Crusader Robotics

Brother Rice High School
Chicago, IL, U.S.A
2018 Technical Documentation

Name	Robotics Title	Future Career Goal	Grade
Jack Clisham	Idea Generator	Engineer	11th
Liam Coughlin	VP of Mechanical Eng.	Aerospace Eng.	11th
Andrew Cwik	Idea Generator	Engineer	10th
Tyler Davros	Camera Researcher	Engineer	10th
Conor Durkin	Prop Builder	Engineer	9th
Charles Dvorak	VP of Electrical Eng.	Computer Hardware Eng.	11th
Brian Gidney	Prop Builder	Engineer	9th
Nolan Greene	Idea Generator	Computer Hardware Eng.	11th
Gabe Gutierrez	Prop Master	Engineer	9th
Nick Kaminski	Engineer	Aerospace Eng.	11th
Malcolm Kindle	Engineer	Electrical Eng.	11th
Jack McBrearty	VP of Mechanical Eng.	Biomedical Eng.	12th
Brian McCann	Prop Builder	Engineer	9th
Matt McCormick	Mechanical Eng.	Biomedical Eng.	12th
James McManus	VP of Mechanical Eng.	Automotive Eng.	12th
Frankie Mesec	Idea Generator	Engineer	10th
Nicolas Perez	Buoyancy Director	Engineer	12th
Ryan Rice	Engineer	Engineer	10th
Gabriel Valles	Prop Builder	Civil Eng.	9th
Austin Veal	Prop Builder	Computer Science	9th
Pat Walsh	CEO	Firearms Eng.	11th
Vince Zampillo	VP of R&D	Engineer	12th
Mentors			
Dan Mostyn			
Eric Gamboa			

Abstract

Crusader Robotics has been operating in Chicago, IL since 2014. The design process of the Remotely Operated Vehicle (ROV) began with team members sketching and constructing prototypes using K'nex. We constructed one prototype using PVC, and built another with fiberglass. Fiberglass proved difficult to manipulate so the team decided the final design would be constructed out of PVC.

The first task the ROV is designed for, "Aircraft," involves the ROV assisting in recovering sunken aircraft in Lake Washington. Two cameras locate the wreckage and identify the plane by studying the tail structure. To remove the wreckage and retrieve the engine, a lift bag is attached with help from the claw.

The second task, "Earthquakes," involves installing an ocean bottom seismometer (OBS) and other sensors in the ocean to study seismic activity. The ROV uses the claw to retrieve the cable connector, close the door, and connect the cable connector to the company's OBS. Then a Radio-Frequency Identification (RFID) card on the ROV activates the OBS, sending the basket and the cable connector to the surface.

The third task, "Energy," involves an ROV assisting in investigating the feasibility of tidal power. The claw brings the turbine base down, attaches and locks the array, drops the mooring, places and locks the I-AMP, and retrieves the eelgrass. The cameras help survey the mooring area for measurement. The dynamic buoyancy system on the ROV brings the robot to the surface quickly to save time. Crusader Robotics is proud of all the hard work put into Edmund Mk. IV.

Photo of Edmund Mk. IV
Photo Credit:David Wolf

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Project Management

Crusader Robotics must keep a smooth flow of productivity to ensure a successful year of competition. To do this, we will elect members of the club to lead specific aspects of the team, such as research & development, mechanical engineering, or electrical engineering. We also use this opportunity to elect our CEO, who will supervise all aspects of production.

Later on, once we receive our mission tasks, we implement the engineering process of design. We start off by defining our problem; we look at our tasks and figure out what we need to do to complete our task. Then, we generate concepts by which we can complete the tasks. We, then, develop solutions to incorporate our concepts into our ROV. Once we develop our solutions, we start prototyping and testing to ensure a properly functioning and efficient ROV. After we have finished our final prototype, we transition it to a working ROV and constantly tweak and evaluate our solution.

To make sure this process happens according to schedule, after we develop solutions, we gather as a team and create our project timeline from then until the day of the competition.

Project Timeline		
Week	**Dates**	**Agenda**
W14	1/21 - 1/27	Build Props, Purchase Claw Materials, Purchase Cameras, Construct OBS
W13	1/28 -2/3	Build Frame, Research Motors
W12	2/4 -2/10	Purchase Motors, Construct Claw
W11	2/11 - 2/17	Attach Claw, Attach Cameras, Attach Aux.
W10	2/18 - 2/24	Wire Tether, Design Shirts, Wire Console
W9	2/25 - 3/3	Misc. Troubleshooting
W8	3/4 - 3/10	Start Poster, Start Spec Sheet
W7	3/11 - 3/17	Misc. Troubleshooting
W6	3/18 - 3/24	Take Team Picture, Misc.
W5	3/25 - 3/31	Practice Product Demo, Make Final Poster
W4	4/1 - 4/7	(Spring Break)
W3	4/8 - 4/14	Practice Product Demo, Finish Spec Sheet
W2	4/15 - 4/21	Practice Product Demo, Practice Presentation
W1	4/22 - 4/28	Practice Product Demo, Practice Presentation
W0	4/29 - 5/5	Regional Competition

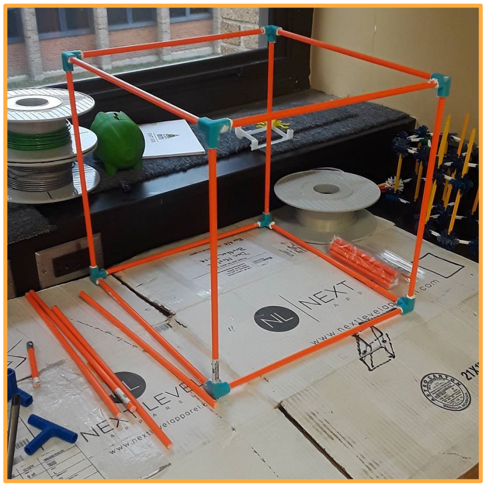
Crusader Robotics 2018 Project Timeline

Design Rationale

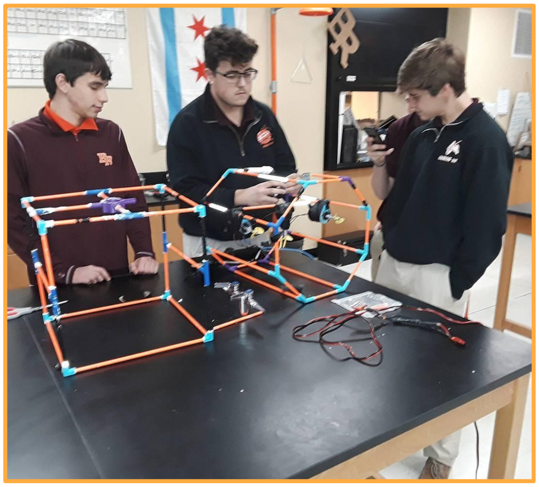
Frame/Motor Layout

At the start of the year the team decided to explore new building materials for the frame. For the past three years the team has used PVC, but this year we wanted to experiment with new materials to make a better ROV. After prototyping and testing PVC and fiberglass models the team decided that we should continue using PVC. Although the fiberglass proved to be lightweight it was not very configurable. The PVC was easy to configure and it worked with 3D printed parts that the team had designed in previous years.

The team also tested multiple shapes for the frame. A cube shape proved to be the most stable and easiest to turn. These were both important features because of all the precise movements that the ROV needs to make in the water.



Prototype Fiberglass Frame
Photo Credit:Dan Mostyn



Testing Different Shapes
Photo Credit:Dan Mostyn

The Edmund Mk. IV is the most powerful ROV ever created by Crusader Robotics. For 2018, the team upgraded the forward-facing drive motors to two 1200 gallon-per-hour (gph) bilge pump motors, which have been modified to increase the flow of water. Every motor is secured with a custom 3D printed motor mount, each of which is designed with channels for ease of waterflow. In addition, the downward facing motors have been upgraded to 800 gph bilge motors to help the improved robot rise and dive. The powerful 1200 gph motors share angled attachment points with smaller 500 gph motors, which are used to steer the robot. In total, six different motors are used to propel and maneuver the Mk. IV.

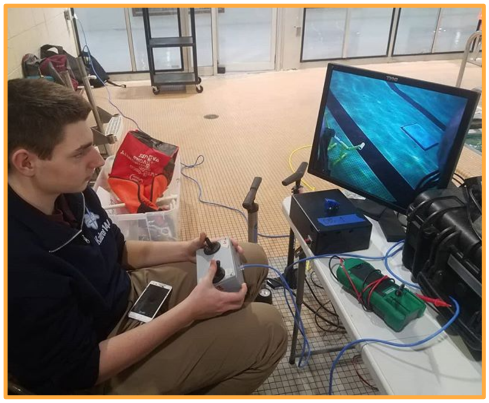
The motor layout is a combination of the the team's previous designs. Two 800 gph bilge pumps are put diagonal from each other facing downwards for balanced up and down movement. The two 1200 gph bilge pumps are in the center of the ROV and allow fast movement forward and backwards. The two 500 gph motors used for turning are angled to fit the size restriction of 60 cm while still providing the tightest turning radius possible.

Design Rationale

Cameras

The ROV features two fishing cameras, one for the claw and one for directional purposes. The team chose fishing cameras because of their wide angle view and watertight seal. The camera on the front helps the drivers get a better view of the claw when the ROV needs to grab something like the eelgrass. The main camera is placed at the center of the ROV to provide a wide view of the ROV's surroundings. These cameras are attached to the ROV's PVC bars by a custom designed 3D printed part. The camera system is one of the features of the ROV that is critical to the competition tasks. Two monitors are used to display each of the cameras' view.

Both Cameras Attached to the ROV
Photo Credit:Dan Mostyn



Nolan Using the Cameras
Photo Credit:Dan Mostyn

Tether Thimble

To provide strain relief and prevent our solder joints from tearing, the ROV has a tether thimble. When pressure is put on our tether, it will tug on the robot instead of the wire connections. This keeps the integrity of the tether intact.

Thimble on Top of ROV
Photo Credit:Jack McBrearty

Design Rationale

Claw

The team chose to expand on the claw design of last year's ROV because of its reliability and ability to be controlled with a waterproof bilge pump. To improve the claw's grip, a gear mechanism was added. The gear train, which is housed inside a protective casing, reduces the speed of the claw and increases the torque, thus giving the claw more precise control and a stronger grip. This element is crucial since the claw is one of the most important tools on the ROV. It is used to transport and recover multiple items such as the lift bag, the cable connector, the turbine base, the mooring, the I-AMP, and eelgrass. The versatility of the claw helps in the recovery of aircraft, studying of earthquakes, and researching of tidal waves.

Picture of Claw
Photo Credit:Mike LaBella

Lift Bag and Inflator

The lift bag is used to move debris and recover the aircraft engine. We modified the lift bag by adding multiple hooks on the bottom, so that it can easily connect to debris and engine. The lift bag inflator tube is attached to the claw for fast and efficient inflation. The inflator air tube is part of the tether and is connected to a bike pump on the surface. To pump air into the lift bag, one of the tether men will pump air through the tube until the driver feels that enough air has been provided to lift heavy items.

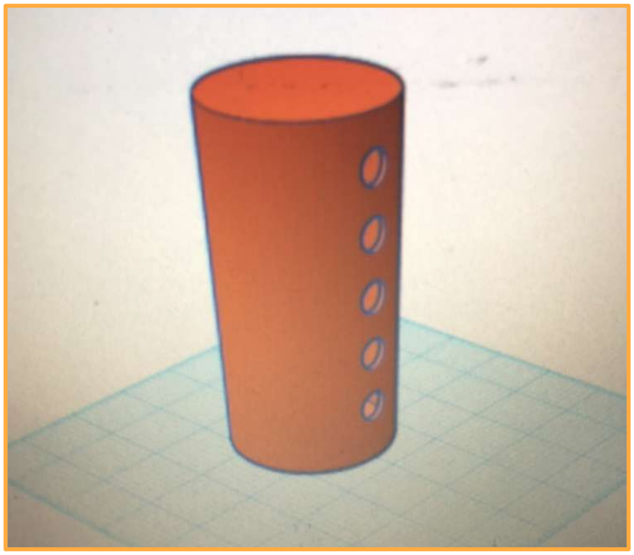
Lift Bag
Photo Credit:David Wolf

Design Rationale

Buoyancy/Gravitational Transit Flotation Utility (GTFU)

The ROV needed to be neutrally buoyant so that it would not sink or float while performing tasks. To make the ROV neutrally buoyant, the wet weight of the robot was measured. Then, using an equation, the team was able to figure out how many inches of empty 2” PVC pipe would be needed to make the ROV neutrally buoyant. To fit size restrictions, the PVC was cut into four pieces. They were attached to the top of the ROV. A dynamic buoyancy system called the Gravitational Transit Flotation Utility (GTFU) was added to provide a quick way of rising to the surface. A bike pump pushes air through a tube into a 3D printed cylinder which has holes on the bottom. These holes ensure that the pressure inside the cylinder never exceeds the ambient pressure. This makes the robot positively buoyant, providing a quicker way up. At the surface, a tether man will open a valve attached to the GTFU to let water flow in and return the ROV to neutral buoyancy.

Pumps for GTFU and Lift
Bag Inflator
Photo Credit:Jack McBrearty

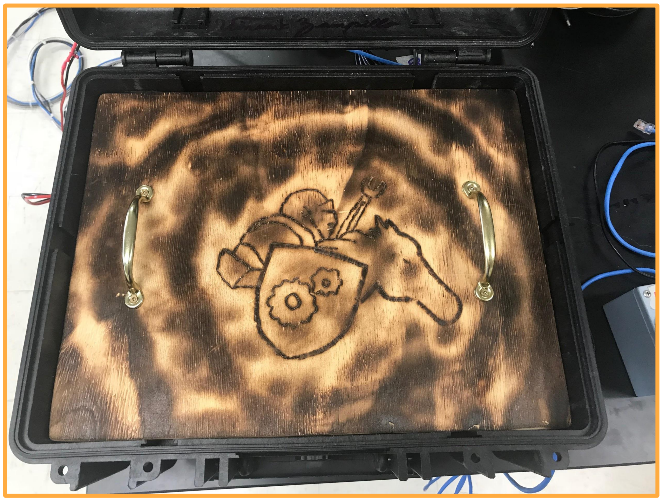


3D Model of GTFU
Photo Credit:Nico Perez

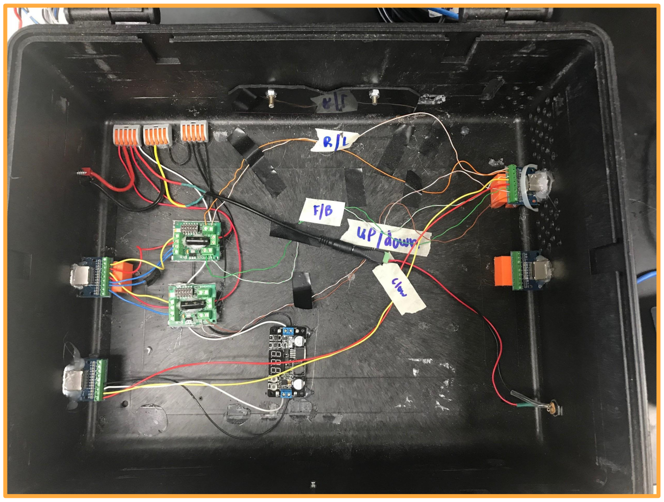
Design Rationale

Control Box

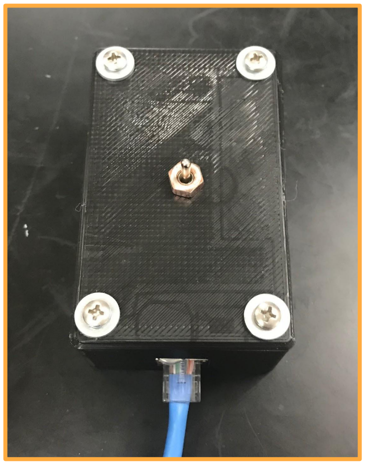
The control box was refurbished from Edmund Mk. III, but it was made much simpler. Inputs from the motor and claw control boxes are on the right, and output to the ROV is on the left. Two dual axis potentiometers that are in the motor control box feed into two sabertooths which adjust the voltage that feeds into the motors. A voltage converter bumps down the voltage for the claw from 12 volts to 9.5 volts so that the gears don't wear down.



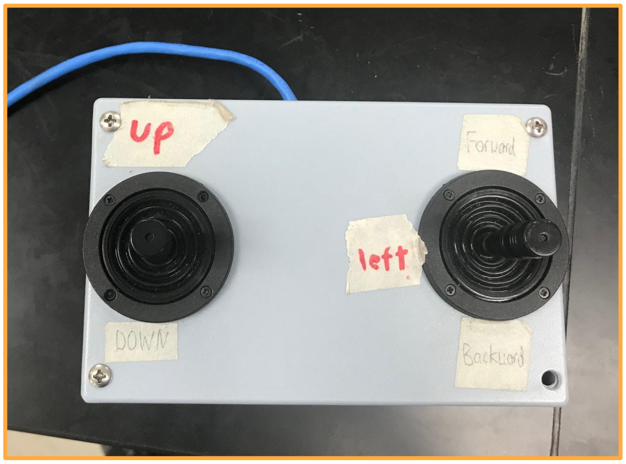
Custom Cover for Control Box
Photo Credit:Jack McBrearty



Inside Control Box
Photo Credit:Jack McBrearty



Claw Control Box
Photo Credit:Jack McBrearty



Motor Control Box
Photo Credit:Jack McBrearty

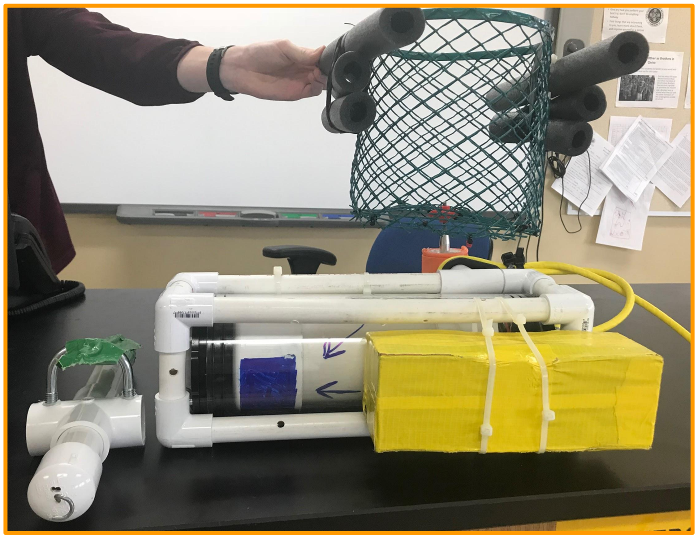
Design Rationale

Ocean Bottom Seismometer (OBS)

When the Request for Proposals was released, the team sat down together and decided that a wireless bluetooth release mechanism for the OBS was the best option. The OBS electrical components are housed inside two tubes: the first being a 3-inch PVC tube nested within a Blue Robotics Tube. This provides the OBS with two layers of protection against leaks. Two bricks were attached to the sides to make the anchor negatively buoyant.

The OBS basket to hold the cable connector was made out of netting for minimal weight. Foam was added to the sides to make the basket positively buoyant. This helps the basket rise to the surface quickly. A nut was put on the bottom of the basket to connect it to a bolt on the release mechanism.

The basket is released when a keycard on the ROV activates a motor with a threaded bolt attached. This bolt will spin, causing the nut to slip off, therefore releasing the entire basket. When the keycard is close enough to a blue designated area, an RFID sensor controlled with an Arduino will read and identify the card. The card holds a special ID number, making it the only card that can activate the OBS. A relay with a voltage converter then provides power to the motor to spin the threaded bolt.

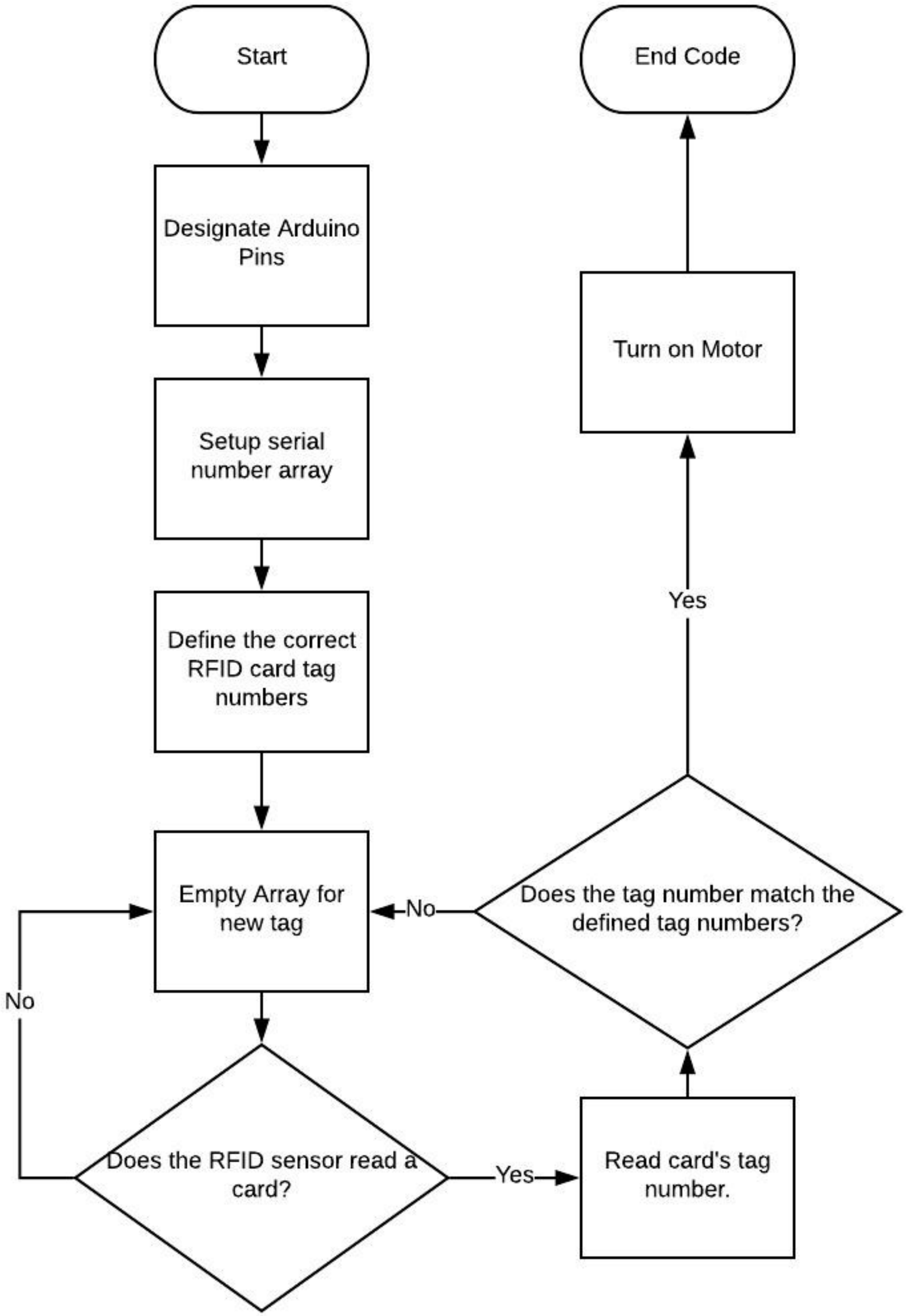


OBS System
Photo Credit:Jack McBrearty

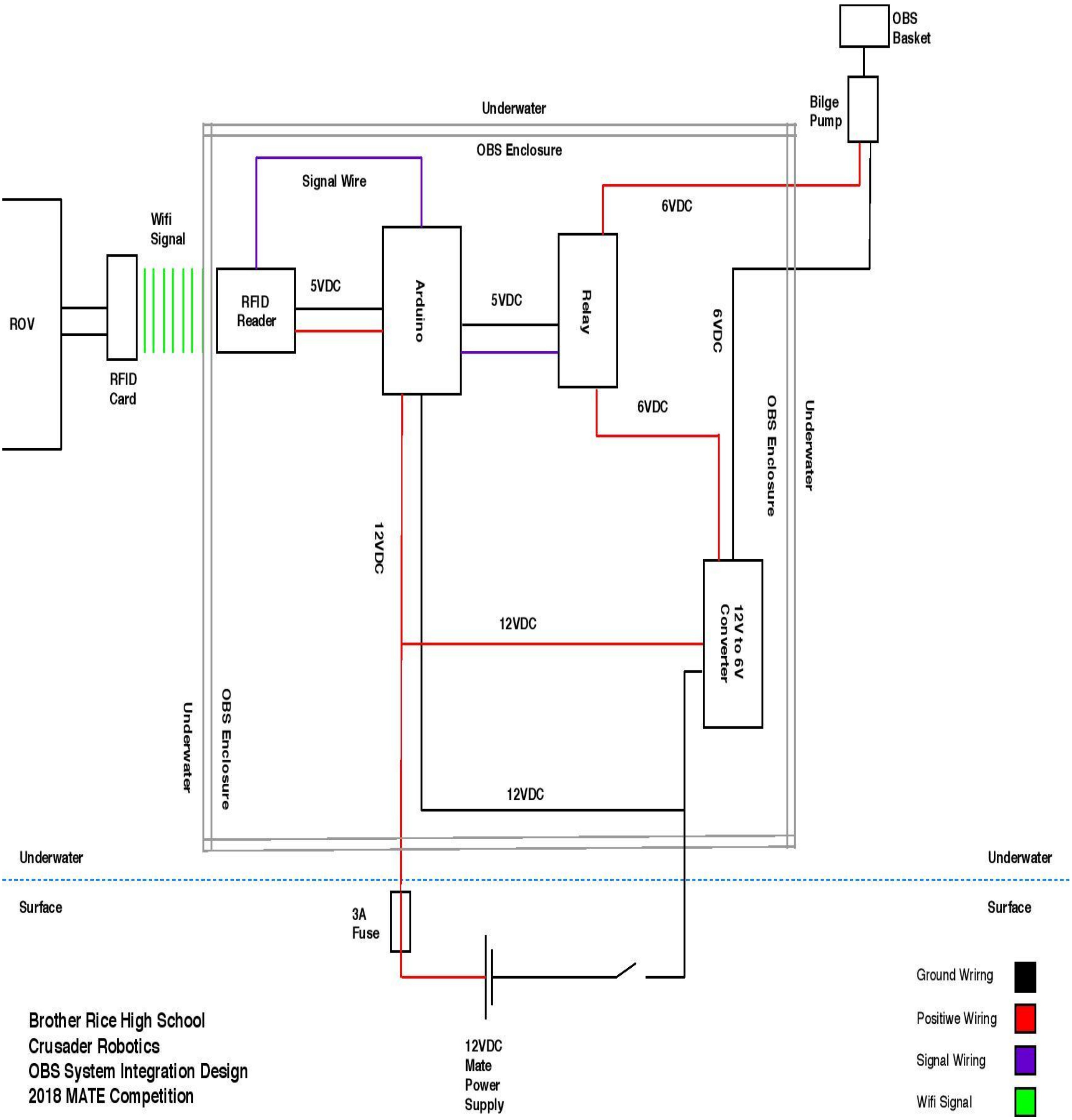
OBS Release Nut
Photo Credit:Jack McBrearty

Design Rationale

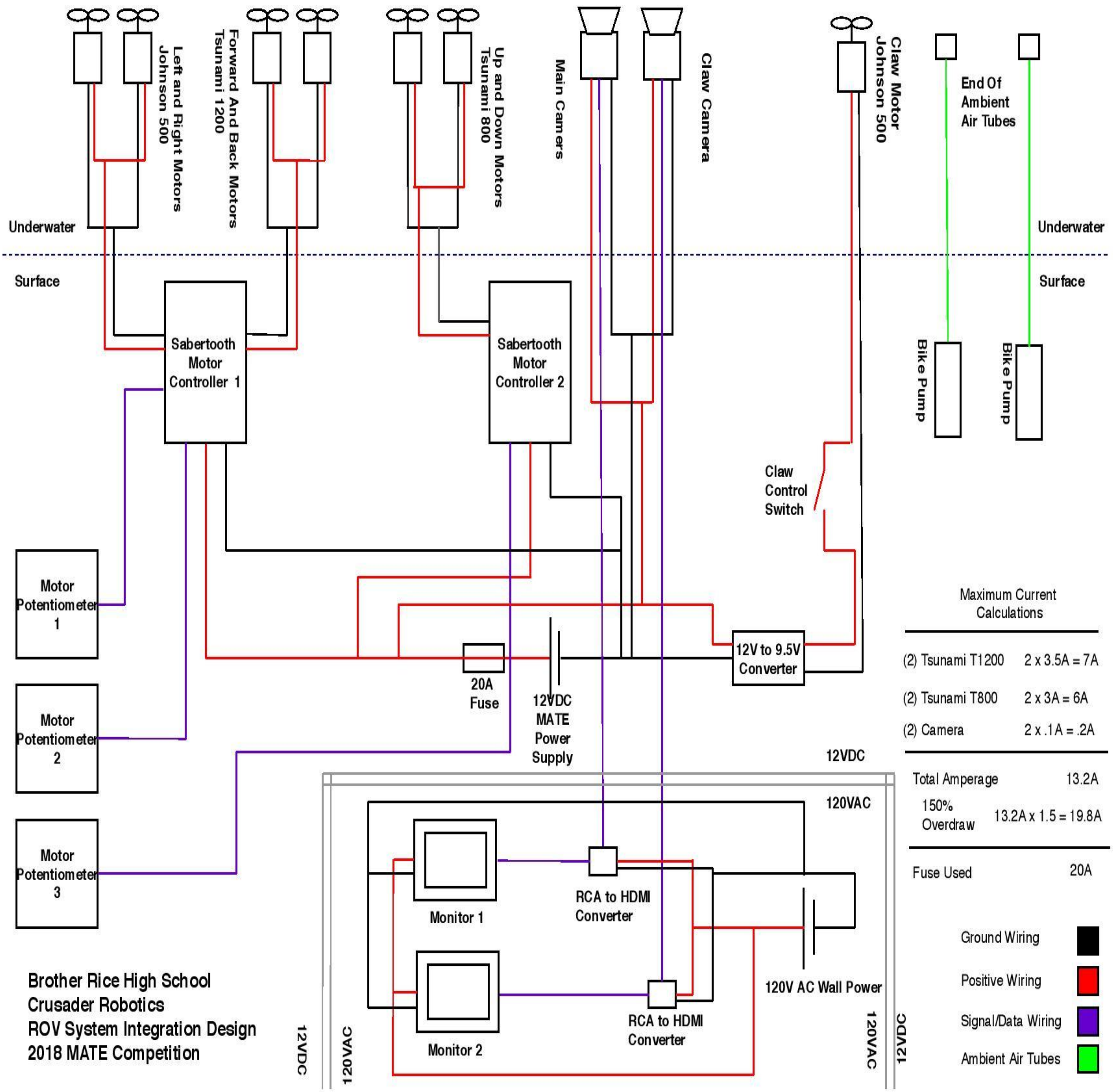
Ocean Bottom Seismometer (OBS) Code Flowchart



OBS SID


OBS
Basket
Bilge
Pump
Underwater
OBS Enclosure
Signal Wire
6VDC
Wifi
Signal
ROV
RFID
Reader
5VDC
Arduino
5VDC
Relay
6VDC
RFID
Card
6VDC
OBS Enclosure
Underwater
12VDC
12VDC
12V to 6V
Converter
Underwater
OBS Enclosure
12VDC
Underwater
Underwater
Surface
Surface
3A
Fuse
Ground Wrirng
Positiwe Wiring
Signal Wiring
Wifi Signal
Brother Rice High School
Crusader Robotics
OBS System Integration Design
2018 MATE Competition
12VDC
Mate
Power
Supply

ROV SID



Left and Right Motors
Johnson 500
Forward And Back Motors
Tsunami 1200
Up and Down Motors
Tsunami 800
Main Camera
Claw Camera
Claw Motor
Johnson 500
End Of
Ambient
Air Tubes
Underwater
Surface
Underwater
Surface
Sabertooth
Motor
Controller 1
Sabertooth
Motor
Controller 2
Bike Pump
Bike Pump
Claw
Control
Switch
Motor
Potentiometer
1
Motor
Potentiometer
2
Motor
Potentiometer
3
20A
Fuse
12VDC
MATE
Power
Supply
12V to 9.5V
Converter
12VDC
120VAC
Monitor 1
RCA to HDMI
Converter
Monitor 2
RCA to HDMI
Converter
120V AC Wall Power
12VDC
120VAC
120VAC
12VDC
Maximum Current
Calculations
(2) Tsunami T1200 2 x 3.5A = 7A
(2) Tsunami T800 2 x 3A = 6A
(2) Camera 2 x .1A = .2A
Total Amperage 13.2A
150%
Overdraw 13.2A x 1.5 = 19.8A
Fuse Used 20A
Ground Wiring
Positive Wiring
Signal/Data Wiring
Ambient Air Tubes
Brother Rice High School
Crusader Robotics
ROV System Integration Design
2018 MATE Competition

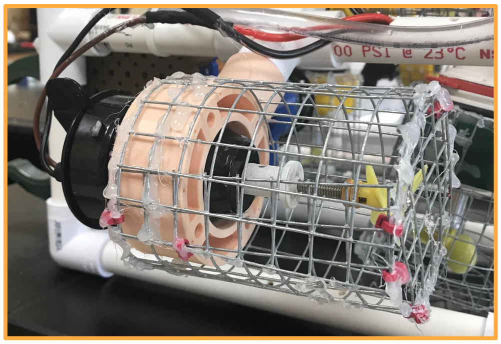
Safety

Introduction

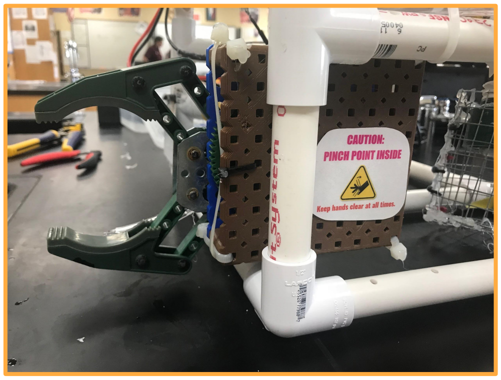
Brother Rice Robotics is a large team with many active members. This is one reason why the company takes safety very seriously. The group, to ensure that nobody gets hurt while on the job, employs heavy scrutiny on nearly every aspect of construction, testing, and competition of the season's robot. The ROV itself is always being combed for things that could potentially harm someone. Then, the problem is dealt with quickly and efficiency. Preventive maintenance of this caliber is why Brother Rice's robotics team is top notch in safety.

ROV Safety

Focusing on the product itself, the Edmund Mk. IV is routinely inspected for sharp edges. When the robot was completed, all edges were located, sanded down, or covered in a protective layer of hot glue. Special attention was taken to eliminate surfaces that could pierce human skin and cause significant injury. Similarly, the whirling propellers of Edmund Mk. IV are shrouded in durable metal wire cages. The spaces in the cage measure under 12.5 mm in width, meaning that they are within MATE's regulations. Advanced shrouding such as this protects the robot from collisions with the environment around it, along with protecting the outside world from the dangers of spinning propellers. A pinch point does exist in the claw gear box. However a casing protects anything from getting inside. A warning label was added as extra precaution.



Shrouded Motor
Photo Credit:Jack McBrearty

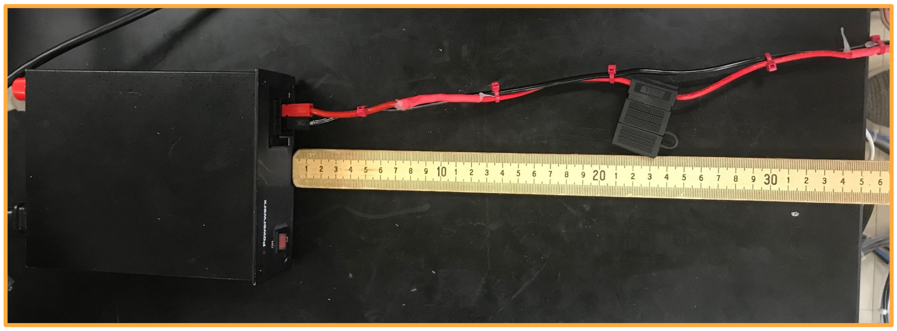


Pinch Point Warning Label
Photo Credit:Jack McBrearty

Safety

Electric Safety

The safety of Brother Rice Robotics' products does not end with the physical aspects of the ROV. The electrical components that deliver AC power to the vehicle's electrical drivetrain are monitored with even more gusto than the frame, as uncontrolled electricity is very dangerous, especially when mixed with water. Starting at the wall outlet 110 volt power, a power supply moderates how much raw electricity is sent down to the robot and control station. 15 centimeters away, a 20 amp fuse is connected to the power supply. 15 centimeters is MATE's standard measurement for a safe distance, so Brother Rice Robotics made sure to wire it in exact specification. There is also a small 3 amp fuse connected to the course's underwater OBS. The team sets a limit of 25 amps coming in regards to fuses, so this fuse setup is designed to be in accordance not only with MATE, but the team's own set standards. Once power is delivered through the power supply and fuse, the team is almost ready to set sail. Moreover, all underwater soldering connections on Edmund Mk. IV are waterproofed in order to further prevent any risk of shock or electrocution. To waterproof a connection, the soldered joint is first covered in a sleeve of heat-shrink. Then, the connection is plugged on either side with hot glue. Finally, heat is applied to the joint in order to activate the heat-shrink and seal the soldered wires off from water. This process is done on every underwater connection, and the company makes sure to document every waterproofed wire. The last aspect of company safety in regards to electricity involves the control console; it is kept shut doing all operations in order to keep the internal computers dry and reduce the risk of shock.



Fuse is within 30cm of power supply.
Photo Credit:Jack McBrearty

Team Safety

Finally, there is an advanced culture of safety that surrounds every member of Crusader Robotics. The team periodically employs mock safety inspections in order to guarantee consistent safety and quality. In addition, the team always wears safety glasses while both on the pool deck and off. At the beginning of the season, Crusader Robotics hosted soldering lessons for new and returning members so they could hone their soldering skills and to ensure they could solder safely. Finally, every member that wanted to use a specific power tool received pointers on how to use the tool safely and effectively.

Critical Analysis

Testing and Troubleshooting

Crusader Robotics believes that practice is essential to doing well in the pool. It was a priority to get into the water as soon as possible to test. We would set up a mock MATE Competition using the props the team built and practice constantly so that drivers could became more familiar with the robots functions and perform better.

It also allowed us to test prototype attachment parts. A great example would the the dynamic buoyancy system. The Gravitational Transit Flotation Utility (GTFU) went under multiple design changes before it became what it is today. Multiple lift bags were also prototyped and tested before deciding on a final model.

Getting in the pool early in the season also allowed us to adjust and improve the ROV earlier to make it into what it is today. Team members who went into the pool and setup the practice run were able to check issues such as waterflow or turning on the ROV. Tether men were able to check the buoyancy on the ROV. Drivers were able to see the responsiveness of controllers and cameras. Mechanical issues were easier to spot and fix in the workshop. Electrical issues were pinpointed using a multimeter to watch voltage drops.

Challenges

We originally faced a problem with the voltage drop on a type of wire we had hoped to use as our primary tether wire. We fixed this problem by replacing the wire with RJ45 CAT5 wiring which carries current with a much lower voltage drop. This allows us to have more voltage reach the ROV. This helps the motors and claw have more power.

The shrouding was difficult to decide on because of the new rules requiring that no gap exceed a ½ inch. Our ROV was slowed down because water did not have a lot of space to flow through in our early shrouding designs. The cover for the bilge pumps had to be sawn down to allow more water to enter. We designed our 3D-printed motor holder to have ducts to allow more water to flow through the motors and grant us the maximum amount of thrust to help navigate through obstacles.

The team was divided on whether or not we should switch our original PVC design to a fiberglass frame so that we could move around more easily, as the fiberglass was much lighter than the PVC. We had a meeting and decided to make a prototype of the fiberglass frame while also making a PVC frame in case the fiberglass frame fails. During the process of constructing a prototype out of fiberglass, we found that fiberglass was difficult to adjust unlike PVC, which is much more interchangeable and adjustable. Ultimately, the team decided to use PVC for the final design.

Our team had many ideas for the motor placement. Some layouts emphasized strafing, while others offered a tight turning radius. By laying out the Pros and Cons of each motor layout and then voting as a team, we ultimately settled on the layout currently on our ROV. This process let everyone agree on one layout and it also showed everyone what our motors were used for so that we all would know the advantages and disadvantages of our options.

Critical Analysis

Lessons Learned

Many of the older and veteran members of the team were able to pass their technical knowledge to newer members. New team members were able to learn how to solder, design 3D printed parts, work with PVC, and crimp wire.

All members were able to build time management skills. The team set deadlines to keep the project on track. It helped members learn how to space out their work. Communication skills were strengthened as the year went by. The more we held meetings, the better we were able to communicate ideas and apply them to the ROV. Our communication also helped us operate the ROV in the water better. Repeatedly practicing in the water allowed our drivers and teathermen to work more smoothly as a team. An efficient system has developed where the main driver directs the other members while also listening to their inputs with respect. This has allowed us to score points effectively in the water.

The biggest thing everyone gained from this year was friendship. Most of us came from different walks of life. We had football and track players, swimmers, gamers, boy scouts, entrepreneurs, honor students, average students, and much more. None of us ever thought that this group of guys would have so much fun this year. Lots of jokes were made and memes were very abundant. Each of us know that we now have lifetime friends. It is sad to see some of the seniors go this year but we wish them the best of luck in college.

Team Photo
Photo Credit:Dan Mostyn

Future Improvements

Reflection

One thing that the team would like to improve on is the motors. Although the bilge pumps have been very reliable they were a struggle to use this year. The motors had a flat disc on top that blocked waterflow which made it very difficult to move backwards. Even after shaving most of that disc off the ROV still moves backwards slowly. The shrouding requirements also added to the struggle of getting enough water flow. Our original shrouding blocked so much flow that the ROV crawled through the water at an alarmingly slow pace, and even though our current shrouding allows us to move at a reasonably fast pace, we feel we could do better. We have explored the idea of using Blue Robotics motors, which are designed to allow more water to flow through. Shrouding wouldn't be very difficult to design and 3D print. Blue Robotic motors also have a lot more thrust, which would make the ROV significantly faster and thus making it possible to acquire more points in the pool. It can be a painful experience when we run out of time before completing a task because we were to slow. The Blue Robotic motors would help save a lot of time traveling from task to task. We did not implement them this year as we were concerned about the amount of amperage it took to run them, and we feared that they could have put us over the 25 amp limit. Overall we are very pleased with Edmund Mk. IV but we do know that it can definitely be improved upon.

Pat Shaving Down the Motor Cover
Photo Credit:Dan Mostyn

Accounting

Budget

Total Budget Used				
Unit	% Budget	Budget	% Budget Spent	Budget Spent
ROV	40%	$600	38.7%	$580.87
Console	40%	$600	37.6%	$564.42
OBS	20%	$300	14.9%	$233.76
Total	**100%**	**$1,500**	**92%**	**$1,379.05**

Cost Accounting

Console Expenditures		
Item Description	Condition	Cost
Case	Re-Used	$80.00
2x Sabretooth	Re-Used	$140.00
2x Dual Axis Joystick	Re-Used	$30.00
2x Bike Pumps	Donated	$50.00
20 Amp Fuse	Re-Used	$8.00
1920x1080 Monitor	Donated	$89.99
1280x1024 Monitor	Donated	$53.95
Toggle Switch	Re-Used	$25.00
5x Ethernet Jack	Re-Used	$5.00
Barrel Jack + Splitter	New	$5.00
2x VGA to HDMI Converter + Power Supply	New	$25.00
2x2 Plywood + 2x Gate Handle	New	$13.48
1x1x1 Neodymium Magnet	Re-Used	$1.00
Voltage Converter	Re-Used	$12.00
Surge Protector	Re-Used	$7.00
Anderson Power Cord	Re-Used	$5.00
Misc. Wiring	New	$10.00
Calculator	Donated	$4.00

Accounting

Cost Accounting

OBS Expenditures		
Item Description	Condition	Cost
RFID kit	New	$50.00
Arduino Uno	Re-Used	$30.00
Breadboard	Re-Used	$5.00
Blue Robotics Enclosure	Re-Used	$60.00
Blue Robotics ROV Wire	New	$30.00
LED Switch	New	$3.00
Hobby Box	Re-Used	$10.00
Voltage Converter	Re-Used	$12.00
800 gph Bilge Pump	Re-Used	$19.76
Misc. Hardware and Wiring	New	$14.00

ROV Expenditures		
Item Description	Condition	Cost
2x 1200 gph Bilge Pumps	New	$49.16
2x 800 gph Bilge Pumps	Re-Used	$39.52
3x 500 gph Bilge Pumps	Re-Used	$41.19
2x Fishing Cameras	New	$300.00
Vex Claw	Re-Used	$20.00
Tether Thimble	Re-Used	$5.00
Ambient Air Tubing	New	$30.00
CAT 5e Cable	New	$10.00
Plastic Ball Valve	New	$3.00
PLA Filament	New	$30.00
Misc. PVC	New	$35.00
Misc. Wiring	New	$5.00
Misc. Hardware	New	$13.00

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