Lost Rockets

Limestone County Career Technical Center

Figure 2: The Lost Rockets. Credit: Monica McConnell

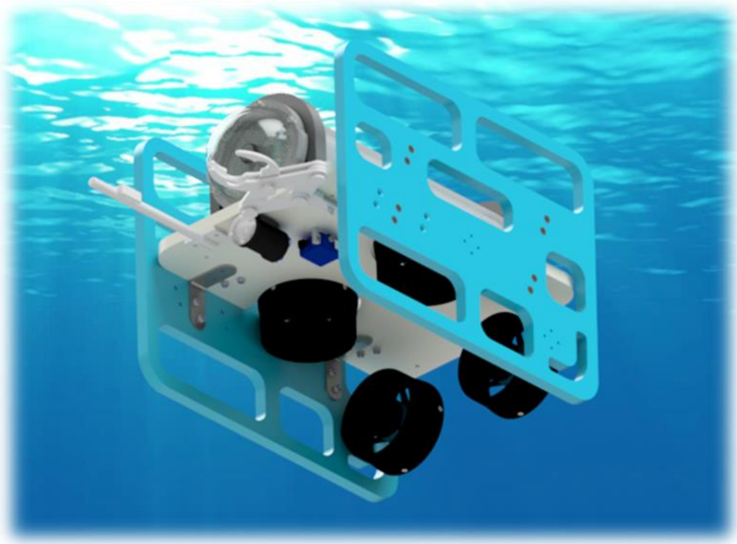

Figure 1: The Predator. Credit: Coleman Cook

Member	Position
Baylee Brewer	Marketing
Coleman Cook	CEO
Preston Lewis	Technician
Tyler Pressnell	CMO, Pilot
David Sanchez	Website, Technician
Bailey Webb	Marketing
Casey Wigginton	Mentor
Monica Mcconnell	Mentor

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Abstract

The Lost Rockets ROV company has produced a remotely operated vehicle in their second year of operation. This ROV, named The Predator, has been designed and built to aid with commerce and entertainment industries in major port cities around the world.

Figure 3: Long Beach Harbor Bay. Credit: Commerce.gov

The Predator has been assembled to take water temperature, depth, and heading of the ROV. It also can rotate valves, manipulate power plugs, retrieve and place fountains, place rebar rods and hoses, and place a buoy. In addition, the ROV is equipped to scan crates for RFID tags and ID the highest hazard crate.

To achieve these goals, the ROV is composed of a precision-machined high-density polyethylene frame material for frame rigidity, ROV robustness, and ease of mounting points with other components. ROV tools include a retractable claw, a hooked prong, pressure and depth sensor, gyroscope, a single camera, and variably controllable thrusters. The ROV is programmed using an open-source UI software that has been programmed and configured to interface with the ROV. The Predator is controlled using two separate microcontrollers that communicate through ethernet to a computer that utilizes an Xbox 360 afterglow controller to control robot function.

For ease of transportation, The Predator has been designed to fit within a 48cm circle for ease of transport, and weighs less than 10 kg. The frame also contains carrying handles to be easily lifted by a single person.

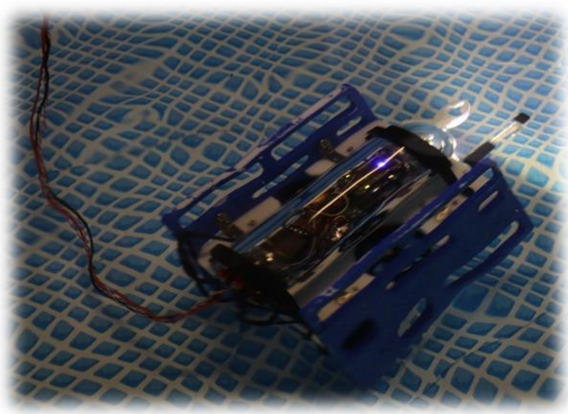

Figure 4: The Predator being water tested. Credit: Preston Lewis

The Lost Rockets, utilizing The Predator, has been successful during the course of this year due to the effectiveness of the corporate structure of the company. The efficient implementation of the engineering design process has culminated in a strong, consistent indicator of the company's efforts.

Design Rationale

Design Process

The Lost Rockets used several design techniques when building The Predator. No parts were reused from the previous year due to the heavy usage of all of the previous ROV components, which would likely result in failure of the parts if they were used again. The company utilized custom-made parts whenever possible, which is exemplified by usage of 3D-printed mission-specific equipment, and the precision-machined frame plates from a CAD model. The greatest example of usage of CAD in the company is the electronics housing electronics tray, which was custom made with screw holes to specifically fit electronics on the tray.

Frame

The Predator utilizes 3 machined plates of 0.5” high-density polyethylene that are attached by stainless steel brackets. This frame design was chosen due to its high strength and ease of access to the plates to mount sensors and tools. In order to reduce weight, the original solid plates of the frame have had holes machined into them to reduce weight, while maintaining the structural integrity of the frame. Aesthetic design was added to the frame by painting the frame side plates blue, and then laser engraving an image over the painted side plates, achieving the desired design.

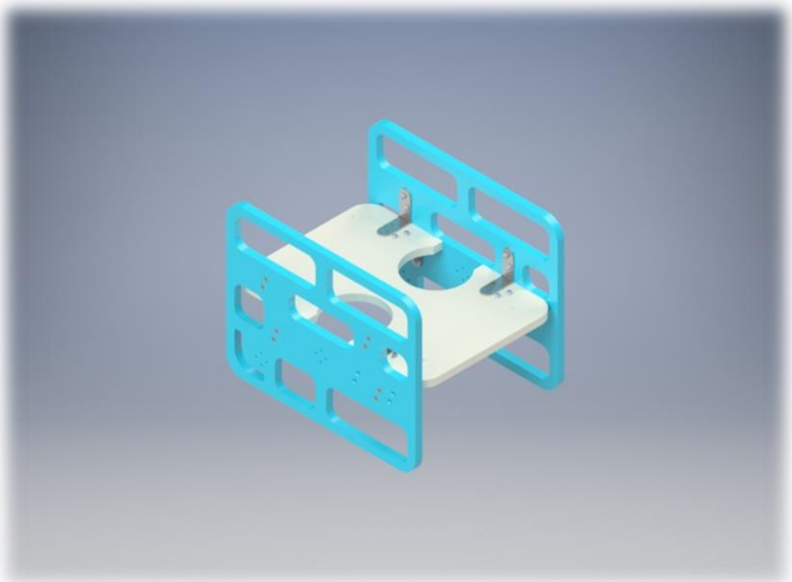

Figure 5:Rendered model of the ROV frame. Credit: Coleman Cook

Electronics Housing

The ROV electronics housing is comprised of a BlueRobotics 4" diameter acrylic waterproof housing. This electronics housing was chosen for its consistent waterproofing in past usage, and for its reliability at lower depths. The electronics housing has a dome at the front for the ROV camera, and is protected from water at by 3 separate O-rings for a secure seal.

Figure 6: Rendered image of the electronics tray. Credit: Coleman Cook

The interior of the electronics housing contains the majority of the onboard electronics on the ROV, and therefore needed to be organized. The interior electronics housing tray is a laser-cut acrylic and 3D-printed tray that was designed, built, and assembled to custom fit all of the electronics on the ROV. Before assembling the tray, all of the CAD models of the electronics within were created or downloaded, and the housing was modelled in Autodesk Inventor.

Before putting The Predator in the water, company members follow strict guidelines to ensure that the electronics housing is sealed before testing the ROV. Members accomplish this using the vent plug, a secure plug in the back of the electronics housing that is designed to have an air pump plugged into it. In order to test for leaks, the vent plug is unscrewed and the air pump is plugged in and 10 psi of vacuum is pumped to the electronics housing and left for 10 minutes to determine if a leak is present in the electronics housing. This helps members catch potentially ruinous leaks before putting the ROV in the water.

The buoyancy provided by the electronics housing is equally spread throughout the ROV, giving a central center of buoyancy, and removing the need for buoyant foam on the frame. The housing is also mounted at the top of the ROV to supply a high center of buoyancy and a low center of gravity.

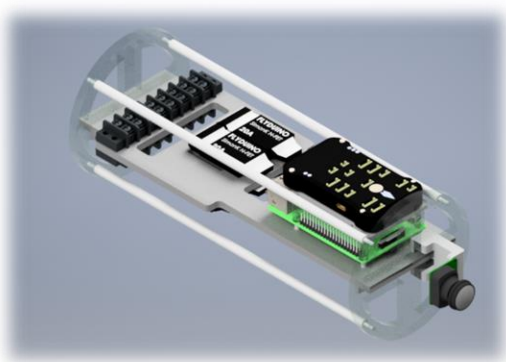

Figure 7: Rendered image of the electronics tray. Credit: Coleman Cook

Cable Penetrators

In order to prevent leaking into the electronics housing, The Predator sports 10 cable penetrators, which are screwed into the housing cap and secured with O-rings. Wires are threaded through the center of the cable penetrators and are subsequently superglued and then marine epoxied to waterproof the wire connection. The cable penetrators allow dry components to communicate not only up the ROV tether to topside controls, but with waterproofed electronics outside of the electronics housing. All wires coming out of the cable penetrators are managed to the ROV frame to prevent tugging on the wires from disrupting the electronics housing cap and the cable penetrators' seals.

Figure 8: A single cable penetrator. Credit: BlueRobotics

Tether

Figure 9: The end plugs of the tether wires. Credit: Preston Lewis

In the Lost Rocket's previous year, a large tether with a mesh sheathing was implemented. This was found to be time-consuming and cumbersome, so a new tether design was implemented. This year's tether consists of two 12 AWG silicone wires (one power, one ground) and four 18 AWG wires for dual signal transmission. The 18 AWG wire pairs are twisted together to reduce signal noise. The tether is bound using interspaced zip ties to prevent fraying. After using Pythagorean theorem to measure the exact furthest distance required for the ROV travelled, the tether was measured to be 22.5 meters long to allow for movement throughout the demonstration area. Buoyancy was added along periodic lengths of the tether to provide neutral buoyancy in the water to avoid dragging the ROV.

Thrusters

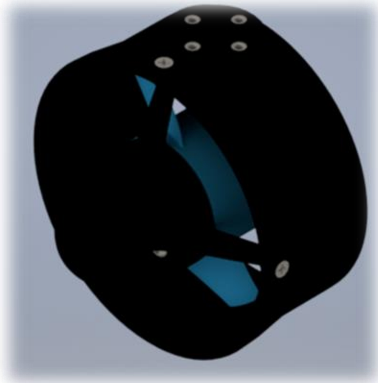

Figure 10: Rendered Image of a T-100. Credit: Coleman Cook

The Lost Rockets were presented with the difficult task of finding a propulsion method that provided the most cost-effective and efficient movement to the ROV. The most effective solution found was the BlueRobotics T-100 thruster. The Predator utilizes four T-100's placed at strategic points on the ROV frame to simultaneously be open to water flow and provide balanced movement. This year, the number of thrusters used was cut down from six to four to reduce amperage draw and provide more frame room to mount tools for the ROV. This allows the thrusters to move on a yaw/pitch/roll style, very similar to that of a fighter pilot.

When selecting the most effective thruster for the ROV, a trade study was conducted to provide an objective standard of comparison of thrusters. This study was conducted utilizing factory figures from thruster company spec sheets, and alternate data pulled from amateur studies in hobby motors and bilge pumps. By comparing the researched figures of thrust and cost, it became clear that the T-100 thruster was the best choice for the ROV.

Upon running physical tests of the thrusters on the ROV, the T-100 thrusters were shown to total at about 10A of current when run at maximum power for all four thrusters. This, along with the standard 1.2A draw that other electronics draw, falls well underneath the maximum current draw of 25A for the ROV. When run at maximum power, the thrusters generate 2.36 kg of thrust at maximum forward power providing 130 watts.

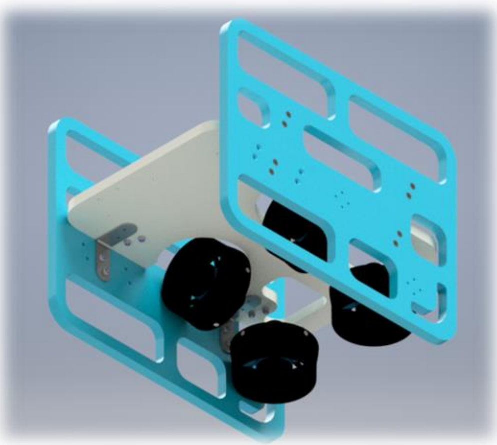

Figure 11: Thruster mounting Locations on the ROV. Credit: Coleman Cook

The T-100 thrusters are mounted to the side frame plates by 4 x 3mm hex screws, which provide solid mounting points. The thrusters themselves are shrouded, and therefore did not require any additional parts for safety protection. However, safety stickers were applied to the thrusters to indicate a hand hazard.

Control System

Hardware

Precision and speed of execution are important qualities of The Predator, which is accomplished through its control system. The T-100 thrusters are, at their core, brushless 3-phase hobby motors, which are controlled by Electronic Speed Controllers, or ESCs for short. The ESCs are powered by a 12v terminal block and receive signals through a pulse width modulation duty cycle from 800 nanoseconds to 2000 nanoseconds from the 3DR Pixhawk microcontroller.

The central two microcontrollers on the ROV are the 3DR Pixhawk flight module and the Raspberry Pi3. The 3DR Pixhawk is an autopilot computer designed for amateur drones which has been adapted for use on the ROV. The Pixhawk sports 8 main output signal channels and 6 auxiliary channels, along with I2C and USB communication ports. The Raspberry pi also contains several output channels, but is utilized for its ethernet SSH communication to the topside computer, USB communication to the Pixhawk, and receiving signals from the Raspberry Pi camera.

Tether communication is over ethernet, which has been minimalized to two wires due to two Fathom-X tether interface boards, which can convert ethernet communication to two communication wires and back again. The ROV contains an onboard Fathom – X to send the signal and another Fathom – X in the control box to turn the signal back to ethernet. This system reduces the needed wiring for the tether and speeds latency of camera feed and response to approximately 400 milliseconds.

The ROV topside controls are comprised of a laptop computer and a single Xbox 360 afterglow controller, which controls ROV movements. The Xbox controller gives analog input to control the ROV, providing adjustable power to the thrusters. The laptop can be used to arm and disarm the ROV, along with configure the Xbox controls, but primary control comes from the Xbox controller.

Controls

Control	Action		Control	Action
Left Joystick X Axis	ROV Yaw control		D-Pad X Axis	Adjust ROV gain
Left joystick Y Axis	ROV Throttle control		D-Pad Y Axis	Adjust light
Right joystick Y axis	ROV Pitch control		X button	Normal flight mode
Start button	Arm ROV		B button	Depth Hold flight mode
Back button	Disarm ROV			

System Interconnection Diagram

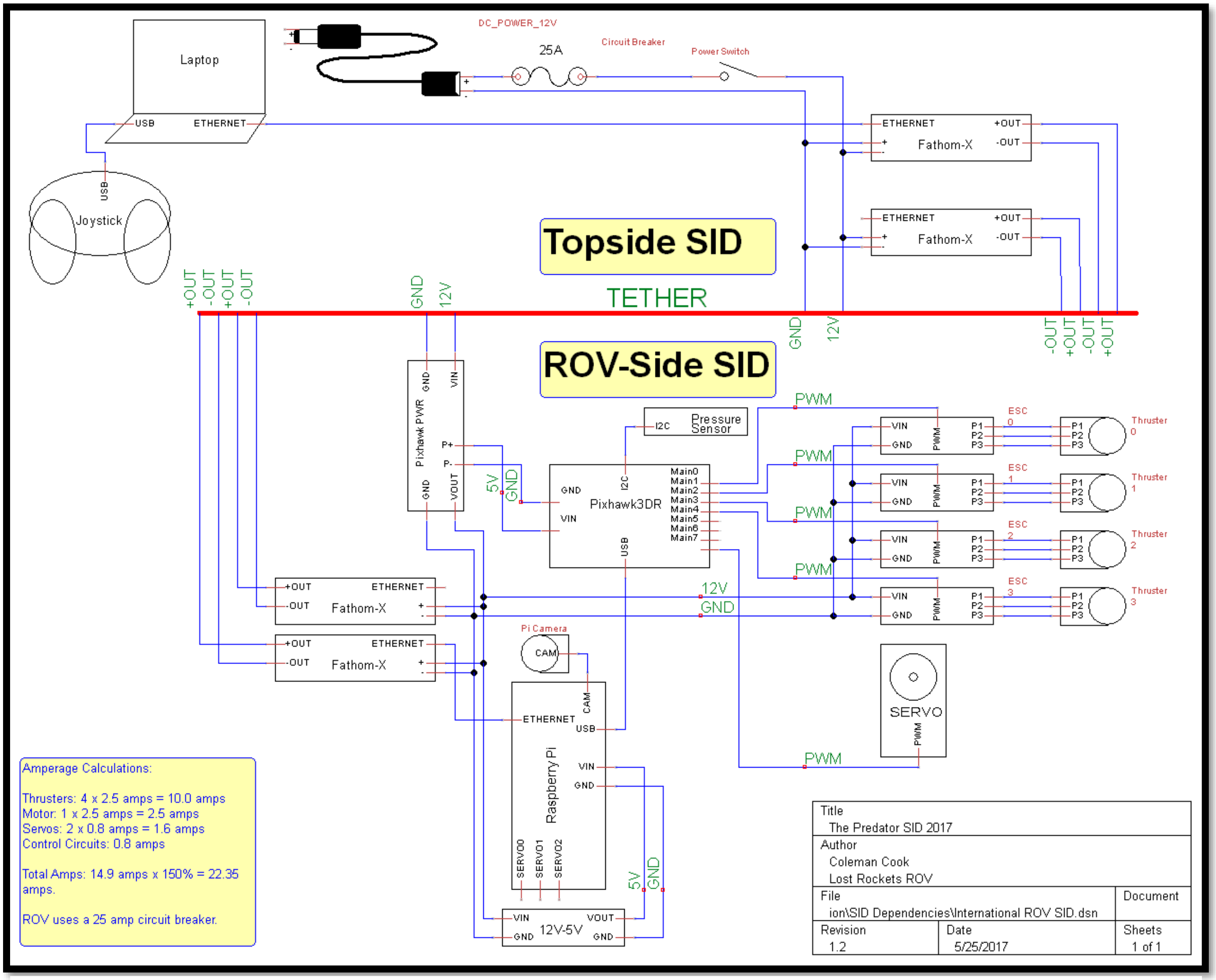

Figure 12: Systems Interconnection Diagram. Credit: Coleman Cook

Software

There are three separate pieces of software running to control the ROV. The first is a custom image file running on the Pixhawk module that receives commands through USB and executes the commands to ESCs and servos while receiving sensor information through I2C and relaying it back to the Raspberry Pi. The Raspberry Pi has a separate Linux image running on it that is designed to communicate through a SSH terminal to the computer. Through SSH, the Pi sends sensor data from the Pixhawk and the camera to the topside computer, while receiving commands from the topside computer and relaying them to the Pixhawk through USB.

The topside computer controls the ROV using a program called ArduSub. ArduSub is an open-source program that is designed to run underwater ROVs, and has been configured to work with The Predator. This code receives data from the Xbox 360 controller sends the analog and digital signals in a packet to the Raspberry Pi. Ardusub also receives and displays camera, angle, and pressure data on the monitor. The camera display data automatically corrects for bright and dark environments to provide an easily viewable image.

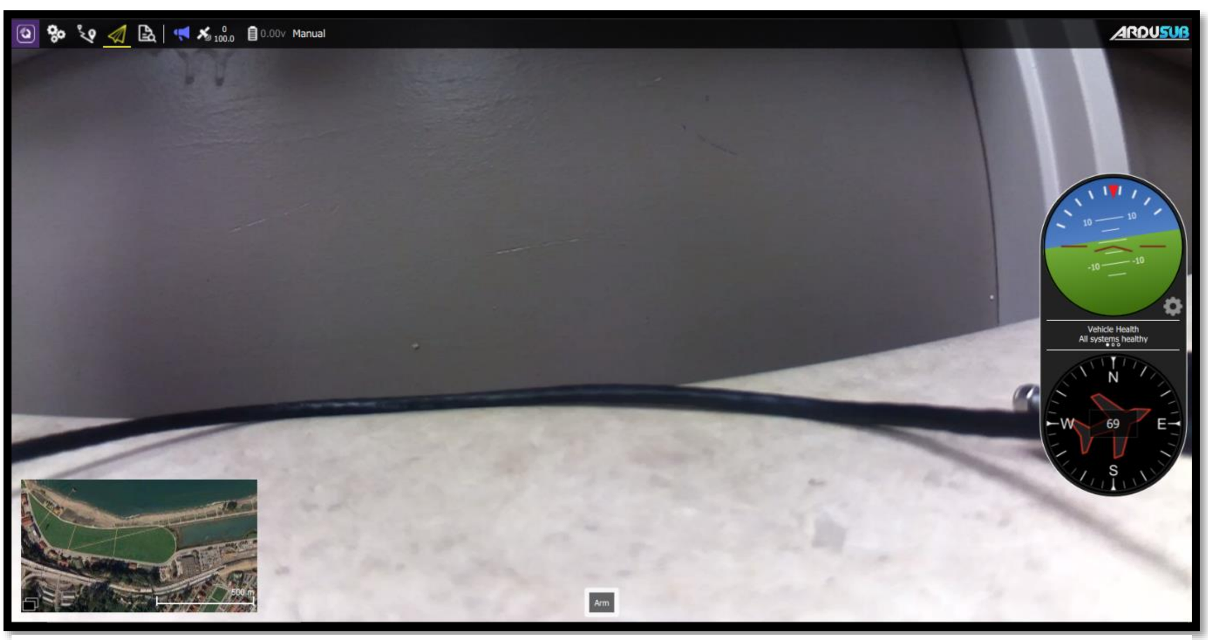

Figure 13: A screenshot of the Ardusub control screen on the laptop. Credit: Coleman Cook

Software Flowchart

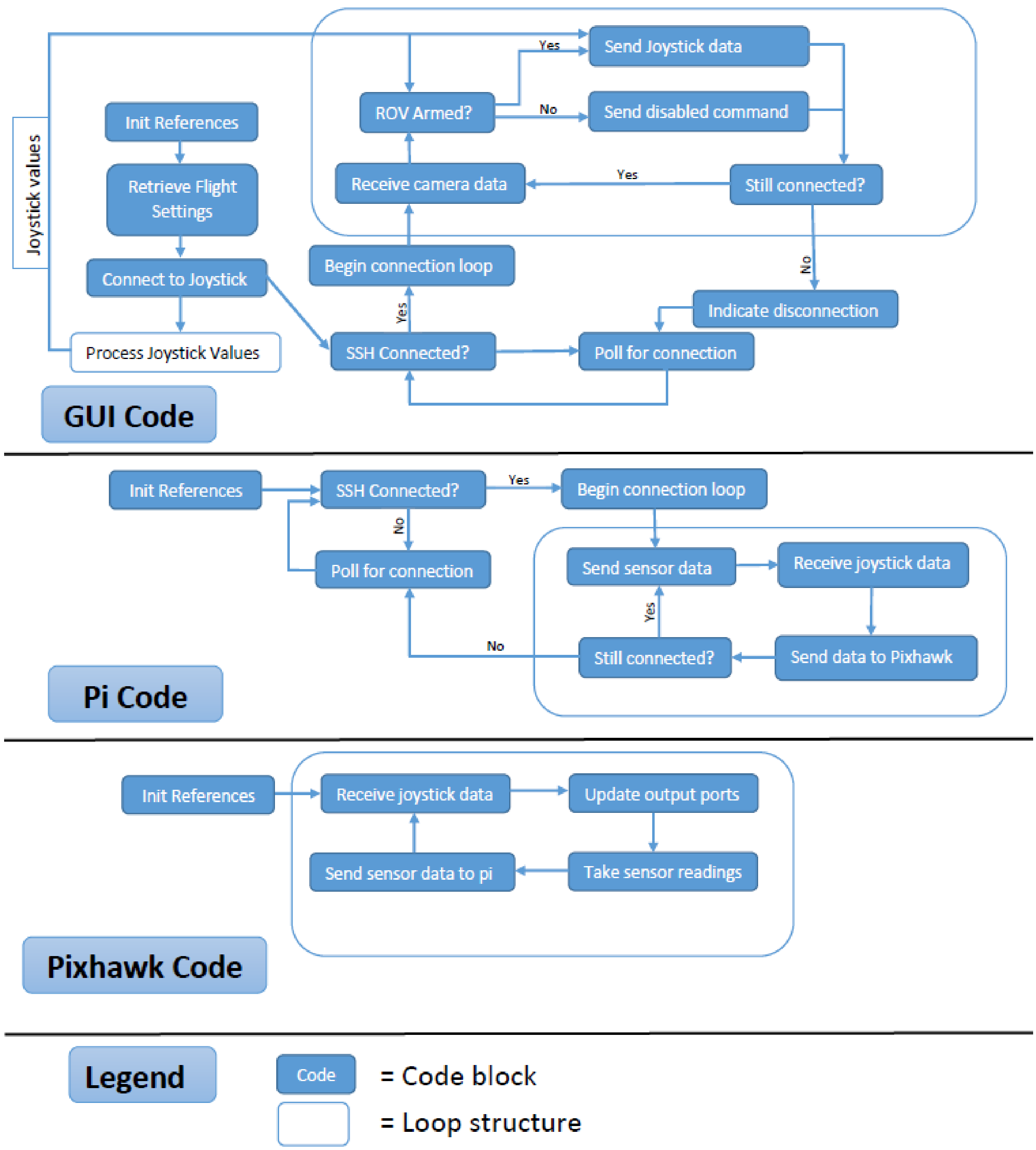

Figure 14: Software Flowchart. Credit: Coleman Cook

Control Features

The ROV possesses several key features that help to set it apart from other ROV control systems. One of these traits is the depth-hold flight mode, which reads a previously assigned set point of depth on the ROV and attempts to level the ROV to the selected depth. This assists with fine motor movements to achieve higher precision while working with the ROV.

Another key feature of The Predator is the ability to increase and decrease gain on the ROV. Gain on the ROV represents the percentage of power that the thrusters will receive relative to the distance that a joystick is pushed on the Xbox controller; thus, if the gain is set at 50%, the ROV will move at half of full speed if the joystick is pushed all the way forwards. This made small movements much easier for the pilot, while still giving the ability to propel at full speed when needed, aiding in handling of the ROV.

Mission-Specific Equipment

Claw

The ROV is equipped with a 3-pronged claw, which has been designed for the purpose of gripping bolts, rebar rods, and hoses. The claw is driven by an underwater servo, which allows the claw to open to any size. This enables the claw to accomplish a variety of tasks, as it can open to accommodate items of varying sizes. The claw is constructed of 3D-printed ABS plastic because many repetitions of design were required to create a cohesive design, and adjusting 3D-printable parts made it easy to fix design errors and create a workable product. The claw sticks out of the ROV frame perimeter, so it can be bolted on or removed quickly when transferring between transport and demonstration mode for ease of use and to prevent possible damage to the claw.

Figure 15: A rendered image of the claw. Credit: Coleman Cook

Prong

Figure 16: A rendered image of the prong. Credit: Coleman Cook

After brainstorming for a multipurpose second manipulator for the ROV, the company came to the conclusion that a 3D-printed prong with several features would be the best solution to the tasks given. The prong is attached to the frame through a single bolt in the back, which allows it to be easily removed for transport. It also has a single threaded 3mm screw hole that is used when attaching the RFID sensor to the prong. The prong also contains a hook on its top to easily grab onto the fountain rope.

Design Theme

This year was the first year that the Lost Rockets attempted to incorporate graphic design into the ROV design, and utilized a unique method to provide a design theme aligning with the company. In order to match with company colors, the ROV was painted blue on the sides, and white HDPE sheets were ordered instead of black to compliment the blue. The side plates of the ROV offered a medium to display design theme, and thus an edited image was laser etched into the side plates. The design is varied on either side, with the team logo being on one and the school logo on the other, with a circuit based background gradient designed to match with company theme.

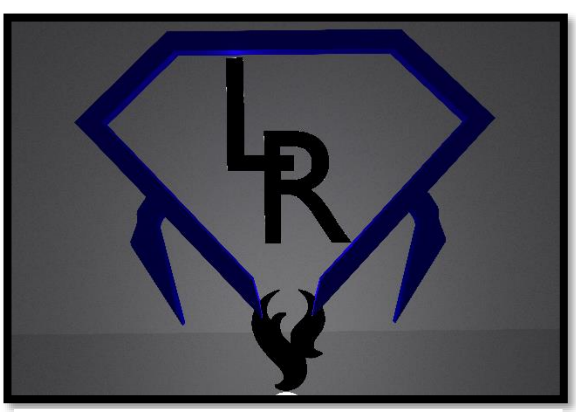

Figure 17: Raw company logo image. Credit: David Sanchez

Figure 18: ROV while being piloted. Credit: Preston Lewis

Safety

The Lost Rockets company members take exceptional precaution to ensure ROV and personnel safety while working on the ROV. The ROV and team members utilize several methods to create the safest possible environment to avoid electrical or physical damage.

Figure 19: 25 Amp inline fuse. Credit: PowerWerx

The ROV itself contains several important safety features. The most prominent safety feature to avoid electrical damage is the 25A inline fuse wired in line with the power supply line to the ROV. In the case of a possible short or current overdraw, the fuse will blow, which prevents possible damage to electrical components or explosion. In the event of current overdraw, all of the microcontrollers on the ROV are protected by separate power modules, which are shielded in the case of electrical surge. Another major safety feature of the ROV is the vent plug, which is used with a vacuum pump to test if the ROV has any leaks. To test this, a team member simply plugs the pump into the plug and pumps 10 PSI of vacuum out of the chamber for 10 minutes. If any pressure was lost in those 10 minutes, then the ROV contains a leak that needs to be addressed.

The ROV also contains physical properties that promote safety. Since all of the frame plates have been precision machined, the frame contains only smooth frame corners, removing all sharp edges from the ROV. The thrusters have been labelled with yellow and black hazard tape to indicate a hand hazard.

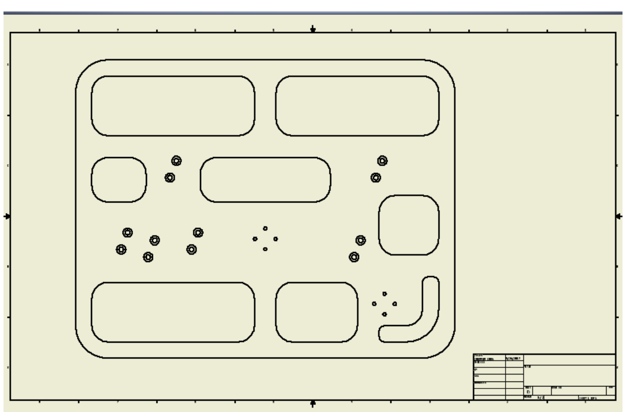

Figure 20: A CAD drawing of the left frame plate. Credit: Coleman Cook

Lost Rockets company members follow a safety protocol to avoid possible safety accidents while working with or testing the ROV. While working, all members wear close-toed shoes, tie loose hair back, and wear safety glasses. Before ever placing the ROV in the water, a safety checklist is scanned to prevent possible slippage or ROV damage while testing.

Troubleshooting

One of our major challenges the company encountered this year while working on the ROV was catching leaks. After assembly of the ROV, the first subsequent test of the ROV resulted in a pressure leak, which signaled to us that the ROV needed to be fixed before water testing. After approximately two weeks of searching the ROV, it was discovered that an O-ring had not been installed in the electronics housing. Another major issue the company ran into was a curious twitching of the thrusters and their lack of operation if more than one ESC was plugged in. After heavy research, it was discovered that the ESCs were providing too much voltage back to the Pixhawk, and were not getting the correct signals. The Lost Rockets used several troubleshooting methods to help solve similar issues to those previously mentioned throughout the company project.

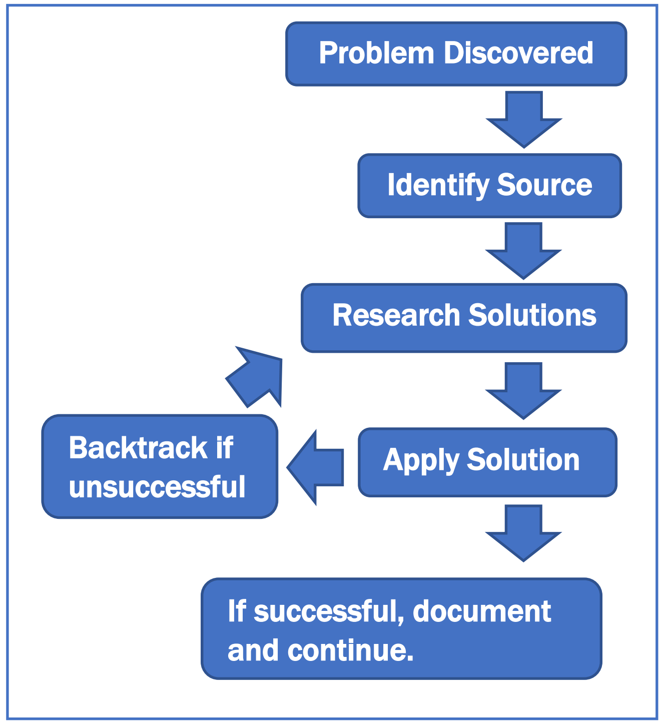

Figure 21:Troublshooting strategy. Credit: Coleman Cook

Challenges Faced

Technical

One of the largest technical challenges the Lost Rockets this year was the frame design of the ROV. The frame design of the previous year of the team was very fragile and did not provide much room to mount ROV tools. It was the consensus of the team to scrap the previous year's design and start over. This, however, meant that another frame design needed to be drafted to fit within the size parameters that provided structure and room for mission-specific equipment.

In order to accomplish this, the engineering design process was followed. After discovering the problem and doing research into previously used frame designs by professional companies, three separate frame designs were turned out after the brainstorming session. After weighing the pros and cons of each, the simplest frame design, utilizing four thrusters, was selected. This because the basis of the ROV design and the future and was a pivotal moment in the ROV design process.

Once the ROV frame design had been established, the material used for the frame became a major challenge. Several materials were evaluated in this process, as ROV framework needs to be simultaneously rigid, robust, and light. This led to another discussion by the entire company. The eventual solution provided by the company was to use high-density polyethylene, which provided a sound technical solution to the challenge presented.

Organizational

The Lost Rockets is a small company, but nevertheless is subject to significant organizational challenges. One of the largest organizational challenges faced by the team was the ability to communicate between morning and afternoon classes. The company worked on the project over the course of this year during classes at a technical center, where different members were taking a morning or afternoon session. This made project assignment very difficult, as the morning class and afternoon class had different skill sets and could only leave behind messages to communicate. This problem was solved by coordinating afterschool meetings, communicating through GroupMe, a group messaging application, and the usage of Trello, which is a group project management site that allows for specific dates to be set for project deadlines. This helped to virtually link the company and get everyone on the same page. This way, team members would always have a project assignment every day, and were capable of accomplishing tasks more quickly and effectively.

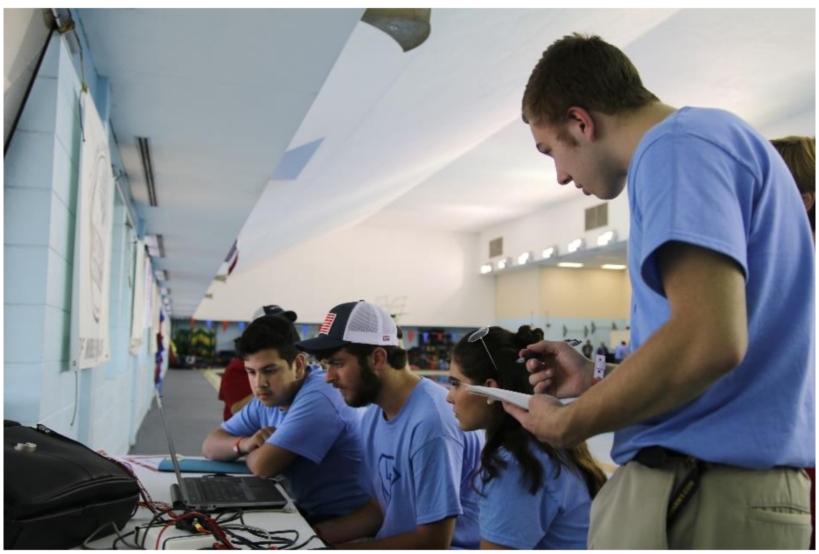

Figure 22: Company members during a product demonstration at the Gulf Coast Regional. Credit: Preston Lewis

Lessons Learned

Technical

One of the more important lessons learned in this year's company project is the difficulty in manufacturing high-density polyethylene. The company's original plan was to take various #2 plastic that people were recycling and melt down the plastic to create the HDPE sheet. However, upon actually testing this theory, it was rapidly discovered that the plastic did not bind in the way that the company had hoped for. The rather smelly mess had to be disposed of and the company had to buy sheets to machine for the ROV frame.

Nontechnical

One of the most important nontechnical challenges learned by the company this year was the importance of delegation in the company project. The entire ROV project was very large if the entire project was scanned in full, which often made it seem difficult for the company to know where to begin working. However, the company learned that dividing the main project into many small projects and separating them out throughout the team would allow work to be done in parallel, and would make the entire project less daunting. For example, Preston could work on control systems management while Tyler would manage tether wiring while Baylee would work on the marketing display. Utilizing the cooperation of the group, the Lost Rockets were capable of more efficiently accomplishing their company goals.

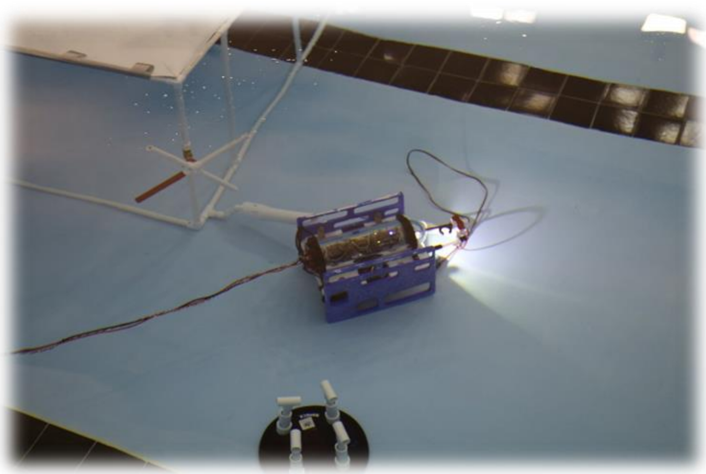

Figure 23: The Predator during a product demonstration at the Gulf Coast Regional. Credit: Preston Lewis.

Future Improvements

One of the major components of the ROV that the company would like to alter would be the setup of the control system. While the control system supplies many powerful features to the ROV, it utilized several microprocessors and added complexity to the ROV electronics. The ROV control system can be done in several different ways, all of which have unique pros and cons. One way that this could be improved would be through a single Arduino processor, which controls all of the servos on its own programming, which would make a more custom and simple solution (for wiring). However, this would complicate camera feed. Another possible improvement would be to utilize a Digilent processor and program it in LabVIEW, a programming language familiar to most member of the company. This would be the most powerful option, but would require a separate printed control board and a lot of programming. These options will be considered when designing the control system in the future for the Lost Rockets.

Teamwork

Project Management

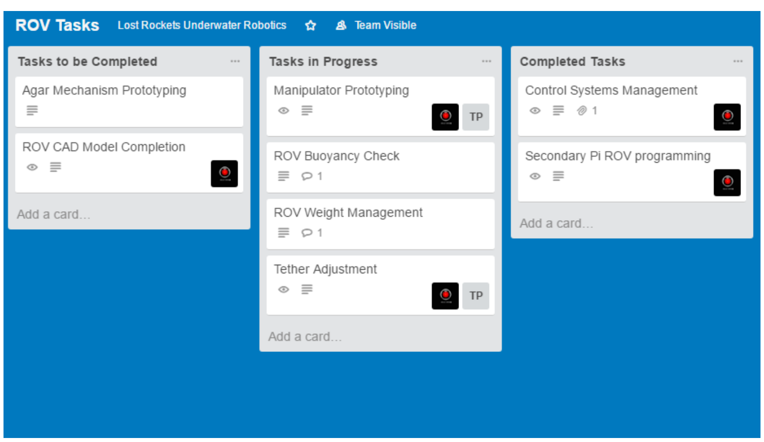

Figure 24: Trello project board. Credit: Coleman Cook

In order to accomplish the company project within the time frame given, a schedule was implemented using Trello to set goals and to keep track of all current ongoing projects. Trello is an online web-based application that can be used to assign projects to “boards” and to assign subtasks of these boards as “cards,” which can be tracked, commented on, and have files uploaded to. This enabled the company to observe, track, and complete projects at their own pace, which made for a more efficient project management of the creation of the ROV.

Task	Date accomplished
ROV frame design finalized	12/08/2016
ROV frame plates machined	12/12/2016
ROV frame assembled	12/16/2016
Control Systems design finalized	12/08/2016
Control breadboard created	12/19/2016
Electronics tray designed and assembled	2/14/2017
ROV electronics fully wired	2/24/2017
ROV assembly completed	3/3/2017
ROV testing and perfection	3/3/2017 - 4/21/2017
Mission-specific equipment testing and perfection	3/3/2017 - 4/21/2017

Company Effort

The company project was an equally spread task between all company members. Every company member of the Lost Rockets has their own unique skill set, which resulted in project assignments correlating to their strengths. The diversity of engineering, graphic design, and marketing ability helps the Lost Rockets to accomplish company projects like The Predator in current and future years.

Budget

Budget Research

In order to determine the most economical outlook to go into the 2017 fiscal year with, the entire team conducted heavy research into the technical reports of previous ranger teams that attended international competition, using the previous fiscal year of the Lost Rockets as a basis as well. Overall team placement was compared to total ROV cost, and the most cost-effective teams were evaluated to determine how they spent their money. The Lost Rockets used this method to determine the overall maximum ROV budget of $2,250, which the company came very close to.

Budget Expenses

ROV Budget

Item	Quantity	Price	Total
12 AWG Silicone Wire	1	$161.99	$ 161.99
Terminal Blocks	2	$ 3.24	$ 6.48
XT60 Wire Adapters	1	$ 6.29	$ 6.29
Fathom-X Tether Interface Board Set	2	$159.00	$ 318.00
1/2"x24"x48" HDPE Sheet	1	$ 55.43	$ 55.43
5 x 90 degree angle brackets	4	$ 13.30	$ 53.20
100 x 4mm hex stainless screws	1	$ 8.00	$ 8.00
50 x 4mm stainless locknuts	2	$ 8.21	$ 16.42
Raspberry Pi Camera v2	1	$ 49.00	$ 49.00
Rasperry Pi3	2	$ 35.70	$ 71.40
3DR Power Module	1	$ 9.99	$ 9.99
12V-5V Step-Down Module	1	$ 6.99	$ 6.99
3DR Pixhawk	1	$249.99	$ 249.99
T-100 Thruster	5	$119.00	$ 595.00
20A ESC	5	$ 12.42	$ 62.10
BAR30 Pressure Sensor	1	$ 68.00	$ 68.00
Bussman 25A Circuit Breaker	1	$ 29.98	$ 29.98
BlueRobotics 4" Watertight enclosure	1	$203.00	$ 203.00
Logitech F310 Gamepad	2	$ 23.99	$ 47.98
HS-5086 Waterproof Servo	2	$ 48.00	$ 96.00
Lumen Subsea Light	1	$ 99.00	$ 99.00
Grand Total			$ 2,214.24

Overall Budget

ROV Budget Total	**$2,214.24**
Estimated Travel Budget	**$10,000**
Total Yearly Expenses	**$12,214.24**

Finished Product

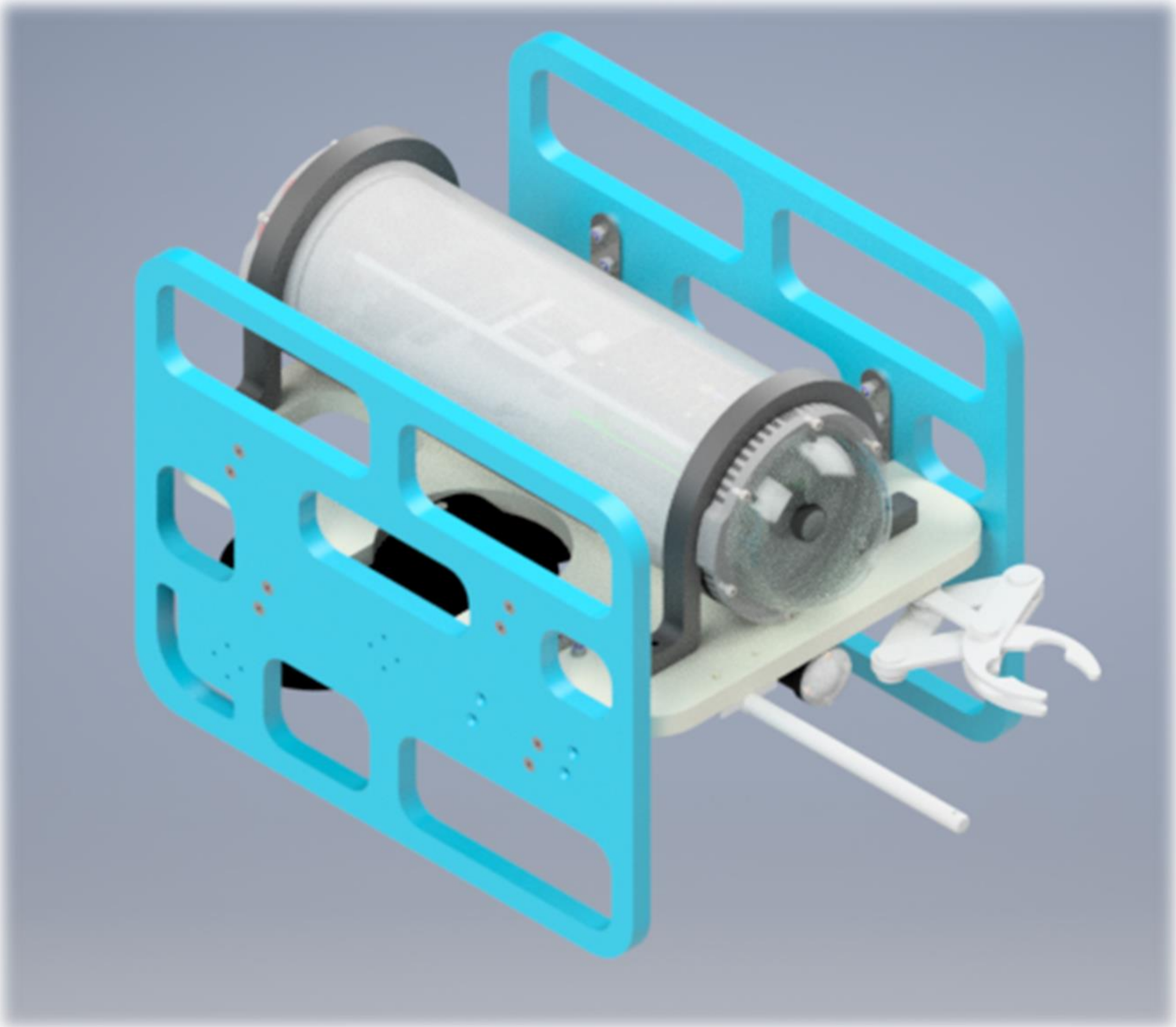

Figure 25: ROV design render. Credit: Coleman Cook

Specifications:

Dimensions: 35 x 27.5 x 27.5 cm

Dry weight: 8.4 Kg

Approximate Cost: $2,214.24

Acknowledgements

The Lost Rockets would like to thank the following sponsors:

- EFi Automotive
- Engineering Solutions Incorporated

The Lost Rockets also would like to thank the Career Technical Center for the facilities in which the team was able to accomplish their goals this year, and for mentors Casey Wigginton and Monica McConnell.

References

"NOAA Brings Precision Navigation to the Busy Port of Long Beach." *Department of Commerce*. USA Chamber of Commerce, 29 Sept. 2015. Web. 26 May 2017.