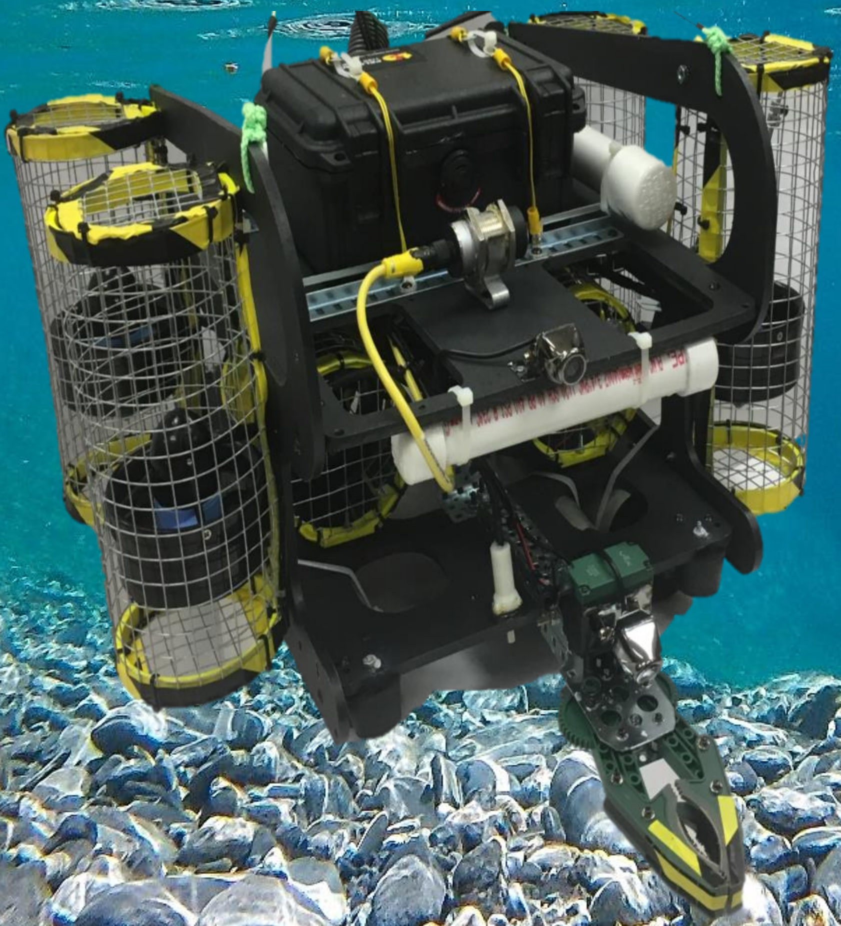
Granby Girls in Engineering

MATE ROV International Competition

O.T.T.E.R.'S. P.U.P.



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ABSTRACT

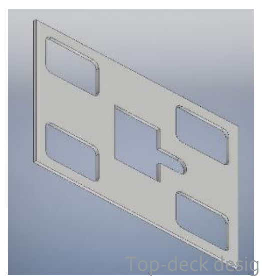
Girls in Engineering is dedicated to producing high quality underwater remotely operated vehicles (ROVs), that specialize in effectively performing specific tasks determined by the request for proposals established by MATE. Implementing various STEM components and creative elements, the company designed and built OTTER'S PUP (OSP) an ROV capable of performing this year's tasks as efficiently as possible. The exclusively female company has engineered numerous ROV's in the past, hoping to encourage women to be more involved in the male dominated field of engineering.

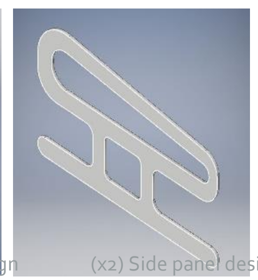
This year, Girls in Engineering strives to perform their best through the most creative ROV design they have created yet. The unique design of the Micro ROV and the claw attachments, such as the cup (intended to relocate the 'fish' and the pebbles) and the extended grip grabber, preforms the tasks presented for the International MATE ROV Competition. These attachments provide a more distinctive design. This year the company developed possible solutions to the tasks through assignment delegation and teamwork. With this process, they have developed an ROV capable of thoroughly accomplishing the required underwater tasks.

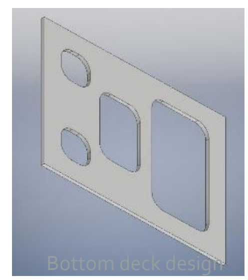
DESIGN RATIONALE

The ROV is entitled: OTTER'S PUP (Operating, Technical, Transporting, Environmental, Retrieval, System) and our micro-ROV is dubbed the PUP (Programmed Under-water Processor). Since the task this year is located in the tumultuous waters of the Boone Dam in Eastern Tennessee, placement and orientation of the propellers were selected for fine maneuverability. To maintain proper safety requirements we protected the elevation motors with 3-D printed propeller guards and labeled them with caution tape. All electrical apparatus and wires were sealed and secured by applying silicone, heat shrink, and liquid tape to ensure impermeability. OTTER'S PUP is equipped with various other special features to accomplish her missions. This includes a two-finger claw, a temperature gauge, a retractable stepper-motor measurement system and 6 cameras. In addition to the main frame, we included the required micro ROV (the PUP), which is tasked solely with inspecting a pipe. The claw is designed to firmly grasp objects and is accompanied by various accessories to complete the intended tasks. The temperature gauge reads and displays the temperature of the surrounding water in degrees Celsius. The retractable Linear Measuring Device measures the cannon's length. The cameras view the submersed surroundings, as well as auxiliary aspects of OTTER'S PUP.

2. OVERALL DESIGN


Top-deck design


(x2) Side panel design


Bottom deck design

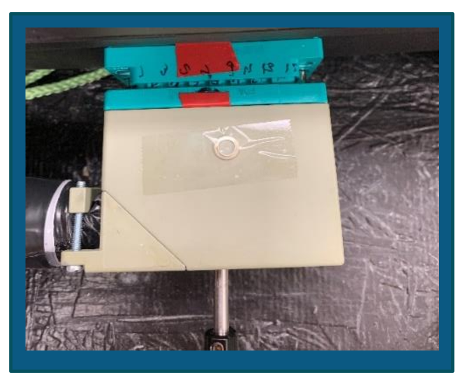
The ROV was developed through the 3-d Inventor computer program with detailed and thorough measurements, then transferred to a computer numerical control router (CNC router) for precision cutting. Cutting the polyurethane board by hand would inevitably display the human error in the process, so utilizing the CNC router eliminates the risk of visual and architectural defects in the material. Our mark-up of OBS (picture 1) was fabricated with the idea that in order to achieve the highest amount of spatial organization- there would be 2 open "decks" each serving the purpose of organizing the components on the ROV.


The CEO and electrical engineer safely constructing the multi-layered pelican box / electronics enclosure.

The durable design of the vehicle is comprised of completely waterproof materials, and the total buoyancy supports stable floating. The circuitry within the watertight electronics enclosure located on the top deck, is equipped with separated layers of labeled wiring that each serve different functions. With the modular design of the electrical components, the identification of possible wiring issues can be appropriately determined.

2.1 WIRING

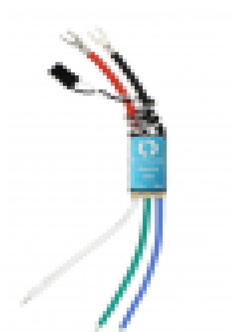
Compared to the previous year's design, the electronic components of OSP, including external connections from the ROV to the control panel, have drastically improved. The ROV tether connection was previously attached to the control panel with a multitude of various connectors. The system was un-organized and inefficient, which lead to the development of the current compact design of OSP's External wiring. The improved design was accomplished by the installment of a multi-pin cannon plug for easy cable management between the vehicle to the control panel.



The newly installed multi-pin connector allows multiple wires to work as a singular connection; improving tether attachment from the ROV to the control panel. Unlike last year, the contingent nature of time does not remain a concern. The ease of fully connecting and disconnecting the ROV makes the entire set-up process more efficient and less time-consuming.

The side of the plug containing the pins connected to the control panel is bolted onto the back of the control panel, while the other half of the plug, (containing pins that correlate to electronics within the ROV) is connected to the tether, separate from the control panel. Interlacing the wires by fastening the plug results in a fast and easy connection.

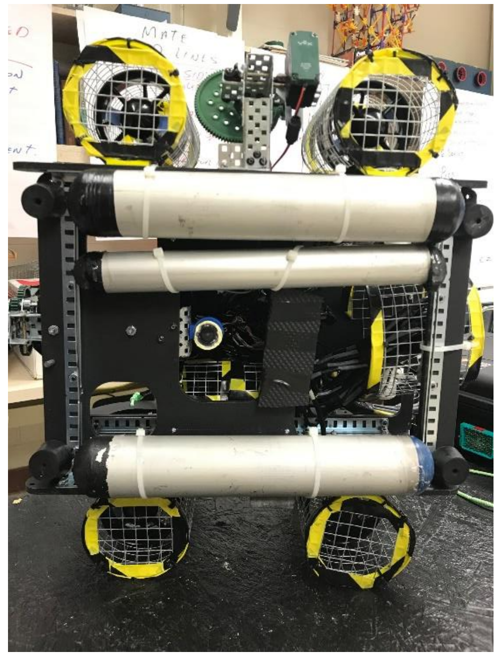
We have also improved our electronics system with the placement of 5- and 12-Volt regulators in the control panel, regulating the flow of electricity through the entire system. The voltage regulators are needed to keep voltages within the prescribed range that can be tolerated by the motors to run properly. This is a critical step to decreasing the interference within the circuitry to protect from shortages in the wiring system.



Blue Robotics electronic speed controllers (ESC's) were installed in the control box to support a high-efficiency, low-heat output design for our motors. The DC current throughout the motor wiring is turned into 3 electrical outputs, each stabilizing and controlling the speed of the motors.

Differentiators act as a stabilization feature throughout the circuit in the control panel. This circuit configuration produces output voltage amplitude that is proportional to the rate of change of the applied input voltage.

2.2 BUOYANCY



Buoyancy is critical to the successful operation of OTTERS PUP. For the tasks at hand, it is important to maintain a neutral buoyancy to ensure that the ROV only moves in the intended direction. Low-density materials like our buoyancy foam, is not only resistant to hydrostatic pressure, but also provides an easy way for stable buoyancy.

In addition, the material is easily accessible and offers a more flexible approach to manipulating the center of gravity of the ROV in water.

After our first trial in the water, we clearly needed to have a more stable buoyancy, because the weight naturally shifts closer to the front of the ROV from the weight of the claw. This caused the ROV to tilt slightly downwards in the front, which we knew would interfere with the view of the camera and completing most underwater operations.

To increase buoyancy in the back of the ROV and center the gravity, we simply taped buoyancy foam to the framing until the ROV had a slightly positive buoyancy and was level in the water. That way we know approximately how much floatation material was appropriate for completing each task and maximizing the efficiency of the vehicle.

We developed a buoyancy system to avoid any problems by attaching segments of capped and sealed PVC piping to the front, side, and back of the ROV. Trapped air in the tubes serve the purpose of floatation upon submersion and consistently throughout the deployment of the ROV.

3. THRUSTERS

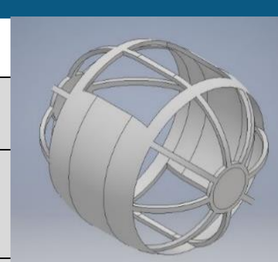
We accomplished adequate thrust capabilities through revised placement of motors on the primary ROV.

Compared to last year's design, OSP comprises a completely inversely related motor layout. Last year's ROV motor design/layout was inefficient in comparison with two elevation motors on the top and 4 drive motors on the bottom deck. This could not properly elevate the ROV because the elevation motors were blocked off by the inside components of the vehicle.

Our improved version of the layout consists of the drive motors becoming producing about 15 lbs of thrust and four elevation motors producing about 20.4 lbs of lifting thrust. This arrangement allows for a slower but more accurate forward and reverse motion and gives the ROV a high lifting capability.

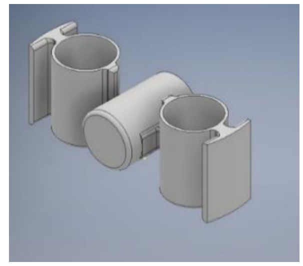
4. MICRO-ROV

The Micro-ROV (PUP) frame was entirely



Type:	ELEVATION	
Company:	4, T-100, blue robotics motors	ue robotics
Location	2 on both sides, flipped vertically	2 on 1st floor pointed horizontally

designed on the Inventor program, and then printed by our in-house 3-D printer. The bullet-shaped body of the micro is useful when driving it through the ridged Corex pipe. To maximize spatial efficiency, we designed, and 3-d printed a compact thruster compartment for the propellers. The drive system is comprised of two propellers, and elevation is driven by one. Identification of possible leakage within the Corex pipe is assessed with a camera located on the front of the ROV accompanied by an LED light. The open portions of the design maximize water flow to produce a smoother and more operable vehicle movement. With this, we can drive the ROV easily through the pipe, avoiding any circumstance where an exterior attachment on the vehicle interferes with the interior of the pipe.



Propeller compartment

Body of Micro-ROV

Through many models, trials, errors, and pool tests, we completed PUP, manipulating the placement of the propellers and re-wiring the vehicle for a more dependable performance. The testing process included determining the maneuverability of the ROV in water and deciding how the buoyancy must be manipulated by adding or taking off buoyancy foam.

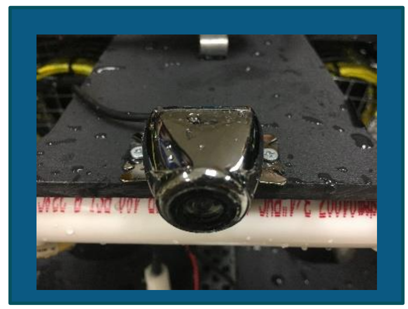
To waterproof the Micro-ROV, the propeller compartment is glued onto the inside of one-half of the frame with epoxy and the other half of the frame is put aside. The motor compartment was glued in the center spanning from side to side. To mount the motors, they are placed inside of the motor compartment and sealed with epoxy, and the caps that further protect the joint where the propeller touches the motor are sealed shut with super glue. Once the motors were mounted on the front half of the Micro-ROV, than the back half of the Micro-ROV shell were attached with epoxy.

5. CAMERAS, MONITORS, LIGHT

Visual ability on the ROV is arguably the most important feature of an ROV.

5.1 CAMERAS

The cameras display the ROV operations conducted under water. Essentially, the cameras and lights work to transmit images to our monitors from submerged areas. The placement of the cameras on the front, back, claw, side, and bottom were designed to view all intended functions of the ROV in the best way possible.

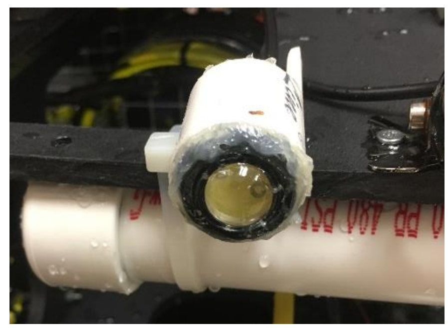


We utilized only 6 cameras because the specific placement of each camera was enough to view the operations of the ROV efficiently. We repurposed car back-up cameras and installed them on the OSP, and that is why the images presented have a distance grid. Had we used less cameras the visual data would have been insufficient, and we could not have used more than six cameras because we were only permitted to use 3 monitors.

5.2 MONITORS

Each Chuananzhuo thin film transistor (TFT) monitor is a type of LCD flat panel display screen on our control panel. Every monitor is a duel transmission monitor allowing one out of two camera channels to be displayed upon selection. The layout of our control panel allows us to view 3 monitors separately, which provides a clearer understanding of the attachments and location of the ROV.

5.3 LIGHTS



The LED lights on the front, back, side, and bottom of the ROV are to help sustain adequate visibility around the entire ROV. We designed a PVC capsule that easily fits around each of the lights to easily secure them onto the ROV. To seal the lights and ensure a water-proof attachment, we applied a generous amount of clear epoxy to the slightly open parts of the lights that could possibly lead to any leaks or damage while the ROV is in the water.

6. TETHER

Our tether weighs approximately 62.3 Newtons (6.36 Kg) and stretches a distance of approximately 15 meters. It is comprised of a 12-gauge main power cable (12vdc), 14-gauge auxiliary power cable (12vdc), 2 CAT 5 control and lighting cables, 6- 75-ohm video cables, and a 4-lead watertight cable.

7. CLAW

The claw of the OSP open and closes on a double-pole double-throw momentary switch. It is designed to complete numerous operations. Multiple detachable appendages were constructed for successful completion of desired functions. The OSP's claw is a VEX system attached to the bottom deck. The VEX motor that conducts the opening and closing operations is a standard VEX EDR 393 motor, and according to the VEX robotics website, the claw is capable of lifting a soda can and grabbing a feather. The claw also is equipped with functional hinges attached that allow it to fold up, which reduces thepossibility of damage in storage.

The tasks this year established by the Request for Proposals require multiple modes of material transportation. Particularly, a lot of transferring is involved, including the relocation of: Mexican beach pebbles, trout fry, a degraded rubber tire, a fish/reef ball, and a water canister which is surfaced to measure phosphate and pH levels. In addition, we utilized the claw to detect ferrous materials using an induction sensor.

8. SECONDARY CLAW ATTACHMENTS

8.1 ROCK-FISH CUP

The Rock-Fish Cup was designed on inventor with the purpose of transporting the Mexican beach pebbles and the trout fry, hence the name 'Rock-Fish' which pays tribute to the two products it is intended to transfer. It has the appearance of a cup split into two sections with a cone/funnel-like bottom. One half of the cup is attached with Velcro to one side of the claw, as is other side. This is done so that when the claw is closed, the cup looks like a regular cup; however, when the claw opens up each cup half is pulled apart to safely drop off the substance sitting inside. The bottom of the cup is not flat so that when it is opened the transported materials can slide out and not get caught on a flat surface. The grate on the top prevents any material from escaping the cup during the course of transportation.

8.2 SECONDARY TIRE CLAW

The Secondary claw was designed to lift and move substances the regular VEX claw could not grip. For example, the tire is too wide for the regular claw to get a hold on, but the Secondary Tire claw appendage has no problem with the wider load.

Our attachment is comprised of two re-purposed VEX 1x25 zinc plated cold rolled steel bars curved to form a scissor-like gripping device. The handles attach with Velcro to the claw. When the claw opens, the grip widens. When the claw closes, the grip clamps down, thus able to grab the sunken tire.

8.3 INDUCTION SENSOR

Induction Proximity Sensors detect metallic objects without contacting them directly. The operating voltage of this system is about 10-30 VDC, while the load current is 200 mA. The output is normally unshielded open sink. The sensor on the OSP works by first being secured in the claw on the surface, and then submerged and located at the desired testing site. The task requires that we detect whether or not disguised identical appearing pipes are metallic.

When the sensor is hovered 15 mm away from the pipe, it will alert us whether or not it is a ferrous material. If the substance is a metal, the sensor will send a signal to the control panel that flips on an alert light which we know indicates that a ferrous material has been detected. If the material is not metallic, the sensor will simply not identify it as such and the light will not cut on.

9. ROTATIONAL MEASUREMENT ATTACHMENT

To properly measure, an external attachment must be rotational to measure a crack or object at any angle.

-used in task 1 to measure largest crack on transect line, and task 3 to measure cannon

-stowed position and extended position

-vex robotics framing, small and large vex gears minimalize the rotational movement of the ruler, moves in smaller intervals for more precise measurements (the increase in diameter of one gear)

Vex motor turns a shaft connected to the larger gear

10. CONTROL SYSTEM:

Our control system is designed to be controlled by one person with one VEX Robotics controller, however the mutual work of 4 employees is needed for proper piloting. Programming issues leading to faulty elevation patterns were easily changed and a more innovative button and programming layout was achieved. The VEX robotics controller is programmed in the arcade setup, to make driving the ROV more user friendly.

10.1 ARCADE SETUP

- What the joysticks accomplish

Right joystick	Left joystick
- Forward and backwards thrust	- Elevation up
- Left and right drive	- Elevation Down

We maintained the same format/ controller system from last year but improved the programming software to contribute to a more efficient pool schedule and operation.

11. CONSTRUCTION SAFETY CHECK LIST

✓ Check	Safety procedure
	All sharp edges are carefully filed down, and smoothed to avoid possible injuries.
	Long hair tied back when testing the motors, gluing or soldering materials, and working with power tools.
	Eye protection and respirators/ masks worn when doing heavy sanding or filing with a machine.
	No open toed shoes in the building area
	Proper usage of machinery or tools. (No horseplay or violent behavior when in the classroom vicinity.)
	Stationary fan for circulation to rid of fumes from epoxy.
	All work with dangerous or hazardous tools/materials is under proper adult supervision.

12. SAFETY FEATURES DESCRIPTION

Black and yellow hazard tape	The black and yellow hazard labels are taped around thrusters, providing a safe way to warn that there is danger, and to avoid unnecessary injuries.
Hardware cloth	The small squares throughout the galvanized steel "cloth" mesh is designed to stop any electrical or mechanical components from external interference. This avoids any possible hazards for people observing or working on the ROV. When cutting the cloth, sharp edges were thoroughly tended to and filed down, and hazard tape was wrapped around the edges.
Fast blown fuse	With the fast blown fuse, the electrical current in the circuit is cut off to avoid electrical overload. It also avoids electrical shock caused by the exposure of wires to the conductive properties of water, avoiding full system failure.
Smoothed edges	There are no sharp and possible hazardous edges on the ROV, every edge is properly filed down until smooth to the touch.
Tether strain relief	The string lifting line located on the top allows the ROV to be handled gently to relieve the stress on the tether when lifting the ROV from the water.

13 PROJECT/ TASK DESIGNATION

To manage assignments and construct the ROV as efficiently as possible, the tasks within the manual were evenly designated to employees. This way, everyone always has something to be working on and everyone specializes in a specific area of the ROV's fabrication process.

In addition to the effective use of time, the CEO conducts regular meetings for employees to share important information about thoughts, ideas, repairs, and additions to the ROV. This process allows everyone to have a general idea of the components on the ROV.

14. COMPANY COMMUNITY OUTREACH

TYPE	DATE
• Granby High School's freshman and new student orientation	August 28, 2018
• Nauticus Girl Scout STEAM Night	October 13, 2018
• Girls In Engineering Lunch and Learn	November 9, 2018
• Barnes and Noble Maker Fair	November 10, 2018
• Virginia Academy of Science and Math	January 15,2019

Girls in Engineering Presentation

- Granby High School Sophomore/ AP Night — January 31, 2019
- Crossroads K-8 School STEM club Presentation — February 7, 2019
- International Technology and Engineering Education Conference Showcase — March 28, 2019
- Nauticus Women in Stem Day — March 30, 2019

15. COMPANY SCHEDULE

The goal of our company is to run in a well-organized manner to achieve maximum productivity. We designed a system to reach this goal, and in return have produced a well- equipped and highly efficient piece of machinery, our very own, OPS.

Our schedule consists of meeting in a high-school engineering classroom after school twice a week: Monday and Wednesday, from 2:15 to 4:00 PM (when buses provide afterschool transportation). However, with the ongoing dedication to thoroughly and quickly complete, run tests, and repair the ROV in time for the competition, many employees stayed after on days not already scheduled, from 2:15 to 4:00 PM normally on Tuesdays or Thursdays, and provided their own transportation from school.

16. TESTING AND TROUBLESHOOTING

To test the ROV, we collaborated with the Norfolk Fitness and Wellness Center to utilize the pool as a testing site. Before pool testing, we conducted 3 tub tests to ensure the buoyancy of the ROV was adequate for piloting in the pool. The tank/ tub that we test the ROV in has a 110-gallon capacity and sits outside the classroom site. Weekly pool tests for the necessity of diagnosing the ROV for problems were a critical step to knowing how our ROV reacts in water at various depths. In the pool, the

CEO practices piloting with those assigned to the control panel and monitors, while other employees tend to the tether and ROV at the pool.

17. REFLECTION

This year our team encountered a multitude of obstacles while designing and constructing OTTER'S PUP. Although we have a program that has been involved in MATE competition and the world of under-water robotics for seven years; each year the different request for proposals keeps us redesigning and innovating.

Compared to our past ROV's, the OSP has an advanced design. We did an excellent job this year of designing our frame to maximize water flow to the thrusters. To eliminate the elevation control problems and minimize interference/blockage, we installed four thrusters on the outside of the frame shielded with safety galvanized steel cloth mesh casing. The pelican box has been air tight through every pool test, and although all of our wires are safely sealed and water-proofed, never in our history as a Company have we had a perfectly sealed box on the submerged ROV. The singular cannon plug connecting the tether to the control panel is an immense advancement from the difficult individual connectors we had installed in previous years. The location of the claw is ideal for the attachments necessary for completion of the various tasks. We utilized every aspect of the claw that we could, making it multi-purpose was one of our biggest strengths. The placement of the cameras and lights is optimal for displaying all important aspects of the submerged areas and transmit to the monitors clearly. The micro ROV was an innovative design that addressed many realistic factors. As a team, we are very proud of the accomplishments we achieved in the development of our ROV this year.

Although the OSP is the most efficient product our company has developed so far, there are areas where we should improve on in the future. The water-tight sealing on our lights and cameras were not successful and we ended up having to replace them. The buoyancy of the tether and the ROV itself presented an enormous effort to level it. The motor connections within the electronic box and control panel were constantly requiring repair. The microprocessor programming system developed serious problems. All in all, learning from these mistakes (and others from the past) and not making those same decisions is how we plan to improve as a company and keep moving forward with our development of future ROV's. The best learning opportunities arise from errors, and we look forward to growing our Company and advancing to become the best we can be.

As a team of women in STEM, we learn so much about ourselves and become well rounded individuals due to our exposure to the STEM field.

18. FINANCIAL COST TO BUILD THE ROV

Items:	Quantity:	Price per Unit (USD)	Total Cost (USD)
Rear backup camera	6	17.99	107.94
Portable 7" Digital Color Screen Monitor	3	34.11	102.33
LED Lights	4	18.81	75.24
Pelican Box (small)	1	25.95	25.95
Pelican Box (Large)	1	134.95	134.95
Sea Board (Black)	4	16.92	67.68
T-200	2	169	338
T-100 Motors	4	119	476
Mini motors	3	3.49	10.47
Pro Boat Propeller comp (set of 3)	1	10.99	10.99
3D printer Support material	1	100	100
3D printer material (ABS)	1	200	200
Basic 30A ESC	6	29.41	176.46
VEX Microprocessor	1	454.53	454.53
VEX Claw kit	1	19.95	19.95
VEX Servo Motors	2	50.55	101.1
Miscellenious VEX hardware/	1	45	45
Anderson Powerpole connectors	1	17.03	17.03
12 gauge cable	1	54.55	54.55
500ft network cable	1	75.07	75.07
4 in. Black Nylon Wire Tie 18lb Tensil (100-pack	1	6.67	6.67
7 in. Natural Wire tie 50lb Tensile (100 pack)	1	6.93	6.93
1/2 inch hardware cloth (1 10ft roll)	1	10.95	10.95
EDAC plug 120 pin	1	27.06	27.06
Temperature Meter Gauge	1	12.68	12.68
Inductive sensor (unit and cable)	1	125	125

Heat shrink wire wrap cable sleeve tubing slee	3	9.4	28.2
Black spray Paint	1	8.93	8.93
Hinge set	1	2.48	2.48
Nuts & Bolts	1	7.87	7.87
Epoxy	1	5.47	5.47
Liquid Tape	3	7.49	22.47
Silicone sealer	3	3.98	11.94
Electrical Tape (10 pack)	1	17.64	17.64
Pool noodle	1	3	3
Ruler	1	6.48	6.48
			$2,897.01

19. REFERENCES

1. https://www.vexrobotics.com/vexedr/products/accessories/motion
2. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&cad=rja&uact=8&ved=2ahUKEwjymubfjq_iAhVS11kKHSRhC4kQFjAEegQIDxAI&url=https%3A%2F%2Fab.rockwellautomation.com%2FSensors-Switches%2FInductive-Proximity-Sensors&usg=AOvVaw1dnS78EzrtcqtPoyV6EdLD
3. https://www.bluerobotics.com/
4. https://www.marinetech.org/rov-competition-2/
5. https://www.electronicshub.org/operational-amplifier-as-differentiator/

20. ACKNOWLEDGEMENTS

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- Rodes United Methodist Church – United Methodist Women
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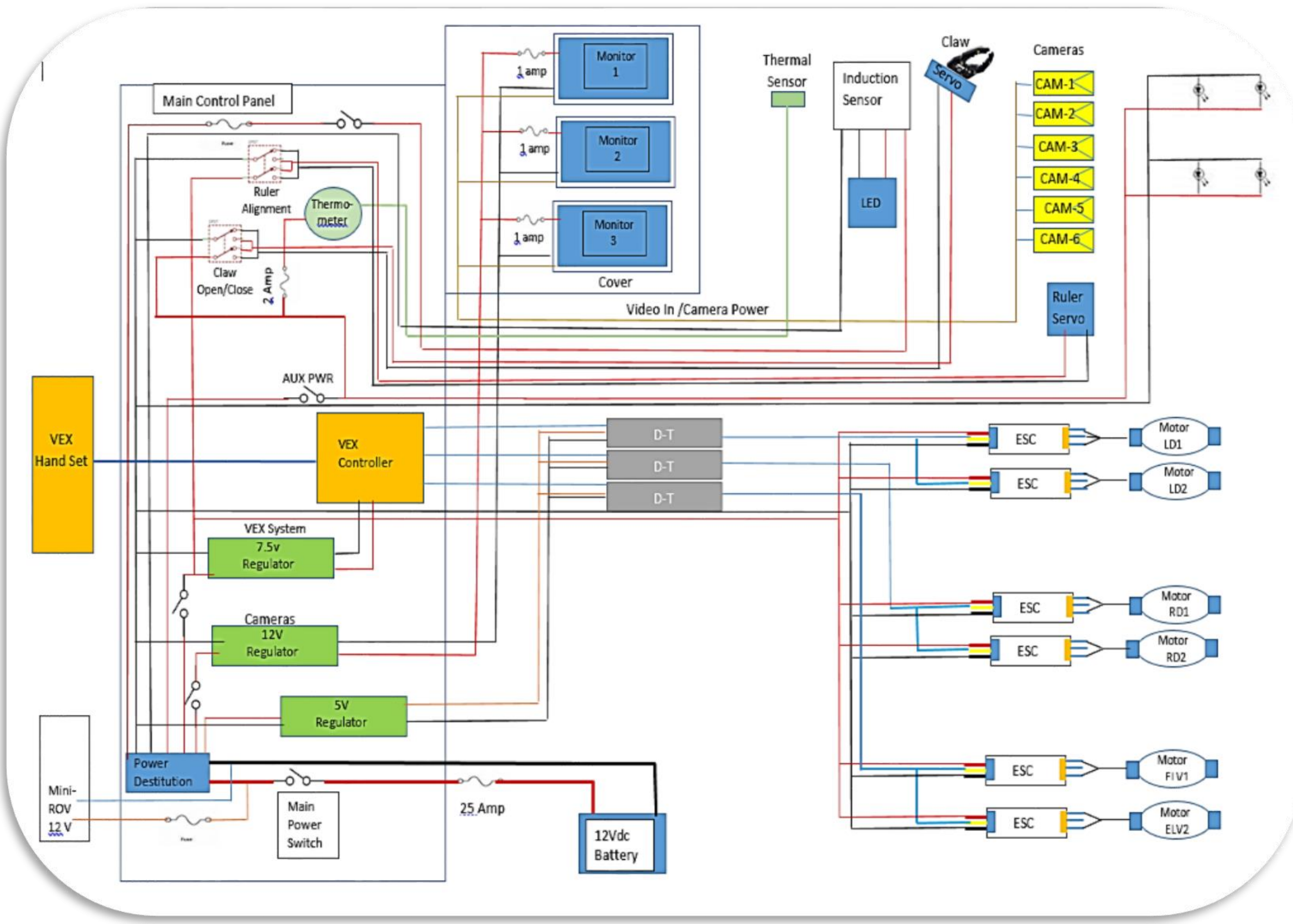
- Marshall Severin aquatics manager for Norfolk fitness center
- Staff and Faculty at Granby High School for moral support and donations

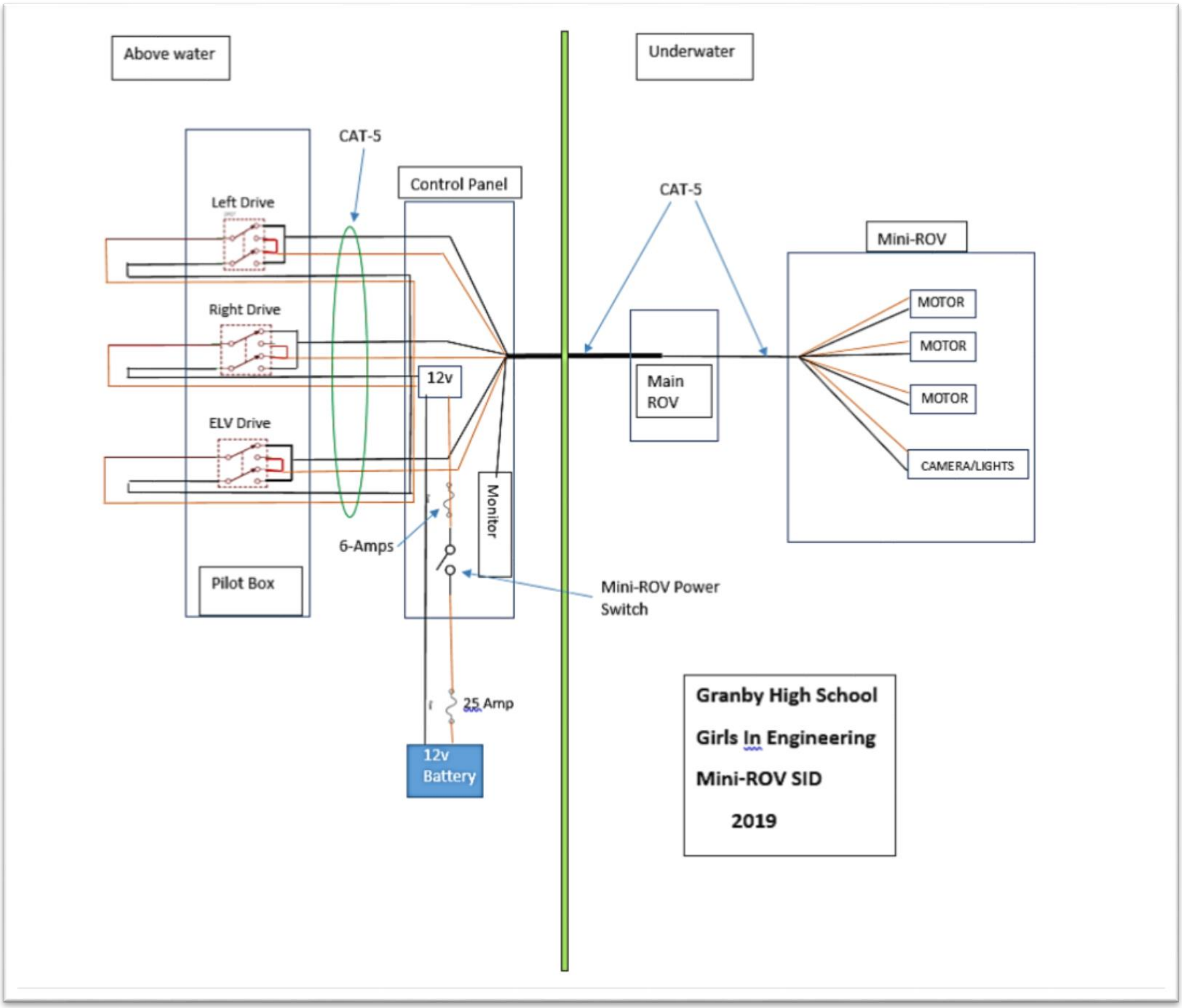
APPENDIX I

PRIMARY ROV SID:



APPENDIX II

Micro ROV SID



APPENDIX III

Fluid AIR BAG SID