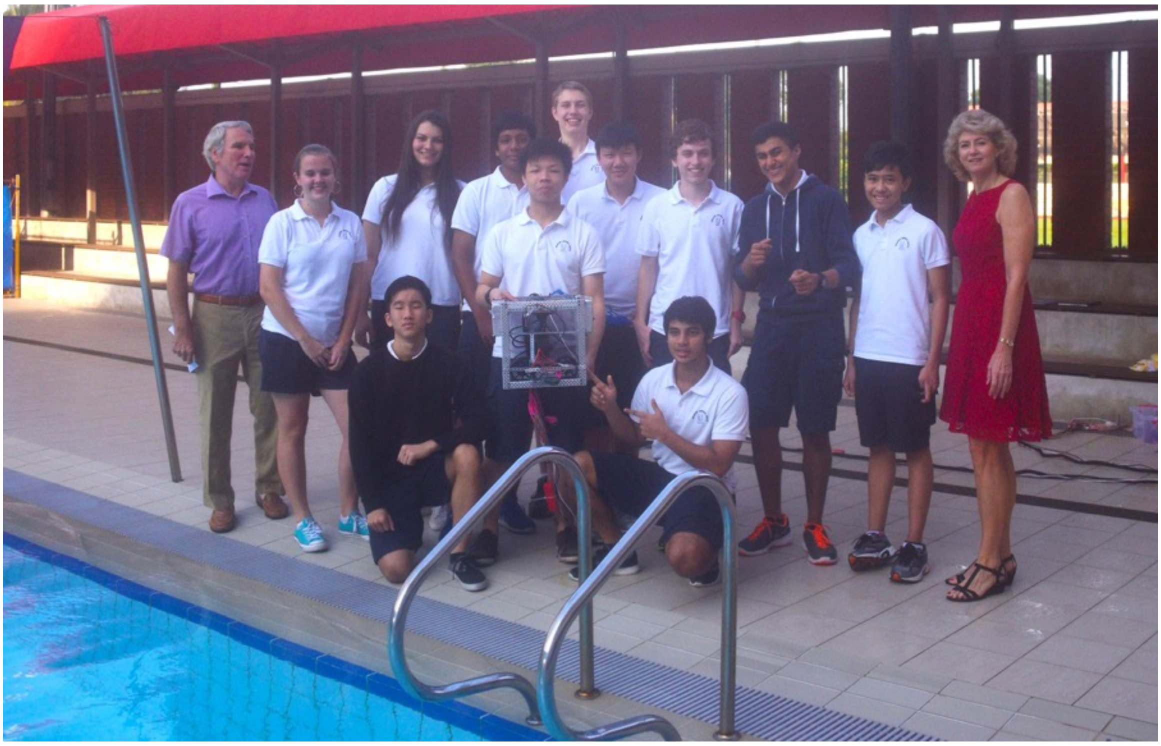


Figure 1: Team Photo on Poolside (Credit: Xi Huan Koh)

SAFETY

After each member successfully passed the safety test, we were ready to work with various tools and machines. To ensure an enjoyable, efficient work space, One Degree North Red strictly regards safety as the top priority.

Safety features and practices are important for any electrical appliance. Safety was of utmost importance to our team especially since this was a robot which would be in close contact with water. Therefore, this year's vehicle has all of the required safety features including: a 25amp fuse within 25cm of the battery on the positive line, caution labels for moving parts and thrusters that are both inboard and shrouded. In addition to the required safety features, the team introduced several of their own, including a main power shutoff switch.

During construction of the ROV, the company followed a comprehensive safety protocol and this includes the use of safety glasses, closed-toe shoes and gloves. Below is a checklist which the team followed in order to maintain a safe workspace.

Safety Checklist for Usain Boat

Workshop Checklist	ROV/Tether Safety Checklist
Am I wearing safety goggles?	Is there any exposed wire?
Am I wearing closed toe shoes?	Is there a fuse?
Is the ROV off while I'm working on it?	Are the motor shrouds firmly in place?
Do I know how to use this tool?	Are there any loose parts?
	Is the tether tangled?

TABLE 1: Safety Checklist

With abundant resources to build our robot, each member follows specific precautions for each tool. The robotics workspace consists of two rooms separated by a sound-proof door. The basic requisites to enter and use tools or machines in the heavy machinery room are to always wear safety goggles, closed tied shoes, ear mufflers, and to have supervision from our mentors. Because some of our members were inexperienced with tools, each team member always entered the heavy machinery room with a partner to provide and remind to follow safety precautions.

Because we considered safety as an essential aspect, there were no damages and hinderance to our progression of the robot. Our members were persistent to remind each other to strictly adhere to the safety measures.

VEHICLE SYSTEM AND DESIGN RATIONALE

There were many special design considerations that went into designing an ROV which needed to be capable of operating in some very extreme environments. Firstly, we had to try to make our robot as small and as light as possible in order to save money shipping the robot and to gain the extra 40 points for size and weight. Another unique part of our robot is that it only has 4 motors, hence making it very simply and easy to manoeuvre. We also had to take in many environmental factors, and we had to make sure that we achieved neutral buoyancy to ensure manoeuvrability.

Furthermore, the ROV obviously needed to be able to perform all of the 2016 mission tasks. Due to the large number of tasks that have to be accomplished, the ROV's manipulator and design was not only created to be efficient, but the team also created its own task order in order to save time and reduce the number of trips to the service. Below is the order used for Task 1: Mission to Europa.

#	Task 1 (Mission to Europa)	Points
1	Measure thickness of ice crust	Up to 10
2	Measure depth of ocean under ice	Up to 10
3	Connecting ESP to power and communications hub	Up to 50
4	Installing temperature sensor into venting fluid	Fixed 10
5	Measuring temperature of the venting fluid	Up to 20

TABLE 2: Efficient order of tasks for Mission 1

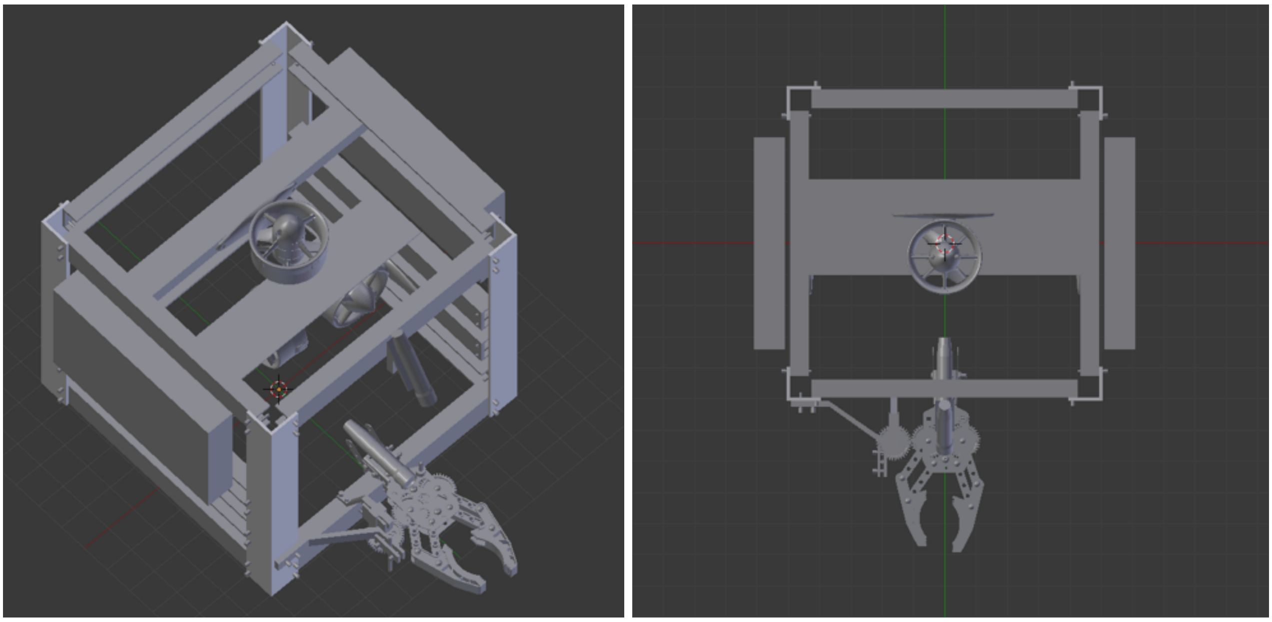


Figure 2: CAD by James Quek

FRAME AND FLOTATION

The frame is made from lightweight VEX aluminium parts. Some of it's beneficial properties include its e its strength, light weight, feasibility, cost, durability and its ability to insulate electricity. The frame was designed to be as light and as minimalistic as possible. Since we kept all our electronics above ground, it did not require complex parts such as a waterproof electronics canister. This made our job much easier and our bot itself much easier to manoeuvre.

The frame was created using a simple process of trial and error and although we had many frame ideas such as an octagonal shape, we decided that a simple cuboid might be more durable. No bolts were needed for this setup hence producing a clean, rigid structure which both minimises weight load on the thrusters and created more space on the frame to mount other tools such as the manipulator.

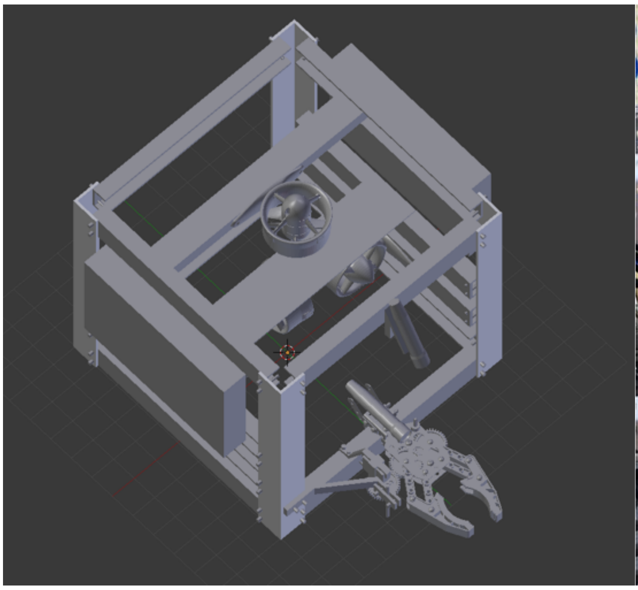


Figure 3: CAD of Frame (Credit: James Quek)

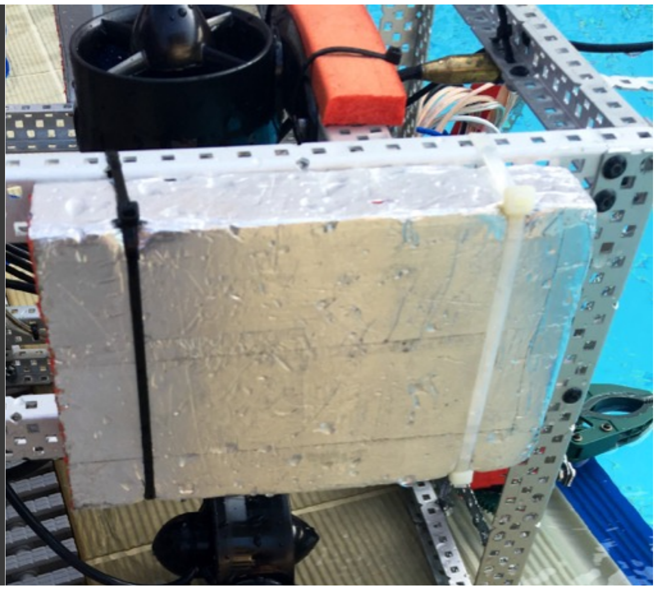


Figure 4: Flotation (Credit: Sae Jin Jang)

In terms of flotation, our goal was obviously to achieve neutral buoyancy in order to make the task of going up and down a much easier process. But, how much floatation and where the flotation needs to be placed would require thorough testing in the pool. For our flotation we used High-density polyethylene (HDPE) which was extracted from a kick board. This was chosen since a small amount of it would be enough for flotation. But, in order to make sure that they did not get worn off, we wrapped them in aluminium tape to make it watertight and ensure endurance and reliability.

THRUSTERS

For our thrusters, we used BlueRobotics T100 thrusters. These motor were chosen for their immense power, reliability and cost-effectiveness. Furthermore, these motors were already waterproofed and enclosed in its casing, making it much easier to use with our the worry of water leaking into it.

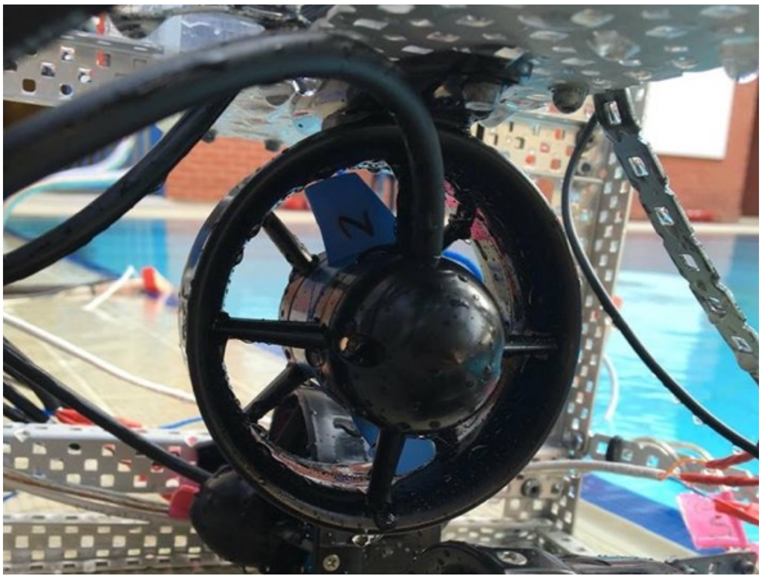


Figure 5: The BlueRobotics T100 Motors

The thruster is attached to the frame using a ready-made mount with 2 bolts to secure it in place.

There are four thrusters in total: two for horizontal motion, one for crab motion, and one for vertical motion. The horizontal motors allow for turning left and right while also allowing for an optimal amount of forward motion. The vertical thruster help us go up and down while also allowing us to tilt when objects need to be picked up. The crab motor helped us go sideways for extremely easy manoeuvrability underwater. Furthermore, the propellers were all shrouded for maximum safety. These thrusters also produce a whopping 5 pounds of thrust giving us a huge amount of torque in addition to speed.

CAMERAS

The ROV is equipped with four 15 metre, USB powered cameras. These cameras were chosen for their compact size, cost, and its intuitiveness. These cameras were also readily waterproofed and sealed. The first camera is mounted so that it looks down for viewing our manipulator and temperature sensor. The second, third and fourth camera are also facing forward but at slightly more behind the main camera to provide for a wider view. This was done so we do not get penalised for hitting the Paramuricea coral species and to be able to view more objects at once. Video is sent through the USB cable which can then be viewed on a computer.

Figure 6&7: Camera Pictures. Source: amazon.com

MANIPULATOR

Most of the tasks throughout the mission require a very strong manipulator. These missions include the tasks in Mission to Europa, where we have to perform the complex task of attaching a ESP cable to the power and communications hub. Our manipulator was a VEX claw operated by a servo, and some stainless steel metal strips. It was shaped almost like a claw to ensure reliability. We also coated the manipulator with rubber bands to ensure grip and so that nothing get out of our grip once grabbed.

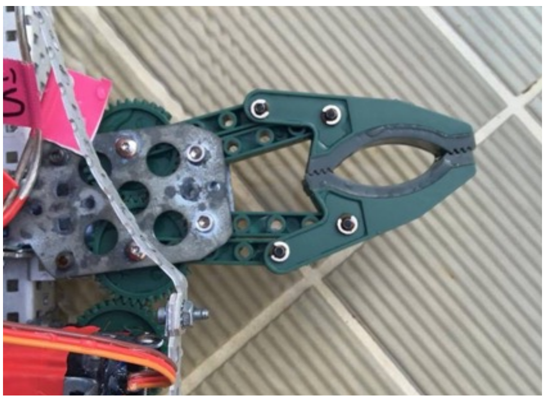


Figure 8: Manipulator in Early Design (Credit: Sae Jin Jang)

TEMPERATURE SENSOR

One of the tasks in Mission to Europa required our ROV to measure the temperature of a venting fluid. In order to achieve that task, we used a DS18B20 waterproof temperature sensor. This was chosen for its reliability, durability, and low cost. The sensor could directly be connected to the Arduino and a simple program could be run to determine temperature using voltage.

Figure 9: Temperature Sensor (Source: SgBotic)

Figure 10: Mounted on Robot (Credit Sae Jin Jang)

SONAR

One of the tasks in mission to Europa required us to measure the depth of a pool. We decided this could be achieved by using a sonar or ultrasonic sensor. We chose these for their accuracy and simplicity. The sonar would give us a value in milliseconds of how long its "sound" took to be sent and come back. From this, we would use the equation: 2D=V X T where V is the speed of sound in water and T is the time. The speed of sound in water is 1482 m/s so the final equation for depth would be D= ½ (1482 X T). This would be quickly run through a computer and a distance will be given to us.

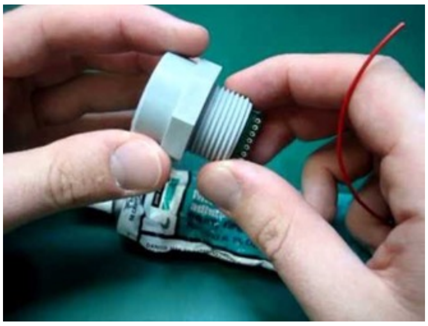


Figure 11: Sonar (Credit: Sohit Gatiganti)

FUTURE IMPROVEMENTS

In order to become a stronger team, each member strives to initiate any kind of activity. As our confidence grows by getting our hands on construction or coding, our experience builds up to allow us to become more of a leader. Although not anyone can become a leader, we must still push ourselves to become not only a better robotics contributor but also to become a better person. As there are three 12 graders in the team now, new freshmen students coming next year need leaders with confidence, professionalism, good behavior, and exceptional skill and creativity. There wasn't such a clear cut leader at all times and that factor may have hindered some operations. The absence of a clear leader was clear when our team was first established. Later on, people stepped up to exemplify work ethic and determination by working longer hours after school and even late at night. There were many uncertainty in who will become the "CEO" of the team because nobody really wanted to be the head of the team: members were unconfident and ambivalent. We later decided on the leader of the group on his leadership that grew exponentially, showing a stand-out immense commitment and passion for the robot and the competition. Leadership from our members is so much better than what it was when the team was started, but our team would have strolled through so much more obstacles if a confident leader stepped up from the beginning.

In terms of the robot, there were many improvements that could be made as well. For example, next year, we would like to have a more aerodynamic design as opposed to a sold cube this year. As a team, we were happy with the first MATE ROV we ever built, but we knew that we always have room to improve. We believe that we could have made our ROV better by placing some of the electronics underwater. We believe that this will reduce the number of wires in the tether and make transportation hassle free. This would also reduce the need to make the motor wires be 50ft long and we could have just had one Arduino wire and two came wires in the tether rather than the additional eight motor wires. Also, another improvement we could make is that we could have focused more on our manipulator and made sure it was the best we could make it since we did the manipulator towards the end. Vision is crucial to complete a task underwater. Therefore, more cameras should be mounted, and their FOV should be well considered. More viewing angels will help to counteract the missing depth perception.

LESSONS LEARNED

Experience: Professionalism and Teamwork

With almost every student coming back from the MATE 2016 regional competition, our team gained some experience from being exposed to the environment of MATE. The team's moments included being a highly encouraged working unit, stepping back and focusing on one problem one by one. However, we struggled, at times, to work in a professional manner. Sometimes we left tools in unnecessary locations, causing confusion and disorganisation like complicated wiring caused slight delays that disrupted our team's progress. Soon we realised that a high degree of professionalism will propel us to become more productive. Simply putting tools back where they came from could cut down time for us and other people in the work space. Small nuances of professionalism were healthy habits that brought efficiency and even raised the morale of our team. At times our members were isolated, each working on different chunks of the project, but we never forgot to come together again to check on each other's progress, reevaluating, giving advice, and listening to each other. From cleaning and organizing all items away at the end of our working sessions to allowing members to talk one by one without interruption to having clear-cut roles for each member but offering flexibility to check on other members to telling each other to wear protective goggles at the work space, we slowly but surely became a solid team that was relentless to succeed. The team still has many areas to improve; however, each and every member gave their all to strive for the best.

Since we made this robot from scratch with no ROV experience, we were extremely proud of the robot we managed to produce. But, arguable the biggest lesson we have learnt is to always keep on schedule. This is vital since if one part falls behind schedule, the whole robot will be delivered late. This can be catastrophic, especially in such a short timespan. Next time, we should have better organisational skills and always finish tasks on time to make our robot as good as possible.

CHALLENGES

Technical Challenge: Organization

The main technical challenge our team faced was organization skills. Since our team is basically new to the game, at first we had to memorise novel safety rules that some of us never were aware of and, eventually, pass a test. Sometimes our whole team got frustrated from minor setbacks, but we learned from our mistakes and moved on. One case our whole team were stuck because of complicated wiring that could have been avoided if we were organized.

“ Our team encountered an unknown discrepancy in our wires. There are around ten wires that we have to test by the voltmeter. We had to find and observe the amount of volts passed through each wire. There were many wires that displayed minimum numbers; we needed to find a wire that displayed 12 volts. However, we actually couldn’t find a wire with twelve volts even after testing each wire. There were two wires that showed electricity activity, but the numbers deviated like crazy. We tried connecting these wires separately to the motors of the robot, but the motors did not budge. Some of us suggested to open the electrical tape that connected the two thick wires to the yellow box to see if there was a possible power loss. We were stuck. We were so close to getting the robot in the water for a crucial test run yet so far. The next class we figured out the solution- the wire four and three in the yellow box weren’t correctly arranged, causing a disturbance. Finally, the robot worked well, and we proceeded to go for a test run.”

Although a seemingly minor problem, our group members came together, as a unit, to face an obstacle. It was quite a challenge to us to figure out what was the problem with so many wires; however, our team managed to pull through with full team effort.

Non-technical Challenge: Teamwork and Cooperation

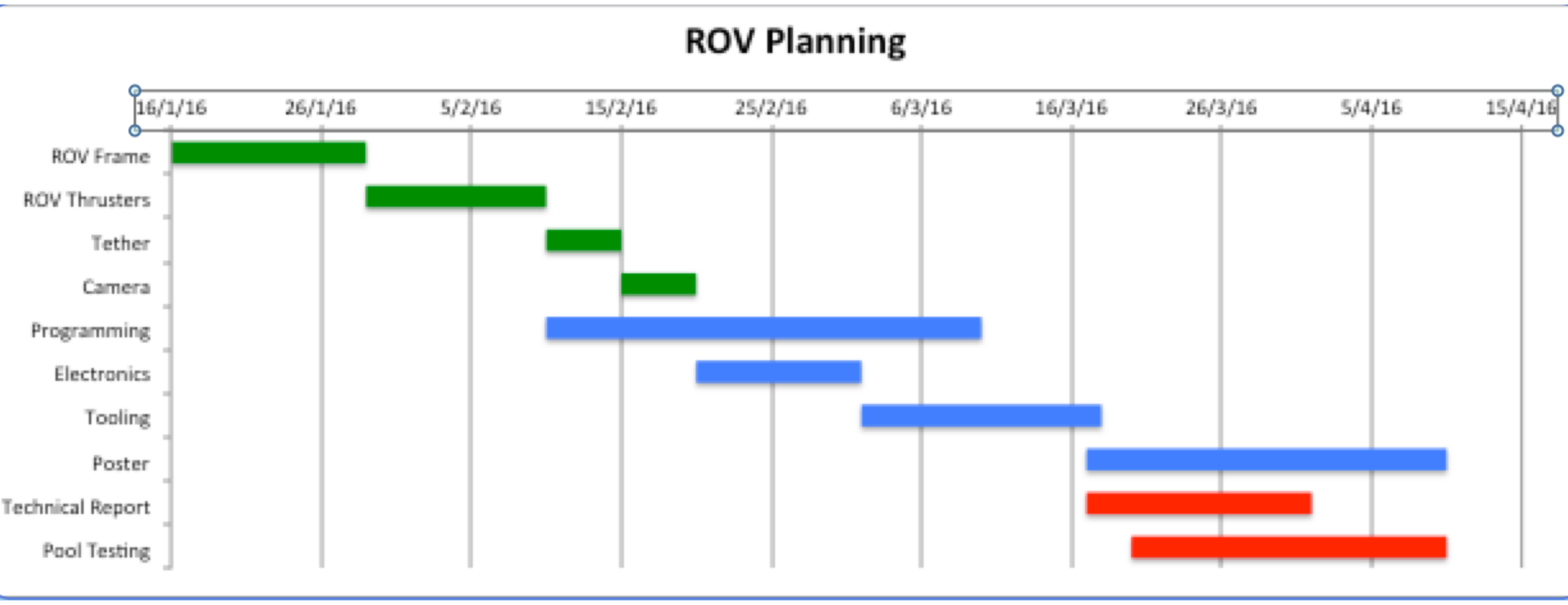
Occasionally, multiple team members felt that they had created the best design for a particular task and were reluctant to compromise. However, since we had to eventually decide on a single solution, we found that the best way to find one was to prototype and test all possible designs so it can be proven that one is better than other. By doing this, we made sure that the opinions of all the team members were taken into account and that no one felt disrespected.

PROJECT MANAGEMENT

This year's design process began in January of 2016, after recently completing a VEX competition in Taipei. We came in knowing little about robotics underwater and learnt many things along the way. It was a healthy challenge to take up and we enjoyed every part of the experience.

In order to achieve everything we wanted this year, we made multiple deadlines for ourselves. We made these deadlines so we would not spent and inordinate amount of time, effort and money on one competent of the robot. Having the deadline of the regional competition was another motivating factor since we recognised that the ROV would be a priority and we would have to give up our other commitments. Refer below for a Gantt Chart.

GANTT CHART



TROUBLESHOOTING AND TESTING

A specific instance of troubleshooting involved the wiring for our motor controllers and Arduino board. Our wiring would be very weak occasionally since we would have some loose connections. This was because we ran out of crimps at the last minute and we did not have time to order more. Instead, we made use of the resources we had and made some wires to be tight without crimps by coiling them and screwing them in. Although this process is much more tedious, we managed to make it works since now al the motor controllers work without fault. To make sure there were no loose connections, we used a voltmeter to check every waypoint. Then, we finalised this wire setup by carefully soldering some wires together on the tether to achieve maximum strength without the crimps. This was just an example of how we fixed one of our numerous problems. We approached each one methodically and sorted each one out with maximum efficiency.

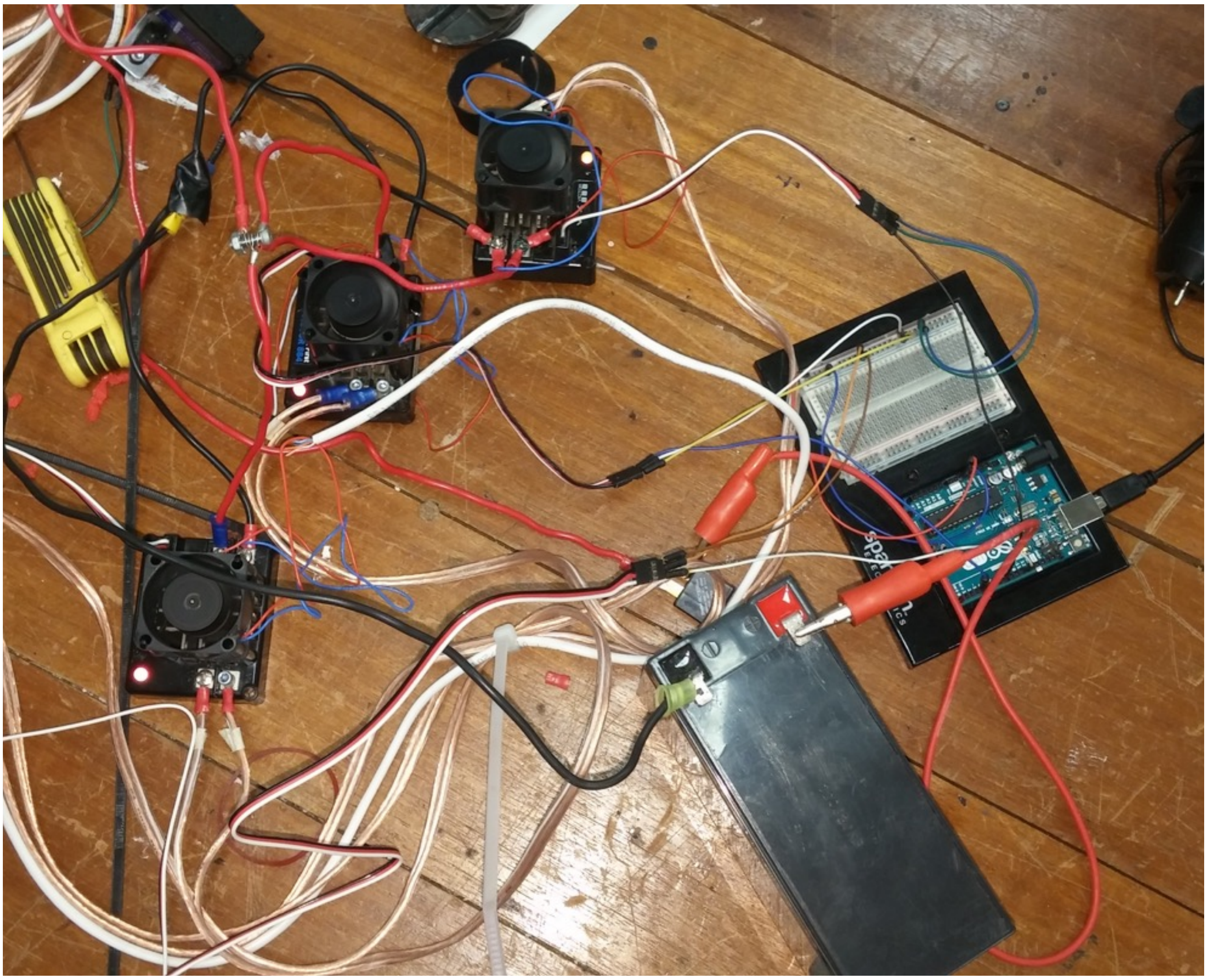


Figure 12: Initial Motor Controller Setup (Credit: Sohit Gatiganti)

REFLECTION

Through frustration, hard work, and risk taking, the team got to know each other more. Sometimes we were yelling all at once on the deck when we were performing a test run which was really the "dark ages" of our times together. There were also code issues, design arguments, disorganisation, non-initiating moments that was fatal at times: numerous problems that went wrong. But what did we do? Did we just give up? That was one philosophy our team stuck strong to. Members worked after school days trying to reconfigure code and add or detach items to benefit the robot. Since we started as a group, where almost all members were new to MATE, we were all just shy minnows pondering around, afraid and unsure what to do. We all took a stab in the dark, stretching us past our comfort zones, that enabled our team to become an actual team with traits of respect of one another, responsibility of our roles, care for each other, and a high work ethic that all brought us to improve in skill and as a person. Winning is a goal of One Degree North Red, but our company also keeps in mind the fun, growth, and relationships built when competing in this prestigious competition. Our team may have lacked in experience, skill, and familiarity with underwater robot designing and creating, but we all grew in areas of interest, created relationships, and embraced the excitement and fun in fierce competitiveness of MATE. Many of us stepped in and took a risk to test ourselves to our best abilities.

Sohit's Reflection:

"Throughout the process of building this MATE Robot I have picked up an innumerable amount of skills on electronics and engineering in general. I have mastered the art of being patient and troubleshooting each and every problem methodically"

James' Reflection:

" During my time building this robot, I have learnt and picked up many vital engineering, electrical and DIY skills. This experience was very valuable to my learning and sparked an interest in engineering.

Sae Jin's Reflection:

"My first time competition in a robotics competition brought me new insights on life"

Vijay's Reflection:

"This was a great year as this was my first major Robotics competition. I learnt a lot and I couldn't have asked for a better team to work with. Although there were many problems which we faced, My team and I powered through and gave our best effort to succeed."

BUDGET

One Degree North Red is accosted with Singapore American School so it receives much of the funding from that organisation. But, we still need to control how much money we spend. To do this, we considered setting a budget. Our budget was very low not because we did not have the funding, but because we could reuse many of the parts we already have and we could save money and also time by re-using and not purchasing. As a matter of fact, our purchased parts only cost $2100, a low number for a robot of such complexity. We were always conscientious of our spending are more information can be found below on our project costing page.

PROJECT COSTING

Table 3: Robot Costing

Type	Category	Expense	Description	Units Ordered	Unit (SGD)	Amount
Purchased	Camera	Underwater camera	Placed for different angles for drive	4	$28.00	$112.00
Re-used	Propeller	Blue Ocean Propeller	Used in MATE 2015 (Horizontal thrust)	4	$230.00	$920.00
Owned	Kick board	Cut-out of a swimming board	Used for buoyancy	1	$19.00	$19.00
Owned	Arduino Uno	Main control	Used as microcontroller	1	$40.00	$40.00
Owned	Victor 888	Motor controller	Used in MATE 2015	1	$94.40	$94.40
Owned	Laptop	Code	Controller	1	$1,550.00	$1550.00
Owned	Temperature sensor	Sensor	Used in MATE 2015	1	$20.00	$20.00
Re-used	Ultrasonic Sensor	Sensor	Used in regionals	1	$175.00	$175.00
Re-used	VEX Claw	Claw attachment	Pick objects up	1	$20.00	$20.00
Re-used	Waterproof Servo	Servo	Power for claw	1	$50.00	$50.00

Re-used	VEX Aluminium Body Parts	Structural framing	Body structure	6	$5.00	$30.00
Re-used	VEX Angles	Structural framing	Body structure	4	$3.75	$15.00
Re-used	Electronic Speed Controllers	Motor controller	Regulate motor speed	4	$15.00	$60.00
Purchased	Cable Sleeve	Cover up	Protection (Safety precautions)	1	$15.00	$15.00
Re-used	50ft Speaker Wire	Tether	Power to robot	6	$10.00	$60.00
Re-used	12V Lead Acid Battery	Power	Used in regionals	1	$50.00	$50.00
Re-used	Logitech 3D Extreme Pro Joystick	Controller	Used in regionals	1	$50.00	$50.00
Purchased	Hex Fence	Protection	Used in regionals	5	$1.00	$5.00

Table 4: Travel Costs

Type	Item	Quantity	Unit Price	Total
Purchased	Flight	1	$1,500.00	$19500.00
Purchased	Hotel	1	$300.00	$3900.00

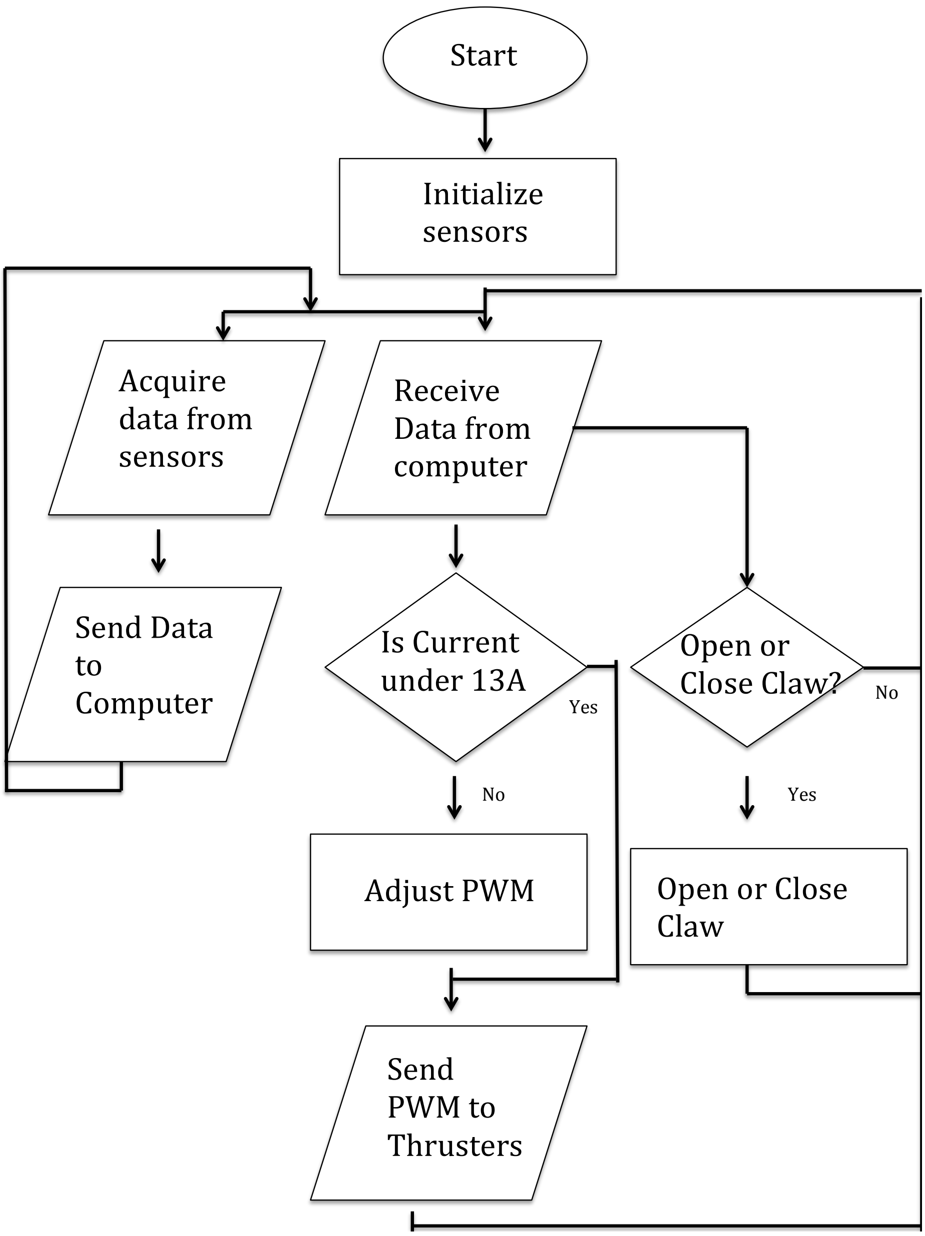
Table 5: Totals

Total fee for robot	$3229.44 SGD
Total for Team Travel	$23,400.00 SGD
Grand Total	**$26,629.44 SGD**

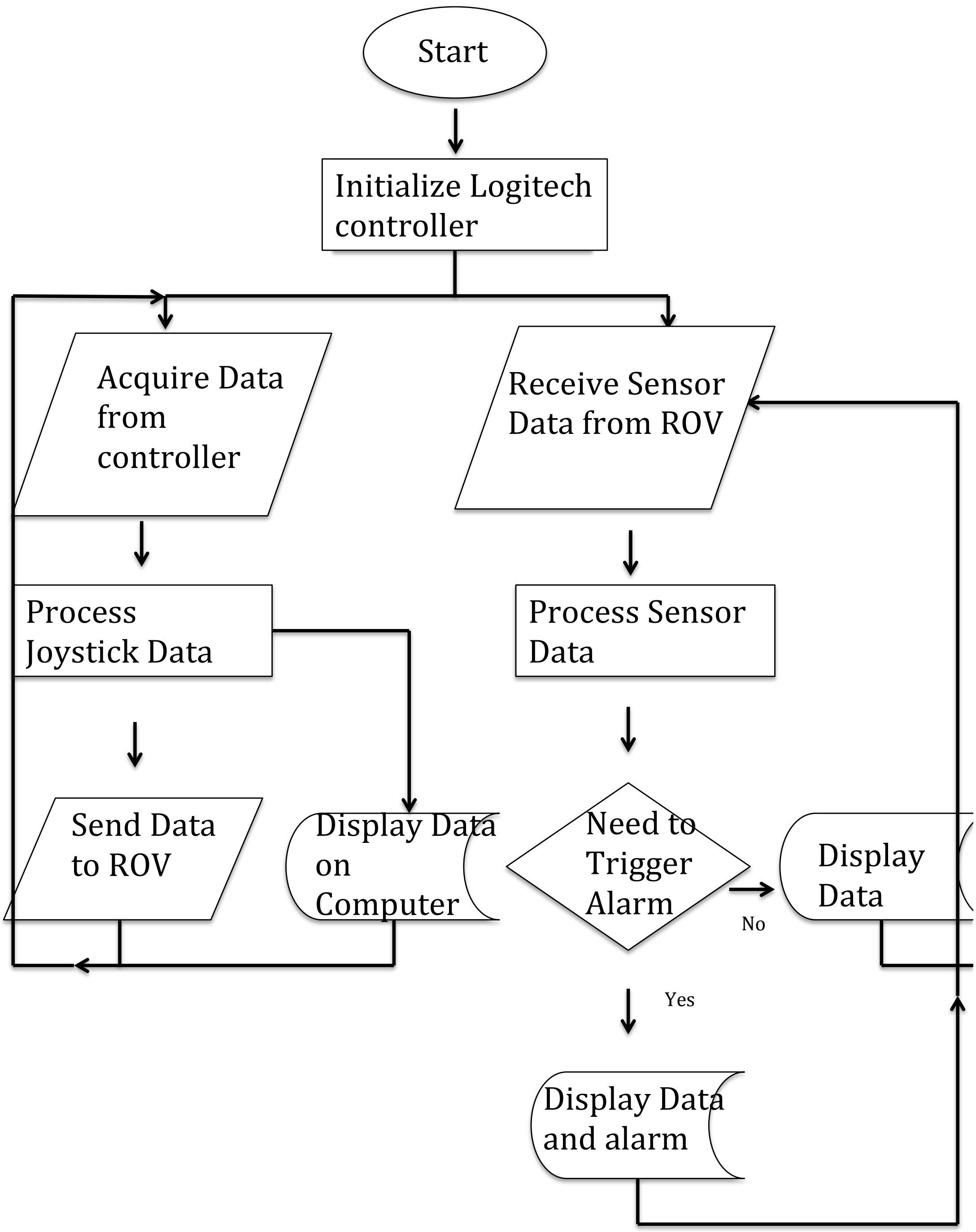
SOFTWARE

The software is running both on the Arduino and the computer. Nearly All the processing is one on the computer since it is much quicker and to reduce strain on the Arduino. After the program had been started, it would initialise the Logitech Joystick, Motors and Sensors.

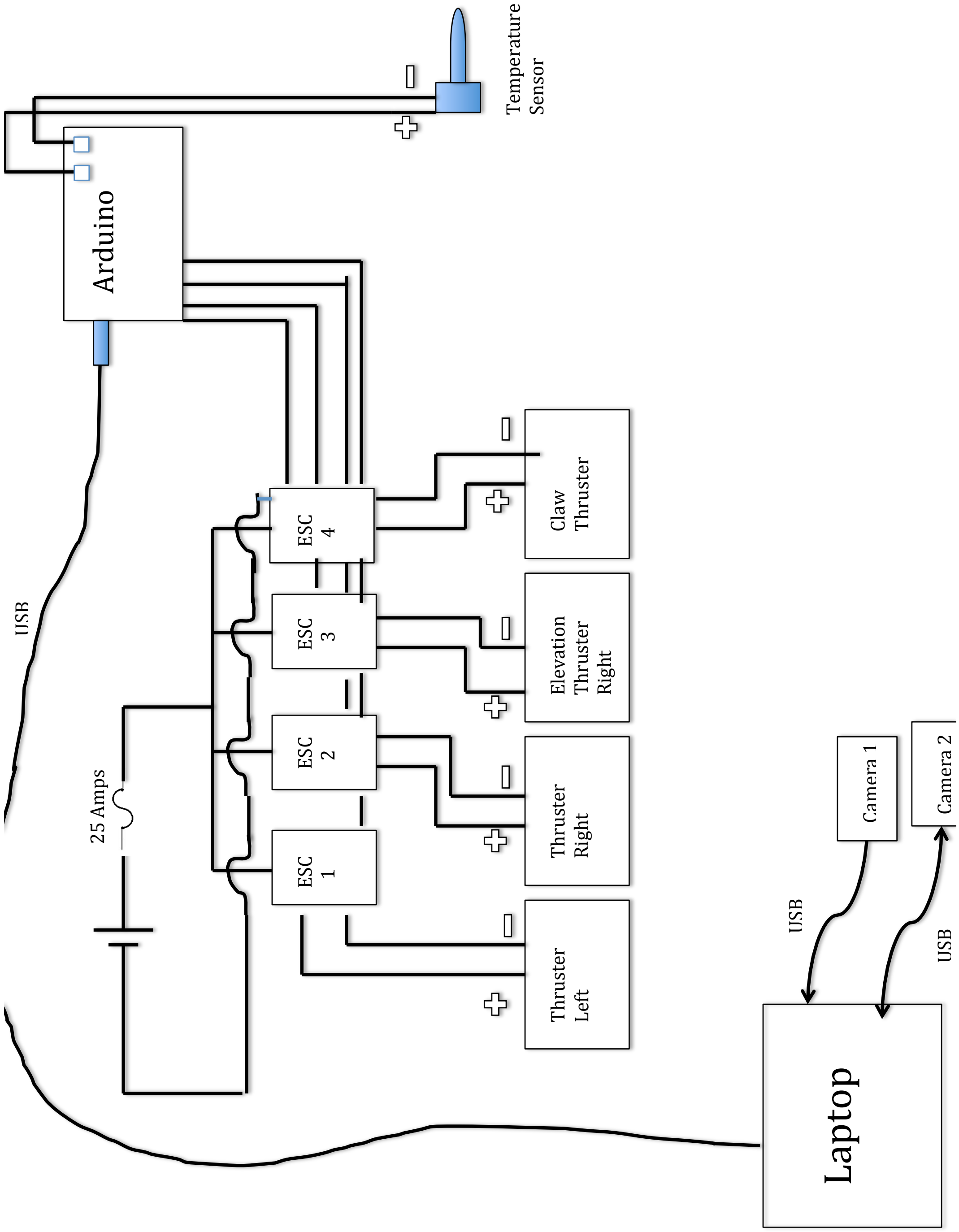
On the computer, the steering algorithms are applied based on the data from the joystick and then sent to the ROV. This datas is also displayed on a GUI to help manoeuvre the ROV. The computer is also consistently receiving sensor data. Below is a software flow chart.



First, the Arduino receives data from the computer. This data is used to control the thrusters and grippers by PWM signals. If the current consumption gets near the limit of 13A, the PWM is adjusted to make sure the current consumption stays below 13A. The Arduino is also passing sensor data from the Arduino to the computer. Below is another software flowchart.



System Integration Diagram



ACKNOWLEDGEMENTS

This opportunity to participate in a unique competition would be not possible without the MATE Houston host organisers, NASA center, sponsors, mentors, and other MATE members who gave advice and tips.

We would also like to especially thank the Hong Kong Regional Sponsors who have allowed us to qualify for this prestigious competition.

We would also like to thank Pratt&Whitney and AutoDesk for their support and funding throughout the building of this ROV.

Thanks to Singapore American School, we had the opportunity to use the workspace and machinery with safety items as well as use funds to buy specific parts for our robot. Mr. Millar and Ms. White helped our team by offering their opinion on our robot designs while still keeping an appropriate distance away to let ourselves learn from our mistakes and tackle problems independently.

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