The Dalhousie Privateers

DAL ROV

Dalhousie University, Halifax, NS, Canada

2011 MATE International ROV Competition

Explorer Class

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Acknowledgments

We would like to sincerely thank our generous sponsors:

- **Ultra Electronics Maritime Systems**
- **Shell Canada**
- **Dalhousie University Faculty of Engineering**
- Vehicle Safety Research Team
- Encana
- Donald Church
- Dalhousie University Department of Mechanical Engineering
- Dalhousie University Department of Electrical Engineering
- Welaptega Marine Inc
- Dominion Diving
- IEEE
- Engineers Nova Scotia
- Dalhousie Student Union

We would also like to thank our mentors for all the help they have given us:
Dr. George Jarjoura, Dr. Mae Seto, and Reg Peters.

A special thanks to:
Dr. Joshua Leon, Albert Murphy, and Angus MacPherson.

Finally, we would like to thank all of our families, friends and those who helped and supported us throughout our endeavour.

Abstract

This report documents the Dalhousie Privateers' entry into the 2011 MATE International ROV competition. The report details how the team consistently followed a *tools-first* design approach for efficient mission completion, while also focusing on overall reliability. The team continues to take pride in designing, constructing, programming and testing as much of the craft as possible to create a customized solution not possible with off the shelf parts.

The ROV features custom tools, tailored to the needs of each individual mission to complete each task as quickly and efficiently as possible. A rigorous testing routine was used to ensure tool effectiveness.

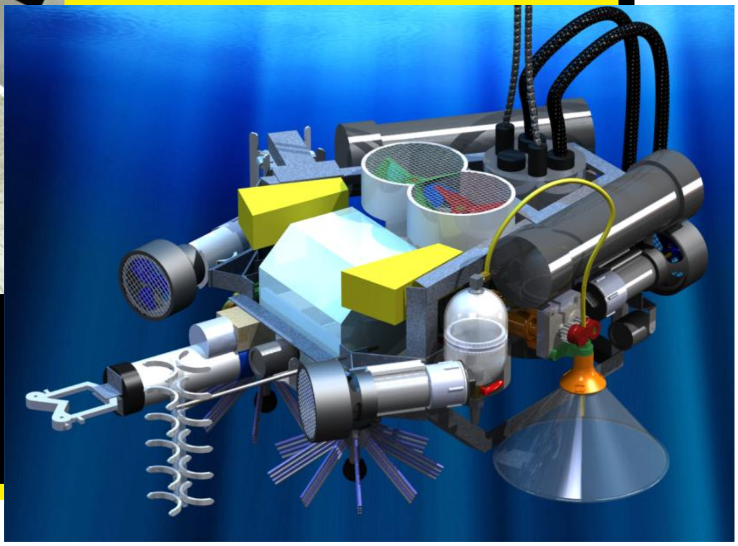
The craft is driven by a set of variable speed custom designed thrusters. Four thrusters arranged in a vector arrangement provide the craft's lateral movement, while a powerful single thruster moves the craft vertically. The craft's vertical manoeuvring is assisted by an active buoyancy system that allows for a rapid ascent at the end of the mission.

Our onboard electronics are housed in an aluminum electronics casing. These interface with a portable command center for controlling the ROV and displaying video feeds at the surface.

Our sleek and efficient aluminum frame was designed around the aforementioned components and has as little wasted space as possible, with a shape that optimally positions the tools to complete the mission tasks.

It is with great pride that the Privateers introduce their fourth generation ROV:

The Betta Project



The Dalhousie Privateers

Company Structure & Purpose

The Dalhousie Privateers follow a relatively simple company structure designed to aid the company's dual purposes: the development of quality ROVs and the continual training of members. ROV design is broken down into subtasks, each of which is headed by a team leader selected for experience, leadership, and interest in that subtask. The team leader is responsible for guiding the development of their subtask and for ensuring their team members follow responsible, safe building practices. They are also responsible for holding skills training sessions to aid members in developing related technical skills. The team leaders report to the company CEO, whose responsibilities include organizing team leader meetings, and developing the technical and leadership skills of the team leaders. At the team leader meetings, the project's progress is reviewed in relation to the schedule set at the beginning of the year to ensure its timely completion.

Figure 1 - Company Photo

Our Product

Since the company's creation, the Dalhousie Privateers have endeavoured to provide high quality ROVs, tailored to each client's specific needs. All vehicles that leave our workshop are outfitted with unique tools, customized to perform the client's tasks with the utmost precision and efficiency.

Our Facilities

The Privateers' main facility is a dedicated workshop for ROV construction, pictured in Figure 2. The workshop is outfitted with a full range of handheld tools, multiple soldering stations, and several bench tools including a band saw, a drill press, and a belt sander. The shop is well stocked with safety gear, including protective glasses and ear protectors. The workshop is also outfitted with a large tank, approximately 1.5m deep and 2m in diameter, used for testing prototypes in water. For testing at a greater depth, the team uses the Aquatron, a 10.3m deep aquatic research facility generously provided by the Oceanography Department of Dalhousie University.

Figure 2 - The Privateers' Workshop

Design Rationale

This year, the Dalhousie Privateers chose to focus on two specific goals throughout the entire development process. The many returning members provided a base of knowledge familiar with the construction of basic ROV systems: frames, propulsion units, simple control, and power management. While the Privateers chose to develop a new craft from scratch, this company experience allowed the focus to shift away from simply completing a functioning craft in time for the competition. Instead, the Privateers' were able to focus on creating an easy to operate and reliable craft.

Ease of Operation

The 2011 mission tasks, particularly the capping of a pressurized wellhead, are complex. This complexity is exacerbated by the 12m depth of the NASA facility and the short mission duration. The Privateers chose to make ease of operation a primary design consideration. A vehicle that is simple for the pilot to control and use to complete tasks has a much higher chance of successfully completing all missions. This strategy meant the craft development followed a tools-first approach.

Reliability

Having won two Guts & Glory awards over the previous three competitions, the Privateers are completely aware that even an extremely easy-to-use craft can suffer at the competition if it is not physically robust. To improve reliability, the ROV was designed in a modular manner and each individual component - particularly within the propulsion and control systems - underwent rigorous testing. Backup units for each component were developed and are ready for quick replacement pending failure of the primary system.

Company Budget

The budget for the Dalhousie Privateers is shown below in Table 1 and Figure 3.

Table 1 – Detailed Team Budget

Outflow	Qty.	Ea.	Cost	Source
Construction				
Prototyping			**$700**	**Sponsors**
Control System			**$1,800**	**Sponsors**
Tether + Elec Box			**$375**	**Sponsors**
Propulsion			**$585**	**Sponsors**
Command Center			**$450**	**Sponsors**
Cameras			**$225**	**Sponsors**
Frame			**$225**	**Sponsors**
Props			**$225**	**Sponsors**
Tools			**$450**	**Sponsors**
Buoyancy			**$300**	**Sponsors**
Supplies & Equipment			**$750**	**Sponsors**
Sub Total			**$6,085**	
Travel				
Air Fares from Halifax	5	$760	**$3,800**	**Dean**
Air Fares from Halifax	1	$760	**$760**	**Sponsors**
Air Fare from Ottawa	1	$760	**$760**	**Dean**
Air Fares from Labrador	1	$1,760	**$1,760**	**Dean $760, Sponsors Remainder**
Room & Board	16	$350	**$5,600**	**Team Contributions**
Road Trip (milage)	1	$2,600	**$2,600**	**Sponsors**
Car Rental	2	$500	**$1,000**	**Sponsors**
Contingency	1	$500	**$500**	**Sponsors**
Sub Total			**$16,780**	
Total			**$22,865**	

Inflow	Amount
Industrial Sponsors	
Ultra Electronics Maritime Systems	**$5,000**
Shell Canada	**$5,000**
Engineers Nova Scotia	**$600**
Dalhousie Student Union	**$500**
Dalhousie Mechanical Engineering Department	**$500**
Dalhousie Electrical Engineering Department	**N/A***
Donald Church	**$100**
Dominion Diving	**$250**
Jentronics	**N/A***
** = donation of electrical equipment on request*	
Other	
Team Travel Contributions	**$5,600**
Dalhousie Engineering Travel Support	**$5,320**
Total	**$22,870**

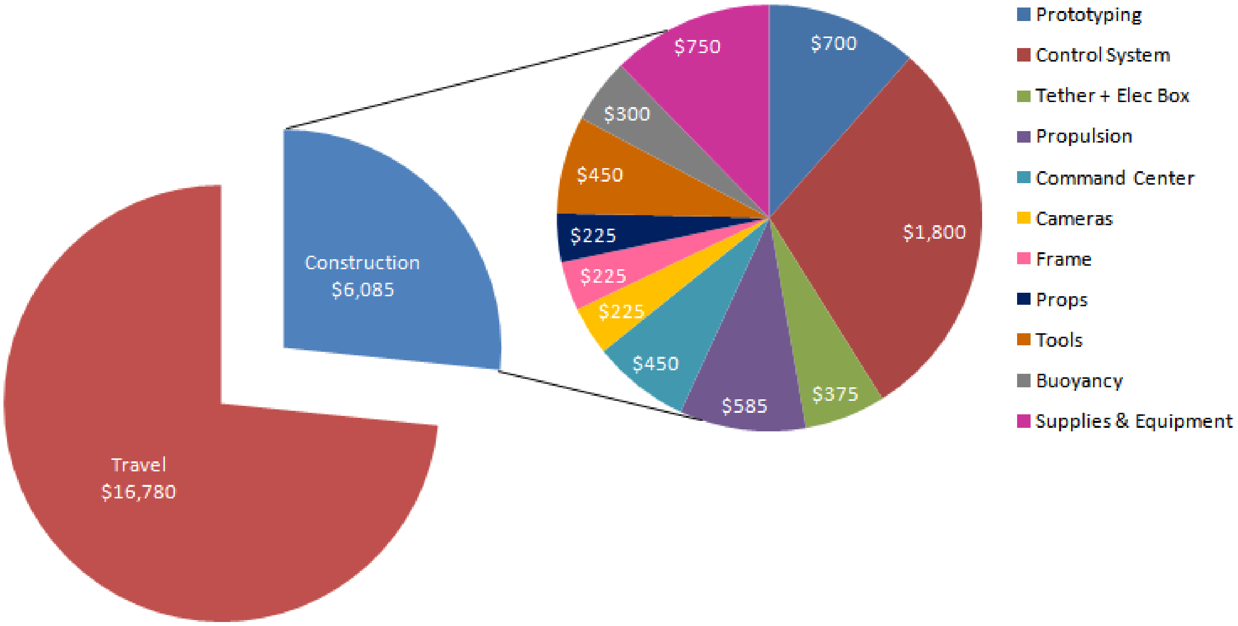


Figure 3 – Team Budget

The Development of *The Betta Project*

The Mini ROV

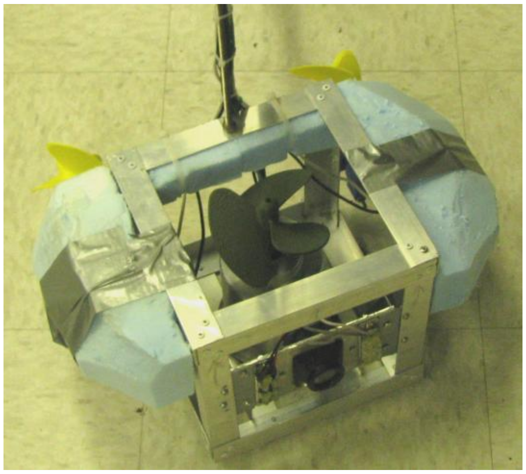


Figure 4 – The Mini ROV

To have an effective tools-first design strategy, a way to test individual tools under realistic operating conditions was required. The most realistic operating condition is mounted to an ROV. The Mini ROV is a small ROV that was quickly built by scavenging parts from last year's model, the Aluminum Falcon. Depicted in Figure 4, this ROV consists of a cubic frame and a basic propulsion system. The Mini was used to test prototype components to ensure they would work at depth and to troubleshoot potential issues as early as possible. It was instrumental in comparing the effectiveness of tool prototypes and ensuring the performance of other components such as the active buoyancy, propulsion system, and cameras. Once the ROV was in a stage that it could start being tested the Mini was used as a remote operated camera to observe the craft's testing at depths of up to 10.3 m, such as the video recording shown in Figure 5. Such detailed observation would have been otherwise impossible from the surface. The Mini ROV was instrumental in the designing and testing of the tooling and components for The Betta Project.

Figure 5 – Recording an Active Buoyancy Test

Tools

Cap

The single most important task of the competition is capping the leaking wellhead. Due to the significant wellhead pressure, the cap must be able to withstand internal forces of up to 75lb. Due to this overwhelming force, the early design stages determined that any cap designed should execute the following operations:

1) Attach to wellhead in a manner that allows for continued leaking while preventing cap from sliding up off the well.

2) Generate a watertight seal between the cap and wellhead, while still allowing for continued leaking.

3) Use a mechanism internal to the cap to cease leaking, thus stopping the flow.

4) Disengage the ROV from the newly installed cap.

This order of operations was chosen to make initial cap installation as efficient as possible; by allowing the leaking to continue during the installation, the ROV encounters no vertical forces as no pressure build-up occurs.

As seen in Figure 6, the cap consists of four main subsystems. First is a mesh cone, which guides the cap into place while allowing the pilot to see through it. The second is a set of grappling hooks, which are designed to allow the cap to easily drop over the wellhead. As the ROV drops, the hooks catch the groove in the wellhead, preventing any further upward motion. As seen in Figure 7, the cone and hooks are designed to not interfere with the wellhead structure when installed. Third, a skirt assembly is used to create a watertight seal between the cap and wellhead circumference. A standard pipe flex coupling is used as the skirt, which is tightened onto the cap via a bolt drive hose clamp. The bolt is driven with a standard gearbox DC motor. A unique feature is used to tighten the hoseclamp while simultaneously disengaging the drive system from the motor. The driveshaft incorporates a left-handed bolt/nut combination, where the bolt is attached to the motor and the nut is used to drive the hose clamp. Initially, relative motion between the bolt and nut is prevented via a shear pin driven through a hole in both components. The shear pin is calibrated to snap when the hoseclamp has achieved a good seal on the well. Once the cap has been placed on the wellhead, the shear pin snaps and the left handed threads backspin to separate the driveshaft, automatically disconnecting the motor from the wellhead. Fourthly, as the ROV disengages, a valve plunger is released which finally stops the leaking. The cap was designed in a manner to make it efficient to install, with little insertion force and manoeuvring required.

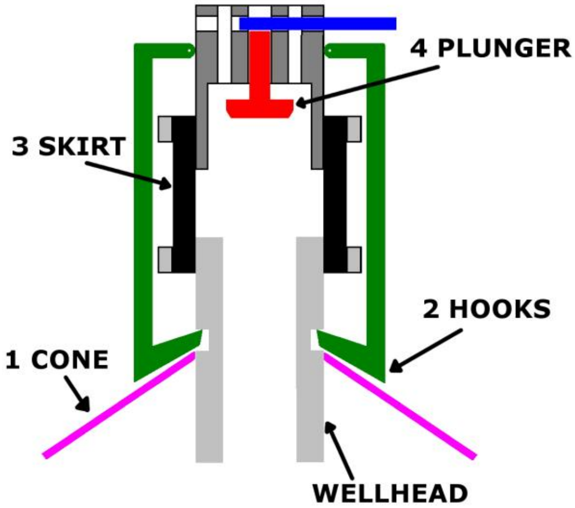


Figure 6 – The Wellhead Cap Cross Section

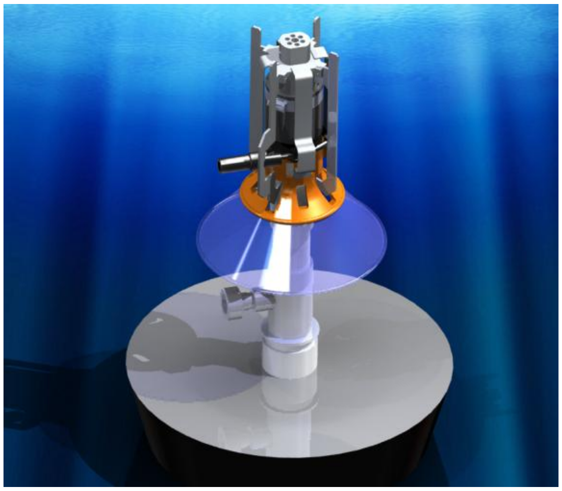


Figure 7 – The Wellhead Cap Installed

Pipe Cutter

The pipe cutter is designed to remove the Velcro strip from the wellhead by hooking onto the attached ring. Multiple prototypes were tested: the simplest, most effective, version featured six double-sided hooks, as seen in Figure 8. This design

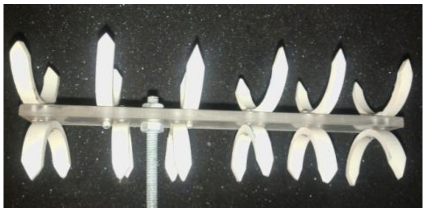


Figure 8 – The Pipe Cutter

allows the ring to be hooked from either direction, and requires minimal precision on behalf of the pilot, thanks to the large number of hooks.

Line Attachment

The design of our line attachment tool, depicted in Figure 9, was inspired by carabineers. The tool has a pair of spring loaded jaws which open in only one direction. These passive jaws open easily to clip on to the U-bolt, and will not slip off afterwards. The jaws are attached to a tube packed with a coil of rope, one end of which is held at the surface. As the ROV descends, the line uncoils as needed. This whole tool is attached with a magnet and pins to the body of the ROV, which allows the tool to slip off the craft once attached to the pipe and be pulled to the surface via a team member pulling the rope.

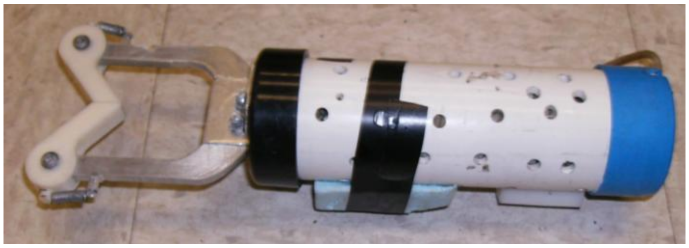


Figure 9 - The Line Attachment Tool

Water Sampler

The water sampler consists of three main components: guiding cone, tube feeder and storage tank. Each went through several prototype iterations before making it to the final assembly stage. The guiding cone consists of fine wire mesh, allowing the operator to see through it for ease of positioning over the inlet of the water sampling pipe. Once in position, the pilot engages the tube feeder assembly which uses rollers to force a ¼" tube through the pipe inlet all the way to the bottom of the sample bag. Finally, a solenoid valve connected to the storage tank is opened. Prior to starting the mission, the air in the storage tank is evacuated, leaving a vacuum inside. Opening the valve draws in the coloured water through the air tube to fill the vacuum. Upon visual confirmation that the clear walled storage tank has been filled, the solenoid valve is closed by the pilot and the sample is brought back to the surface. The guiding cone and tube feeder can be seen in Figure 10, while the storage tank can be seen in Figure 11.


Figure 10 – The Guiding Cone and Tube Feeder


Figure 11 – The Storage Tank

Crustacean Collector

The tool for collecting crustacean samples has been affectionately dubbed "the chicken grabber" due to its inspiration from a barnyard device used to catch chickens. It consists of two brushes rotating in opposite directions mounted side-by-side on the bottom of the ROV, which sweep the crustaceans into a holding basket. An alternate design that used water jets to push the crustaceans into the basket was prototyped but did not have sufficient force to push the larger crustaceans. The original concept of the tool was an external basket and brush assembly that would be self contained and able to mount to the bottom of the ROV. The final design, seen in the upside-down view of Figure 12, is completely integrated into the frame of the ROV to minimize its physical footprint. The brushes are constructed of pieces of a broom head mounted around central shafts. The holding box has a Velcro hatch on one side that opens to allow removal of collected specimens. This is a superior method of crustacean collection as it does not require the pilot to individually pick each one; rather, the craft simply sweeps across the bottom forcing them into its basket. As a safety feature, mesh completely covers the geartrain, eliminating any pinching hazards.

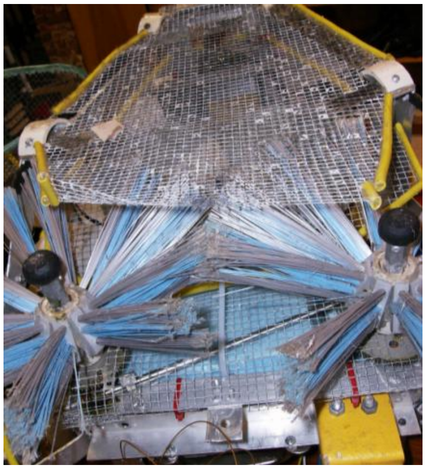


Figure 12– The Crustacean Collector

Active Buoyancy

This year, due to the depth of the pool, the team designed an active buoyancy system to quickly lift the craft upon mission completion. This is the first time that the privateers have undertaken an active buoyancy system, so emphasis was placed on simplicity and reliability. For safety, all elements of the buoyancy system are unpressurized. The final system consists of a soft, expandable reservoir.


Figure 13 – The Active Buoyancy Bag

The soft, expandable reservoir shown in Figure 13 is a bag that has an air hose run to the top of it. It is folded and tucked into a canister to keep it compact and isolated until deployed. Once the missions are complete and the ROV must return to the surface, air is pumped into the reservoir causing it to balloon, as seen in Figure 14. This inflation shifts the ROV to a positively buoyant state and returns it to the surface in a matter of seconds. The bag is completely open on its bottom, ensuring that the air within inherently cannot exceed ambient pressure; if it does, air simply bubbles out to the surrounding environment.

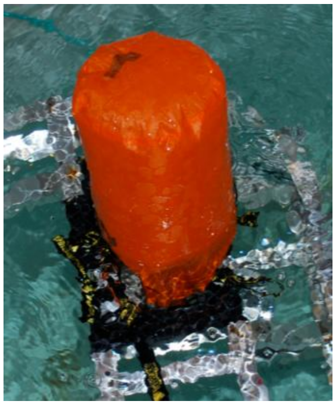


Figure 14 – The Inflated Buoyancy Bag

Propulsion Systems

Custom Propellers

This year the team wanted to maximize the efficiency of the propellers by designing them to harness maximum amount of power that our motors could output. To accomplish this objective an internal competition was held in which a number of the members designed propellers, which were prototyped using a 3D printer. These designs, shown in Figure 15, were

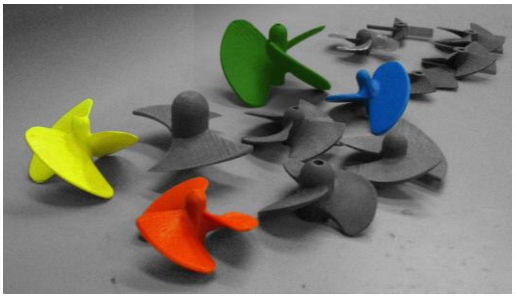


Figure 15 – Propeller Testing

tested on a homemade thrust-gauge to find the most efficient design. Several variations on the best design were then printed and tested to create a final, optimal design. This final design is a four blade propeller with a pitch of 9.9cm on the blades. It measures 7.6cm in diameter and is designed to fit inside a cowling to increase efficiency and enhance safety.

Vertical Propulsion

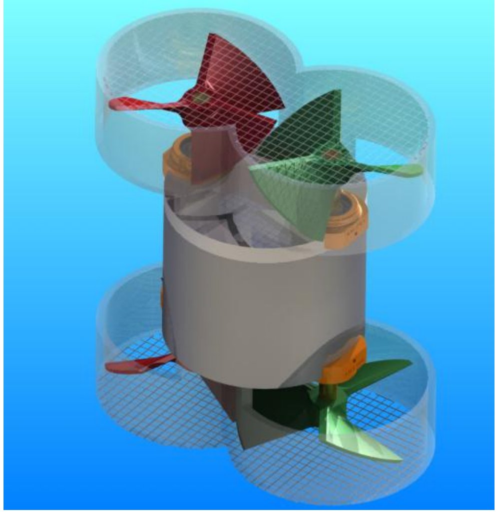


Figure 16 – The Hyperdrive

The vertical propulsion for the craft is achieved through a single centrally mounted high power thruster nicknamed the Hyperdrive, seen in Figure 16. The main benefits of the Hyperdrive – high thrust output, compact form factor, and negligible net torque on the craft – were achieved by designing one motor to run four large counter rotating propellers which overlap without interfering with each other. Custom constructed by team members, the Hyperdrive is powered by a DC permanent magnet motor which runs at 18V and outputs up to 180W of power during operation. This motor is mated to a custom 6:1 gear reducer driving two counter rotating output shafts. The shafts protrude out both sides of the assembly allowing 4 propellers to be driven without any thrust bias between directions. The enclosure of the Hyperdrive is aluminum and has 5 sealing interfaces: 4 shaft seals for the output shafts and single O-ring seal for the main lid. These seals have been tested to withstand twice the required pressure. Refer to Appendix A for an exploded view showing the Hyperdrive design.

After careful testing it was determined that the Hyperdrive motor can withstand 48V for short periods of time without damage. To take advantage of this, a secondary power system was developed which will run the Hyperdrive in a single direction from unregulated 48V using a set of relays. This feature allows for exponentially larger thrust output from the Hyperdrive and will be used to quickly descend to the bottom of the pool upon mission start.

Horizontal Propulsion

The horizontal propulsion system is made up of four custom made thrusters in vector arrangement. These bi-directional thrusters can be engaged to produce net force that not only moves the craft forward and back but also allows it to strafe or turn on the spot. A diagram explaining the how this system works is shown in Figure 17. The custom lateral thrusters, like the one seen in Figure 18 were designed by the team to consist of low cost, easily replaceable components. The thruster assembly is enclosed in a watertight case made

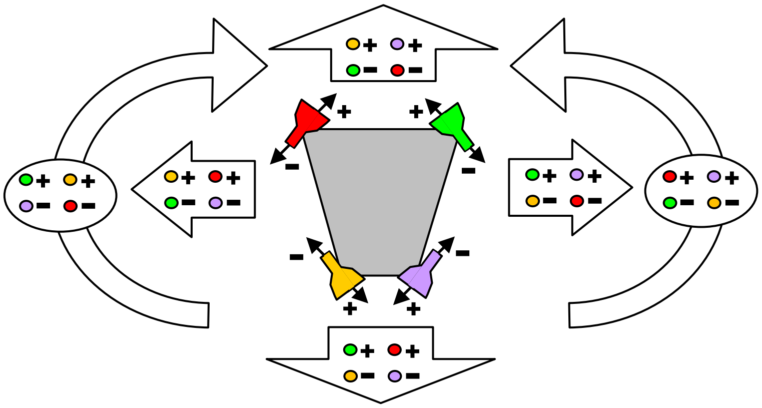


Figure 17 – The Vector Propulsion System

of ABS fittings with a grease packed double seal interface tested to withstand up to 30 psi of pressure differential. The source of power to the thruster is permanent magnet 24V DC motor operating at approximately 40W. The thrusters were designed to be swappable in under one minute, and spares have been assembled as emergency replacements. A detailed view of the horizontal thruster assembly and its components can be found in Appendix B.

Figure 18 – A Lateral Thruster

Command Center and Dryside Electronics

Figure 19 - The Command Center

The Command Center, pictured in Figure 19, acts as the interface for the ROV, sending power and data to the system, and receiving the return data. The command center consists of power control units, safety and current control measures, and two monitors for displaying camera feeds. These elements are packaged in a clamshell casing with components behind protective plastic shields, resulting in a sleek, self contained, and portable unit

Video Switching

The signals from the four cameras on the craft are all run up separate coaxial cables. A pair of signals is routed through a single pull changeover switches. This results in the ability to have four cameras displayed across three screens, using the switches to change which camera is currently being displayed on the corresponding screen.

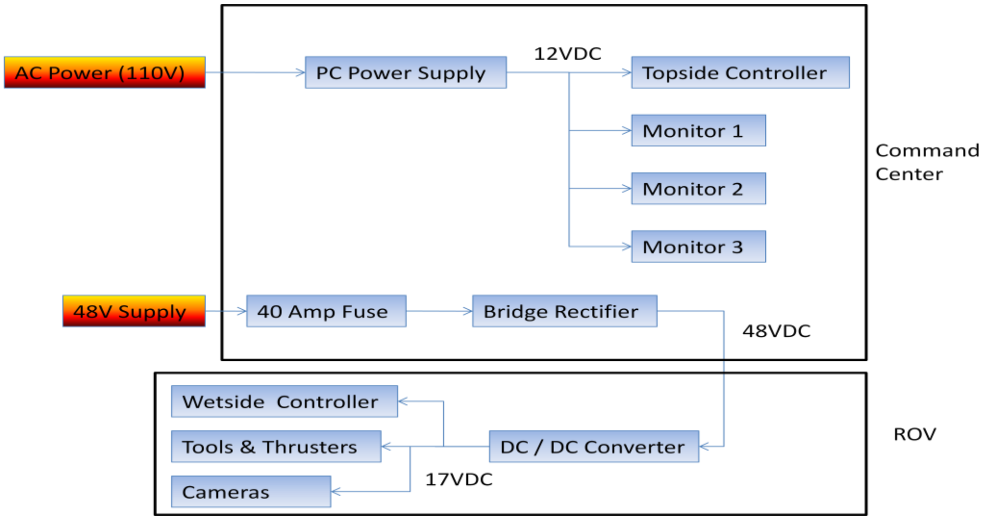


Figure 20 – Power Schematic

Power Routing

The 48 volt DC competition power supply routes into the command center and directly through a 40 amp fuse before entering a diode bridge rectifier which provides reverse polarity protection. A 50 amp switch controls supply through the tether and ROV. The 120 Volt AC power goes through a PC power supply to give the required filtered +12 volt DC for monitors and topside control systems. A schematic showing the power routing is seen in Figure 20.

Custom 48VDC Power Box

The 48V DC power box was built last year as an easily transportable power supply for the ROV. It is useful when testing in remote locations such as the deep water tank. It incorporates safety features such as a 40A fuse and an emergency stop button.

Tether

The ROV's tether is used to transmit power, data and air between the ROV and the surface. The tether consists of a power line, two data lines, four camera lines, an air tube, and an outer wrapping to hold it together. The signal lines are shielded twisted pairs for transmitting video signals, control data, and depth sensor signal. By using the shielding of the twisted pairs to ground the video signals, much of the noise in the cable can be eliminated, resulting in a clearer signal and leaving the second wire from the pair to be used for differential signals. The air tube is a length of flexible plastic tubing with a 4.3mm inner diameter used to inflate the ROV's active buoyancy system. This tube is rated to the 100psi competition requirements. The tether measures 24m in length, to allow the ROV to reach the bottom of the pool with plenty of slack for maneuvering, and is neutrally buoyant to avoid placing an unbalanced force on the craft.

Wet-side Electronics

Electronics Housing

The housing for the onboard electronics, depicted in Figure 21 is an aluminum pipe with a removable cap on one end, and a welded cap on the other. The housing features a

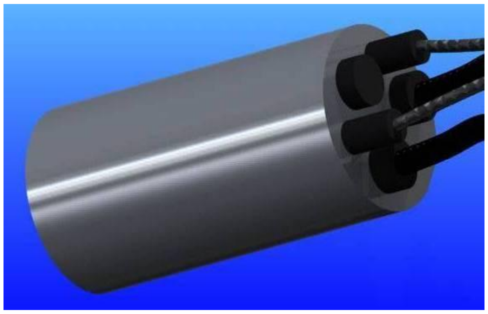


Figure 21 – The Electronics Housing

removable cap with two o-ring grooves machined into it to seal the tube. The dimensions for the o-ring grooves were taken from the *Parker O-Ring Handbook*[1] and are rated for up to 10 MPa. That cap also has five waterproof electrical connectors to facilitate easy tether removal. There are two NPT threaded holes in the welded end cap of the housing. This gives the option to fill the housing with oil to help cool the electronics, and as an extra safety measure to prevent any water from damaging the hardware. Aluminum was chosen for its strength, low weight, good heat conductivity, and relatively low cost. All machining was done in house at Dalhousie University by ROV Team members.

The electronics hardware is mounted on an aluminum plate, with the plate attached to the inside of the removable cap by a bracket. By mounting the electrical hardware on the aluminum plate, the plate acts like a heat sink with a thermal circuit directly connecting it to the surrounding water. Additionally, by having the plate attached to the cap, the electronics are pulled out with the cap to allow easy access to everything inside the housing.

Power Conversion

The ROV receives power through the tether at 48VDC, which must be taken down to lower voltages to be used by the motors and onboard electronics. A switching DC-DC converter regulates the voltage down to 17V to power the motors. This power is further regulated to lower voltages for the onboard electronics.

Cameras

The Betta Project features four miniature NTSC security cameras, such as the one pictured in Figure 22. Identical cameras were used last year, but suffered from leakage and lens fogging. To prevent similar issues from reoccurring, the entire camera case except the lens was filled with epoxy potting. This waterproofing system creates both a perfect seal and reduces the volume of air inside the camera to levels too low for lens fogging to occur.

Figure 22 – An NTSC Security Camera

Depth Sensor

The ROV depth sensor uses two MPX4250 absolute pressure transducers on a custom circuit board housed in a section of ABS pipe. A vinyl tube connected to the housing and open to the water allows the air in the depth sensor to be equal to the surrounding water pressure without letting water leak in. Using the ADC of the microcontroller, the analogue pressure data is converted to cmH2O in the firmware using a calibration curve and sent to a topside laptop and displayed on screen. There is a tare function in the firmware which allows the depth reading to be set to zero at any pressure to account for possible changes in atmospheric pressure and to set a reference point on the ROV to zero depth. The depth sensor measures in increments of 5 cm with an accuracy within 1.5% as found via system testing.

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[1] P92, Parker Seals, *Parker O-Ring Handbook*, Cleveland: 2007

Control System

Overview

The student-designed electronic control system for the ROV consists of two parts that communicate with each other. The topside of the system contains a physical Xbox controller and a PIC microcontroller to read and interpret the button presses from the command center, as well as the positions of two analog joysticks. Control data is sent through the tether from the topside processor to the wetside in the form of serial data packets. Motors and tools are switched on and off by also by the wet-side microcontroller. The variable speed ROV propulsion system is controlled by Pulse Width Modulation (PWM) signals generated by the wet-side microcontroller.

Topside

This chip acquires variable speed motor control data by reading the analogue values from the four potentiometers in a modified Xbox controller through the 10 bit analogue to digital converter module in the PIC18F4685. The raw ADC values are calibrated in the software to provide an 8 bit number in the range of -100 to 100. When the joystick potentiometers are in their zero position, they may move approximately 5% of their total rotation angle in any direction while maintaining an output of zero. This is to prevent accidental engagement of the perpendicular axis when moving a joystick in one direction. The on-off data is read from up to 16 buttons connected to the I/O ports of the microcontroller.

This data is formed into a "packet" of information, and transmitted down to the ROV itself. This packet consists of 10 bytes of information: a “start signal”, a set of 4 analog values that define positions of the analog joysticks, 2 bytes that contain information about the status of the controllers’ buttons, and a “finish” signal. Electrically, the system uses an RS422 type signalling, which utilizes a differential mode of communicating ones and zeros. Any noise induced in the line is common-mode, and is filtered out on the terminating end. See Figure 23 for details on the communications software flow.

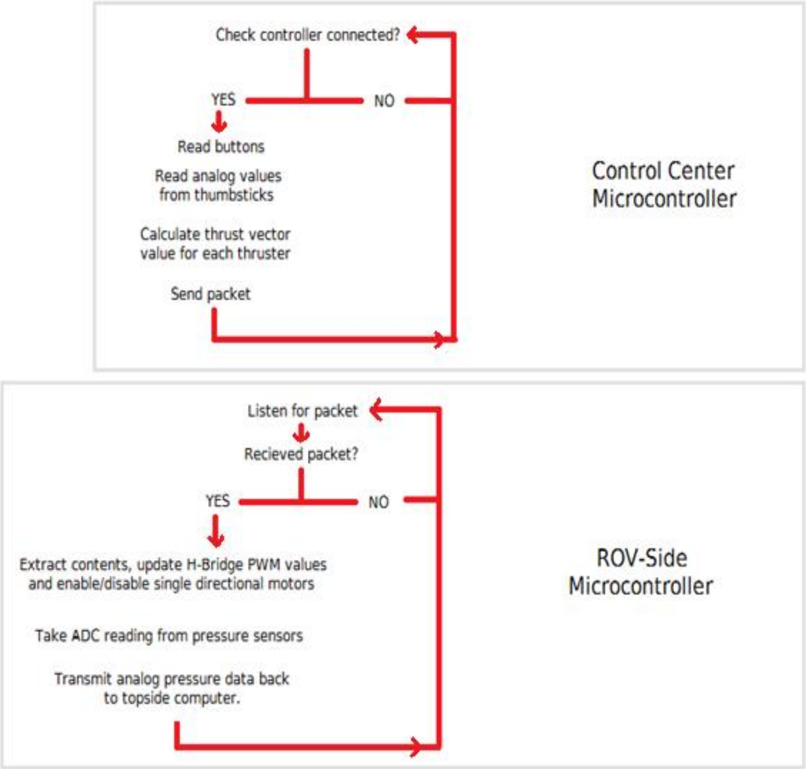


Figure 23 - Software Flowchart

Once the bottom side receives this data, it decompresses it into individual control signals, which activate MOSFET-based motor drivers, PWM-based H-Bridges, and any other utilities needed. Our H-bridge modules are controlled with a PWM signal provided by the microcontroller. A duty cycle of zero to 49% powers the motor clockwise, 50% is a “brake” condition, and from 51% to 100% is a counter-clockwise motion. The topside and bottom side control printed circuit boards were designed and populated by team members specifically to match our ROV in order to accomplish this year’s missions. Particularly important is the variable speed control offered by the use of PWM motor drivers; this gives the pilot extremely fine control over all thrusters, greatly enhancing drivability. A photo of the wetside control circuit can be seen in Figure 24, and a comprehensive schematic can be found in appendix C.

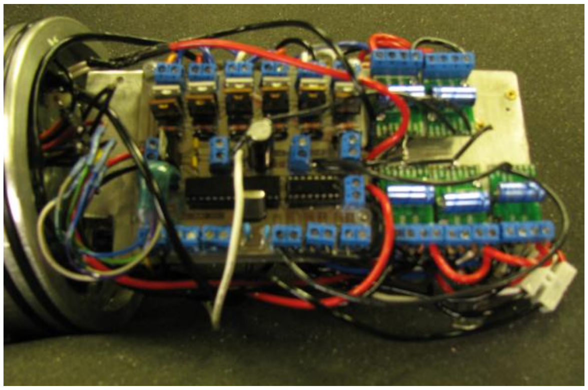


Figure 24 – The Control Circuit

Frame and Assembly

The frame was the last system the Privateers designed. The goal was to make it conform to the tools, propulsion system, and electrical system as closely as possible to conserve space. The team first created styrofoam mock-ups of each piece. These pieces were assembled into a single central unit. Cardboard mock-ups of angled aluminum were used to build a frame around this core, leaving as little empty space as possible. This frame was used as the blueprint for the final frame made of angled aluminum: the sleek blunted arrow shape seen in Figure 25


Figure 25 – Frame Design

Challenges Faced

This year, the team faced both technical and non-technical challenges. A significant technical challenge was the depth that the ROV would need to operate at. At a depth of 12m, this year’s competition pool is nearly seven times as deep as last year’s, which requires an ROV that can withstand higher pressures, and make faster ascents and descents. This challenge was met by the team investing a great deal of time and effort into optimizing their vertical propulsion system and developing an active buoyancy system.

A unexpected non-technical challenge encountered this year was the team’s rapid growth, which led to some issues with crowding in the Privateers’ workshop. At the beginning of the year, many sub-teams had their work sessions scheduled on the same night as other sub-teams, leading to interference and lack of results. This was solved in two ways. Firstly, meetings that didn't require workshop resources such as brainstorming meetings were moved to other rooms to help make space. Secondly, the team moved away from rigid meeting times. Instead, the team leaders made an effort to keep the workshop open on as many nights as possible, allowing individual members to come in at times that fit their individual schedule. This spread the members out over all nights of the week, leading to a far less crowded room.

Troubleshooting Tools and Techniques

Waterproofing was one of our biggest concerns, and it was difficult to test whether the ROV's wiring was perfectly waterproof, as a small leak in relatively non-conductive freshwater wouldn't affect the craft's performance enough to be detectable.

The troubleshooting technique employed was to break the problem down and design ways to test the individual components, before bringing the craft back together for assembly testing.

To accomplish testing of individual units at depth, a small pressure vessel was used. This pressure vessel, designed last year, can be filled with water and pressurized with an air compressor to simulate the water pressure at depth. The pressure vessel was modified from last year's model to include electrical inputs, allowing the team to test operating thrusters under pressure. Small containers of salt water were used to test components in a highly conductive environment.

Once individual components had been verified, the Privateers made their whole workshop test tank highly conductive by dissolving 100kg of salt in it. This allowed for easy diagnosis of connectivity issues, ensuring the craft will run in any pool.

Future Improvements

Every year, the Privateers strive to increase the efficiency and manoeuvrability of their propulsion systems. One of the goals for next year's propulsion system is to give the pilot control over the ROV's pitch and roll to allow our pilot to manoeuvre the ROV in any conceivable orientation.

The team also has room for improvement in the PR department. While the team has a website and various brochures to show potential sponsors, the team would benefit greatly from a dedicated PR manager. The person who holds this position would be responsible for documenting the ROV's progress with pictures and brief descriptions of completed tasks every week. They would also be responsible for compiling monthly newsletters, which can be sent to current sponsors to update them on the team's progress. These weekly updates and monthly newsletters will also prove extremely valuable for writing the team's final report.

Lessons Learned and Skills Gained

Some of the most valuable lessons the Privateers learned this year were on team organization. In previous years, the team organized itself into two large subteams: electrical and mechanical. This year, the team attempted a much more distributed structure with many smaller subteams, each with their own leaders. With frequent meetings called by the CEO between all of the leaders, the project stayed on task, and was completed well ahead of schedule. We have learned through this experience that breaking the team down into small specialized teams is an extremely productive way to organize a large and constantly growing team.

The team made a dedicated effort throughout the year to continually improving the skills – leadership and technical – of its members. Team leaders practised peer mentorship by holding workshops in fields such as CAD drafting and microcontroller programming. More experienced members actively sought to increase their skills by investigating engineering design guides such as the *Parker O-Ring Handbook* and by approaching Dalhousie technicians for machining advice. All members gained teamwork skills working together as the largest Privateers team to date.

Reflections

"Being on the team made my classes more relevant as I could picture how the circuits I learned in class could be applied to practical design. Organizing new members and teaching them basic electrical engineering principles and techniques gave me confidence and valuable practice in a leadership role"
– Irenee Jantz-Lee

"My time with the Privateers helped me decide between computer science and electrical engineering by giving me a hands on experience with aspects of both degrees."
– Michael Duguay

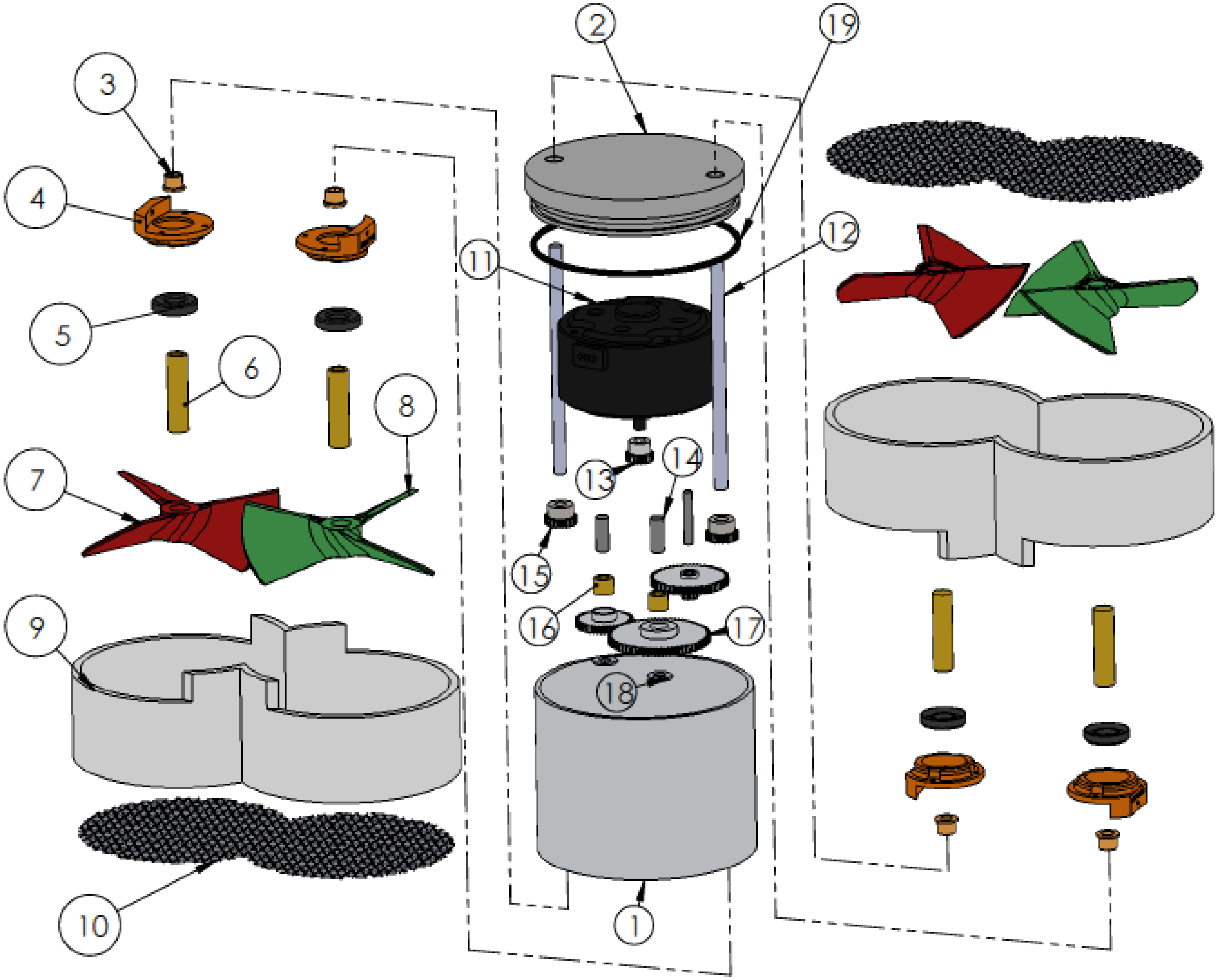
"I enjoyed overseeing the whole project – I had a lot of experience from the last few competitions, and could use that knowledge to push the craft in a direction that would make it even more successful."
– Dainis Nams

"The past two years on the Privateers have really boosted my confidence with power tools, prototyping, and all the hands on construction skills that are so important in my future career as a mechanical engineer"
– Andrea Felling

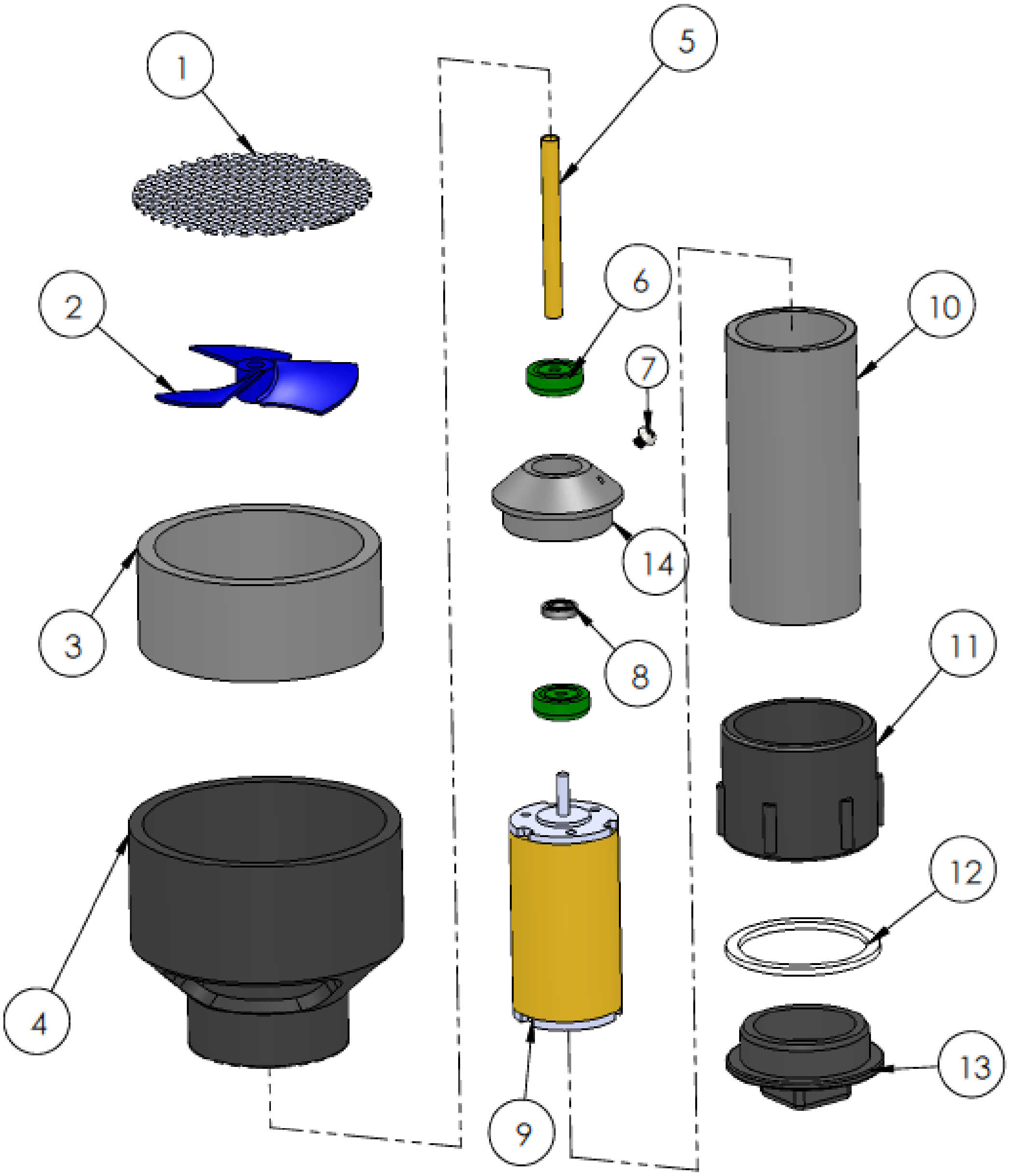
Appendix A – Hyperdrive Exploded View

Legend

#	Item
1	Main Enclosure
2	Enclosure cover
3	Brass Bearing x4
4	Seal Housing x4
5	Seal x4
6	Shaft Extension x4
7	LH Propeller x2
8	RH Propeller x2
9	Cowling x2
10	Mesh Guard x2
11	DC Motor
12	Propeller Shaft
13	Motor Pinion
14	Gear Retaining Shaft x3
15	Output Gear x2
16	Brass Bushing x2
17	Intermediate Gear x3
18	Spacing Washer x2
19	O-Ring



Appendix B – Lateral Thrusters Exploded View



Legend	
#	**Item**
1	Mesh Guard
2	Propeller
3	Propeller sleeve
4	Cowling
5	Propeller Shaft
6	Shaft Seal x2
7	Grease Hole Plug
8	Bearing
9	DC Motor
10	ABS Pipe
11	Endcap Fitting
12	Sealing Washer
13	Endcap
14	Seal Housing

Appendix C – Control Circuit Schematic