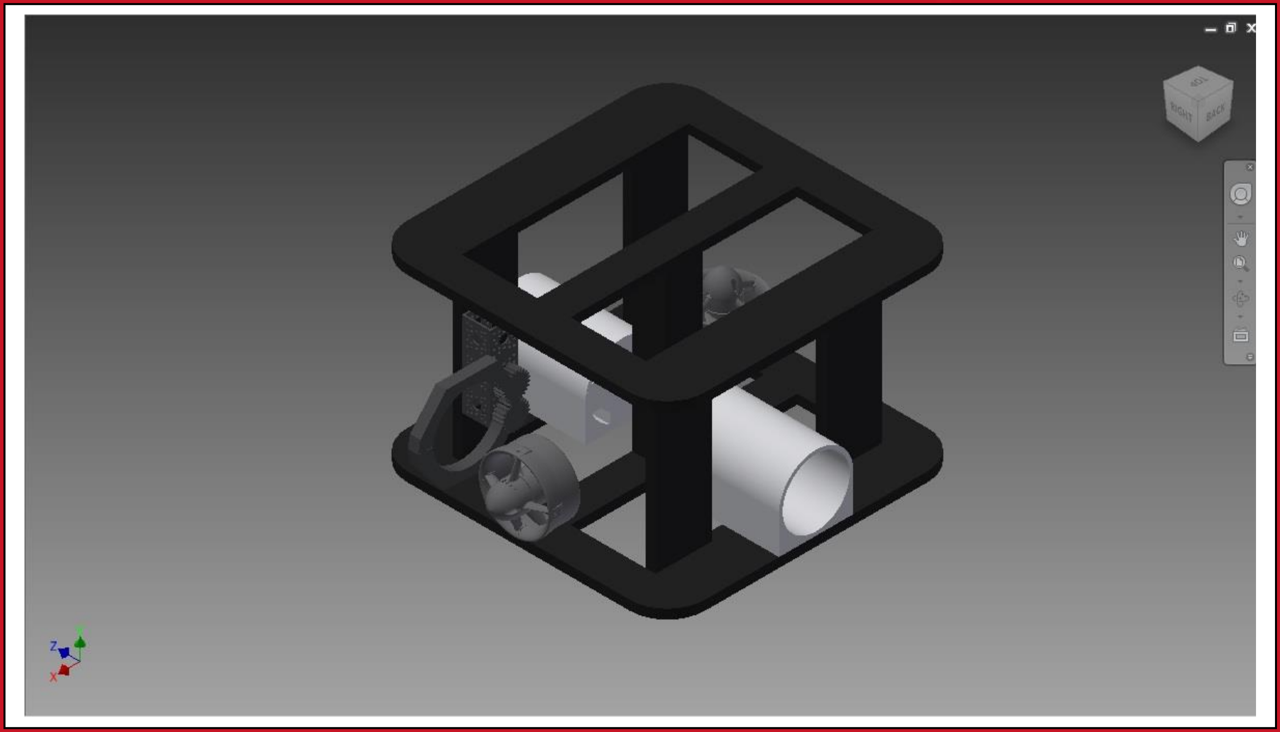
one degree north red

singapore american school
singapore, singapore

R26



Technical Report

Janvi Kalra (10th Grade) – CEO
Jayendra Minakshisundar (12th Grade) – VP
Alexina Haefner (12th Grade) - Head of Technical Writing
William Maurillo (11th Grade) - Head of Engineering
Sam Veloso (12th Grade) - Head of CAD
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Meredith White - Mentor
Barton Millar - Mentor

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Abstract

CheckMATE is the latest submersible created by the One Degree North Red robotics corporation. Its advanced components and modular frame allow it to perform complex maneuvers underwater, allowing it to investigate icebergs nimbly and effortlessly. Apart from accurately measuring iceberg dimensions, CheckMATE can also collect scientific data and aid in oil pipeline repair.

With advanced machinery suited to completing the tasks at hand and expertly trained drivers who have been heavily involved with CheckMATE's construction from start to finish, CheckMATE can adapt itself to the given situation fluidly. The powerful claw that was custom-made for the ROV will allow specific actions, while the impressive array of basic operation tools like motors, cameras, and a ballast, have been personally outfitted and adapted to solve the problems at hand. With a compact design and unique polycarbonate frame, the ROV blends form and function by being nimble, creative, and eye-catching.

With an eye on the price, One Degree North Red has managed to outdo itself, rising above past years' expectations by creating an affordable yet unbelievably powerful machine. This long-lasting, durable robot can perform mission-critical jobs and responds efficiently to driver commands. Safety has always been a top priority for the company, and with unparalleled new safety requirements this principle has been kept close to heart.

CEO & VP Reflections

"It has been a great run thus far. Throughout my time with the team I have watched everyone grow. At first, we started off as a group of novices. Most of us were in our first or second year of Robotics and many of us were confused as to how to tackle this large of a project. We started off slow: we built our first prototype out of cardboard. Despite the apprehension from our mentors, our second prototype was built out of wood. We've come a long way from our makeshift designs and today our final design is made out of laser cut polycarbonate.

Over the months of brainstorming, riveting and hammering, we've become a real team. We have come to recognize everyone's areas of expertise: we harness each other's skills, bringing out the best in everyone. We teach each other and in turn lift the whole team's capability. More so, we laugh, talk and have heated discussions on political issues, creating a strong team bond. Building CheckMATE has been a memorable experience for the One Degree North Red team."

- **Janvi Kalra, CEO**

"Last year, I was recruited to One Degree North for my abilities in CAD and 3D printing. I was able to design and print a claw we used. With the graduation of most of our MATE veterans and the splitting of our company, I was brought into a leadership position by our mentors. Moving from a small role to such an important role was very difficult. The MATE new-comers on the team looked to me for guidance and advice, which I often had to research myself.

Being in charge of a new team has a whole host of challenges. We struggled to find suppliers, faced bottlenecks because of human resources issues, and I had to motivate members of the team to commit their time.

The experiences I have gained will surely help me as I go to college. Solving problems, organizing people, persisting in the face of challenges, dedicating time and energy, and dealing with setbacks are all skills I know will be useful as I continue in my studies. Going into the field of physics, specifically, I have gained a new view on how 'classroom physics' is applied in the real world."

- **Jayendra Minakshisundar, VP**

Theme

ROVs are valuable tools for scientific exploration and environmental protection, especially in marine ecosystems, as they allow users to explore areas unsafe for humans from a safe location. Icebergs are a particularly difficult area to explore since around only a tenth of an iceberg is above water. Icebergs can provide us with valuable information on climate change as they mirror the breakup of ice shelves. Research also follows the way that melting icebergs affect ocean currents and provide the surrounding marine organisms, such as the algae and sea stars simulated in the 2015 MATE competition, with nutrients.

Algae are the main oceanic primary producers, creating an important base in ocean ecosystems and increasing the quality of the water through photosynthesis. As climate change reduces the size of Atlantic ice sheets, increasing light availability and photosynthesis, leading in turn to a greater algae production, which quickly leads to a lack of nutrients as the algae consumes the area's supply. ROVs can provide valuable scientific information in this area by collecting algae samples and taking nutrient measurements.

Another area of ROV importance replicated in the 2015 MATE competition is oil pipeline repair. Marine pipelines are valuable ways to transport gas and oil, but are challenging to install and repair due to the underwater environment. To prevent oil leaks and other pollution disasters pipelines must be routinely inspected, and today companies are turning towards ROVs to do so. ROVs check for corrosion, monitor the surrounding water for evidence of leaks, and perform repairs. Sonar and other equipment allow ROVs to work more efficiently and accurately than humans in murky waters.

Vehicle Systems and Design Rationale

Frame

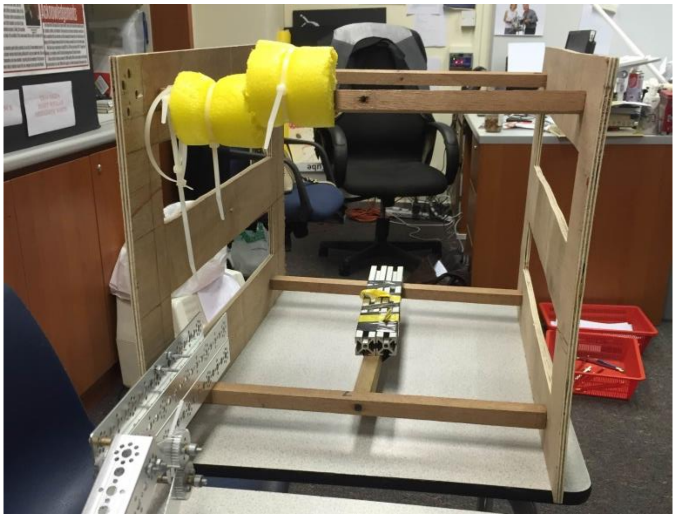
The first consideration that came to mind when designing CheckMATE was the material. In the interest of moving away from the reigning paradigm and expanding One Degree North Red's knowledge base, the team decided against using PVC, the material used every year since the founding of Singapore American School's Robotics program. Deliberation began between wood, aluminum, and polycarbonate. Wood was easily accessible and cheap; as the team was located next to a large wood supply, but the concern arose that it would warp or rot and be difficult to waterproof. The second choice, aluminum, would require difficult to access machinery. The team settled on polycarbonate, which was cheap and accessible from Singapore. Singapore American School had recently acquired a laser cutter that could cut polycarbonate, so machinery was not an issue.

Singapore American School's laser cutter
Photo by Alexina Haefner

The team then split into two groups, one to work on the body and the other to work on the claw. The body design group narrowed designs down to a rectangular frame and a cross design similar to the previous year, and eventually settled on the former. The initial idea was to have two side panels with sections cut out for better water flow through the robot and connecting cross sections to mount components.

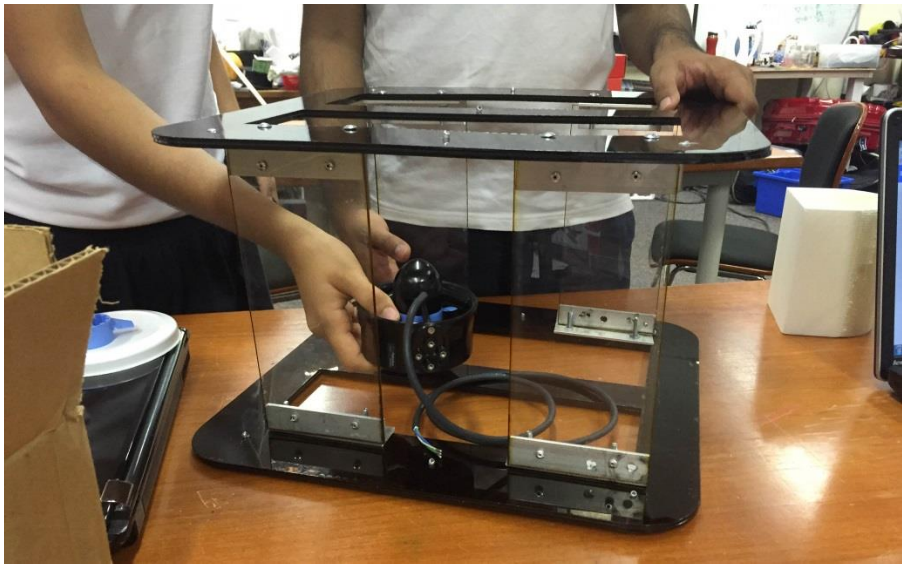
The body design group created a cardboard prototype to better visualize the design
Photo by Alexina Haefner

The next step was to create a prototype to test how the design moved in the water, which the group did out of plywood.



The plywood prototype
Photo by William Maurillo

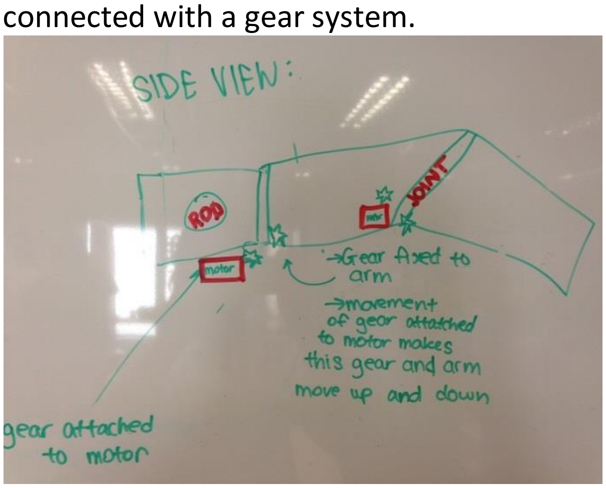
After testing the wood prototype One Degree North Red decided to cut down on the size for better maneuverability and easier transport. The final frame designed consisted of two plates with two square sections cut out of each one, connected at the top and bottom with four rectangular cross sections connected with 90 degree aluminum pieces.

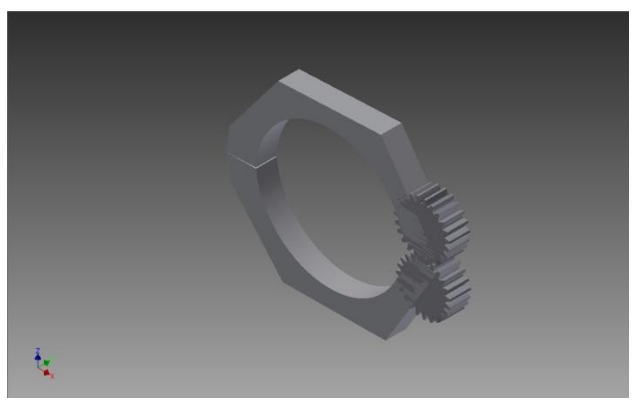


Final polycarbonate frame
Photo by William Maurillo

Manipulator

For the mission at hand the team decided that the claw needed to excel in precision and grip, therefore went for a claw that focused its pressure at a single point. At the same time that the body design group deliberated between a cross design and a rectangular design, the claw design group was deliberating between an arcade claw and a two-finger pincher claw design. An arcade claw would require pneumatics or hydraulics to operate, so the group went with the latter. Polycarbonate was too flexible and aluminum harder to cut into complex shapes, so the group chose wood as the claw material and waterproofed it with acrylic paint. The claw consists of two fingers with rubber at the end for better grip, connected with a gear system.



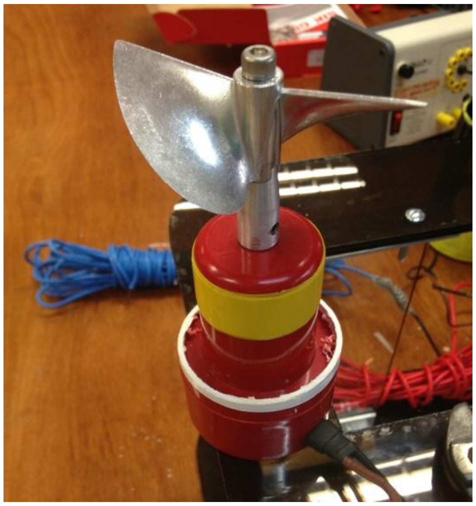


Initial claw design brainstorming(left), final CAD claw design (right)
Photo by Janvi Kalra, CAD by Sam Veloso

Left claw finger
Photo by Alexina Haefner

Propulsion System

All of the motors and propellers used on the CheckMATE submersible were specifically chosen to create a truly agile, quick underwater robot. One Degree North Red purchased two Blue Ocean thrusters specifically designed for marine robotics, one to face upwards and the other forward-facing this year. The team also created two lateral motors by taking apart bilge pumps left over from last year for their motors pairing each with aluminum propellers. As the Blue Ocean thrusters were more powerful than the bilge pump thrusters, the team decided to use them for the forward and upwards directions. This was also an optimal position for them as they could change directions easier than the bilge pump thrusters and worked with almost the same efficiency in each direction.

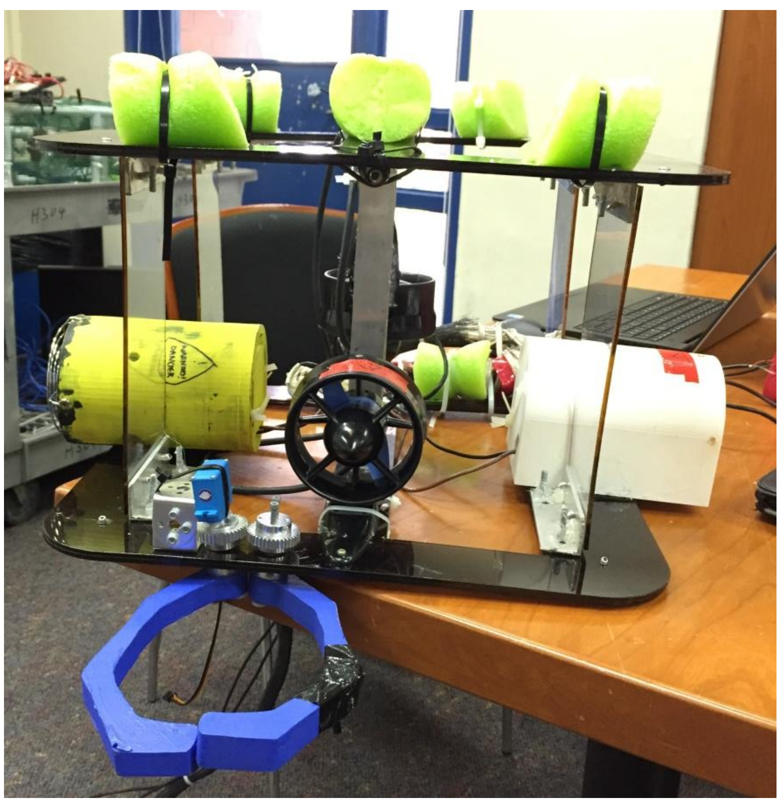


Blue Ocean thrusters and bilge pump thrusters
Photos by Janvi Kalra

Control System

This year, our control system was not purely mechanical. One Degree North Red decided that in order to best take advantage of the new directional thruster drive system and integrate the readings received from the claw and the sensors. All of the user interfaces (including for the lights, cameras, and motor controls) could also be consolidated by moving to a computer-based system.

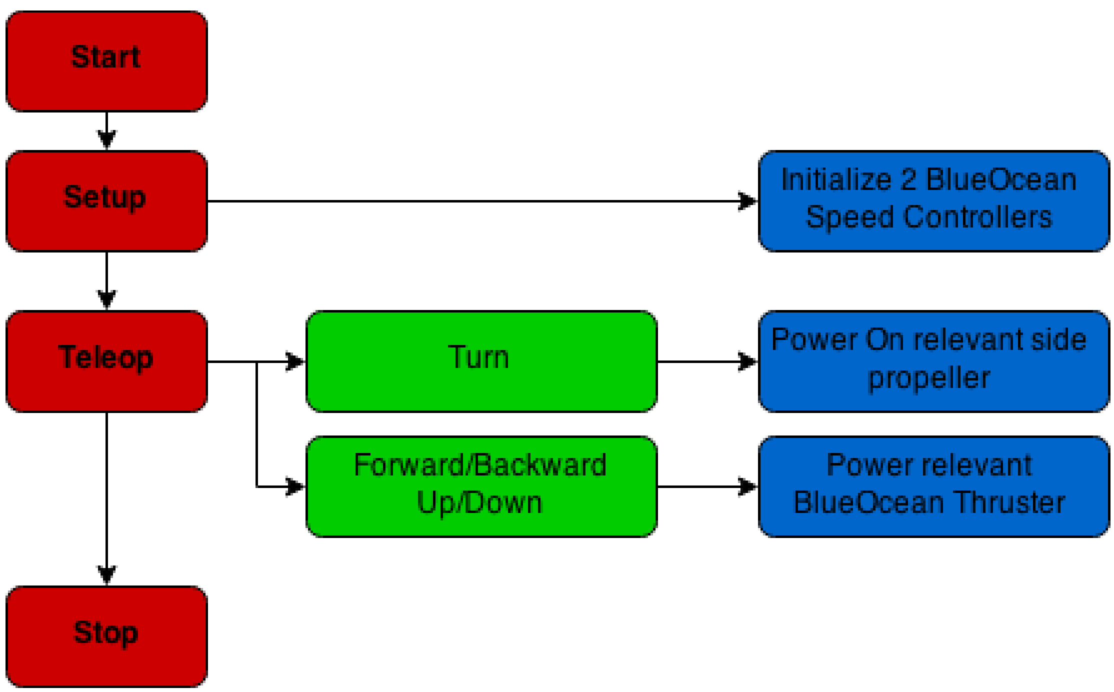
After building the code and the programs entirely from scratch, our team a laptop-based control system to effectively control the robot's movements. The arrow keys control the robot’s horizontal movement and the page up and page down keys control the ascension of the robot. The Mission tasks that required a high level of maneuverability were perfectly served by this new program. All of these actions are benefited by the agility of the directional thruster drive and the simplicity of the control program.

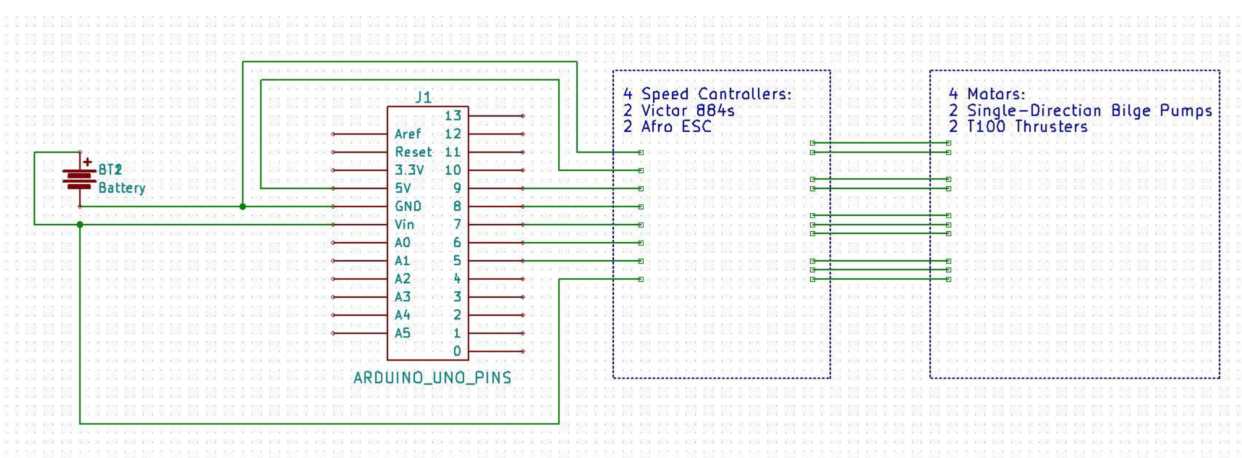


The robot following the Hong Kong Regionals
Photo by Alexina Haefner

During Regionals the main issues the team faced were in the claw, the programming, and the camera. The gears were too far apart and the servo not secure, so the team fixed the spacing and created a mount for the servo out of polycarbonate. During the competition the control system broke down and the Head Programmer had to enter manual codes to turn the robot. For Worlds the team is debugging the program, testing the code repeatedly, and training better ROV drivers. The camera also broke down due to corrosion on the USB from the pool chlorine. For Worlds the team is purchasing new waterproof cameras.

System Integration Diagrams





Budget/Expense Sheet

Date	Type	Category	Expense	Description:	Units Ordered:	Unit Price(SGD):	Amount:
01/03/15	Purchased	Propeller	Body-Drive System	2 Blade Alu Propeller D70xP1.2xM5	8	$26.00	$208
01/03/15	Purchased	Propeller	Body-Drive System	Aluminum Shaft Dog 12x25mm	8	$12.50	$100
03/03/15	Purchased	Body	Polycarbonate Sheet	4x8ft, 3mm thick	1	$160	$160
03/04/15	Purchased	Propellor	Propeller	Aluminum, 3.5 in	2	$2.00	$4.00
03/07/15	Purchased	Propeller	Blue Ocean Thrusters	Vertical and horizontal drive	2	$230.00	$460.00
13/03/15	Owned	Propeller	Speed Controllers	Motor control	2	$34	$68
16/03/15	Owned	Control System	Arduino Uno	Main control	1	$40	$40
17/03/15	Purchased	Control System	Voltage Regulator	Main controling component	1	$27	$27
19/03/15	Owned	Claw	Wood	Claw design	1	$20	$20
25/03/15	Owned	Body	Tetrics Parts	Foundation	3	$5	$14
						Total:	$1,101

Safety Report

Company Safety Philosophy

In order to provide an enjoyable experience for all of our members, One Degree North has instituted a comprehensive safety philosophy. Our company prides itself on the advanced machinery that we use and engage with, but we place safety above all else in the use of these tools.

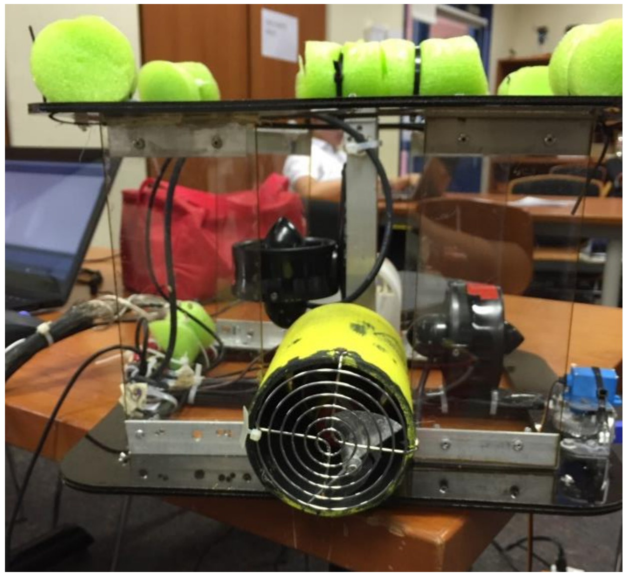
Our robotics lab itself is purposefully designed to allow students to take full advantage of tools while being as safe as possible. The partitioning of the room into a sound-proof heavy tools room, a linoleum workstation and a carpeted classroom allows all members to work together in close proximity while still allowing safety protocols to be tailored to the situation at hand. In the heavy machinery room, separated from the other sections by a soundproof glass, not only are closed toed shoes, gloves, safety goggles, and other basic safety precautions required, ear protection and veteran mentors are also necessary. Each student has their own pair of safety goggles with their name on it. In the linoleum section, students can work on parts with hand tools like drills and saws, and are required to wear safety goggles at all times. Most of the ROV assembly occurs in this section. Finally, the classroom area is the only place where students can eat, allowing for casual collaboration, design meetings, and business events. The basic safety precautions in this area (such as close-toed shoes) ensure that students are able to take full advantage of this area for its intended purpose. Finally, the location of a teacher sponsor/parent mentor desk in the middle of this room means that an adult is present at all times.

Janvi Kalra follows safety regulations by wearing safety goggles and keeping long hair in a ponytail
Photo by Alexina Haefner

Our mentorship program also promotes good safety practices. In our lab, all new members must be trained by a teacher before being authorized to use any power tools and must pass a safety exam. Also, we hold veterans responsible for themselves and new members, ensuring that all members of the team are looking out for each other. These kinds of policies make sure that our company can be safe and efficient during construction.

Vehicle Safety Features

CheckMATE, like past One Degree North Red ROVs, is designed modularly. The modular design means replacement of tools that have become safety hazards is easy, while also allowing us to efficiently pick out potential threats because of the simplicity of component testing. Furthermore, all motors are self-contained within the robot. All of the thruster units are shielded with 3D-printed cylinders specially designed by the team to protect users from propeller blades and allow for easy attachment to the ROV, with fan guards sealing the cylinders off.



Side motor enclosed in 3D-printed cylinder with fan guard
Photo by Alexina Haefner

For the ROV's electronics, One Degree North Red has left no stones unturned in its pursuit of safety. Especially given the fact that this submersible needs to be used in a civilian pool, the company has used individual component and full machine tests to ensure a human-safe ROV. All wiring has been waterproofed.

Safety Precautions

Our safety practices while using the robot consist mainly of methods to ensure strong cooperation and collaboration between engineers on deck and our pilot. This is done because of the remote operation requirements of the mission. For example, before any member is allowed to pick up or touch the robot they must yell "clear" to the driver, who will then shut the motors down. Furthermore, any testing or modification done to the robot is always done with the power off and the tether unplugged.

Safety Incidences

One Degree North Red is pleased to report that we have not had any safety incidences thus far in constructing and testing CheckMATE.

Troubleshooting and Testing

CheckMATE's systems rarely run into glitches, but when they do, One Degree North Red's comprehensive troubleshooting system mitigates the effects of these problems. Apart from a focus on 'all eyes on every project,' a philosophy in which everyone is responsible for monitoring the progress of each component, the company also uses Github to troubleshoot programs. Github is an online, open-source repository of code that others all across the world can access. When we run into code issues, the vast network on Github can help us effectively find solutions to our problems.

Furthermore, another troubleshooting method we use is individual component testing. Our modular design allows for components to be taken off and individually replaced or examined, especially as wear and tear takes its toll on the machine. In this way, we can examine the seaworthiness of individual parts in a process of elimination to determine where the true problems lie. Once on the machine, it is once again rigorously tested and modified in conjunction with the other parts. Examples of component testing are numerous, since One Degree North Red tests each component separately before integrating it into CheckMATE. The bilge pumps were each run separately in a water bucket to test their effectiveness. Our motor controllers, handmade for the occasion, were extensively tested, as were our servo motors that power our claw.

Challenges

Part Procurement

Living in Singapore, one of the biggest challenges for One Degree North Red is finding parts that are available and affordable. Oftentimes, the inability to interface metric parts with imperial parts shipped from the US, or the sheer costliness of most consumer goods in the country, or the time it takes to transfer items to our lab from overseas, can be prohibitive to our dreams and designs. Creating a sustainable, long-term robotics program in Singapore must be done with part procurement in mind, because this issue is unlikely to resolve itself in the near future.

In response to this challenge, One Degree North Red has adapted by building our own components. We bought basic parts like wires and polycarbonate, and used 3D printed shields to protect our thrusters. These are but two ways we used our knowledge of engineering and our resolve to build the best ROV possible to circumvent the seemingly insurmountable supply chain issues in front of the CheckMATE machine. On our final ROV, most components are self-built.

A major challenge faced by the team was acquiring material for the robot frame. After spending a long time looking for somewhere to order aluminum from, our team was unable to find a machine shop to cut it. Instead of ordering the aluminum we ordered polycarbonate, but as our school's lab technician was replaced in the middle of doing so we ended up with polycarbonate that was too thin. We didn't have the time to order more, so we chose to bolt two sheets together for each side panel instead.

Side panel consisting of two layers of polycarbonate bolted together
Photo by Alexina Haefner

Teamwork

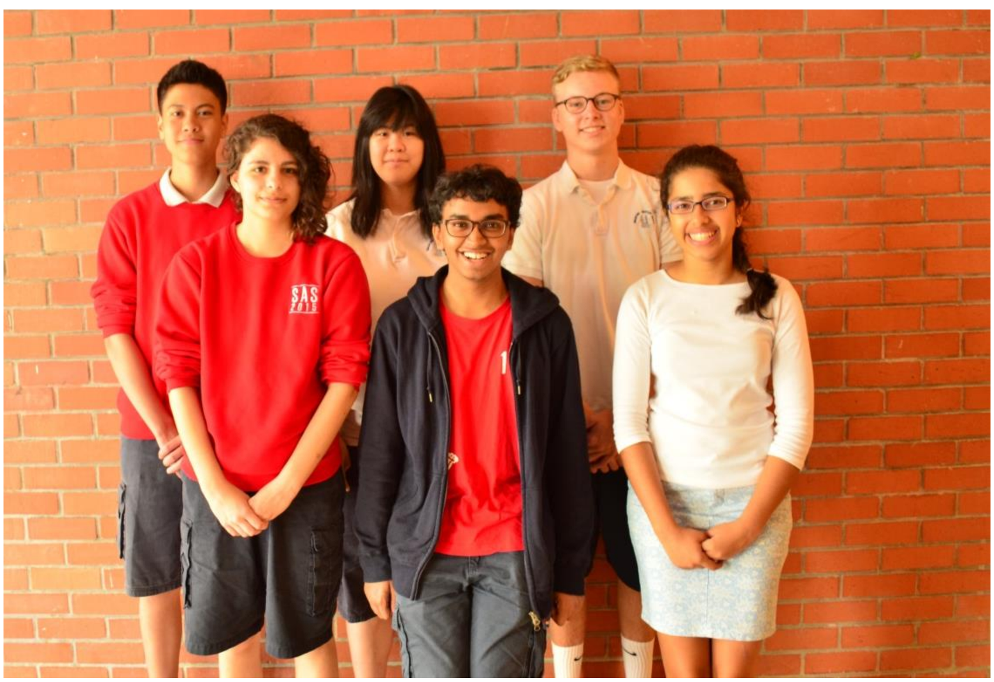
Another problem we had was with coordinating the schedules of the 13 members of our team. Given the wide variety of activities, extracurriculars, and organizations that each of our members is part of, finding times to work together efficiently and move forward as a group was very difficult.

We overcame this problem by splitting up the roles by our areas of expertise, thereby lowering the quorum necessary within each group to make decisions. In these smaller groups (like the mechanical engineers), it was easier to find common times to meet up and discuss solutions to new problems. Finally, we developed a long-term schedule in our first meetings that illustrated a general plan for our ROV's construction. This schedule let everyone know that the team's progress would not be contingent on any one individual.

Lessons Learned

Compared to last year, we our team improve a lot. We've learned how to draw up interest for both upperclassmen and underclassmen to join. We made sure that everyone on the team was willing to learn, from all grades, interests, and genders. To do this, we allowed other people to become interested in and experience robotics by advertising it on various platforms, or at school. We made sure to attract people who were not only engineers but those with non-engineering interests who could discover their passions through MATE.

While designing and building our robot, we faced many issues that provided us many opportunities to learn and improve. For example, as mentioned earlier, our initial design featured an aluminum robot which would be manufactured at a metal shop. However, no metal shop we approached was willing to take up such a small project. This helped us learn that we needed to create not only a Plan A, but a Plan B and a Plan C too. Another issue we faced was when we were trying to purchase polycarbonate. The school required us to go through the lab technician, but the lab tech was replaced three times for various reasons. This taught us to be flexible with changing circumstances, and persistent.



One Degree North Red team photo (Left to right, back row: Sam Veloso, Vivian Wei, William Maurillo. Left to right, front row: Alexina Haefner, Jayendra Minakshisundar, Janvi Kalra)
Photo by Barton Millar

Future Improvements

In the future, One Degree North Red plans to maintain better contacts to reduce time spent waiting for parts and materials. The team also plans to make a control system concurrently with the robot, so as to not be pressed for time in the final few weeks. The team hopes to delegate more tasks for increased efficiency and increase team outreach in the hopes of finding more mentors.

Acknowledgements

One Degree North Red would like to thank the MATE center and the Hong Kong and Newfoundland regional organizers, sponsors, mentors, and volunteers. They have given us the chance to participate in a world class robotics competition that has improved our skills tremendously.

We would also like to thank AutoDesk, Pratt and Whitney, and the Singapore American School for the funding and mentoring we needed to carry out this robotics project.

Finally, we'd like to thank our mentors, Mr. Millar and Mrs. White, who have helped us with the design and construction of our robot. Without their support, our robotics team would not have grown to near the size that it is today.

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One Degree North Red

CheckMATE Safety Procedure

1. Securely fasten connections to the control

2. Check male and female connectors for defects or debris

    a. Control box power cable terminals

    b. Soldered connections within control box

3. Ensure propellers are free from entanglement

4. Check claw for operational readiness

    a. Monitor rotational and gripping servos

    b. Check wire connections and claw gears

    c. Utilize 'gentle pull interface test' on claw mount

5. Check fuses

6. Gently deploy ROV in water

7. Open laptop

8. Plug in 12v power

9. Turn on the master power switch

10. Check systems functionality

    a. ROV motion in all directions

    b. Claw functionality

    c. Camera functionality

ROV is ready for mission deployment