Prometheus Robotics

"The speed you want, the tools you need."

Members from left to right:

Grace Ostiguy-Mechanical Engineer

Kyle Trahan-Mechanical Engineer

Sheila Ferreira- System Engineer

Kristen Vezina-Electrical Engineer

Ednir D'Oliveira-Safety Engineer

David Dompierre-Safety Engineer

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Abstract

The Prometheus Robotics team has designed and constructed an underwater ROV that will complete all product demonstration tasks for the MATE ROV 2016 International Competition. We are eight future scientists and engineers participating in MATE for the first time. At Prometheus Robotics, our philosophy is to use teamwork to develop custom robots for our client's needs at an affordable price. To accomplish this, we diverted the majority of financial resources on powerful propulsion systems and state of the art camera systems, while focusing our ingenuity to develop clever solutions to each task. This means that our frame, tools and control system are inexpensive shop-made solutions tailored to each specific task.

Figure 1: Members assembling frame
Teamwork was the key to success

Figure 2: Rov Testing
Frequent testing allowed for fast trouble shooting

With this system we developed the TURBOTRONIX 3000, a remotely controlled vehicle with eight Seabotix BTD-150 Thrusters for speed and power, a Multiview camera system with four interchangeable HD quality camera displays on one screen and precise, custom built tools for each operation. Our tools are designed and constructed specifically for each task in-house, resulting in an innovative and cost-effective tool system, making our NASA-inspired designed robot your ideal solution. The analogue joystick driver controls are efficient and reliable. All these features are mounted on a buoyant PVC frame with 20 meters of tether, giving the robot a very large work envelope. Prometheus has been successful as a result of our ability to combine effective tools mounted on a fast vehicle with a clear view of the operation.

Figure 3: Camera System
Multiple view options.

Figure 4: Propulsion
Designed for speed.

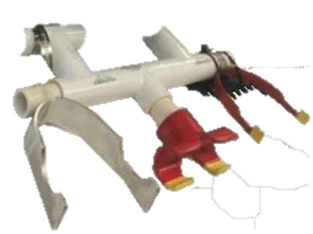


Figure 5: Tools
Specialized for each task.

Vehicle Systems

Corporate team memory

As a new team that has never entered this competition or even built ROV's before, we started the process with research into competition requirements. For each task a team member created a PowerPoint presentation explaining the objective and requirements to the group. By making presentations we all learned what the competition was about. Next we learned about previous ROV's used in this competition. We viewed YouTube and Vimeo videos of past competitions to get an understanding of the types of vehicles that have been successful in the past.

Figure 6: Sheila Presenting
Learning about competition tasks

One of the fun ways we learned about the competition was to interview previous GNBVT graduates who competed in MATE. One previous participant, Diarny Fernandez, who himself competed in the New England regional in 2012, was gracious enough to be interviewed by our current team member Ednir D'Oliveira who happens to be his little brother. Diarny is graduating this spring from UMass Dartmouth with a BS in Mechanical Engineering, and he shared his experiences and a few laughs. Based on his advice we decided it was worth the resources to build the competition props, to help us better understand the requirements and test our tools, robot and piloting skills. Having the props had another beneficial effect; we tested our approach to completing all the tasks in 15 minutes. Our team created and reworked task orders to maximize efficiency.

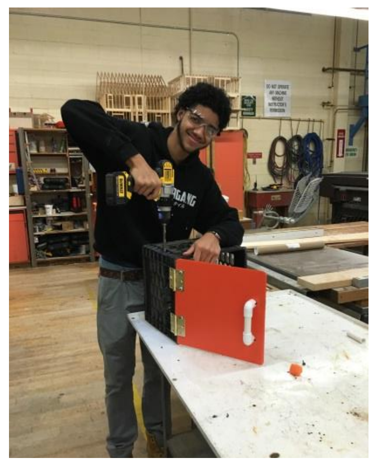


Figure 7: Ednir Building Props
Testing our tools was essential.

Original vs Commercial

Figure 8: Team Building Frame
Manufactured was fun & challenging.

Prometheus Robotics prides itself on building all of our systems. We purchased only basic components and we designed and manufactured every system on our rig. The only components we purchased that we would consider manufacturing ourselves next time are thrusters and live cameras. Since this is our first underwater ROV project, we had plenty to work on and didn't have the time to build our own thrusters and to cameras. Our company had no commercial assistance in our design or construction. We built our ROV from scratch as a team, in our schools' Engineering Technology workshop.

New vs Re-used

The Prometheus team did not reuse any systems for Turbotronix-3000. The only items we did not purchase for our robot were four Seabotix BTD-150 thrusters. We found the thrusters in our shop and used them for our ROV, these thrusters were actually never used on any other robots at all. The thrusters were still in their original boxes when we found them. Our decision to use these thrusters was based on saving the cost of purchasing and gave us a great starting point for thruster options. We noticed many teams used Seabotix thrusters on their ROV's, but we had never used them before, so were excited to see what they could do. We constructed a brand new PVC frame for our ROV and designed all the tools on our rig to complete the five tasks, including a bolt inserter that can turn the bolts 90 degrees with no moving parts. We also designed and built our control box from scratch using simple wood frame to support clear acrylic panels leaving our original wiring on display. All the way to our tether, which we assembled by cutting 12 colored coded 18gauge stranded wires into 20 meter lengths and taping it together, spacing the tape at exactly 10 cm so the tether can be used to measure the depth of the ROV.

Figure 9: Team Building Frame
Manufactured was fun & challenging.

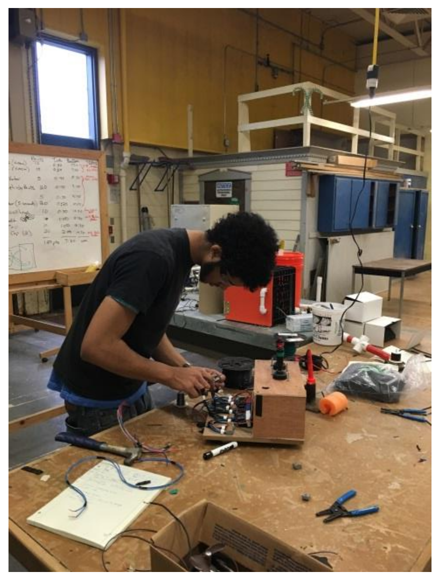


Figure 10: Ednir Wiring Control Box.
We built several versions of our control box.

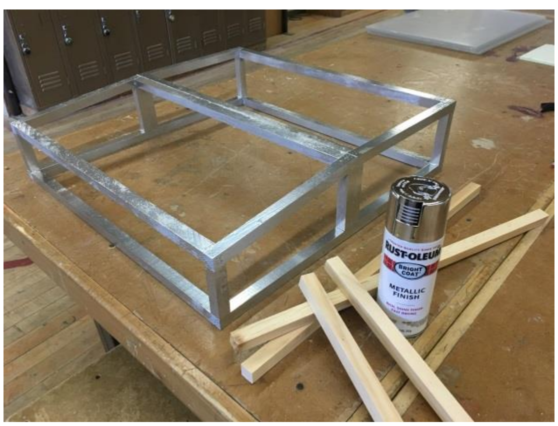


Figure 11: Final Control Box Frame
Wood painted metallic color.
This creates a strong frame with a modern, finished, appearance within our tight budget.

Figure 12: Tiffany and Kristen Measure Precisely
Marking off measuring tool used to find depths.

Propulsion – Cost Analysis

We researched the cost of various components and compared them to the benefits to decide how to spend our limited funds (see budget and project costing sections for complete details). One import feature of the ROV to consider cost options was propulsion. Our research indicated 3 general categories of options; "homemade" thrusters, bilge pump motors converted to thrusters and manufactured ROV thrusters. We searched the shop for thruster options to explore and found bilge pump motors (we removed the impellers and added propellers) and 4 Seabotix BTD-150 thrusters in the shop (actually in a box in a closet that had never been used). We did not have the time learn how to build 'homemade' thrusters, so they were not considered. After building simple frames we mounted the bilge pump motors and Seabotix thrusters to time the rig over 10 meters of forward & reverse runs and 3 meters of ascend & descend runs, to obtain speed in meters per second for different propulsion options. Our testing results indicated much faster speeds with the Seabotix thrusters and considerably more impressive speed with all 4 thrusters propelling the vehicle in the same direction. This table summarizes our testing results.

Testing Thruster Configuration Speed vs Cost						
		Time in Seconds (Speed m/s)				Cost
		10 meters		3 meters		
	Thrusters Configuration	Forward	Reverse	Descend	Ascend	
1	2 Bilge Pump Fwrd/Rvrse & 2 Bilge Pump Ascnd/Dscnd	19.1 S 0.5 m/s	23.6 S 0.4 m/s	16.4 S 0.18 m/s	13.7 S 0.22 m/s	$170
2	2 BTD 150 's Fwrd/Rvrse & 2 BTD 150's Ascnd/Dscnd	13.5 S 0.7 m/s	17.8 S 0.6 m/s	12.5 S 0.24 m/s	11.3 S 0.27 m/s	$0
3	4 BTD 150 's Fwrd/Rvrse & 0 BTD 150's Ascnd/Dscnd	8.6 S 1.2 m/s	11.2 S 0.9 m/s	n/a	n/a	$2,780
4	0 BTD 150 's Fwrd/Rvrse & 4 BTD 150's Ascnd/Dscnd	n/a	n/a	8.4 S 0.36 m/s	6.9 S 0.43 m/s	

Fastest speed in each direction highlighted m/s

Figure 13: Thruster Options
4 Configurations were tested.

Since the time frame for product demonstration is very restrictive, we decided we needed that speeds from configuration 3 AND 4 so we purchased 4 more Seabotix BTD-150 thrusters for $2,780 making it a total of 8 BTD 150's (4 re-used and 4 new). Further testing revealed the need for strafe capabilities so we decided to dedicate 1 thruster to sideways motion. The question was which direction (horizontal or vertical) would sacrifice a thruster? Since we travel forward more often and further than ascend/descend, we decided on a final configuration of 4 forward reverse thrusters, three ascend/descend thrusters and one strafe thruster. This especially makes sense since we only strafe a few times per run and we are fine tuning our position at that point so minimal power in that direction allows for precise adjustment of our position.

Propulsion

After researching previous competitions it appears the NASA NBL pool has one of the deepest settings for a MATE event. We have a significant distance to travel with every dissension and operation. This reassured us that the decision to spend a large percentage of our budget based on the cost analysis shown above would give us the best opportunity to succeed. The final thruster configuration shown in Figure 14. Four motors propel the vehicle forward and reverse. Three motors are used to control ascending and descending. And one motor is capable of strafing left and right. The power and speed on our robot is one reason the vehicle was named Turbotronix-3000.

Figure 14: Thruster Layout
Final configuration selected.

Camera Systems

The goal of our camera system was to provide detailed feedback for piloting and collecting information in a flexible way. Our system features four new Eyoyo fish finder cameras that can be viewed on one screen in several configurations. To accomplish this we used a 4x1 quad splitter that can take in 4 HDMI video feeds and output one HDMI feed with all four simultaneously. The Eyoyo cameras have an RCA plug output, so to pair them with the 4x1 quad splitter all camera feeds are connected to and RCA to HDMI adapter. With this system any monitor or TV that can accept an HDMI connection can display relatively large displays of live camera feeds individually, one large and 3 small (Figure 15) or all 4 split screen (figure 16).

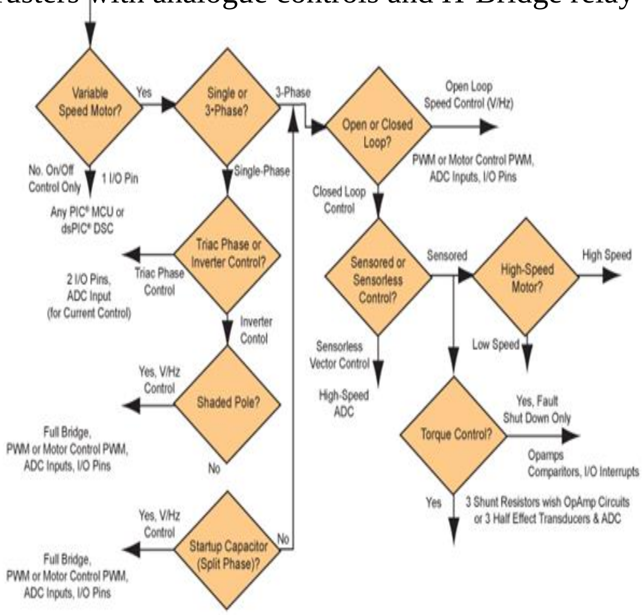
Figure 15: Video Display Option A
1 Large view and 3 smaller at the same time.

Figure 16: Video Display Option B
4 Equal size views in quad split screen.

Hardware vs Software

One of the main decisions Prometheus had to make was to decide whether to use analogue controls or a digital electronic control system. We explored the possibility of using Blue Robotics on an Arduino platform as an alternative to our Seabotix BTD-150 thrusters. One team (Ednir and Davon) worked on setting up the Seabotix motors while another team (Kristen and Tiffany) worked on the Blue Robotics setup. The Seabotix motors were able to quickly be hardwired to our controls with an H-Bridge relay setup to allow the thrusters' to operate in both directions, though no speed control was available with this set-up the configuration worked well, was easy to trouble shoot and was very stable. Whereas the Blue Robotics thrusters experienced software glitches with two different types of joysticks. After several communications with Blue Robotics and some coding alternatives provided by the manufacturer, the thrusters still exhibited some inexplicable faltering during testing. So we decided to use the Seabotix thrusters with analogue controls and H-Bridge relay setups.

Figure 17: Blue Robotics Thruster
The software alternative explored.



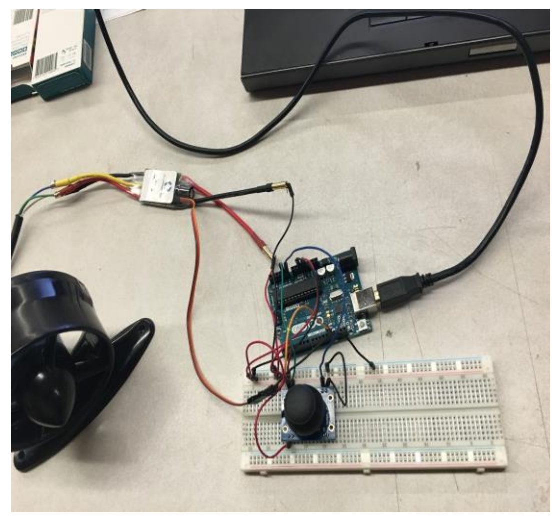


Figure 18: Flow Chart for D.E. Thrusters
Source http://www.microchip.com/design-centers/motor-control-and-drive/motor-types/acim.

Figure 19: DE Thruster Testing
Our Blue Robotics testing set up.

Control System

We developed several versions of our control systems improving with each successive iteration. The regional competition control box for example was small, made of wood, open in the back, with a steep top panel angle (for maneuvering the joysticks), and did not provide the best platform for mounting monitors when the ROV was operating. This sort of competition proved very valuable to ascertain the areas for improvement and strengths of our design. For example we learned that the regional competition control box had intuitive and easy to understand controls for efficient performance, therefore use of the two analog joysticks and 'tank' controls were kept for the next design.

Figure 19: Control System
Custom made for our needs.

Designing the control box in Autodesk Inventor was one of the keys producing an effective system. Not only were we able to accurately layout the components but we also used to file to cut the clear acrylic glass with the laser cutter. The structure was made of a wooden frame painted silver. An access panel to the back of the new design to protect the wiring and users while still providing access. Plexiglass® The top of the control box was given a shallow slope for piloting ease and the joysticks were spaced farther apart for a more natural feel. Our new and improved control box uses the same controls as during the regional competition. The 'tank' controls are easy to use and the right joystick controls strafing left and right and also controls ascend with the button at the top. The button on the left joystick allows the ROV to descend.

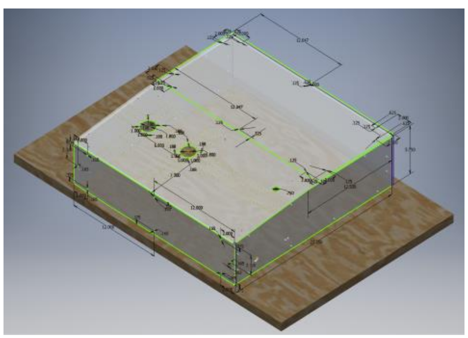


Figure 20: Control Box Design
Design in Autodesk Inventor.

To size the control system fuse we calculated the anticipated power draw and added 20% for possible fluctuations. The 25A fuse will help protect people, animals and the ROV as well.

Calculating Maximum Power Draw & Size Fuse

Thrusters	Volt (v)	Power (W)	Current (A)	Quantity	Total Current (A)
Seabotix BTD-150	12	32	2.67	7	18.7
Eyoyo Camera	12	6	0.5	4	2
				Total Current Drawn =	20.7
				20% current flucuation tolerance=	4.1
				Minimum Fuse Size=	24.8
					Therefore, use a 25A fuse

Note:
Data for Seabotix BTD-150 thrusters provided from Telydyne on Seabotix BTD-150 Data Sheet.
Data for Eyoyo Camera system derived from shop tests.

Figure 21: Calculating Current
Use calculation to size fuse.

Design Rationale

Prometheus Robotics has developed Turbotronix-3000, an ROV inspired by the ingenuity and efficiency of NASA, even adopting NASA's color scheme. The goal for Prometheus Robotics was to create an ROV that is fast, efficient, and completes all product demonstration tasks in 15 minutes while staying within a small work envelope. Our compact and neutrally buoyant design allows for ample mounting area for the thrusters, specialized tools and super rocket boosters (SRBs) that provide buoyancy and ballast while tackling and completing a series of five product demonstrations. Through professional workmanship, efficient operation completion, and dynamic teamwork, Prometheus Robotics succeeded in constructing an efficient ROV that is able to complete all of the five tasks during the product demonstration time period.

Figure 22: Regular Team Meetings
Daily review of progress & next steps.

Our process began with defining the problem; the first step of the typical engineering design process. Since this is our team's first time working with MATE and with designing an ROV, each individual created a small frame from their own imagination out of PVC pipe and then attached two bilge pump motors and wired them to rocker switches (SPDT On-On). This gave each member the basic foundation skills for creating our own unique and efficient ROV. From there, we worked on our teamwork skills and collaborated on two different designs for more complex robots. We quickly progressed testing each design to learn how best to improve.

Figure 23: Testing In Shop Tank
Frequent testing for feedback.

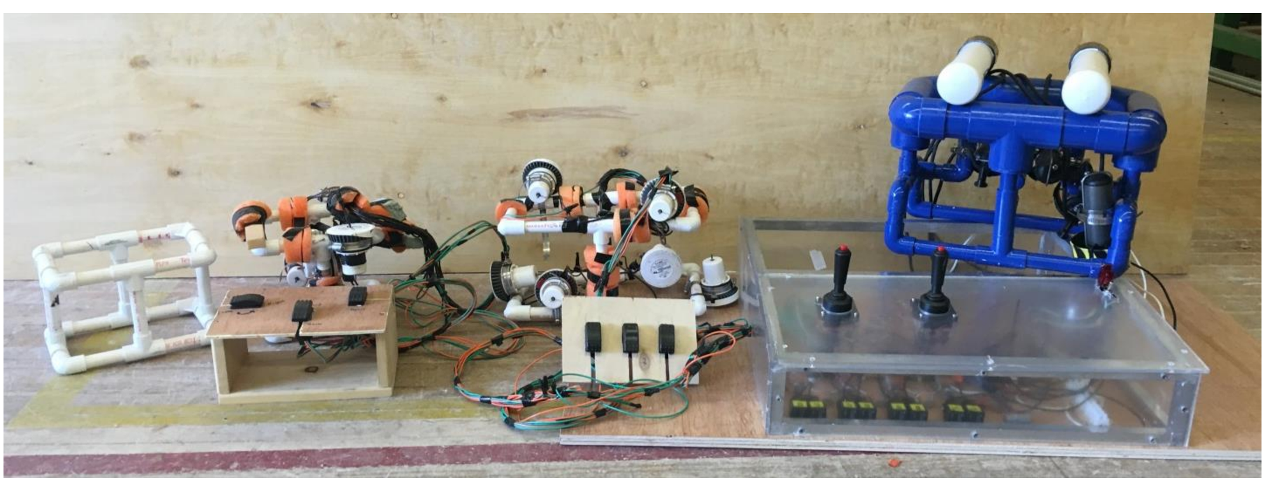


Figure 24: ROV Progression
A few of the robots along the way.

Design Rationale - Tools

Now that a vehicle was established, tools became the focus of our work days. A total of five final tools were designed to complete the tasks: the Oil Sample Retriever, Thermometer, the Coral Tangler, the Bolt Inserter, and the Measuring Device.

1) The Oil Sample Retriever was developed from the simple hand motion a person can use the pick up an oil sample. This tool can also pick up the CubeSATs, and open the door to the power and communications hub. To make it even more useful we designed our 2) thermometer to match the shape and size of the oil sample making this tool perfect for inserting the thermostat as well. A bent piece of flat metal with notches cut into it allows this tool to perform several critical tasks. Lastly we spaced the opening in this tool to match the flange and wellhead cap so now it can also pick up both of these items and install them on the well head.

Figure 25: Thermometer
The thermometer is designed the same shape and size as an oil sample therefore the Oil Sample Retrieval Tool can work them both effectively.

Figure 25 & 26: Retrieving the Well Head Cap
The Oil Sample Retrieval Tool is designed to be the exact width of the cap to be lifted from the ocean bottom and installed on the well head.

3) The Coral Tangler is an attachment to the Oil Sample Retriever made from a comb to tangle the coral samples while driving across the ocean floor. 4) The Turbotronix-3000 Bolt Insertion tool retrieves bolts from their seats and can insert the bolts both vertically and horizontally. It can turn the bolts 90 degrees without any moving parts making it reliable and cost effective. Throughout our testing the bolt insertion was the most difficult challenge to overcome, we actually reserved it for the last task to tackle.

We started by carefully observing how a human hand can accomplish this task with many different movements and worked to accomplish this with few movements of the hand instead. We realized one of the best ways to retrieve the bolt was to use a ¾" PVC-T cut open to act like a stationary hand with fingers spread to pick up the bolt. This picks up the bolt effectively but the bolt sits snugly preventing rotation after pick up. So we used a PVC-T that is larger (1") and allows movement after pick up. With many minor adjustments to the cuts made on the 1" PVC-T, the Bolt Inserter became able to retrieve bolts vertically and while descending and moving backwards rolls the bolt 90 degrees until the nut on the bolt head lodges in the PVC pipe end holding the bolt in place for horizontal installation.

Figure 27: Bolt Insertion Tool
The steps involved in using the Bolt Insertion Tool.

5) The Measuring Device is another noteworthy tool created by Prometheus. The ROV will descend and the attached Measuring Device will come free and float when it touches the water due to its buoyancy. This tool is made from PVC and allows it to be easily pushed around by the ROV without any entanglement. Since the device floats, measurements start from 0 at the water's surface and the ROV only has to be able to see the bottom of the ice sheet and the ocean depth next to the device through the camera to get a measurement. Measurements were also added to the 20 meter tether to be read from the surface and calculated by the tether team as a second measurement used for verification and to allow for a more accurate reading when combined with the data from the Measurement Device.

This is the design flow chart we followed to create our custom frame & specialized tools.

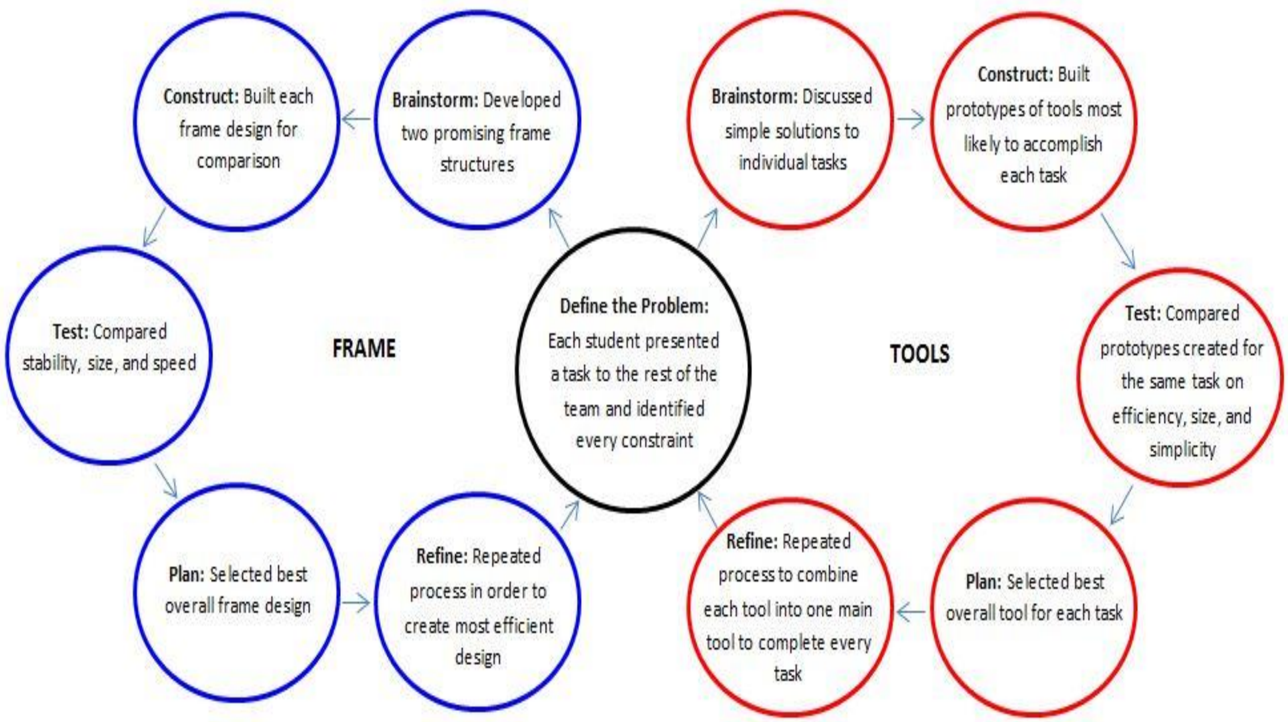


Figure 28: Design Flow Chart
The steps involved in designing custom frames and specialized tools.

System Integration Diagram

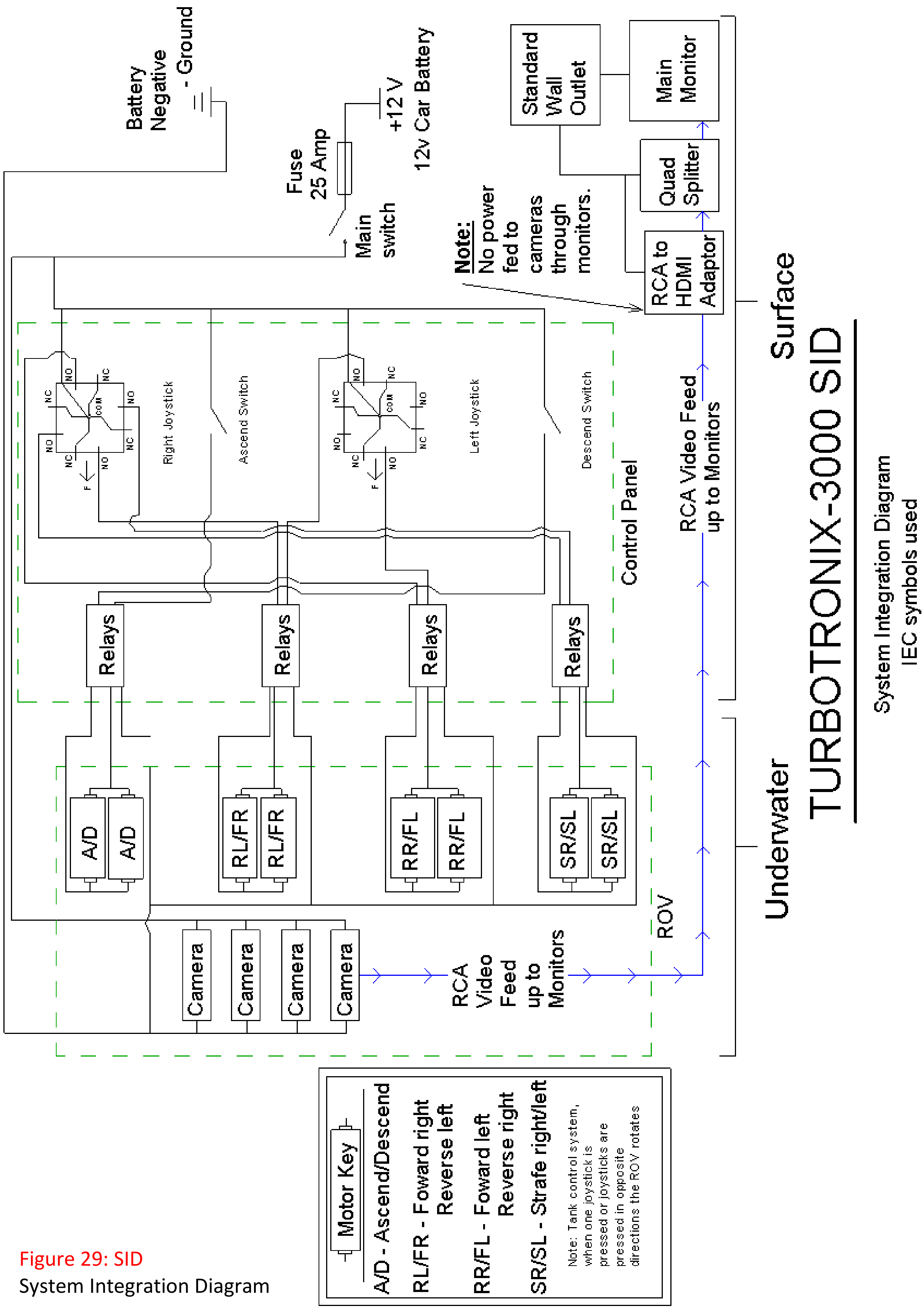


Figure 29: SID
System Integration Diagram

Budget

Since we had not worked on an ROV previously, we consulted the MATE archives to look at the budgets of the previous MATE ROV Ranger Class International winners. In 2015 Amno & Co. won with a total vehicle cost of $8,931, in 2014 Clarenville High School won with a cost of $4,340, and in 2013 Aptos High School won with a cost of $2,095; the average cost of these winners was $5,122. We requested $6,000 from our school to give us a competitive budget, and we were granted $5,000. Judging by the increase in cost each year though, we determined that more funds would be required to build competitive ROV. To raise additional funds we held a fundraiser, we sold raffle tickets for $5 each, with the winner receiving two tickets to a New England Patriots football game. Through this we raised an additional $1,700 which raised our total budget to $6,700.

When researching what to purchase, we decided to focus on thrusters and cameras. Our largest expenditure was the 4 BTD-150 thrusters which cost $2,780 on 4 thrusters, comprising about 50% of our total budget. This allowed us to create an ROV that delivers our tools with speed and precision. Our second biggest purchase was $1,358 on the camera system, comprising about 24% of the budget. We decided it was necessary that we have a clear view throughout the dive to most efficiently pilot and accomplish the tasks. The electronic components and control box cost approximately $600 (about 11% of the budget) were next largest and well worth the expense, as the controls how we communicate with the ROV. It was also crucial to spend $725 (about 11% of the budget) on making the props, allowing us to test and refine our tools.

Figure 30: Seabotix BTD 150
Quad forward thrusters.

Figure 31: Control Box.
Final configuration selected.

We reused materials where we could and in our design that meant propulsion. The Turbotronix-3000 has a total of 8 Seabotix BTD 150 thrusters yet we only bought 4, the other 4 were found unused in a box in shop. By using the 4 Seabotix motors found in our shop, we saved nearly $3000.

Figure 32: PVC Frame
ROV frame being painted.

Budget Worksheet 1

Available Funds		
Item	**Description**	**Amount**
1	Funding Provided by School	$5,000.00
2	Fundraiser	$1,700.00
		$6,700.00

ROV Expenditures				
Category	**Item**	**Description**	**Item Cost**	**Subtotal**
Props	1	Building props for testing	$ 588	
	2	Prop accessories, stickers, string, etc.	$ 137	
13%		Subtotal for Props		$ 725
Frame	3	PVC pipe - 2" & 3/4"	$ 118	
	4	PVC Cement & Cleaner	$ 24	
	5	Paint & Clear Coat	$ 46	
3%		Subtotal for Frame		$ 188
Electrical & Control Box	7	Stranded Wire (18 AWG 30 meter rolls)	$ 378	
	8	Wiring blocks	$ 11	
	9	Main power switch	$ 7	
	10	Zip ties (1000 count bag)	$ 22	
	11	Electrical tape (rolls)	$ 16	
	12	6.35mm x .5m x .5m clear acryllic	$ 94	
	13	25mm x .5 m x 1 m plywood	$ 28	
	14	Relays	$ 40	
11%		Subtotal for Electrical & Control System		$ 596
Tools	15	Thermometer	$ 8	
	16	Metal ribbon 6mm x 2 cm x 0.25 meters	$ 5	
	17	PVC Pipe & Fittings	$ 48	
	18	Comb, hose clamps & misc parts	$ 31	
2%		Subtotal for Electrical & Control System		$ 92
Camera System	19	27" Computer Monitor	$ 159	
	20	Eyoyo camera(s)	$ 316	
	21	Quad View Camera System	$ 725	
	22	RCA to HDMI Adaptor	$ 158	
24%		Subtotal for Camera System		$ 1,358
Propulsion	23	SeaBotix motor(s)	$ 2,780	
	24	Joysticks for controls	$ 39	
	25	Hose clapms for mounting	$ 21	
50%		Subtotal for Electrical & Control System		$ 2,840
General Supplies	23	Fastners, adhesives, cable ties	$ 124	
	24	Wood, plastics & metals	$ 89	
	25	Foam, brackets, misc.	$ 210	
8%		Subtotal for Electrical & Control System		$ 423
		Total ROV Expenditures		$ 5,626

Budget Worksheet 2

To determine the value of our ROV we add the ROV expenditures to the value of the reused items and determined the Turbotroinx-300 value id $8,406.

Reused Items			
4	Motors - Seabotix D150	$	2,780

Total Vehicle Value			
1	Purchased Items	$	5,626
2	Value of Reused Items	$	2,780
		$	8,406

Final Vehicle Accounting			
1	Project Budget	$	6,700
2	Project Expenses	$	(5,626)
		$	1,074

After winning the MATE New England Regional competition we approached the Greater New Bedford Regional Vocational Technical School Committee with the following travel budget to the International event in Houston, Texas. We are so very appreciative of the school committee, our department head Mr. Steven Walker and our superintendent Mr. James Obrien for approving our request and allocating these funds for our travel.

Traveling & Logistics

Item	Description	Unit Cost	Units	Quantity	Total Cost
1	Flights: Boston, MA - Houston, TX	$ 359	Seat	10	$ 3,590
2	Lodging - Hampton Inn, Houston, TX	$ 1,325	Room for 6 nights	7	$ 9,275
3	Meals - Per Diem	$ 59	Per person, per day	70	$ 4,130
4	Rental Car - 2 Minivans	$ 985	Per van	2	$ 1,970
5	Incidentals - Tip, parking, etc.	$ 50	Per day	7	$ 350
6	Shipping	$ 185	Each way	2	$ 370
		Total for Traveling & Logistics			$ 19,685

Troubleshooting

We created many designs and each time built any portion of the ROV we tested it before proceeding. Often times it did not perform as expected. This process of determining exactly what the problem is, was the most common task of the entire project, troubleshooting. The method of troubleshooting varies by the type of problem from; tweaking PVC parts to reworking failed buoyance, to reshaping slipping tools, but the most common type of troubleshooting was electrical issues. We troubleshoot wiring with a multimeter to find breaks in continuity. We use a DC power supply that measures wattage to check for circuit overload. After each tool design the sub-team that designed it creates a mockup and demonstrates that tool for the full team. We are looking for feedback on the design and construction. If the tool has potential and we decide it is worth additional investment of time and resources we develop a more permanent version with improved features and materials. This process allows us to trouble shoot our designs and tools as we go along. And allows us to focus on tools that are working well while avoiding investing time in ideas that will not pan out. We perform tests with the robot in our test tank. We perform full tests with all props and 15 minutes time limit at the YMCA pool, this allows us to trouble shoot our entire system and our team assignments and our strategy to accomplishing the tasks. We are always looking forward to improve from systems to assignments to task order. During testing of the ROV at the YMCA pool we have notice that the tether always gets caught on the ROV frame. This makes the ROV get stuck and unable to move. To prevent the tether to not get tangle with the ROV, we as a team decided to tighten the wires together so it can be like one durable wire. Also added some foam on the tether to stay positively buoyant so the long remaining wires can float and won't get in the way of the ROV and won't get tangle to the frame. The tasks was surprisingly going smoothly with no complications but task 1 that involve opening the crate door. The ROV cannot open the door with the claw we made to grab to grab hold of the door handle. The ROV can open the door by grabbing hold of the side door and pull it but it use up too much time. We as a team decided to do this task last so can do the other tasks and gain points instead of wasting time opening the crate door gaining no points.

Figure 33: Tool Demonstration
Team gathers to watch a demonstration and help the cause of failures.

Figure 34: New England Regional Competition
As soon as we returned to shop, we started addressing the list of items that did not work as planned. The regional competition was a great catalyst to trouble shoot our robot.

Safety

To ensure the safety of all the members of Prometheus when operating Turbotronix-3000, a safety checklist was made along with a JSA. All the members of Prometheus received a 10-hour OSHA certification. The safety supervisor is in charge of running through the safety checklist before each run of Turbotronix-3000. The safety checklist, as shown in the next section, was designed by the safety supervisor and approved by the rest of the team. The safety checklist has a section called notes to be used for any questionable safety issues that will need to be addressed as soon as possible by the team. All the appropriate PPE is used when necessary, such as safety glasses, gloves, and boots.

To avoid any electrical issues, a fuse was placed on the control box, as well as the temperature sensor. All wiring that was spliced was also heat shrunk to maintain the connection and meet the safety requirements. The wiring was neat and organized so to avoid any disconnections from the control box or the frame. The motors were not only shrouded, but also striped to show the safety hazard. The rig was positively buoyant in case of a power failure to allow easy removal from the pool. When Turbotronix-3000 is moved, at least two people are carrying him and his parts to avoid any injuries. Prometheus always takes all the appropriate safety precautions because safety is the number one priority.

Figure 35: Seabotix BTD-150
Before and after hazard warning paint.

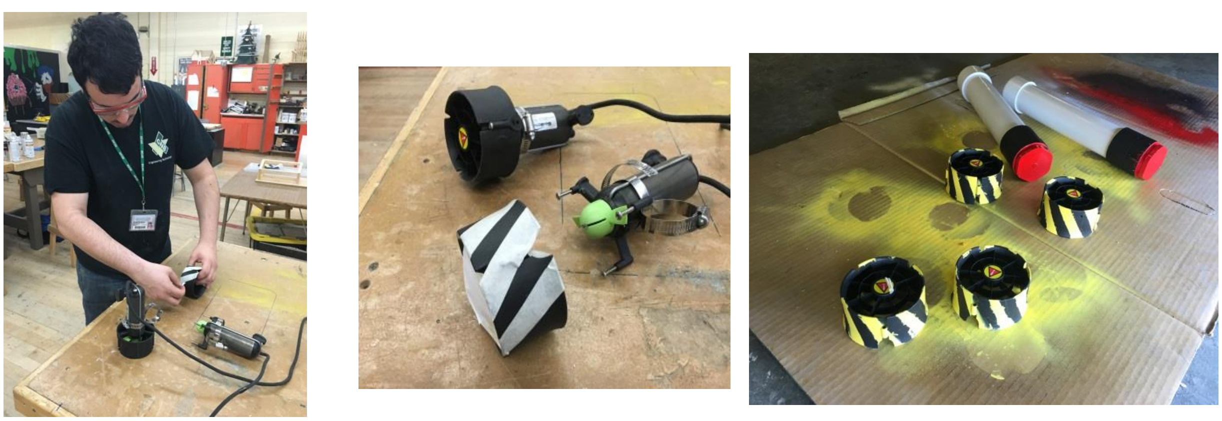


Figure 36-38: Process of Painting the Propeller Guards
The propeller guards were removed by Kyle. Then taped off and painted with bright yellow and clear coated three times to protect against chipping. Finally remounted.

Safety Checklist

Safety Personnel:__________________ **Testing Location: ___________________** **Testing Date:__________**

Personal Protective Equipment

- ❑ Safety glasses worn at all times
- ❑ Proper personal protective equipment worn at all times (i.e. gloves)
- ❑ No open toed shoes, shorts, jewelry, hats, flammable clothing, or loose clothing
- ❑ No earbuds, headphones, personal electronic devices, or other distractions
- ❑ Proper safety certifications to use hand tools, power tools and machines
- ❑ Each team member is OSHA certified
- ❑ Never work upset, distracted, or rushed

ROV Operation Checklist

- ❑ Power is off on power supply and control box when ROV is not in use or being modified in any way
- ❑ ROV is always left on stable, safe surface
- ❑ ROV is never left on floor or in obstruction of walking path
- ❑ More than one person transports the ROV to ensure nothing is dropped or broken
- ❑ Motor guards, cameras and all parts of the ROV are secured to the frame properly
- ❑ All necessary guards are being used over thrusters to ensure that the tether, wires and tools do not obstruct their operation
- ❑ Everyone is clear of the ROV when power is connected
- ❑ Inspect ROV before and after each use

Tether and Wiring Safety Checklist

- ❑ All wires are intact; no exposed wires, terminals, solder joints or connections
- ❑ Heat-shrink is used on all electrical connections
- ❑ Tether is rolled up and stored properly after each use
- ❑ Tether is never left on the ground
- ❑ Tether is kept clear of sharp or hazardous objects
- ❑ Nothing heavy is left on the tether
- ❑ No one steps on or rolls anything over the tether
- ❑ Tether is secured properly so that no wires protrude
- ❑ Fuse is secured properly and insulated to prevent accidental disconnection
- ❑ Give adequate amount of slack to tether when ROV is in operation
- ❑ Inspect tether before and after each use

Notes: ____

____

Safety Supervisor Approval: ____

Challenges

With a project so complex, we were bound to encounter numerous technical challenges. With the wiring and the control box it was very difficult to keep the wiring neat. The beginning of the control box was functional, but the mess of wires made it much harder to understand it and fix any problems. It needed a complete redesign, this time making sure all wires were secured while maintaining order. For the tools, it was necessary to perfect them in order to most efficiently accomplish all tasks. When brainstorming initially there were many complex ideas for carrying out the tasks, but we focused on tools that were simple, with few moving parts. This simplicity allowed for easy changes and fixes if necessary, but also for tools that could be specialized for multiple tasks, such as the Oil Sample Retriever.

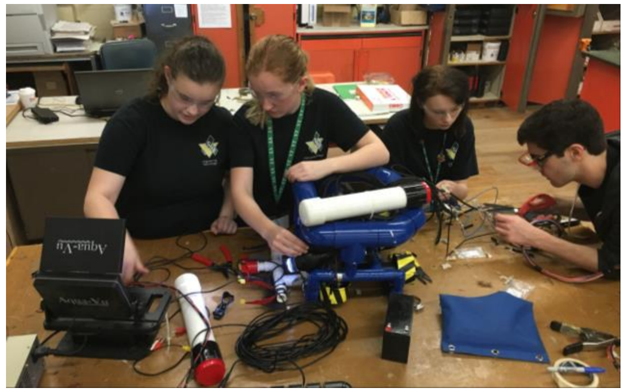


Figure 39: Troubleshooting Tether & Controls
The team works on wiring tether to control system.

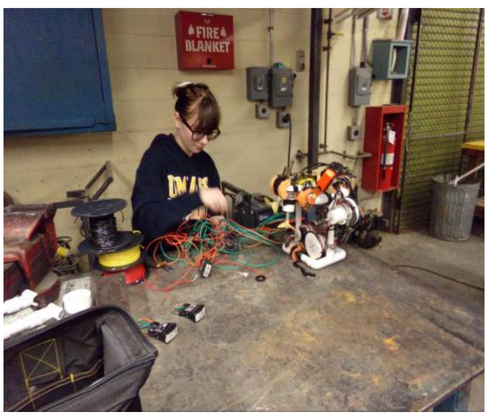


Figure 40: Kristen Sorts Wires
The tether system needed a redesign.

There were many non-technical challenges as well, often due to managing the team. We valued each team member's opinion in order to maintain a positive work environment, but managing the time to hear everyone out was sometimes a challenges. Balancing between the fastest solutions and exhausting every possible solution became a team focus. Which solutions to implement were chosen by the entire team based voting, and the evaluated based on how effective they were. Even then, we would always accept feedback as valuable critique, changing the design if a better solution was found. Proper time management was necessary to the success of the project, as we had to keep our focus on the most important aspects.

Lessons Learned

We learned many things while building Turbotronix-3000 whether they were technical or non-technical. Some of us learned how to use a mill while creating a tool for picking up the coral. Some of us also learned how measure and cut PVC pipe. We learned how to create an SID. We also learned the importance of having neat diagrams for wiring the control box. This helped especially when troubleshooting.

There were also non-technical things that we learned. We learned it was more efficient to divide up requirements and let each person have their own creative way of accomplishing a task. We also learned it's better to accept criticism and feedback to improve designs quickly. Time management was also crucial in setting certain dates and times to finish a tasks.

Future Improvements

To improve on our design we should use better motor controls and placement. This means equipping Turbotronix with a molded or injected plastic frame to have a more dynamic shape that cuts through the water with less resistance and with built in mounting points. The digital electronics can also allow for a smaller more flexible tether that would certainly improve our robot as tether issues often creep up in testing. Other improvements would include making the tether closer to 25m instead of 20 m in order to give the ROV better range. One main improvement with Turbotronix that we would work on would be aesthetic. The blue paint currently blends in too much with the water and sometimes can be hard to see. Furthermore the PVC pipe is often a deal breaker to customers who do not see the economic advantage to using it. We would find a better way to clean and hide away the PVC, as a layer of spray paint doesn't hide the PVC's shape. Besides the ROV itself we would also like to find a way to organize and shield the tether so that the bundle of wires we use to communicate to Turbotronix doesn't look confusing.

Figure 41: Commercially Available ROV
Molded frame and digital electronics light tether.

Reflections

Ednir D'Oliverira

Ednir: Seeing as though we had never built an ROV before this project was much more successful than we first thought. We have never built such a complicated project of any kind actually. This project forced us to work as a team and grow as a group. I've become closer and work better with my teammates compared to before working on the project. We are so proud of working a project with a dozen systems over a three month period and seeing it come together. Seeing the final project makes us realize what we are really capable of, it gives us motivation to keep creating and building and making it better, safer, and more effective. Being able to work on a small scale gave us appreciation for large companies like NASA that work on projects with not just a dozen systems but hundreds or thousands on a ten year project. It must be quite rewarding to complete such a large project.

Teamwork

TURBOTRONIX-3000 is the result of all team members working hard without personal ego getting in the way. Throughout this process we jumped in and help each other out with no second thought. The morning meetings, and setting the day's agenda were key to organizing the tasks. But every step of the way we would interrupt what we were doing to support each other. Like when it was time for tool demonstrations we all gathered round to provide honest feedback, or when we had a disconnected wire in the controls and all jumped in to find the loose end. Although our mentors guided us in the right direction, they never built a single part of the ROV: as a matter of fact our shop mentor was absent for over a month leading up to the regional competition due to health issues, for that critical time we worked under the supervision of temporary substitute teachers who had no understanding of what we were doing. It took leadership and responsibility on everyone's part to complete the robot and its presentation. In the end we decided that our company was mostly NASA inspired because of our teamwork. We felt like the employees all ready to launch a rocket ship to space and thinking about how we could end up at NASA gave us hope.

Figure 42: Final Team Picture
Proud of our finished product.

Each person was assigned or chose projects based on their strengths. Leaders were chosen by their teammates based off of their leadership abilities when something went wrong. Kristen Vezina and Ednir D'Oliveira being chosen for CEO and CFO. Their quick-response was essential to the team. Kyle Trahan's ability to work on specialty tools and as co-pilot next to Grace Ostiguy, the pilot, to help her if something goes wrong with the panel. Davon Andrew's vigorous attitude put him in the spot for systems engineer and technical writer. This also includes Sheila Ferreira whose caring demeanor was a good representation as the team as a whole: she's smart and very determined and this warranted her the positions of outreach member and systems design engineer. Tiffany Saraiva was an obvious election for electrical engineer as she'll be attending college to study electrical engineering. She was also chosen as our safety supervisor because of her stern attitude toward following the rules. Last but not least, David Dompierre was chosen as safety engineer and research & development manager for his amazing ability to gain and hold knowledge.

Team Primary Assignments

Responsible for frame design and construction.
ROV Pilot

Responsible for wiring control box.
Tether manager.

Ednir D'Oliveira

Responsible for motor mounting & painting.
Reading charts on deck.

Sheila Ferreira

Responsible for bolt insertion tool.
Co-Pilot.

Kyle Trahan

Responsible for frame design and construction.
CEO

Kristen Vezina

Responsible for oil sample p/u tool & tools.
Tools on deck.

Davon Andrews

Responsible for tether construction & wiring.
Co-Pilot.

Tiffany Sairiva

Responsible for thermometer & safety.
Tools on deck.

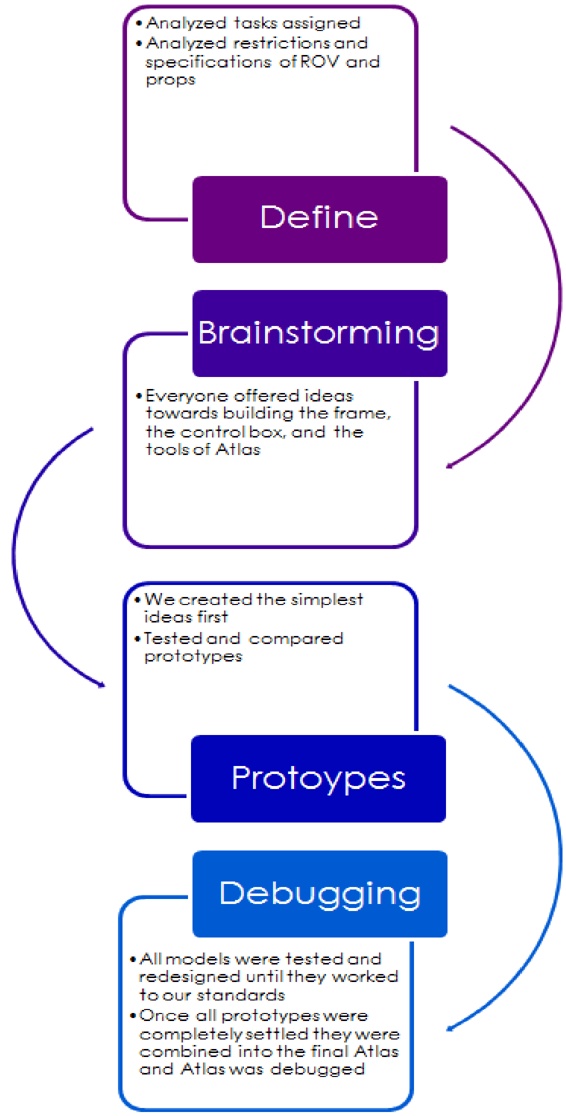
David Dompiere

Project management

Prometheus follows the same project management process that many other engineering firms follow. Each morning before we began work we gather around the main table and talk until everyone was settled. This allowed the group to connect and relax before beginning our day. Once everyone was settled and accounted for we would lay out our goals for the day. Each team member would either decide what they wanted to work on, or be assigned a task based on their individual strengths. Once everyone had a project for the day, we set out to work.

Each person followed the same basic design process. We would brainstorm ideas and would decide on which idea to prototype based on simplicity, efficiency of cost, size, and weight. Simplicity was a major factor of our design selection because our team found that complicated ideas often took longer to create with many problems along the way; whereas simpler ideas were easier to comb over and fix, eventually becoming the perfect match for our ROV. The idea would then be prototyped, tested, and prepped for demonstration when the team regrouped.

The end of our day was spent regrouping and going from task to task assessing each prototype created and reflecting on what could be made better and what worked well.



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Our team had support from many different people during the construction of our ROV, Turbotronix-3000. The first person we would like to acknowledge is Jenn Corey for helping us with fundraising for our project. We would also like to acknowledge the YMCA for letting our team use the pool inside of their building. Without the help of YMCA the team would not have been able to test Turbotronix-3000 before the MATE ROV competition. Throughout the duration of the project we had the support of a former GNBVT student, Diarny Fernandes. Finally the Prometheus team would like to acknowledge our shop coordinator, Steve Walker for providing support and allowing us to pursue this endeavor.

Mr. Walker