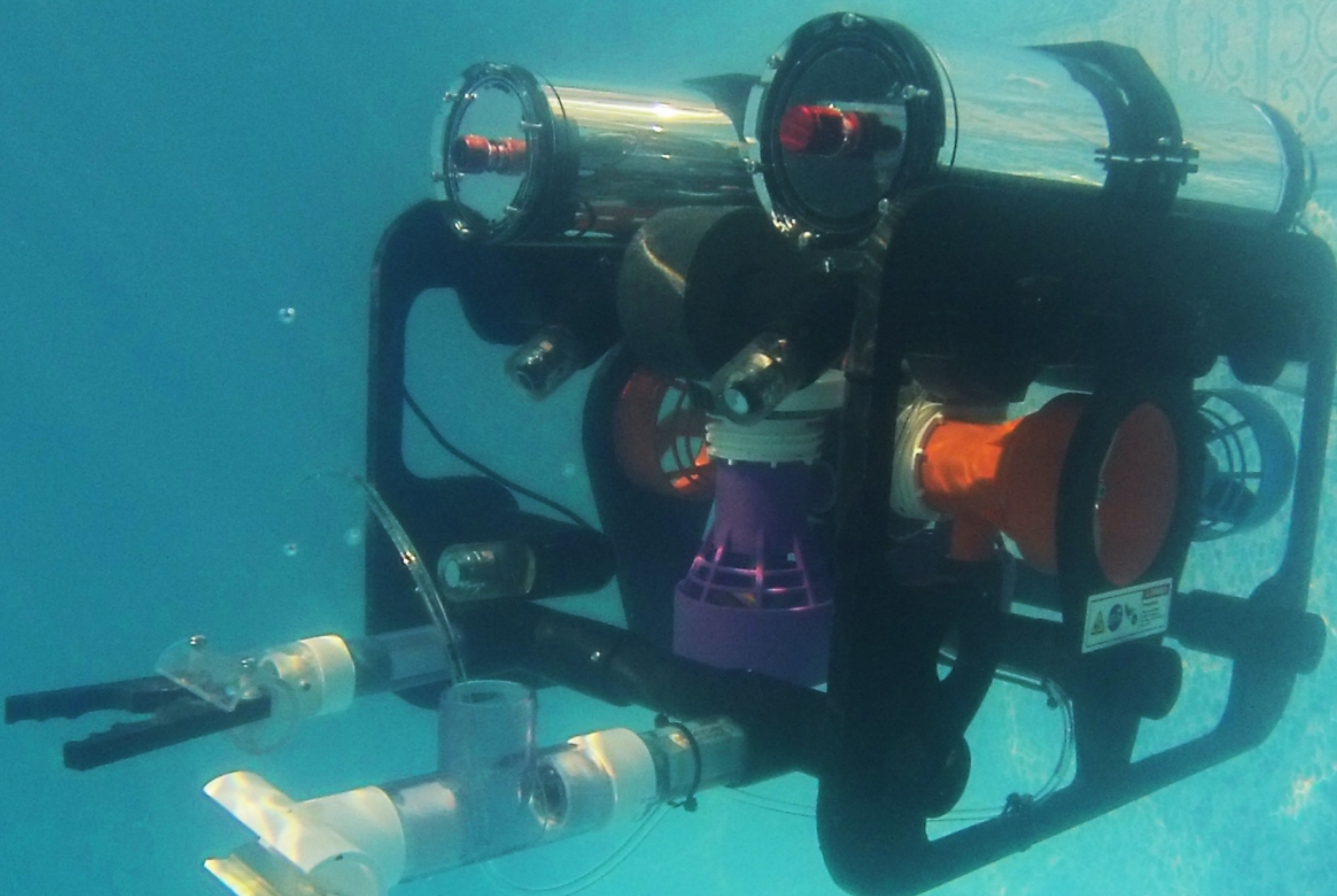
FIRST FLIGHT ROV

FIRST DESCENT SOLUTIONS

2018 Technical Documentation



2018 Team Members

Mac McClary, Senior: CEO
Jacob Thomas, Freshman: COO
Jack Voight, Freshman: CFO
Eliot Piland, Freshman: Staff
Will Roepcke, Freshman: Staff
Drew Whitehead, Freshman: Staff
Robert Amoruso, Senior: Intern
Noah Corbett, Freshman: Intern
Isabell Eckard, Senior: Intern
Ashby King, Sophomore: Intern
Bryce Pugh, Senior: Intern

Andrew Thomas: Mentor
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I. Abstract

Since 2008, First Descent Solutions (FDS) has specialized in developing unmanned, underwater Remotely Operated Vehicles (ROVs), and continues to design and adapt high quality, low cost ROVs that are specialized to collect data and perform tasks in the waters of the Pacific Northwest. FDS' latest prototype, ROV-*PHIL*, is designed to complete mission tasks set forth by the Applied Physics Laboratory, as well as maintain flexibility in all types of work environments. ROV-*PHIL* features integrated components that ensure safe and efficient completion of diverse requirements. FDS has engineered new tools to quickly and reliably recover vintage aircraft, recover a subsea seismometer, install a tidal turbine array, and place a sensor array to monitor the environment. The assimilation of multifunctional payload tools into the ROV frame allows for more time in the water and less time in the maintenance facility.

FDS aims to create innovative and efficient ROVs that set FDS apart from industry competition and puts our ROVs at the peak in their field. Building on an award-winning platform, this year's prototype has the potential to be FDS' best performing vehicle yet.

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II. Introduction

First Flight ROV has worked to design and innovate ROVs since 2008. After competing in numerous regional and international MATE competitions, as well as a first-place international finish in 2010, First Descent Solutions, a division of First Flight ROV, has acquired an understanding of the requirements and expectations as a competitor in the MATE competition. FDS is presenting our latest prototype, ROV-*PHIL* for your consideration as stated in the Request For Proposal. ROV-*PHIL* has been purposefully designed to accomplish a diverse range of mission tasks. ROV-*PHIL* is the culmination of advances that have been refined over the past three years. FDS' sleek design and user-friendly software platform is perfect for applications all over the world.

2018 Team members, left to right:
Mac McClary, CEO, 3rd year member
Ashby King, Intern, 1st year member
Bryce Pugh, Intern, 1st year member
Isabell Eckard, Intern, 1st year member
Drew Whitehead, Staff, 3rd year member
Jacob Thomas, COO, 3rd year member
Robert Amoruso, Intern, 1st year member
Will Roepcke, Staff, 3rd year member
Noah Corbett, Intern, 1st year member
Jack Voight, CFO, 3rd year member
Elliot Piland, Staff, 2nd year member

III. Corporate Structure

In order for FDS to remain productive full time with a large, 11-member company, FDS employs a chain of command throughout the company to cooperatively delegate necessary assignments. While the entire team contributed to the comprehensive design of ROV-*PHIL*, there is a deliberate breakdown of task assignments. Operating with administrators named as CEO, CFO, COO, and other specialists allows FDS to efficiently manage and inform its eleven members. FDS' CEO is responsible for finalizing all decisions, overall management of tasks, and ensuring that correct protocol and procedures are being followed. The CFO is responsible for all financial documents and decisions. This individual also works with the team closely to guarantee the most cost-effective, productive, and safe ROV, as well as ensuring that the company is within budget constraints, which are constantly changing with dynamic capital. The COO oversees the team as a whole and directs the day-to-day operations of the team. The CEO and COO work closely with the engineers to assign fitting jobs to each, while keeping all team members capable of working on diverse projects. Areas of work during the design and building processes are software, financial responsibility, electronics, construction, mechanics, testing, and payload tools. Using this system of workload designation allows FDS to operate at full capacity and efficiency while not limiting its quality expectations. The structure provided by this division of labor allows for the sharing of ideas and opportunity for constructive criticism.

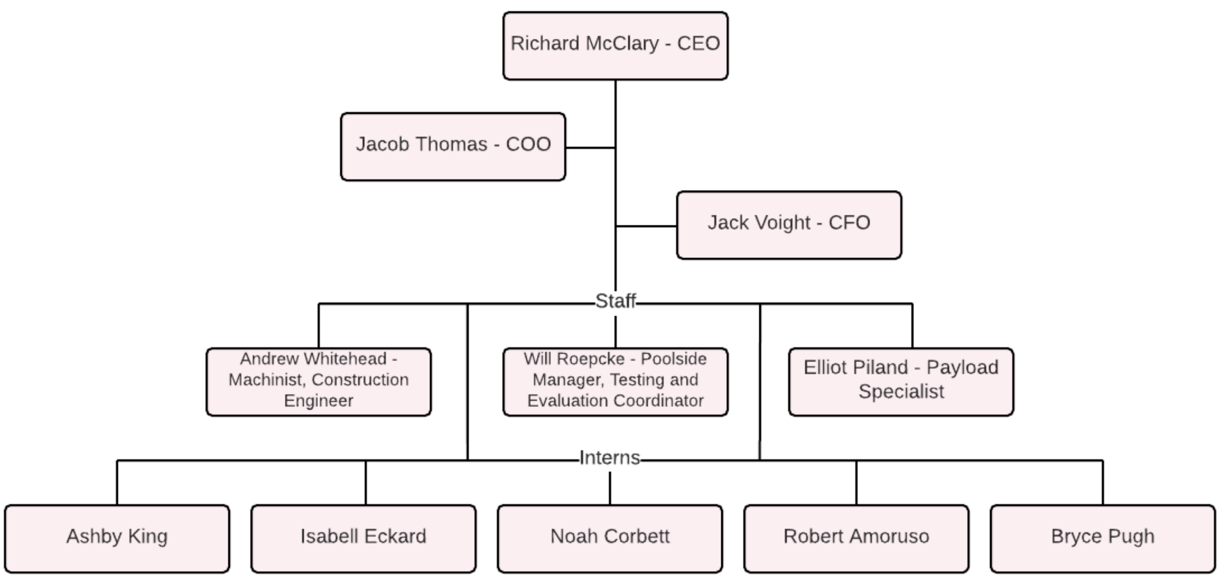


Figure 1: Corporate Structure Flowchart

IV. Design Rationale

All FDS ROVs are designed with safety as well as performance enhancement in mind. In order to accomplish this, the design ROV-*PHIL*, FDS' latest prototype, began with a collaborative discussion with all team members. Size and weight restrictions, tooling needed, and safety were all considered during initial design discussions. The overall design of ROV-*PHIL* is the product of planning, as well as the combination of previous successful vehicles. Hosting an open collaborative design discussion allowed all team members to put forth ideas and address potential obstacles that may need to be overcome.

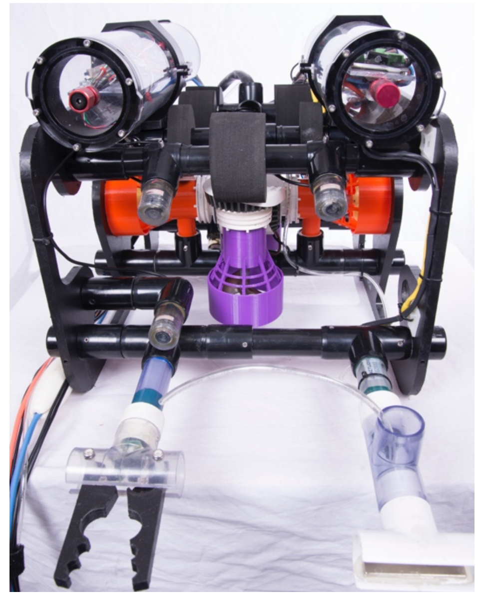


Figure 2: Completed ROV-*PHIL* (Photo McClary)

a. Frame

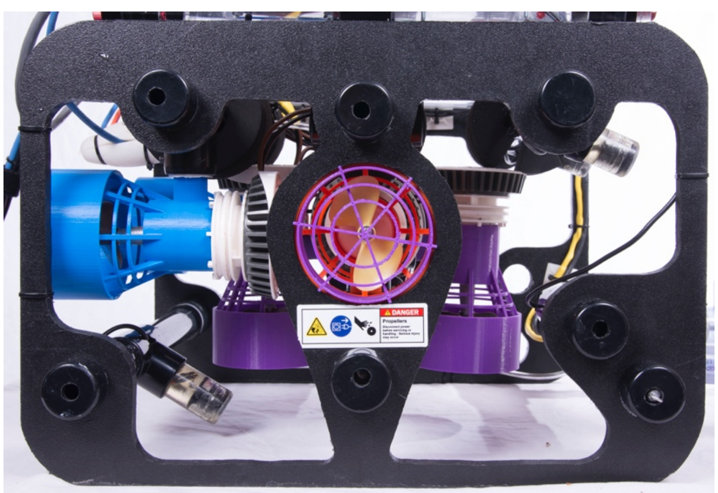


Figure 3: The right-side panel of ROV-PHIL's frame (Photo McClary)

Designed to be lightweight, safe, sturdy, and serviceable, ROV-*PHIL's* frame consists of two side panels made of low-density polyethylene seaboard connected with furniture grade PVC. Medium Density Fiberboard (MDF) was used to prototype the frame, and size the vehicle. The frame design was finalized by mapping out where each hole should go on the MDF frame. To cut the seaboard frame, a straight router bit was used. The cut MDF stencil was fastened onto the seaboard frame and traced with the router, essentially copying the cuts made in the MDF to the seaboard. In between the two sides are six thrusters, four cameras, a linear actuator driven manipulator, linear actuator driven lift bag release, and two watertight electronic housings. ROV-*PHIL* was designed

specifically to ensure that the integral components are protected on multiple sides. This acts as a protection from debris and accidental external involvement.

b. Thrusters

In an effort to reduce weight, increase functionality, maneuverability, and safety, FDS has implemented 3D printed motor housings into this year's prototype, ROV-PHIL. In previous years attempts were made, but the company failed to devote enough time to perfect the motor housing designs. In order to ensure that the motor housings would be designed, printed and tested in a timely fashion, a 3D printing department was created. Over fifty hours of designing, printing and testing were dedicated to the design of new housings until the optimal motor housing design was achieved. The housings had to be aesthetically pleasing, increase efficiency, maximize safety, and comply with this year's Request for Proposal (RFP).

The first step in the design process was learning the RFP inside and out. As a company FDS had to make sure that ROV-PHIL would not just fulfill safety expectations, but rather exceed them. The overarching mission at FDS is to always innovate and go beyond the competition. After learning what was expected of the company, FDS began to gather measurements from this year's Tsunami T-1200 thrusters. The next phase was to design a prototype on Sketchup. Using these measurements, the designers created a custom fit housing for the thrusters. A major design component was the integration of safety coinciding with efficiency. Housings are designed to ensure that no loose articles of clothing or fingers are able to penetrate through the motor housing and make contact with the propeller. Sharp edges and minor print defects from the printing process were sanded down to ensure that there was no threat of personal injury.

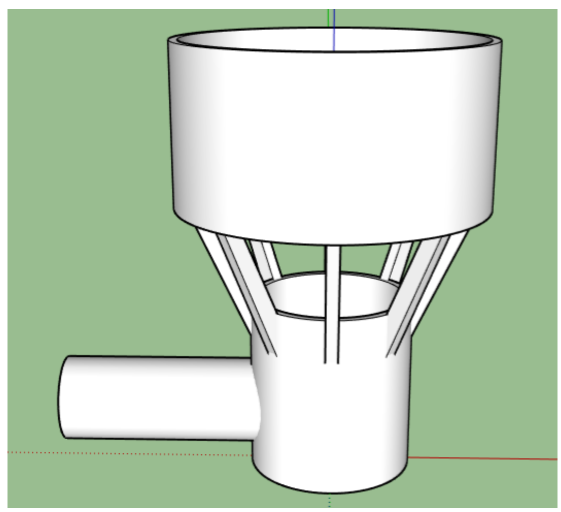


Figure 4: Initial motor housing design

FDS' high quality standards prevented the company from implementing the exact model seen in Figure 4. The bottom portion that attaches to the motor was too tight, and this made it extremely difficult to remove it from the motors without damaging the more delicate pieces. The housing also did not fit over the bilge pump motor as wanted. The good thing that came out of V1.0 is that it gave the designers a base model to work off of. From V1.0 to V4.0 the only things the engineers

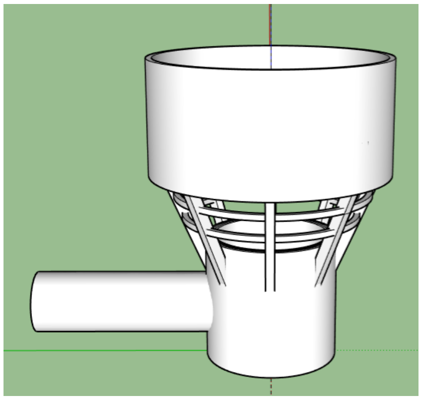


Figure 5: second motor housing design iteration

tweaked were the dimensions of certain sections. In order for the motor housing to attach to the frame of ROV-PHIL a ½in mock PVC pipe was designed to fit into the pre-existing PVC frame system. Within the final revision of ROV-PHIL's motor housings, FDS added additional safety measures including rings around open space, and a separate cap to cover the propeller. Pictured in figure 5 is the second iteration of motor housing designs. The rings prevent fingers and loose articles of clothing from being caught in the propellers.

To maximize safety an additional cap was designed. The cap slides inside of the propeller shroud, the upper section, and further closes down on excess space. For a snug fit the outer dimension of the cap is equal to the inside dimension of the propeller shroud. To prevent it from slipping too far in nubs were added on the outside to stop it. It is 23cm deep which allows it to sit roughly two thirds of the way down the propeller shroud.

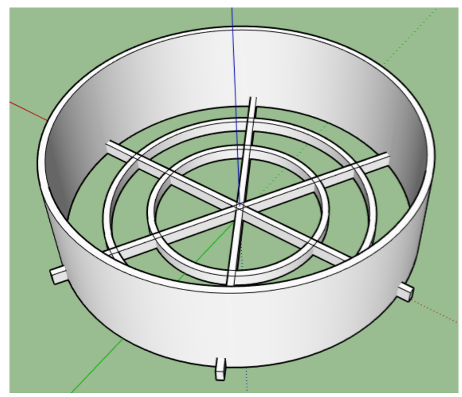


Figure 6: Safety Cap

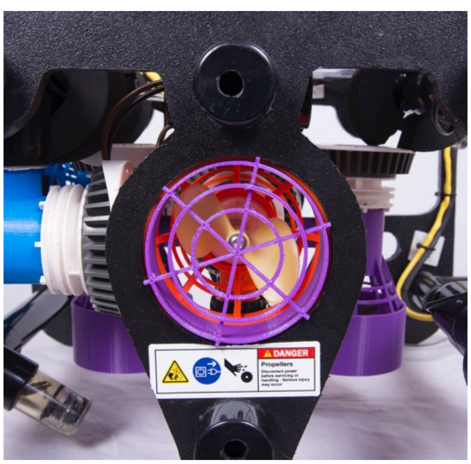


Figure 7: Installed Safety Cap (Photo McClary)

The frame of ROV-PHIL was designed around the thrusters, ensuring that there is no wasted space within the ROV frame. Instead of designing a frame structure, and fitting thrusters into spaces where they won't function at max capacity, FDS used the thrusters as the core of the vehicle. The frame, tools, and electronics housings were all designed with the thrusters in mind. No work could be started on frame until the housings were completed and installed. That is why this was one of the toughest and most important challenges FDS tackled.

Before fitting the motor housings onto the bilge pump motor, the bilge pump motor must be modified. First, the team sands down the shafts to fit the propellers. Next, props are attached to the modified bilge pump motors using prop adaptors. Two different 700mm, dual blade propellers are used on ROV-PHIL. Propellers with a 1.2 pitch are used for strafe motion, and allow for faster

acceleration, but a lower top speed. 1.4 pitch propellers are used for surge and heave motion, and allow for slower acceleration, but a higher top speed and maximum thrust output.

c. Tools

Manipulator

When designing the manipulator, the goal was a simplistic and robust tool, so logically the same material used in the frame, polyethylene seaboard, was used. The polyethylene is connected to a linear actuator located inside a length of ¾" acrylic PVC piping. Marine grease is layered into the linear actuator to prevent water from entering and damaging the inner parts of the actuator. Silicon is applied after the potting compound has set and leveled to ensure that it is watertight. The potting compound prevents electrical shorts and provides wiring with strain relief. The linear actuator employed by FDS is an Actuonix L12-s Micro Linear Actuator, with a 50 mm stroke and a max voltage rating of 13.5V. Contained within this is a DC motor with a 210:1 gear ratio. This gives the manipulator a middle ground between torque and speed.

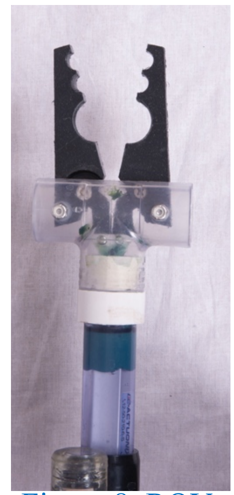


Figure 8: ROV-*PHIL*'s Manipulator (Photo McClary)

Lift Bag Inflator

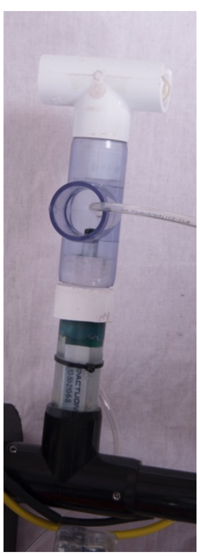


Figure 9: Lift bag release system (Photo McClary)

FDS engineering team's priority when it comes to a design is safety and efficiency. The lift bag inflator is made from a furniture grade PVC pipe and a snap-tee with a small fuel line that runs directly from an air compressor, along the tether, directly to the lift bags. FDS' lift bags consist of a beach ball with a custom fabricated locking mechanism using a linear actuator potted into the snap-tee to be able release the lift bag once it is full. The lift bag is a tool that when inflated has the ability to burst and release a large amount of pressurized air, designing a way to prevent the lift bag from bursting is necessary step for safe operation. To prevent the lift bag from bursting an open system is integrated so all excess air can flow freely through the opening in the bottom of the lift bag. An open system allows air in the system to interact with air outside and vice versa, this enables air inside the beachball to escape if the pressure is too great. This insures a low-pressure system to prevent dangerous working conditions.

Magnetic Release

The magnetic release was designed by FDS to open the OBS. It follows FDS' ideals of simplicity in design. It leaves very little room for error, and any user can easily learn how to use it. FDS aims to create innovative solutions through simplicity. The magnetic release system onboard ROV-PHIL is no different. The magnetic release system consists of a nickel-plated neodymium magnet and one ¾" PVC snap tee. FDS' first step was inserting the neodymium magnet into the two-way opening of the snap-tee. Once the snap tee has been inserted the nickel-plated neodymium magnet is epoxied onto the base in the snap-tee. When the epoxy is set the magnetic release tool is ready to be attached to ROV-PHIL and be utilized.

d. Sensors and Cameras

ROV-*PHIL*'s four cameras are positioned strategically for optimum viewing angles to aid in the completion of mission tasks. Two cameras located on the front of the vehicle are angled down to view all tools and are used for piloting the vehicle. A third camera is mounted directly above the manipulator to provide a level view of onboard tools. The cameras chosen for the vehicle are automotive backup cameras (figure 10).

Figure 10: One of four cameras onboard ROV-*PHIL* (Photo McClary)

Backup cameras are a cost-effective and simple ensuring integrity and quality, with a strong reliable connection. While they are perfect for use on ROVs, these cameras are not made watertight. To rectify this, all cameras are waterproofed in-house. In order to safeguard the integrity of the camera and the safety of others in the mission site, no water can enter the camera and interact with the cabling, In the waterproofing process, a camera is first placed in a ¾" acrylic PVC tube with an acrylic end cap fixed onto the lens of the camera. This prevents external damage to the camera and provides a means of attaching the camera to the vehicle's frame.

After the camera is well fitted into the PVC, the wires are cut short and soldered camera cables in the tether. Minimum soldering on each camera ensures superb video quality is maintained. To ensure no water enters the solder joints, dual wall heat shrink is added to give the solder joint needed insulation. Lastly, Scotch Weld potting compound is added into the clear PVC until the

solder joints are covered. Potting is a process of completely filling an electronic assembly with a solid or gelatinous compound for resistance against shock and vibration, and for exclusion of moisture and corrosive materials. With the potting compound set, a level layer of silicon is added to ensure proper strain relief of the cable entering the camera assembly. All four camera cables run from ROV-*PHIL* directly to a quad splitter inside the control box, allowing all four cameras to be viewed simultaneously.

Figure 11: Video Quadsplitter (Photo McClary)

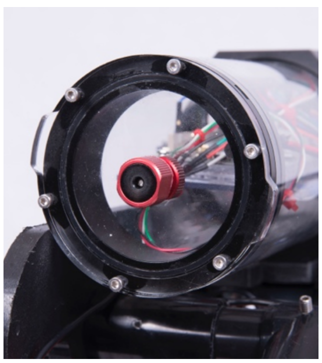


Figure 12: Installed depth sensor (Photo McClary)

ROV-*PHIL* features a Blue Robotics Bar30 High-Resolution 300m Depth/Pressure Sensor (figure 2). The sensor is used to measure distances during the energy task of the mission. In addition to measuring depth for mission tasks, the depth sensor ensures that the pilot does not exceed its max depth rating of 20 meters. The depth sensor is pre-calibrated by Blue Robotics to a depth resolution of 2mm. The sensor communicates using an I^2C communication bus, and is fixed to ROV-*PHIL*'s Blue Robotics Watertight Electronics housings. By utilizing preexisting code for the Bar30 sensor and the arduino I^2C library, FDS software engineers were able to integrate the depth sensor into ROV-*PHIL*'s software. In addition to collecting depth data, the sensor also collects temperature data, which can be utilized for future advancements and missions if needed.

e. Ballast

Buoyancy is considered as soon as planning and construction begins on the ROV. By starting with a negatively buoyant system, flotation can be added in order to achieve neutral buoyancy. Keeping low weight and maximum maneuverability in mind, no weights should be added to the vehicle to achieve naturally buoyancy when starting with a negatively buoyant system. To ensure that the ROV reflects its actual buoyancy during initial testing, all frame pipes are flooded with water, removing the trapped air that would add buoyancy. Once the ROV is negatively buoyant, Archimedes' Principle is used to calculate the amount flotation needed to achieve neutral buoyancy. Archimedes' Principle states that the force of buoyancy is equal to the volume of water

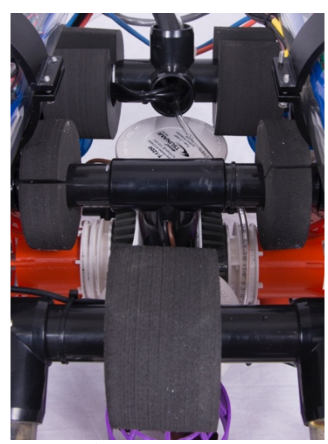


Figure 12: Foam flotation pieces (Photo McClary)

displaced. The frame of the ROV has a mass of 10.5 kilograms, equating to 11 liters of water displaced by the vehicle. The two Blue Robotics watertight electronics housings are responsible for most of ROV-PHIL's floatation, each being three inches in diameter with a mass of 0.2 kilograms. The remainder of the flotation needed to achieve neutral buoyancy is achieved using mobile pieces of high density foam that are attached to the frame of the ROV. The low mass and large volume of the foam creates a perfect material for displacing water and adding floatation. The use of foam pieces (Figure 12) allows for position adjustments to quickly level the ROV.

f. Tether

Figure 13: ROV-*PHIL*'s tether (Photo McClary)

ROV-PHIL's tether consists of two power cables, four camera cables, one Cat5e cable, and a 3/16in polyurethane airline. FDS chose 10-gauge Arctic Ultraflex Blue wire (made by Polar Wire) because of its high flexibility at subzero temperatures, and extremely high flexibility at warm temperatures. 10-gauge wire was chosen over past years 8-gauge wire in order to decrease weight and further maximize flexibility. By decreasing tether weight and increasing tether flexibility, vehicle maneuverability is dramatically increased. The Cat5e cable carries serial data between the topside and onboard Arduino microcontrollers. The four individual camera cables are separated to ensure superb video quality with no interference. All four cameras are displayed on a home security quad-splitter. The 3/16in polyurethane air tube delivers air to the lift bag inflation system. This is controlled by a valve on the surface. The tether is bound at 50cm with Velcro as opposed to zip ties, which would create a hazardous sharp edge. In order to ballast the tether, small fishing buoys are placed along the tether at 50cm intervals to achieve neutral buoyancy. With a neutrally buoyant tether, drag in the water is reduced, as the tether does not pull the vehicle downward. FDS' new tether is a great improvement from past years' 18-gauge, 18 conductor wire. By moving ROV-PHIL's motor controllers from the control box to onboard the vehicle, less voltage was lost with the 10-gauge power cable, and greater overall thrust was achieved. With a smaller and lighter tether, maneuverability and speed in the water is maximized.

g. Control System

This year, FDS opted to implement an all new, microcontroller-based control system. The control system consists of two 32 bit Arduino Due microcontrollers, one housed in the control box, and one onboard ROV-PHIL. The microcontrollers communicate over a custom 2-wire Transistor-Transistor Logic (TTL) level serial communication protocol. The new control system dramatically decreases the size of the tether (as only two wires are needed for communication), allows for the addition of sensors, and creates a platform for future software expansion.

Within the topside microcontroller, two processes are occurring: transmit motor command data and receive sensor data. Two potentiometer joysticks feed analog signal into the topside microcontroller. These analog values are concatenated into data strings, which are then packetized. The packetized serial data is sent to ROV-PHIL's onboard microcontroller utilizing two conductors of a Cat5e cable. The topside microcontroller simultaneously reads sensor data packets from ROV-PHIL's onboard microcontroller. The sensor data packets are deconstructed and read out on to an LCD screen inside the control box. Depth, pressure, and temperature data are all displayed on the LCD screen.

The control box (figure 14) houses the topside microcontroller, joysticks, video quad splitter and all DC wiring. ROV-PHIL's onboard microcontroller as well as the Sabertooth 2x5 motor controllers are housed within two Blue Robotics Watertight Electronics Housings (figure 15). In addition, Blue Robotics cable penetrators are used to ensure that all parts (acrylic tubes, flanges, end caps, and cable penetrators) fit together seamlessly to prevent leaks. After ROV-PHIL's microcontroller receives command data from the topside microcontroller, it then outputs Pulse Width Modulation (PWM) signals to the Sabertooth motor controllers.

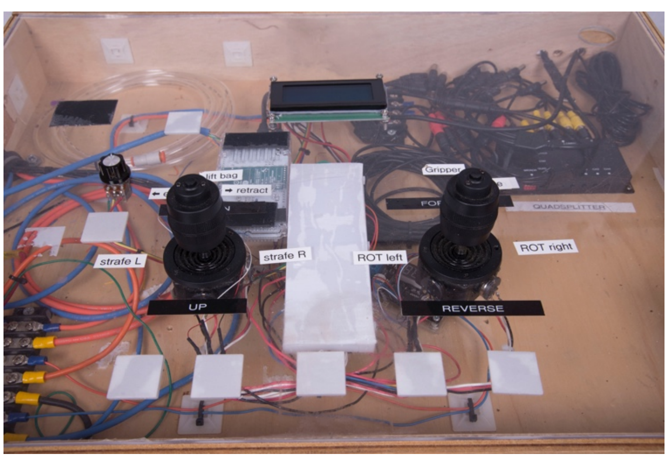


Figure 14: Control Box (Photo McClary)

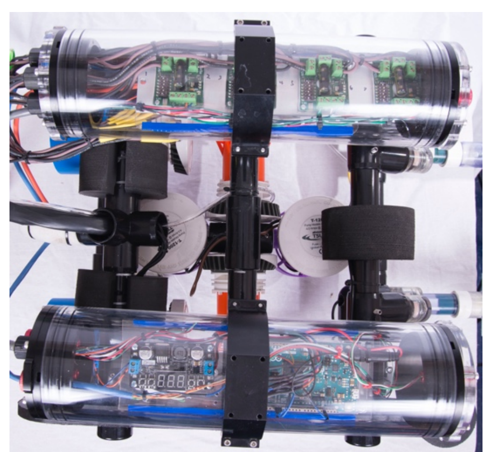


Figure 15: Watertight electronics housings (Photo McClary)

h. Software

Both of ROV-PHIL's microcontrollers are responsible for sending and receiving serial data packets. In order to accomplish this, both the topside and bottom side microcontrollers use a state machine to wait for an start of packet character ({) and an end of packet character (}). This ensures that extraneous serial data that is not part of a data packet is not read and processed. Within FDS' proprietary software, there are two different types of serial packets: command packets and sensor data packets. Command packets are used to carry motor control data. Example: {CMDSRV1XXX}. "CMD" tells the software the packet is a command packet and is processed as such. "SRV1" tells the software the command packet is a command for motor 1, and "XXX" is the control value to be sent to the motor 1 motor controller. Sensor data packets are used to transmit sensor data from ROV-PHIL's onboard microcontroller to the topside microcontroller. Example: {RRXDEPTYYY}. "RRX" tells the software the packet is sensor data packet and is processed as such. "DEPT" tells the software the sensor data packet is data from the depth sensor, and "YYY" is the depth value.

Both topside and bottom side software went through numerous revisions, as changes and bug fixes were constantly made. All software uses a packet checking system, in which all data packets are only processed if they are 10 characters long.

ROV-PHIL's depth sensor is integrated directly into the control system without any additional hardware. The Bar30 depth sensor is connected to the onboard arduino microcontroller and is housed in the same watertight electronics housing. The depth sensor sends depth data to the onboard arduino over and I2C communication bus, which is then translated into packetized serial data and transmitted to the surface to be read out on the topside LCD screen.
(See Appendix B, Software Flowchart).

V. Product Demonstration

In accordance with the 2018 RFP, teams are tasked with salvaging underwater aircraft debris, recovering a subsea Ocean Bottom Seismometer (OBS), and determining the optimum location for a hydroelectric turbine array.

Aircraft

FDS uses an excel spreadsheet (Figure 16) to calculate the crash zone of the aircraft. Next, the pilot and navigator use the onboard cameras to confirm the tail number with the flight data records.

Next, the pilot attaches the air bag to the debris on the engine. The navigator then uses the low pressure air bag system to lift the debris and set it down next to the engine (Figure 17). After disconnecting the airbag, the pilot surfaces the ROV, and the poolside technicians attach a new airbag. The pilot then attaches the second lift bag onto the airplane engine, and, once again, uses the low pressure air system to safely inflate the bag. The pilot uses the airbag system to retrieve the motor to the surface, where poolside technicians remove the engine from the ROV.

Figure 17: Lift bag fully inflated (Photo Thomas)

Aircraft Search								
Given Data		**Units**	**Final Vectors**	**Distance (m)**	**Distance (km)**	**Distance (cm)**		**Direction (deg)**
Heading	182	degrees	Ascent Vector	4,002	4.00	2.72	at	182
Ascent Air Speed	138	meters/second						
Ascent Rate	11.3	meters/second	Descent Vector	4,117	4.12	2.80	at	182
Time Until Engine Failure	29	seconds						
Descent Air Speed	98	meters/second	Wind Vector	723	0.72	0.49	at	68
Descent Rate	7.8	meters/second						
Wind Direction	248	degrees						
Wind Speed	17.2	meters/second	5 km on map = ___________ cm (enter to the right)			3.4	cm	
			or					
Final Altitude	327.7	meters	1 km on map = ___________ cm and multiply by 5, enter in box above					
Decent Time	42.0	seconds						

Figure 16: Vector calculation spreadsheet

Earthquakes

The Pilot first uses the Manipulator on the power connector pulling it out of the communications hub and inserting the connector into the company designed and fabricated Ocean Bottom Seismometer (OBS) (Figure 18). After inserting the plug into the OBS, the pilot uses the manipulator to close the door on the communications hub. lastly, the pilot uses the onboard magnet to disengage the OBS and release it to the surface where poolside technicians can safely retrieve the data from the OBS.

Figure 18: Ocean Bottom Seismometer (Photo McClary)

Energy

FDS first uses tidal data and a nautical chart to find the optimal location for the tidal turbine. Next the data analyst finds the greatest possible output in megawatts. The data analyst uses an excel spreadsheet to get the data calculated quickly and efficiently. Using the manipulator, the pilot the safely navigates the ROV to place the tidal turbine into the optimal location. After the pilot places the tidal turbine down the pilot then locks the turbine into place. The pilot then surfaces and the poolside technicians place the I-AMP into the manipulator, after the manipulator is closed and the ROV has been returned to the water the pilot can then place the I-AMP into its base and latch it into place with the locking mechanism. The pilot and the data analysis then use a tape measure and the onboard depth sensor to place a mooring buoy at a given distance. Once the mooring buoy has been placed the pilot can attach the ADV at a given distance to the mooring line. After the pilot completes the ADV he may begin to use the manipulator to transport two eelgrass samples to the surface using the manipulator to the poolside technicians. Next the poolside techs safely attach two eelgrass samples to the manipulator so that the pilot can position them into a previously undisturbed area.

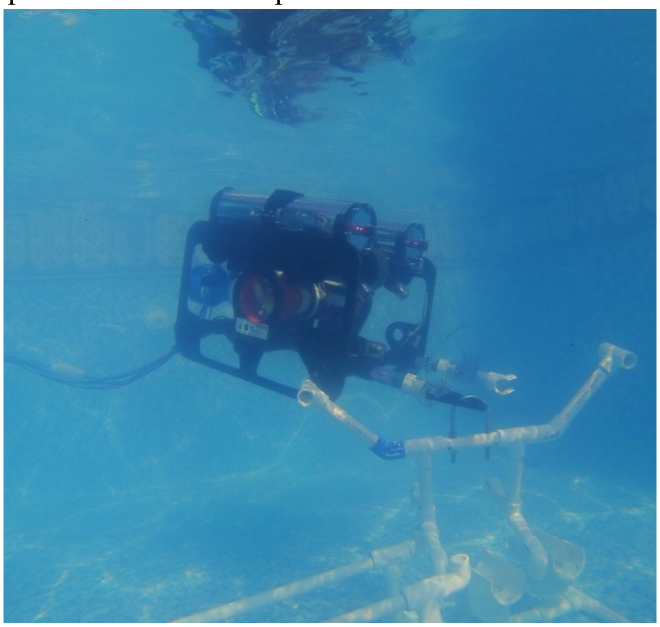


Figure 19: Locking the I-AMP onto the base (Photo Thomas)

VI. Non-ROV Devices

The MATE provided specifications allow for individual companies to design and build their own OBS and lift bag system. FDS recognizes the importance of not only building an efficient and safe ROV, but also investing time into the construction of practical and performance enhancing equipment to accompany a well-designed vehicle.

Ocean Bottom Seismometer

One device that is required for the product demonstrations is a simulated ocean bottom seismometer (OBS) that must be released from a base (Figure 18). FDS' OBS apparatus consists of the positively buoyant OBS itself along with a weighted anchor used to secure the device to the bottom of the operations area. Both components are built to comply with MATE size and weight specifications. The release mechanism of the OBS is housed within the base and consists of an Actuonix linear actuator wired to a magnetic reed switch and a double pole double throw polarity

switch. When a magnet is passed along the housing that contains the reed switch the actuator retracts allowing the OBS to float to the surface. While MATE allows teams to create systems that use batteries housed under the water, FDS opted to supply power from the surface to reduce the risk of a water leak, creating a hydrogen gas buildup.

Lift Bag

FDS chose to use a simple and safe design for the required lift bag (Figure 17). The lift bag is comprised of a 1” PVC coupler, a 1” to 1/2” reducer, and a 6” piece of 1/2” PVC pipe. FDS uses a beach ball attached to the 1/2” reducer using electrical tape. The lift bag is a low pressure, open system to prevent the lift bag from bursting underwater and possibly damaging the environment and sensitive equipment or risking the safety of personnel.

VII. Budget

First Descent Solutions began this competition season with an initial budget projection of $2500, and significantly undercut it with the final cost of the ROV totaling $1,601.31 Keeping the total cost of ROV-*PHIL* low was crucial to the planning. FDS was able to cut the cost of the ROV by reusing parts and manufacturing components instead of purchasing them off the shelf. To originally help fund ROV-PHIL, FDS proceeded to do a fundraiser at DareDevils Pizzeria on November 4, 2017. The fundraiser made about $900 to help start off the process. FDS purchased the majority of their new supplies with this money. Now that FDS is moving onto the international competition, the team has to raise approximately $11,700. That includes $7700 for 11 plane tickets from Norfolk to Seattle, $3500 for four hotel rooms, and $500 for ground transportation in Seattle. Raising that money is a huge deadline for FDS. The group is working on a fundraising event to raise funds and awareness. Currently FDS has sponsorships from local businesses to support the team and invest in the company. At the moment sponsorships are still being collected so a final amount raised is not currently available.

Projected Budget	**Cost**
Electronics	$500
Electronics Housings	$600
Thrusters	$750
Tether Cables	$250
Misc	$400
TOTAL	**$2,500**

Figure 20: Initial budget projection

Build vs. Buy

When FDS is considering whether to build or buy something the team factors in the cost and time that a product would take to make. This is how decisions are made in regard to whether to manufacture or buy a piece for the ROV. Most of the components of ROV-*PHIL* are custom fabricated by FDS, but some are bought to reduce construction time and cost. Two of the larger

components FDS ordered were the Blue Robotics electronics housings, as well as the electronics inside of the electronics housings. We bought the motor controllers and the Arduinos because the production is beyond FDS technical capabilities. Building these components would most likely bring up more errors and difficulty that would hinder ROV operations.

New vs. Reused

Most of ROV-*PHIL* is brand new, to avoid using older parts that have undergone wear and tear over time. Deterioration over time also reduces safety. ROV-*PHIL's* framework and motor setup are similar to last year's ROV. FDS remade or altered most parts to ensure ROV-*PHIL* would be as efficient as possible. The cameras and Sabertooth motor controllers are reused from last year. FDS made the decision to use the same cameras as they were in pristine condition and the purchasing and waterproofing of the cameras would add unneeded cost and production time. The same process applies with the motor controllers, buying four brand new motor controllers would be another unnecessary cost that would further add to the total cost of the ROV. FDS takes lessons learned from past ROVs and applies this information to future prototypes.

Figure 21: Project costs and expenses

Products	Price (Dollars)	Shipping
ARCTIC ULTRAFLEX 10GA BLU 100 FOOT ROLL	$39.44	
ARCTIC ULTRAFLEX 10GA ORG 100 FOOT PACK	$39.44	
ARCTIC ULTRAFLEX 14GA BLU 20 FOOT PACK	$6.33	
ARCTIC ULTRAFLEX 14GA ORG 20 FOOT PACK	$6.33	
ARCTIC ULTRAFLEX 18GA BLK 35 FOOT PACK	$6.33	
ARCTIC ULTRAFLEX 18GA BRN 35 FOOT PACK	$6.33	
HEAT SHRINK 1/4" BLUE 4' ADHESIVE LINED DUAL WALL*2	$8.80	
HEAT SHRINK 3/16"YELLOW 4 'ADHESIVE LINED DUAL WALL*2	$7.54	$88.84
Arduino SKU: 8058333491226 *2	$74.80	$8.92
Penetrator Wrench	$12.00	
Watertight Enclosure*2 (Includes end caps, o-rings, tubes, etc.)	$238.00	
Enclosure clamp*2	$68.00	
Aluminum end cap with 4 holes*2	$24.00	
Cable Penetrator Blank*4	$13.60	
Cable Penetrator for 6mm Cable *6	$20.40	
Cable Penetrator for 8mm Cable *6	$25.50	
O-Ring Set for Cable Penetrators	$2.00	$16.00
Depth Sensor	$84.00	
3/4" PVC End Cap Furniture Grade - Black *24	$23.76	
3/4" Furniture Grade PVC Pipe - Black - 5ft.*2	$14.16	
3/4" PVC Tee Furniture Grade - Black*12	$20.04	

3/4" 3-Way PVC Furniture Fitting - Black*6	$11.82	
3/4" 4-Way PVC Furniture Fitting- Black*3	$6.87	
3/4" PVC 90-Degree Elbow Furniture Grade - Black	$1.27	
3/4" 5-Way PVC Furniture Fitting - Black*3	$7.47	
3/4" PVC 45-Degree Elbow Furniture Grade - Black*4	$7.96	
3/4" PVC Cross Furniture Grade - Black*4	$8.96	$14.05
3/4" PVC Tee Fitting - Furniture Grade - Clear × 2	$4.10	
3/4" Thinwall PVC Pipe, Furniture Grade - 5 ft. - White	$5.20	
3/4" PVC Slip Tee Fitting - Furniture Grade - Black × 6	$1.50	
3/4" External PVC Coupling - Furniture Grade - Black × 9	$1.20	
3/4" Schedule 40 Furniture Grade PVC Pipe - Clear / 5 ft.	$10.50	$16.91
Octura 1270 Plastic Prop*6	$17.34	
FunRCBoats ROV Propeller Coupler*6	$29.94	$12.00
Bar30 High-Resolution 300m Depth/Pressure Sensor	$68.00	
Clear Acrylic End Cap (3" Series)	$10.00	$6.00
Experiment Solderless Breadboard with Adhesive Tape, 400-Points and 830-Points, 2 Pieces	$6.99	
Max485 Chip RS-485 Module TTL To RS-485 Module Raspberry Pi	$6.99	
NSI Epoxy Resin Mixing Kit: 100 Plastic Cups and 200 Wood Sticks	$12.88	
Grainger Coupler	$9.30	$2.44
10ml Syringes with 14Ga 1.5" Blunt Tip Needle and Storage Caps - Great for Glue Applicator, Oil Dispensing	$8.29	$1.34
3M Scotch-Weld Epoxy Potting Compound DP270 Clear, 1.69 fl oz *2	$36.08	
ATP Surethane Polyurethane Plastic Tubing, Clear, 1/8" ID x 3/16" OD, 100 feet Length	$19.84	$12.35
TOTAL NEW PARTS	**$1,033.30**	**$178.85**
Total Parts + Shipping Cost		**$1,212.15**

Re-Used parts:	**Price**			
Joysticks	$80.00		FINAL COST OF ROV:	**$1,672.15**
Misc electrical supplies	$100.00			
Cameras	$200.00			
Camera wire	$50.00			
Ethernet cable	$30.00			
Total-re-used/donated parts	**$460.00**			
Travel Expenses				
Plane Tickets*11	$7,700.00			
Hotel room*4 * 5 nights	$3,500.00			
Ground Transportation	$500.00			
FINAL TRAVEL COST:	**$12,120.00**			

Operation Costs				
Regional Poster	$120.00			
Power Fluid Quiz Fee	$15.00			
Mission Props	$40.00			
FINAL OPERATIONS COST	**$175.00**			

VIII. Critical Analysis

The 2018 mission requires non-ROV devices that must be designed, engineered, and brought to the competition by the companies themselves with few guidelines. This newfound creative freedom leads to a better end product but leaves the design process up to the company.

With a multitude of release system options presented in the competition manual, there are many ways to design an Ocean Bottom Seismometer (OBS) release mechanism. Initially, a group of FDS engineers were tasked to create an acoustic release mechanism for the OBS, in order to score maximum points at the competition. Weeks were spent on this system, and multiple iterations of programs were written, but due to the difficulty of utilizing Fast Fourier Transform (FFT), and the problems of a noisy acoustic environment in the competition pool, the design process stood at a standstill. After great amounts of work were put forth into the acoustic release mechanism, the project was abandoned by the team in favor of a more simplistic, magnetic reed switch release mechanism. Once construction of a new magnetic release was started, a new set of problems arose. The design was created using a 9-volt battery that was sealed and contained under the water. The safety protocol of the MATE competition requires that a pressure release system is implemented in order to eliminate the risk of expanding hydrogen gas that could be caused by a leak. After many design reconsiderations, FDS simply could not create a watertight battery housing that satisfied the MATE regulations and company safety protocol. This issue was caused by a lack of communication and overlooking MATE rules and regulations.

FDS did not only face problems during the design and building process of ROV-PHIL and its non-ROV systems. FDS faced difficulty raising capital to build the vehicle, as well cover travel and lodging cost for the international competition. In addition to financial issues, FDS was also challenged with personnel issues. With an 11-member team (a first for FDS), it was difficult to keep all team members organized and on task at all times. As many team members are involved in other extracurricular activities, meeting attendance and team commitment was not ideal. With 5 new members on the team, it was challenging to delegate tasks and projects, as new members were still learning and not ready to take on projects by themselves. However, by implementing a structured chain of command (see Corporate Structure), FDS was able to overcome this issue, and strengthen our company.

IX. Future Improvements

In order to further advance ROV-PHIL's performance, FDS plans to add new software features. With a depth sensor on board the vehicle, FDS plans to introduce a "hover" function by adding a feedback loop to ROV-PHIL's software. This function would allow for more precise control of the ROV while completing mission tasks. Without the pilot having to constantly adjust to stabilize the vehicle, the pilot can focus on operating manipulators. In addition to vehicular modifications, company-wide time management must be addressed. FDS struggles each year to stay on a strict build and development schedule. To alleviate this issue, FDS will continue to develop timetables for the upcoming competition season (similar to Figure 22). This will ensure that parts are ordered on time, and deadlines are met. By staying on schedule more time can be spent fundraising and presenting our prototypes to the local community.

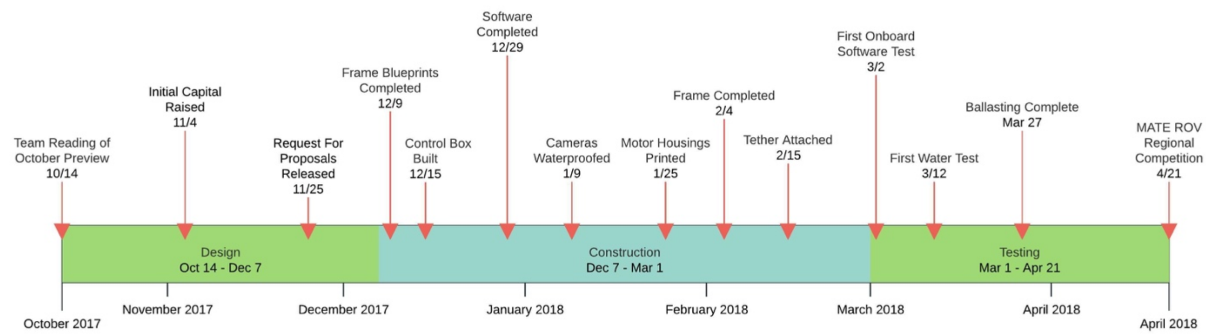


Figure 22: Scheduling matrix
The 2017-2018 project schedule is seen above, and will continue to be implemented in future project planning

X. Senior Reflections

Mac McClary, CEO- 3rd year member, software engineer

As someone who has been interested in electronics and robotics from a young age, ROV has given me a chance to explore the field of marine robotics. My favorite part about being a member of the First Flight ROV team and the MATE competition is the skills learned outside of technical skills. I have learned how to lead a team, how to manage people, as well as how to manage projects. Within technical skills, I have learned to code through ROV. In just a year I have learned a tremendous amount about Arduino programming and electronic prototyping. It was extremely rewarding to work on coding a real project, and not just personal projects. I am excited about a future with the knowledge gained by being a participant in the future, and I hope to pass down my knowledge to the future generations of First Flight ROV, as well as the Outer Banks community.

I hope to continue my passion for technology by perusing an electrical engineering career after high school. I would like to thank our mentor, Andrew Thomas (and his wife, Anna), for graciously hosting all ROV work at their home and letting me stay many late nights, for involving me in ROV in the first place, and for teaching me to think like an engineer.

Isabell Eckard, Intern- 1st year member, media and outreach coordinator

As a first-year member on the First Flight ROV team I have advanced my problem solving and technical skills while gaining priceless experience that I can continue to use throughout my further education and career. The specialized expertise that I have gained will directly translate into my engineering education and training in the future. There is not a single thing that happens within our team that is solely individual, and teamwork is a very integral part of every process. Not only have I gained knowledge in the ROV field, I have also grown as a person and advanced my work ethic and innovation skills. The things that I have experienced via First Flight ROV are those that I would not have had access to otherwise. I plan to study Nuclear Engineering at North Carolina State University, and I can say with absolute positivity that being on this ROV team has influenced me in my post-secondary education decisions. I am extremely grateful for the platform that MATE provides, and I want to thank everyone who is on or has contributed to the First Flight ROV team.

XI. Acknowledgments

We would like to thank Nauticus for hosting our regional competition at the Old Dominion University swimming pool in Norfolk, VA. We would also like to thank all of our sponsors, including Towne Bank, Teresa Osborne, Dowdy and Osborne CPA, Nauticus, Carolina Designs Realty. Thank you to MATE for hosting the international competition and creating this amazing competition. Lastly, a huge thank you to Eric Holsinger for mentoring our team with software design and coding.

XII. References

Balthazar, Willard. "ROVs in Use for Renewables." *Hydro International*, 27 Aug. 2015, www.hydro-international.com/content/article/rovs-in-use-for-renewables.

Capocci, Romano, et al. "Inspection-Class Remotely Operated Vehicles- A Review." Journal of Marine Science and Engineering, vol. 5, no. 1, 2017, p. 13., doi:10.3390/jmse5010013.

Gardner, Matt, and Jill Zande. "2018 MATE ROV Competition Manual ." Energy Information, Dec. 2017, pp. 13–16.

Ma, Michelle. "Support for Tidal Energy Is High among Washington Residents." UW News, University of Washington, 31 May 2017, www.washington.edu/news/2017/05/31/support-for-tidal-energy-is-high-among-washington-residents/.

National Geographic Society, National Geographic. "Tidal Energy." *National Geographic*, National Geographic Society, 9 Oct. 2012, www.nationalgeographic.org/encyclopedia/tidal-energy/.

Ocean Energy Council (2011). "Tidal Energy: Pros for Wave and Tidal Power". Archived from the original on 2008-05-13.

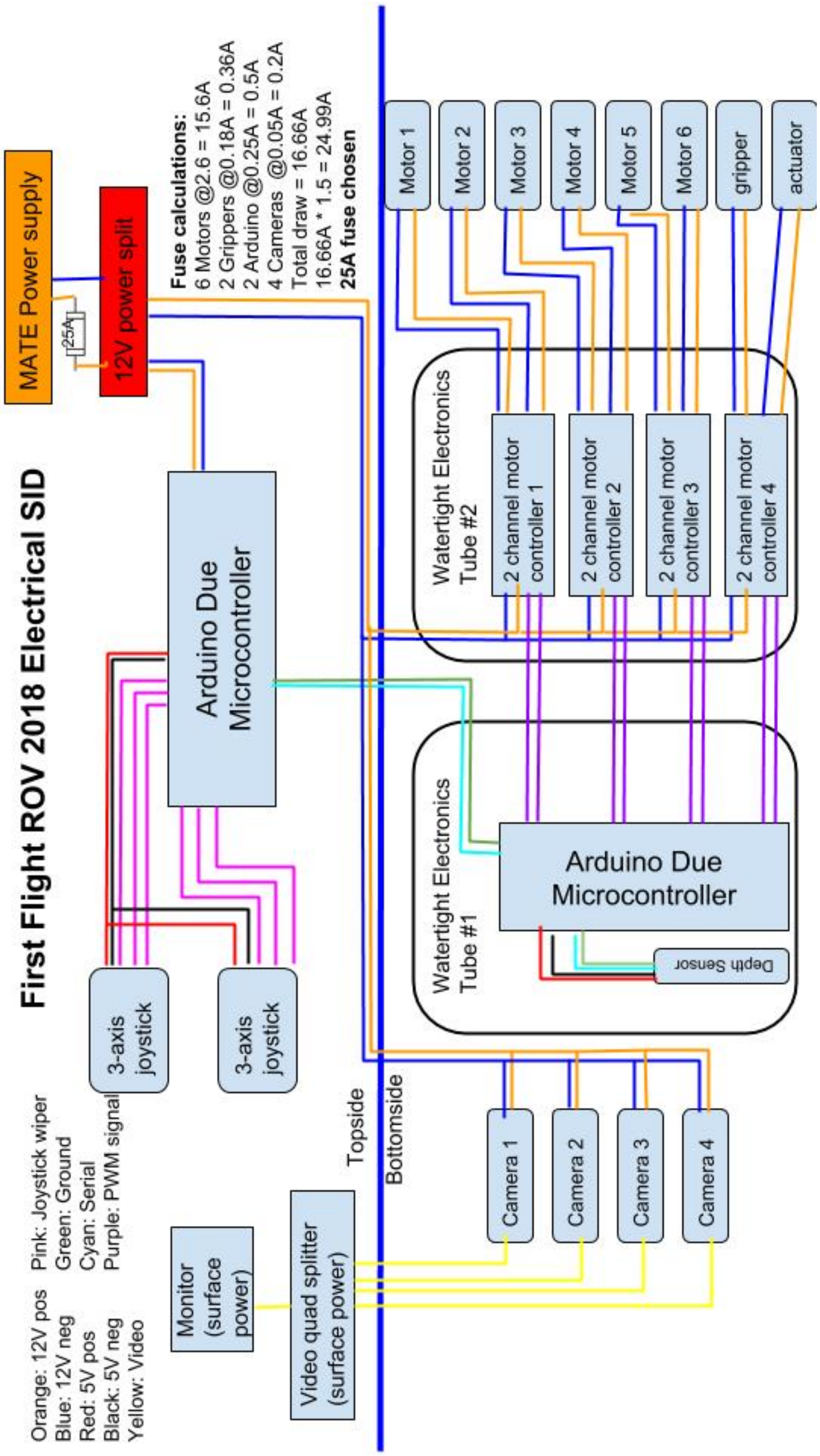
Paschoa, Claudio. "Future ROV Technology." Marine Technology News, 6 Aug. 2014, www.marinetechnologynews.com/blogs/future-rov-technology-700499.

Rush, Ben, et al. "Development of an Adaptable Monitoring Package for Marine Renewable Energy Projects." Proceedings of the 2nd Marine Energy Technology Symposium, Apr. 2014, pp. 1–4.

Toal, Daniel. "Smart ROVs at Sea." *horizon2020projects.Com*, University of Limerick, www.mmrrc.ul.ie/dotnetnuke/Portals/6/H11_Mobile_%20Marine_21300_pro.pdf.

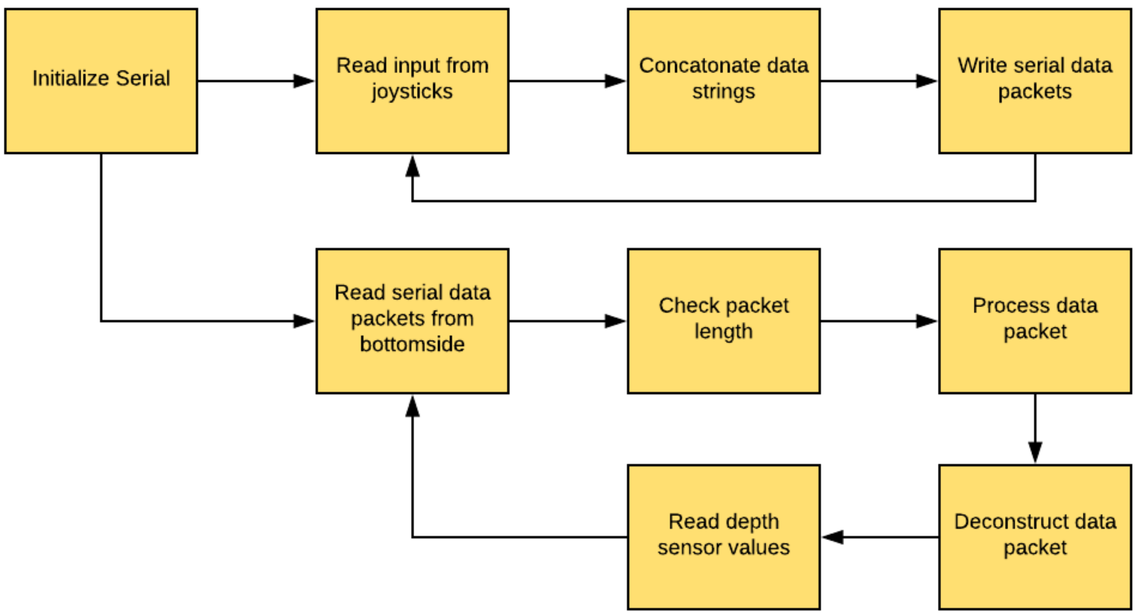
Trauthwein, Greg. "Forum ROV to Support University Renewables Projects." *Marine Technology News*, New Wave Media, 16 Jan. 2017, www.marinetechnologynews.com/news/forum-support-university-renewables-543824.

Appendix A- Electrical SID

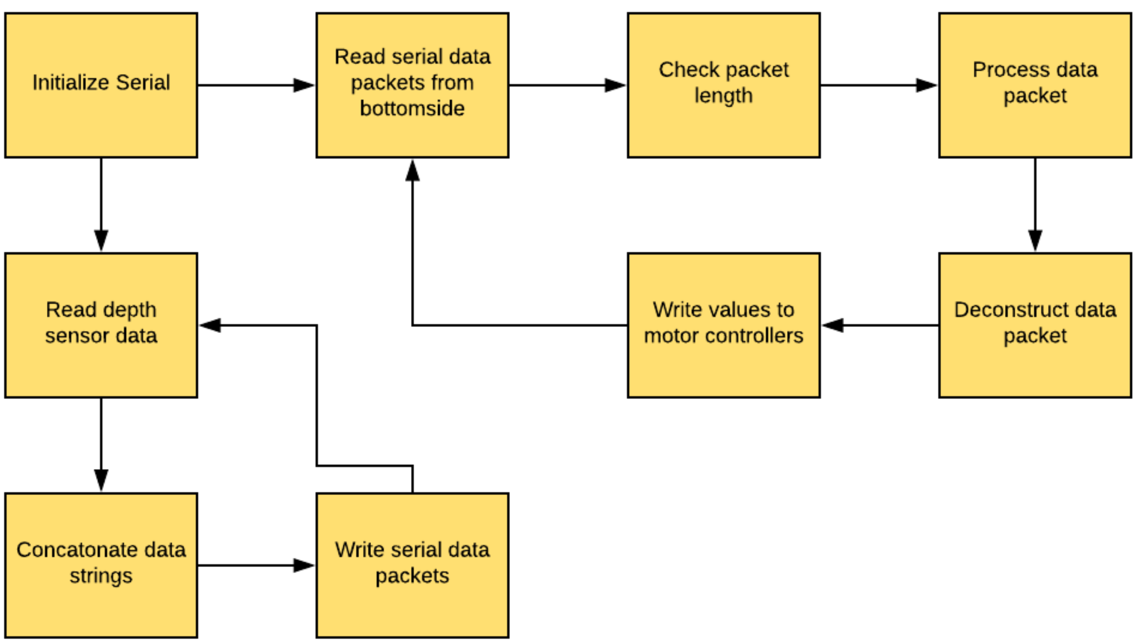


Appendix B- Software Flowchart

Topside Arduino



Bottomside Arduino



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