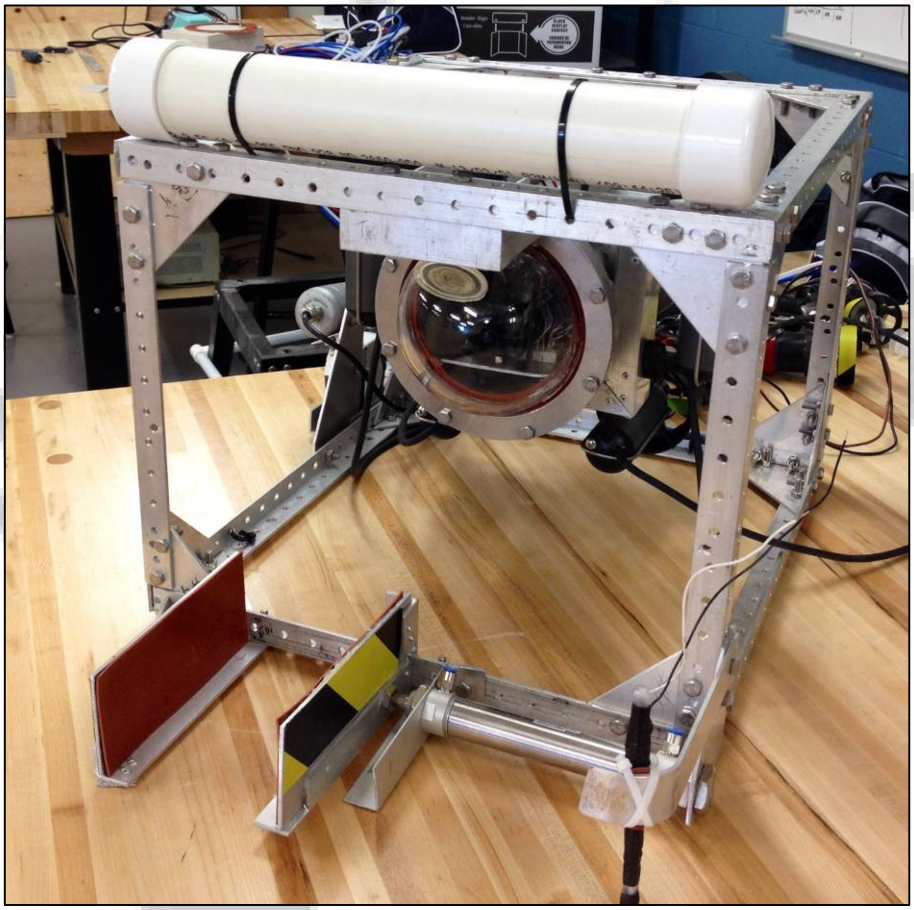
Maritime Underwater Solutions
Prince Andrew High School
Dartmouth, NS, Canada
2013-2014 Technical Report



SILVER SURFER

CEO: Alex Dewar
CFO: Tyler Robinson

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ABSTRACT

Students from Maritime Underwater Solutions have produced a remotely operated vehicle (ROV) designed to be operated as a fully functioning underwater vehicle. The Silver Surfer is a fully tested underwater vehicle that hopes to make a safe and effective effort in the annual MATE ROV competition.

The members of the company designed, programmed, and built The Silver Surfer within 2 years of the operation. The Silver Surfer is a rugged and tough machine made from aluminum bolted together to provide a modular support system that can easily be rearranged, without causing structural damage or weakening its integrity. The frame also allows for many thrusters and sensors to be attached and rearranged to better suit its current objective, from measuring a shipwreck to recovering wreckage.

MARITIME UNDERWATER SOLUTIONS STAFF

Left to Right: Michael, Tyler, Alex, Jake, Jerrett, Charlie
Photographed by Mentor Peter Redmond

Alex Dewar
Company Role: CEO
Competition Role: Pilot, Captain

Tyler Robinson
Company Role: CFO
Competition Role: Pneumatic Control, Mission Commander

Charlie McKay
Company Role: Marketing Director
Competititon Role: Backup Pilot

Jake Graham
Company Role: Electrical Engineer
Competition Role: Backup Tether

Jerrett DeMan
Company Role: Metal works, Mechanical Engineer
Competition Role: Tether Management

Michael Pierrynowski
Company Role: Assistant Mechanical Engineer
Competition Role: Backup Pneumatic Control

MISSION ORIENTATION

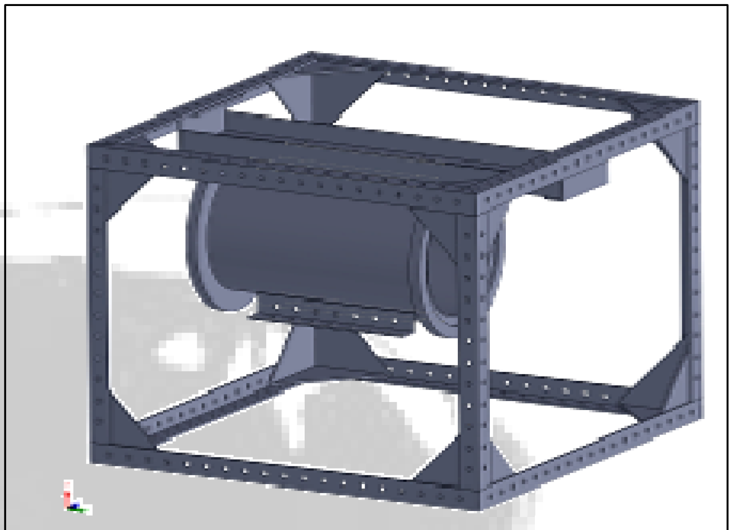
The Silver Surfer was created by Maritime Underwater Solutions to perform multiple tasks in aquatic environments. The robot has three cameras for multiple points of view, and six thrusters that give the Silver Surfer precise mobility, making the machine efficient and effective.

The robot is made of L-bracket aluminum and its modular frame allows for a multitude of different set ups. The basic frame is a rectangular prism and in the centre of this is an aluminum tube that houses all of the electronics. On each side of the cylinder is a Seabotix BTD-150 thruster which provides the Silver Surfer with vertical control and mounted under these are two more Seabotix thrusters that allow for horizontal movement. Members from Maritime Underwater Solutions ordered most of the required parts from Canada, as we wanted to stay local. Through this, we have contacted many small and large companies.

The robot's true purpose is to compete in the MATE ROV competition in the Ranger class. The competition involves exploring and receiving data from a shipwreck, as well as recovering samples and artifacts such as plates and samples.

DESIGN - ROV COMPONENTS

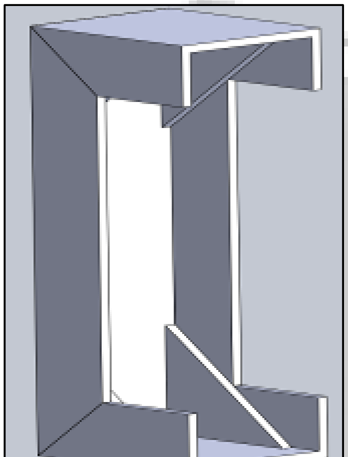
Frame - The frame of the Silver Surfer is made from an aluminum alloy, held together by stainless steel bolts and nuts, with evenly spaced holes on the frame for mounting and connecting purposes. This design allows the ROV to be both strong and durable. It also allows the ROV to be changed later on, enabling the Silver Surfer to succeed in future endeavours. A future possibility for the frame is to weld the various parts together, however; the frame could not be modified and the process is very expensive. During the process of building and designing the Silver Surfer, the frame had to be changed to meet specifications of the MATE competition. The original frame was too wide, meaning the side had to be removed and shortened. This was greatly aided by the modularity of the frame. The holes in the frame of the ROV also allowed the various systems to be mounted by the MUS team. One of the most important parts of the frame is the mounts for the vertical thrusters. These were designed by the mechanical engineer through a SolidWorks isometric rendering sketch and mounted using the various holes in the frame. The central tube was designed as such because it allowed the insides of the ROV to be easily removed and worked upon without compromising the waterproofing.



Frame modeled in SolidWorks (J.D.) (Figure 1)

Thrusters – The thrusters of the Silver Surfer ROV consist of two horizontal Seabotix thrusters for forwards/backwards, two bilge pumps for lateral movement, and two vertical Seabotix thrusters. The horizontal bilge pumps originally used self designed 3D printed propellers, but this was changed to aluminum props from HobbyKing to increase durability and thrust of 4.6N. The vertical BTD-150 motors provide 10N each. During the building phase, the propellers were replaced by 60mm dual blade aluminum props. The thrusters are shrouded by a PVC tube reducer, and allow more water to be pulled by the motor. This also reduces the possibility of the motors to injure the team. The Seabotix thrusters came pre-shrouded and with safety warnings already placed. The placement of the motors was originally 4 bilge pumps, each on a 45 degree angle, and was chosen because it allowed all for to be used for the three horizontal movements that the Silver Surfer is capable of, forwards/reverse, turning, and strafing, in exchange for a higher power draw. This was changed to two Seabotix thrusters mounted under the central tube. This was eventually decided upon because it allows for a greatly improved speed forwards and turning, which we felt was far more important than strafing. Strafing is still included as an option, with two bilge pumps being placed horizontally on the vehicle providing this ability.


Seabotix Thruster (A.D.)

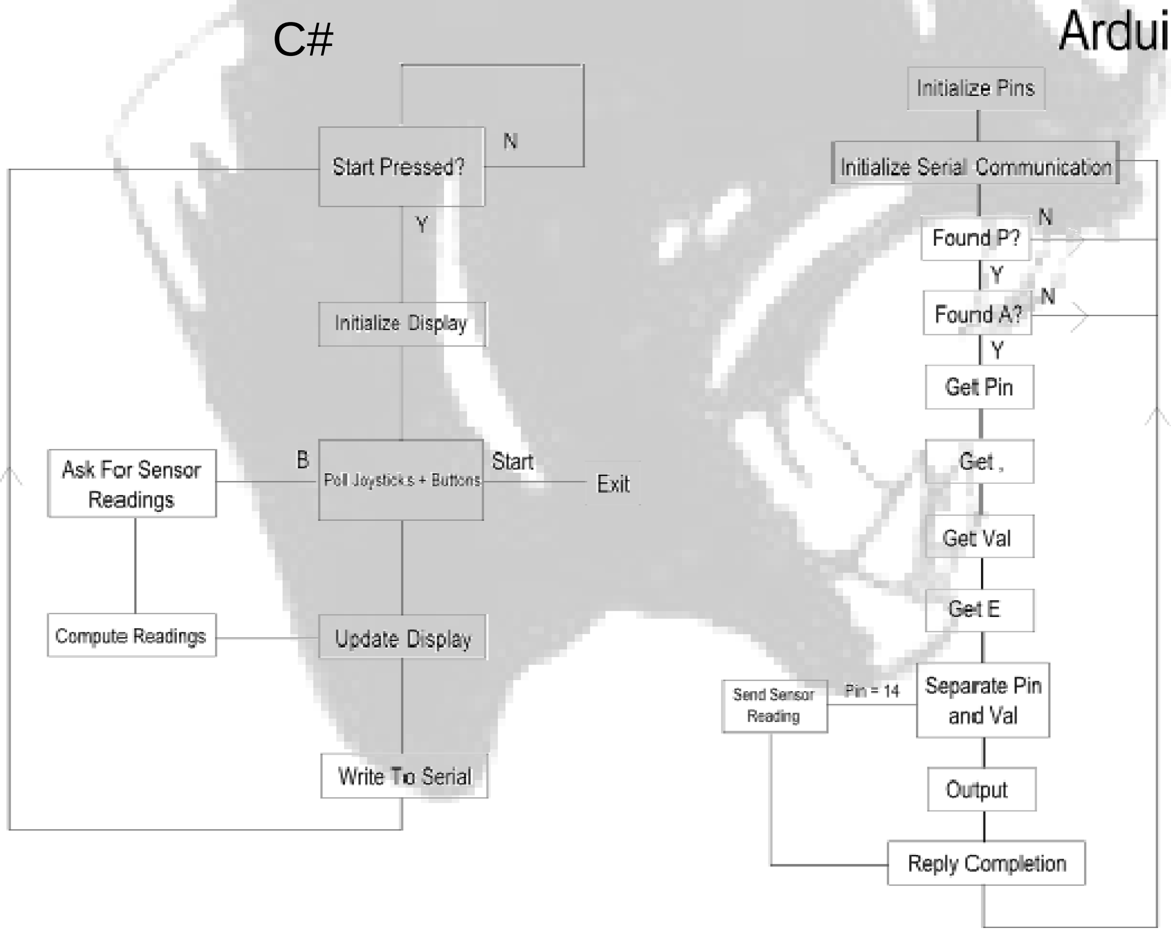

Motor Mount (J.D.)

Camera - The first low-light camera on the Silver Surfer is placed inside the cylindrical aluminum tube that houses the other electronics. It aims out towards a large clear bubble in front of the ROV. This allows for a forwards view, which is the most commonly used on the Silver Surfer. A second camera is mounted on the right rear of the vehicle, providing a rear facing view and allowing for the measuring tape on the back of the Silver Surfer to be easily and accurately read. Finally, a camera is mounted facing down on the front of the ROV, which is integral when using the pneumatic manipulator and when a bird's eye view is needed (like when counting zebra muscles).

Camera mounted inside cylinder (T.R.)

Control – The Silver Surfer features a software system for its control which is comprised of four main parts. The first is the Xbox controller, which allows the pilot to control the ROV in a way that is familiar. The controller features five analog axes: 4 spread over two joysticks and one on the left and right triggers. It also features 11 digital buttons. The second part of the control system for the Silver Surfer is the computer. It is a refurbished model and holds the C# and backup python codes that are used on the Silver Surfer. The two underwater control components are the Arduino Mega and Sabretooth 2x12 motor drivers, with the former bridging the gap between computer and more simple electronic systems. This allows for modified C code to be written for easy analog and digital outputs as well as taking analog and digital input and converting it into a computer friendly format. The latter allows the analog outputs from the Arduino to be converted into higher voltage and current, allowing the motors to operate at their full capacity. They also filter the signal, allowing for a smoother ride.

Software – Silver Surfer's software was developed on C# and was coded mostly from scratch with the help from the original python code. As the team began making changes, like adding in a light and claw control, the decision was made to switch to C#, which has support for controller polling. C# also has the benefit of XNA, extended support for the language which makes graphic displays easy. The Arduino code was written using the IDE from the manufacturer's website. The language is essentially a modified version of C. The Silver Surfer also features a code system written in Python. This backup system is the original code, and the decision was made to continue supporting it because of issues with the speed of C# serial communication. This system features no graphics.



Software Flow Chart describing the execution of the C# code (left) and the Arduino code (right) (Designed by A.D.)

Lights - The challenges that MATE Center presented us with makes us go inside dark areas. To accomplish those tasks we attached a 12 volt 1157 LED light to the ROV. It consists of a black ABS pipe waterproofed with RTV and 2 wires feeding out. A clear Plexiglas sheet is what lets the light shine through and is attached and as waterproof as possible with both epoxy and PL Premium Ultra. The tube is filled with epoxy to keep the light in place. It also provides waterproofing, along with RTV silicon. The light is 124.4mm long and 52.2mm in diameter.

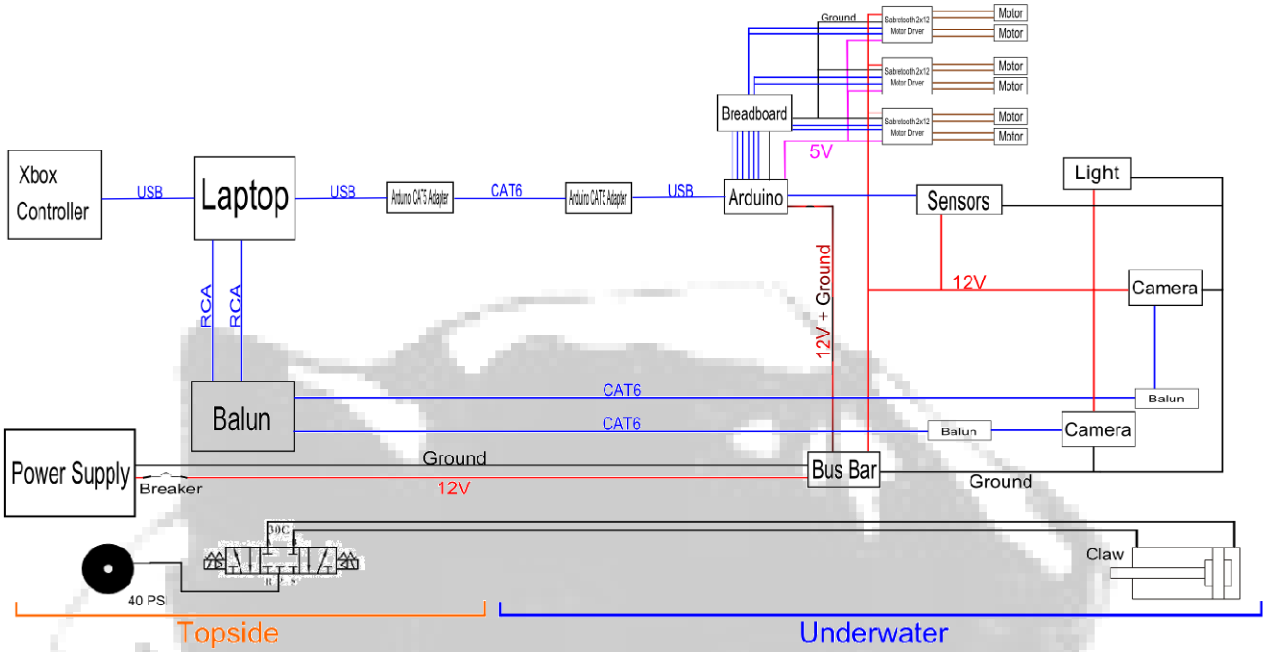
Sensors – To accomplish the challenges presented by MATE ROV, the Silver Surfer has a large armament of sensors and cameras. It comes equipped with a team-built conductivity sensor to assist in measuring the concentration levels of certain minerals, as well as three cameras. The first of the three cameras is located within the main cylinder, and is the primary one used for movement. A second is placed on the rear of the Silver Surfer. This increases the pilot's ability to move backwards and functions as a key part of the distance measuring system on the back of the ROV. Finally, a camera is mounted on the front, facing down, allowing the pilot to estimate depth, accurately count muscles within a quadrat, as well as allowing the pilot to view the trajectory of anything dropped from the pneumatic manipulator. The conductivity sensor is mounted on the front of the Silver Surfer and is placed in a position that would allow us to easily take a reading.

Conductivity Probe
(A.D.)


The pneumatic manipulator (T.R.)

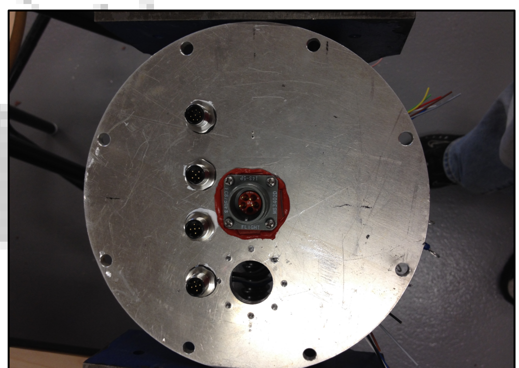
Manipulator – The claw began as a wooden model, using a centered piston to move two claw pieces together. After some thought, the decision was made to change the design to a single anchored claw with a moving claw above it. This design had fewer moving parts, lessening the chance of mechanical failure. The manipulator is designed to pick up and recover artifacts from a shipwreck, as well as move debris. Later, the pneumatic manipulator was changed further to be a horizontal claw, rather than a vertical one. This decision was made because after discussing the mission objectives, the team decided that a vertical claw would be able to complete the majority of the mission less effectively than a horizontal one.

Electronics – The electronics of the Silver Surfer revolve around the Arduino Mega which bridges the gap between software and hardware, allowing for easier control of electronics than with the similar AT Mega integrated circuit. A breadboard was also used for integration of electronic components. More specifically, it functions as a hub for the connections from the Arduino to the motor drivers. It features the use of resistors and capacitors, the latter of which function as a filter, protecting against voltage spikes. The connections within the electronics tube are connected with solder and covered with heat shrink, reducing the potential for shorts. The electronics also feature Sabretooth 2x12 motor drivers, which increase the voltage from the 5V max that the Arduino supplies to the 12V required to optimal motor operation. The Silver Surfer's tether consists of two 10AWG wires (positive and ground), a CAT6 cable for input/sensor output, an 8 conductor communication line for camera output, and pneumatic tubes to power the claw. The power is divided inside the ROV through a bus bar and motor drivers. It is attached the ROV's bulkhead with underwater connectors.



System Integrated Diagram (SID) with both electronics and pneumatic components, divided into topside and underwater components. (Created by A.D.)

Water Proofing – Making an aluminum cylinder waterproof as well as have spots for connection with the surface is easier said than done. The Silver Surfer uses several rubber gaskets and silicon to ensure its electronic components stay dry. The bulkhead houses several underwater connectors, two of which have their own gaskets and silicon to provide energy and signal to and from the ROV, and a shielded cable goes directly to the cameras. The connectors are threaded directly into the bulkhead, which, although a tedious process, reduces the chance of a leak



Each connector is sealed with a gasket and silicone before being bolted into threaded holes. (T.R.)

tremendously. The bulkhead itself is secured using threaded bolts and a gasket. This not only ensures that the no water will enter, but also allows the bulkhead to be easily removed and put back on without having to worry about waterproofing.

SAFETY

The creation of the Silver Surfer revolved around safety first to ensure more realistic, longer lasting, and overall better operation of the ROV. This philosophy also allows better treatment of the environment. During its creation, a drill press, hand drill, grinding wheel and multiple other tools were commonplace, as was the safety goggles and facemasks that accompanied them. During their use, the team was supervised by and instructed by mentors. Other safety precautions such as clamps were used. There are multiple safety features on the robots itself which also reinforces our policy of safety. For motors, shrouds were used to both increase flow and protect the propellers. A 25 amp fuse attached to the power supply provides increased electrical safety and ensures that all electrical components are protected. All equipment and mission tools deployed by the Silver Surfer can be safely removed from the environment to minimize impact on the ecosystem.

Shrouded bilge pump with warning tape (T.R.)

Maritime Underwater Solutions also has several safety precautions that are followed during operation of the Silver Surfer. These include warning signals given by the pilot prior to firing motors, keeping main power off when the ROV is not currently in use, and using stickers and warning tape on devices that can be potentially hazardous. Checks are always made between those on deck when powering on, running the code, and when loading and unloading things onto the pneumatic claw.

COMPONENTS

When designing the Silver Surfer, we gave great consideration to the components that we used. Effectiveness and cost were not the only factors that we looked at; using new systems that we designed was also a priority. We only have a few components that were reused from previous years. One of these is the frame and cylinder, which was reused because construction was arduous and would have taken too much time for our small team. It also goes against the design philosophy of the ROV through removing the most important piece to the Silver Surfer's modularity. Another reused piece was one of the Seabotix thrusters. This was kept because of the cost of each unit was extremely high and these thrusters were extremely effective. The final piece of reused systems is the bilge pumps. The team nearly phased them out, though two still remain on the ROV as a minor system for strafing. We designed the majority of the components, and the ones we didn't would have been too complicated for us to create. One example is the control system. The ROV team does not have the resources or the expertise to create controllers or motor drivers, though the programs that connect these pieces were designed by the team. Another commercial piece of the ROV is the thrusters and bilge pumps. These were also bought because they would have been far too complicated for the team to design, let alone waterproof. One of the final commercial systems on the ROV is the cameras, which, once again, were too complicated for the team to create. All other systems, including the frame, conductivity probe, and the claw were created by the team.

LESSONS LEARNED

Throughout our time working on the Silver Surfer, we learned many valuable lessons about metalworking, SolidWorks, programming, and electronics under the watchful eye of mentor Peter Redmond. The team collectively learned about how to waterproof bulkheads, and how to find an efficient layout of electronics and boards in a confined space. Several members of the team learned how to operate SolidWorks and program an Arduino microcontroller. We relied on each other for help and support to accomplish the several tasks required for the completion of the robot, and we grew as a team and as friends. We also gained skills in interacting with companies on a professional level through sponsorships and the presentation in the competition.

FUTURE IMPROVEMENTS

The Silver Surfer could be improved with a redesigned claw, which would go below the frame and act as a gripper for items dropped along the pool floor. This would act similarly to a CH-54 TARHE helicopter, which is known because of its unique shape and cargo carrying ability. By moving the cargo to the center of gravity, items of much greater weight can be lifted without losing much control over horizontal movement. (By maintaining a static center of gravity) Though the competition does not require objects of great weight to be recovered, even small objects could have the potential of shifting the ROV, vectoring the previously vertical thrusters. Though this effect will be negligible, cargo of greater weight could potentially roll the ROV. A new claw would be constructed that actuates under the frame, creating a balance. Another improvement could be to add more lights. The Silver Surfer makes all of these improvements and more easy through its modular design, as well as adding two more Seabotix thrusters to return to a four vectored horizontal thruster arrangement.

TROUBLESHOOTING

During the development of our ROV we encountered problems that had to be assessed and overcome. The first step in overcoming a problem was to identify the problem and then brainstorm solutions. Once we had a list of possible solutions we would eliminate unviable solutions and select the best remaining option based on the cost, time required and theorised functionality. After a solution had been selected, we would come up with details on how to implement it and shortly execute it. For decisions that had to be executed in a short amount of time, such as just before a dive, the team's first step was not to panic. From there we discussed how to solve the problem, with the team member who had the most expertise in that area leading this talk.

An example of the use of this system is when we discovered our frame was too wide to fit into the ship specified in the mission. The hole that the mission specified we must fit through was 60cm x 60cm and our ROV's width was 58cm from prop shroud to prop shroud. We came up with three solutions for this problem; reorient the props so that they faced inward, cut the horizontal L channel, or both. After an in-depth discussion, we decided to implement both solutions because it would provide the most clearance and make it easy to pilot the ROV through the opening. The final width of our ROV is 45.5cm. Another example was when we received a donation from Welaptega, who gave enough to buy two Seabotix thrusters. This meant that the layout of the horizontal thrusters had to be adjusted. The MUS team put these troubleshooting techniques to great use. One final example is during the regional competition, in which the humidity on the pool deck interfered with computer systems. The team was quickly able to solve this problem, and engaged in a successful dive.

BUDGET

Company	Purchase		Total Cost	Balance
NSCC	**Triggerfish ROV Kit**	Donated		
NSCC	**Testing Tank**	Donated		
NSCC	**Facility Tour and Guidance**	Donated		
Jentronics	**Nichrome Wiring**	Donated		
Jack Thompson	**Plexiglas**	Donated		
NSCC	**Plane Tickets and Hotel Rooms**	Donated		
Workit Grant		$2,500.00		**$2,500.00**
Waleptega		$1,500.00		**$4,000.00**
PAHS		$1,000.00		**$5,000.00**
NSCC		$1,000.00		**$6,000.00**
Shell		$1,000.00		**$7,000.00**
Newegg	**Rosewill Capstone Power Supply**		$87.38	**$6,912.62**
Various Suppliers	**Custom Electronics and Sensors**		$630.21	**$6,282.41**
McMaster-Carr	**Tools and Gasket Material**		$259.54	**$6,022.87**
Princess Auto	**Pneumatics**		$38.34	**$5,984.53**
NAPA	**Wiring (100ft 10G)**		$149.50	**$5,835.03**
BestBuy	**Xbox 360 Controller**		$57.49	**$5,777.54**
Techmania	**Gateway Laptop**		$460.00	**$5,317.54**
Staples	**Printing Reports**		$46.44	**$5,271.10**
Princess Auto	**Pneumatics**		$128.83	**$5,142.27**
Staples	**Xbox 360 Controller**		$68.94	**$5,073.33**
Seabotix	**2 BTD150 Thrusters**		$1,700.00	**$3,373.33**
Seabotix	**Seabotix Thruster**		$860.78	**$2,512.55**
Kent	**SS Fasteners and Terminals**		$100.41	**$2,412.14**
Binder USA	**Underwater Connectors**		$345.65	**$2,066.49**
Hobbyking	**60mm dual blade Aluminum Props**		$175.39	**$1,891.10**
Clippard	**Pneumatics**		$535.18	**$1,355.92**
Jentronics	**Electrical box, Heat Shrink, CAT6 Connectors, Banana Plugs**		$162.72	**$1,193.20**
Dollarama	**Epoxy**		$14.38	**$1,178.82**
Duty Paid on Shipping			$536.88	**$641.94**
		Total Cost	**$6,358.06**	

Reflection

During the build of the Silver Surfer, PAHS ROV team grew not in members, but in commitment and loyalty. The team is full of hard working students and staff who are determined to see the robot compete. Despite the various setbacks, we kept our eyes focused on the future, and in that way, we succeeded. Each member learned about metalworking, soldering, programming and electrical systems, as well as the various skills acquired from simply working as a group. This was one of the most rewarding and enjoyable parts of the experience as members took on new and unexpected roles throughout the building process. Our enthusiasm kept us coming back, and eventually the Silver Surfer was complete. After nearly two years of construction, we have widely expanded our knowledge in the field of underwater exploration. Though the process of creating the Silver Surfer, we discovered the importance of organization when working with complex systems and machinery. In the building phase, companies gave donations to the robot to help support the team, and some other industries gave us school discounts on parts for the robot to be supportive to the team. We would like to thank MATE for this opportunity to learn about oceans and ROVs by allowing us to take a hands-on approach. We would also like to thank them for giving us the opportunity to improve our communication, accounting, and business skills.

ACKNOWLEDGEMENTS

Monetary Donations

Discounts or Non-Monetary Donations

Maritime Underwater Solutions would also like to thank:

Peter Redmond for mentoring us during the entire operation

Mike Duggan for coordinating the regional competition and providing support

Peter Oster for providing technical support

YMCA for allowing us to use their pool for testing

All of the volunteers of the MATE Competition

MATE Center for providing us with this wonderful opportunity

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APPENDIX A

SAFETY CHECKLIST

- Bulkhead Waterproof
- Electronics Screwed Down, Away from Water
- Motor Drivers, Wire Secure
- Arduino Screwed Down
- Breadboard Secure
- Bus Bar Secure
- Fuse in Place
- Code Bug-Free
- Run Through Multiple Tests
- Reviewed by Mentor

- Thrusters Marked And Covered
- Claw Mounted
- Pneumatics
- Lights Secure and Waterproof

- Kill switch on Power Supply
- Safe Connections to Power Supply
- Thrusters and Propellers Properly and Securely Mounted
- Frame Secure
- Cameras Secure and Safe From Water
- Tether Properly Attached
- Pneumatic Valves Properly Attached