NEMO I

Brother Rice High School Chicago, IL, USA
"A Crusade For a Better Tomorrow"

TECHNICAL REPORT 2023

Team Member	Year	Company Role
Alex Novak	12	Chief Executive Officer
Michael Arundel	12	Chief Executive Officer
Aydan Tetrev	12	VP of Electrical Engineering
Peter Connolly	12	VP of Mechanical Engineering
Troy Bever	12	VP of Mechanical Engineering
Nick Morrin	12	VP of Coding
Andrew Hoefler	12	Chief Pool Technician
Elijah Lemay	11	Lead Fabricator
Andres Andrade	11	Lead Fabricator
Jack Tadevich	11	Fabricator
Nicholas Smolek	11	Fabricator
Dan Hernandez	11	Fabricator
Bobby Gilligan	11	Fabricator
Oscar Roa	10	Prop Fabricator
John Kruder	10	Prop Fabricator
Sam Lapenas	10	Prop Fabricator
Derek Van Dyke	Teacher	Mentor

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I. Introduction

A. Abstract:

Crusader Robotics has been operating in Chicago, Illinois since 2014. The design process for this year's Remotely Operated Vehicle (ROV), NEMO I, began with our members deciding to make the framework out of High-Density Polyethylene (HDPE). Then, the frame was visualized on paper and on CAD software using, which allowed our team to see how parts would interact before they were even constructed. HDPE has allowed the company to specialize the ROV for its specific tasks. With the mission of inspecting and maintaining marine renewable energy systems,surveying and restoring marine ecosystems, this ROV is designed with a claw as its main tool.
This claw allows the ROV to install and moor solar panel installations, remove human and biological fouling, release fish fry, cover and medicate diseased coral and install underwater observation equipment. The ROV also includes a camera which allows the ROV to effectively inspect sites for damage/problems, to search for and locate items and to assess and estimate wildlife and sea grass health. Crusader Robotics is very proud of all the hard work put into the NEMO I.

B. Theme

The Global Ocean Community (GOC) has issued a request for proposals for innovative, capable, and reliable remotely operated vehicles (ROV). The purpose of these new vehicles would be to combat global climate change, reverse the decline of ocean health, and monitor the ocean ecosystem for further research and solutions.

Since 70 percent of the Earth's surface is covered in water[1], that leaves limited land space for wind turbines and solar panels to be installed. As the global population grows, land space will become even more valuable to provide housing and agricultural resources. Installing floating solar panel farms within existing offshore wind turbine farms in the ocean effectively opens up an even greater amount of land space which can be utilized by other future means as stated above while still meeting global energy demand. One such offshore wind farm is the Morro Bay wind farm. The Morro Bay turbines have an energy output of 1000 mw which is enough to power 400,000 homes. The company is based out of Morro Bay, California in St.Louis Obispo County.[2] Between the wind turbines, like those of Morro Bay, companies like SolarDuck are working to implement floating solar panel arrays to truly maximize the energy potential of the site. Specifically, SolarDuck's "Merganser" project has already received 8 million Euros in funding, catalyzing the push to develop floating solar panel arrays.[3] In addition, companies like Ocean Infinity are already working to develop a fleet of ROV's to maintain offshore wind farms.[4] These ROV's will now have the dual purpose of maintaining both wind and solar infrastructure. To support these offshore wind and solar farms, and the clean energy they create, ROV's need to perform device installation, regular inspections and routine maintenance such as repairing transmission cables and removing human and biofouling.

A drop of water that begins its journey in an inland pond high in the Rocky Mountains - or even higher up in Lake Titicaca in the Peruvian Andes - will eventually make its way to the sea.[5] Since most water on the planet flows into the ocean, the health of our inland lakes and rivers is vital to the overall health of our oceans. In order to maintain the health of these inland waters, we need ROV's to survey habitats, reintroduce native fish species, assess the health of frog populations, and install devices for long term environmental study. Native Fish are important to aquatic ecosystems because healthy fish populations tend to mean a healthier aquatic environment.[6]

Oceanic waters are vital and need to be maintained as well. The world needs ROV's to collect environmental and biological samples, repair diseased coral and monitor seagrass recovery. Seagrasses occupy 0.1% of the seafloor, yet are responsible for 11% of the organic carbon buried in the ocean. Seagrass meadows, mangroves and coastal wetlands capture carbon at a rate greater than that of tropical forests[7]. Preserving coral reefs is also essential to ocean health. Coral reefs support more species per unit area than any other marine environment, including about 4,000 species of fish, 800 species of hard corals and hundreds of other species, but many are dying out.[8] Over the past 35 years, 50% of coral reefs have died out and scientists also estimate about 70-90% of all remaining coral reefs will disappear over the next 20 years.[9] ROV's are integral in completing the work of coral reef restoration in a safe and efficient manner.

Sources:

1.)https://phys.org/news/2014-12-percent-earth.html

2.)https://castlewind.com/morro-bay-project/#:~:text=Castle%20Wind%20Offshore%20is%20a,and%20San%20Luis%20Obispo%20County.

3.)https://oceannews.com/news/energy/solarduck-and-partners-to-build-and-test-offshore-floating-solar-platform-merganser?utm_source=ONT+Newsletter&utm_campaign=beaf2d8216-EMAIL_CAMPAIGN_2022_11_23_02_11&utm_medium=email&utm_term=0_-beaf2d8216-%5BLIST_EMAIL_ID%5D

4.) https://oceaninfinity.com/

5.) 2023 MATE Ranger Manual

6.)https://www.nps.gov/subjects/fishing/benefits-of-native-fish.htm#:~:text=Fish%20provide%20many%20services%20for,native%20creatures%20is%20still%20vital.

7.)2022 MATE Ranger Manual

8.)https://oceanservice.noaa.gov/education/tutorial_corals/coral07_importance.html

9.)https://brightly.eco/blog/why-are-coral-reefs-dying

II. Design Rationale

C. Design Evolution

The NEMO I (Nautical Environmental Maintenance Operator) is the newest edition to our product line. It replaces our long standing Edmund Mk product line and the short-lived NORM product line. Crusader Robotics has learned a great deal from the Edmund Mk and NORM product lines. The NEMO I takes the best and most ambitious parts of the Edmund Mk and NORM product lines and focuses on construction and integration in the cleanest, most reliable and most functional way. This can be most clearly seen in the control box organization, the optimized tether, the improved thruster performance, and the underwater ESC housing. The goal of any ROV design for Crusader Robotics is to build a machine that is highly versatile and able to accomplish the greatest number of MATE performance tasks possible.

NEMO I is the result of many months of tireless effort by our design and fabrication team. Research, planning, analysis, construction and testing were all conducted under rigorous safety protocols. Strict size, weight, materials and power specifications were all accounted for on the ROV. In order the maximize the reliability and cost effectiveness of the

ROV we spent significant time analyzing whether to build or buy and whether to use an existing part or innovate a new one

D. Design/Build Schedule

Crusader Robotics developed and adhered to a schedule throughout the design and build process. We began meeting in October, before any MATE materials had been released. Tasks during this time included acquiring and educating new team members, evaluating past ROV performance, evaluating past designs and planning for improvements to the ROV that would be valuable regardless of the tasks to be performed. These improvements included adding a 6th motor, attempting to implement vectored thrust, upgrading to more flexible 12 gauge tether wiring to properly handle the motor amperage, moving the ESC's to the ROV in a sealed compartment to reduce the size of the tether bundle, minimizing ROV mass and designing new motor shrouding to maximize motor thrust capacity. When MATE materials were released in January we began to review the material and create plans and designs to meet the performance tasks for the 22-23 MATE competition. Testing and revisions were ongoing during this time. Prop construction also began as early as possible to as not to impede ROV testing. As the product demonstration neared and the ROV began to take shape team members increasingly focused their attention on documentation, paperwork, the marketing display and the presentation. Significant pool training time was also given to our pilots and deckhands over the final month of the season. A our schedule can be seen in Appendix A.

E. Specific ROV Components

Shrouding: The motors are protected with a 3D printed plastic shrouding. The shrouding helps prevent items such as floating debris, wildlife, and people from getting near the moving blades of the propellers, while reducing thrust loss as much as possible.

Buoyancy: The ROV needed to be neutrally buoyant so that it does not sink or float while performing tasks. To make the ROV neutrally buoyant, the weight of the robot underwater was measured. Using a formula, Flotation modules were constructed using 1" PVC pipe, to provide the necessary buoyancy to create a neutrally buoyant ROV. Once the ROV was close to neutrally buoyant, additional flotation and ballast were added as needed to achieve the desired buoyancy.

Motor Design: The motors we chose to use this year are 4 Blue Robotics T-100's and 2 Blue Robotics T-200's. Blue Robotics motors were chosen again due to their excellent control and high amount of thrust. We used a "Modified Traditional" motor configuration that allowed for the freest flow of water through the motors to maximize thrust and maneuverability. The ROV has 2 motors for up/down, 2 motors for strafe and 2 motors for forward/back that can be operated independently to allow for "tank style" turns.

Claw: The team used a modified VEX claw, oriented vertically to maximize gripping potential. A gear train was added to improve the amount of torque applied by the motor and, subsequently, the claw's grip strength. Elastic strips were also added to improve gripping ability and versatility. This element is crucial since the claw is one of the most important tools that the ROV uses to perform its duties.

Cameras: The ROV features two fishing cameras. One camera has a view of the claw and another has a directional view. The team chose to use ice fishing cameras again because of its wide field of eyes and factory made waterproof seal. The top view camera allows the pilot to navigate and align to targets. The side view camera allows for the claw to be engaged and disengaged at the proper time.

Frame: The frame of the ROV is made of high-density polyethylene (HDPE). The from is constructed from 1" x .5" HDPE. A sheet of .25" HDPE was used to support and secure the ESC compartment. 3D printed feet (risers) were added to the bottom of the frame to take the brunt of the force when the ROV impacts the seafloor.

Risers: Risers provide a nice solid landing point, proper ground clearance for the ROV, and protects the claw from scraping against the ground.

Tether/Strain Relief: To provide strain relief and prevent our solder joints from shearing, the ROV has a tether thimble. When stress or strain is put on the tether it will tug on the ROV's frame instead of the wires. This preserves the integrity of the tether, while only adding a small amount of weight. Removable plugs were added to the control box as topside strain relief and to make management and storage of the tether easier.

Other Safety Features: At the surface control station, a 25 amp fuse is installed as a preventative measure for current overdraw. When more than 25 amps of current run through the fuse, it will trip and shut off all power beyond that point. To waterproof soldered connections, hot glue and heat shrink wrap were used. These connections were then covered in electrical tape as an extra measure. The shrouding on our motors meet the 0.49cm maximum hole size requirement, and the shrouds are securely attached to each motor. We have also taken care to ensure that no sharp edges are present on the ROV. For safety the ROV claw uses a switch that defaults to "open". This means that anything that accidentally gets stuck or pinched in the claw can be easily released as there will be no force applied to the system when the claw switch is not being pressed by the operator. Finally our control box never has to be open. This reduces the risk of electrical shock and reduces the risk of damage to the electrical components. Pictures of these safety features can be found in Appendix B.

F. Build/Buy & Use/Innovate

Three important considerations when choosing to build/buy or use/innovate are a.) cost b.) functionality/reliability c.) time. Buying and/or using an existing part or design can often save significant amounts of time but the design and functionality may not be exactly as desired due to the fact that it was initially created for another application. Buying can save time but usually detrimentally affects the budget and/or the final cost of the product which may negatively influence prospective buyers. Building a part from scratch and/or innovating a brand new part, design or system is advantageous as the part can be built exactly as desired but this often takes significantly more design and construction time, as well as significant testing and troubleshooting time as bugs, unintended consequences and unforeseen problems must be tackled and corrected. Below are some noteworthy areas where these decisions were made.

Use

Watertight ESC Compartment - This component had been used for a different purpose in a previous product. It was deemed suitable to housing and protecting the ECS's underwater on the ROV

Claw and Motor - The motor was sealed watertight and the functionality, range of motion and strength of the claw/motor were deemed ideal to use again

Thrusters- Four T-100 and one T-200 motors were re-used for this design. These motors have been a reliable staple of our products for some time.

Controller setup and Programming - Our previous control programming was used again due to its reliability. However, we split the strafe signal to two motors as opposed to one as in previous designs.

Cameras - The cameras are reliable, clear, have good range and field of view and would represent a significant expense to replace and thus were reused

Buy

Motor - This year we purchased a 6th motor (T-200) to improve power and maneuverability.

ESC - We purchased 5 new Electronic Speed Controllers to replace aging ESC's that had failed or were at the end of their life cycle

Tether - We upgrade to larger and more flexible wire to better handle the current to the motors. We also purchased a vinyl sheath to increase the usability of the tether

Build/Innovate

ROV Tether Strain Relief - Many strain relief options were available for purchase, but none that fit our exact size tether. The budget was also tight so we decided to design and 3D print our own.

Thruster Shrouding - The old thruster shrouding was too bulky and restricting, this reduced speed and led to less responsive handling. Our new spherical shrouding went through numerous iterations and numerous rounds of testing before the design was perfected for our needs.

Claw Static Tooth - The team desired a "static" arm to maneuver and manipulate the objects beyond the claw feature. After much brainstorming the team decided to attach an upward facing tooth to the top of the claw that could be used to "statically hook" and manipulate objects.

Onboard ESC Configuration - The team determined from previous failures that thicker wire must be used to deliver enough power to the ROV motors. This would have resulted in a tether nearly 1.5" in diameter. To solve this the team moved the ESC's onboard the ROV meaning only two power wires were needed in the tether and then branched out the power and signal to each separate motor on the ROV.

Single-Hand Lift Bar - Launching and removing the ROV from the water is difficult and runs the risk of the operator falling in and/or a component on the ROV being damaged because the ROV was grabbed or lifted improperly. To reduce these risks the team innovated an easy to use Lift Bar on the topside of the ROV that directs the force of the entry/exit through the frame of the ROV and that sticks above water when the ROV breaches for ease of use.

G. Control and Electrical Systems

A diagram of the electrical systems for NEMO I can be found in the SID in Appendix C.

Motors and Motor Control

The ROV is controlled through the potentiometers on the controller interfacing with the Arduino in the control box. The left and right motors, which move the ROV forward and backward, are each controlled on their own separate, left and right, stick. Each stick allows for forward and reverse thrust. The right control stick can also move left and right, this controls the strafe ability of the ROV. Finally the control wheel on the controller controls both vertical motors which operate in tandem to change the depth of the ROV. The potentiometer in the control sticks send signal through the ethernet cable to the Arduino. The Arduino then executes the code based on the signal from the controller potentiometers and sends signals to down the tether to each motor to the ESC's, which translates the Arduino signal to motor signal. Motors are in a 12v power and ground loop, while the Arduino and controller are in a 5v power and ground loop.

Cameras

The ROV cameras are in a 9v power and ground loop. Power is sent down the tether to each camera, this powers the LED lights and the video feed. Video is sent from the camera up the tether, to the S-video converter boxes that convert the feed to HDMI. The HDMI feed is sent out of the control box to our two attached monitors.

Claw

The claw motor is a sealed bilge pump motor that requires 12v to operate. The claw motor is on a 12v power and group loop that runs from the control box, down the tether to the ROV, back up the tether and back into the control box. An ethernet cable is plugged into this system. A dipole switch is connected to the end of the ethernet cable. When the switch is in the neutral position (default for safety) the circuit is open and the claw is not powered nor under any mechanical stress. When the switch is moved to the up position the circuit is completed and the claw motor runs forward, closing the claw. When the switch is moved into the down position, the current flow is reversed, and opens the claw. `

Control Box

The control box is powered by a 120v to 12v converter box which connects to the control box through Anderson Power Plugs for safety. This converter ensures that the voltage sent to the control box is appropriate. A 25a fuse is built into the wiring to provide overload protection.

Monitors
The two external monitors plug into an external 120v outlet for power. Each is equipped with HDMI connectors that are plugged into the control box to receive and display the feed from the ROV cameras.

III. Safety

Safety is a top priority at Crusader Robotics. Everything from the power systems to the actual systems they power are designed to minimize risk and adhere to MATE safety standards.

H. Company Safety Policies

All team members are also required to follow a dress code: No loose fitting clothes, long pants, closed toed shoes, and hair pulled back. They must also be instructed on how to use a tool by a senior member of the team, and must successfully undergo a trial use of the tool overseen by a senior member, before being allowed to operate the tool on their own. Safety glasses must be worn in the ROV construction area. Hot tools, such as soldering irons, heat guns and glue guns must be operated only in the designated area. Cutting and drilling was done only with a spotter and in the designated area. Horseplay was never tolerated.

I. Job Safety Analysis (JSA)

Crusader Robotics also took care to develop a JSA to be used by future operators of the NEMO I. The purpose of the JSA is to minimize accidents/injuries and prevent damage to the ROV. This will allow future NEMO I operators to utilize the benefits of the NEMO I safely and effectively. This JSA can be found in Appendix D.

J. Safety Checklists

The following checklists were used by Crusader Robotics team members during the build and testing process.

<u>Physical safety checklist</u>
- Securely attached all items to ROV.
- All hazardous items identified and covered.
- All propellers completely shrouded.Reduced hazard of all sharp and jagged edges on the ROV by filing them down.
- ROV testing in the pool area is always done as a team.

<u>Electrical safety checklist</u>
- All wiring securely fastened and properly sealed.
- There are no exposed wires and all splices in the tether are properly sealed.
- Tether is properly secured at the ROV, with adequate strain relief.
- There is no exposed wire or copper and all wiring is securely fastened and sealed.
- All splices in the tether were mended prior to competition.

<u>Control system safety checklist</u>
- Anderson Power plugs are used for electrical attachment.

- Attachment point is connected to a single powersource.
- Fuse is placed in close proximity to the power supply attachment point.
- All electrical components are covered inside the enclosure.
- Proper strain relief and abrasion protection is used for the wires passing through the enclosure.
- All connections and wires/cables are properly labeled
- Properly suited connectors are used for each specific task.

IV. Budgeting

Each year the CEO and mentor of Crusader Robotics work together to set the budget for the year. This year the budget was generously provided by Brother Rice High School. Many years Crusader Robotics team members solicit donations from outside donors to fund the year's project. Team members spend significant time deciding how to complete all required tasks in the most cost effective way. Many times this requires that certain parts, materials and systems are reused and sometimes requires that new parts, materials and systems must be created or sourced in innovative ways in order to keep costs low. When purchases must be made they are cleared with the CEO and VP of the division they will be used in, as well as the club mentor. The club mentor makes the purchase and handles pickup or shipping. The 22-23 budget can be seen in Appendix E.

V. Company Evaluation:

Crusader Robotics primary goal was to complete as many MATE mission tasks as possible. In this sense, Crusader Robotics has been successful in that the ROV is able to complete nearly all tasks in this year's MATE product demonstration. When we embarked on the 2023 MATE ROV Competition in November, the team started by dividing work into smaller groups such as prop making, mechanical and electrical design, marketing, research, and rules. While team members focused most of their energy on their assigned design task, they still collaborated with others in their competition of their taks when necessary. One of the company's important strengths was communication. When important decisions needed to be made a team meeting was held to present and vote on ideas. These frequent meetings helped refine good ideas into great ideas and keep everyone up to date on project progress. We had a lot of ambition among new members of the team who were willing to get out of their comfort zone and try new things. Each year the quality of our ROV has increased. We have numerous 3D printed parts which allow for more creative and innovative ways to help accomplish the tasks. An area of significant improvement this year was in the optimization of the tether and underwater ESC housing. The team is proud of how well they managed their time allowing for significant practice time prior to the product demonstration. Despite any issues that arose, this year's build has been a very rewarding experience. All team members got to learn about topics ranging from soldering, to 3D printing to fabrication. Each team member was able to take away something positive from this season. This is something that Crusader Robotics is very proud of. Overall, Crusader Robotics is proud of the many hours of hard work and collaboration put into the NEMO I.

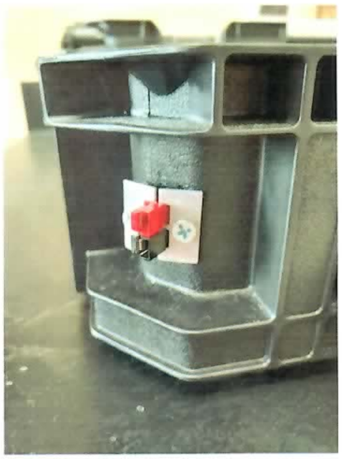
Appendix A

Crusader Robotics ROV Build Schedule 22/23

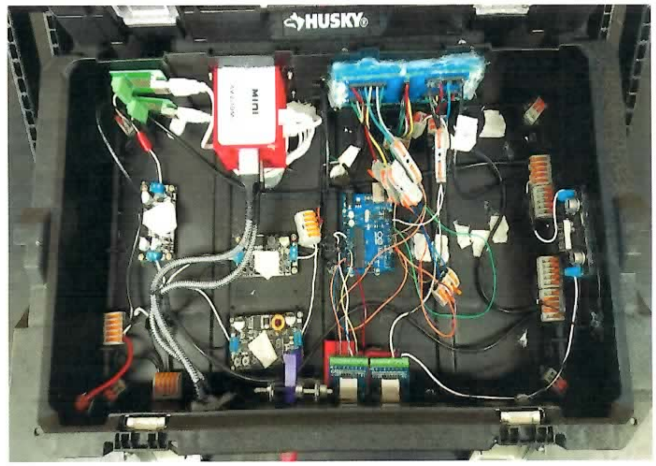
Month	Tasks/Plan
October '22	1st meeting, define company roles, evaluate previous ROV, define and begin planning for non-task specific improvements, evaluate materials and supplies on hand
November '22	Train new members, design non-task specific improvements, begin work on non-task specific improvements
December '22	Continue work on non-task specific improvements, test and troubleshoot
January '23	Review MATE materials, begin planning and design process for task specific needs and improvements, begin prop construction
February '23	Construct, test and troubleshoot task specific design elements
March '23	Documentation and pool testing, repairs and revisions to ROV as determined through pool testing
April '23	Continue work from March
May '23	Finalize all documentation, paperwork and presentation, Product demonstration

Appendix B

Notable ROV Safety Features

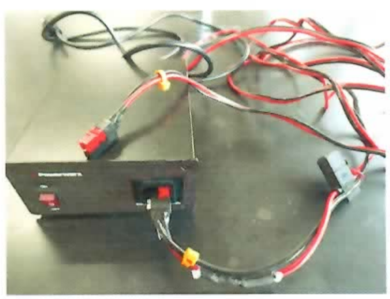


Anderson Power Plugs

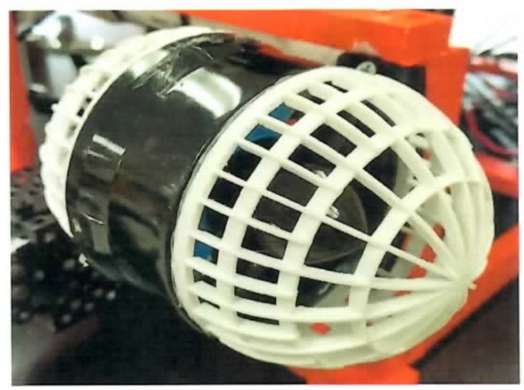


Organized and Streamlined Control Box Wiring
(designed to be 100% closed during ROV operation)

25A Fuse

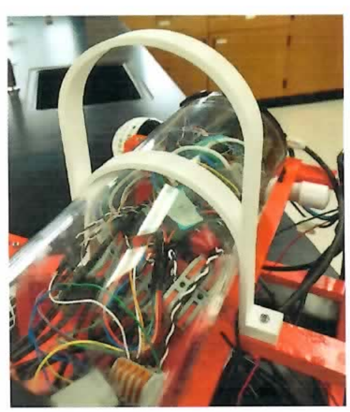


120v to 12v Converter

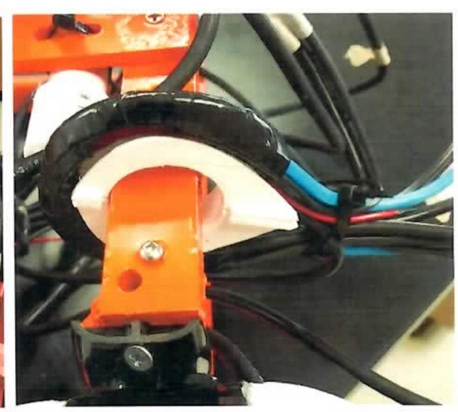


Thruster Shrouding

Red Highlighted Claw Teeth

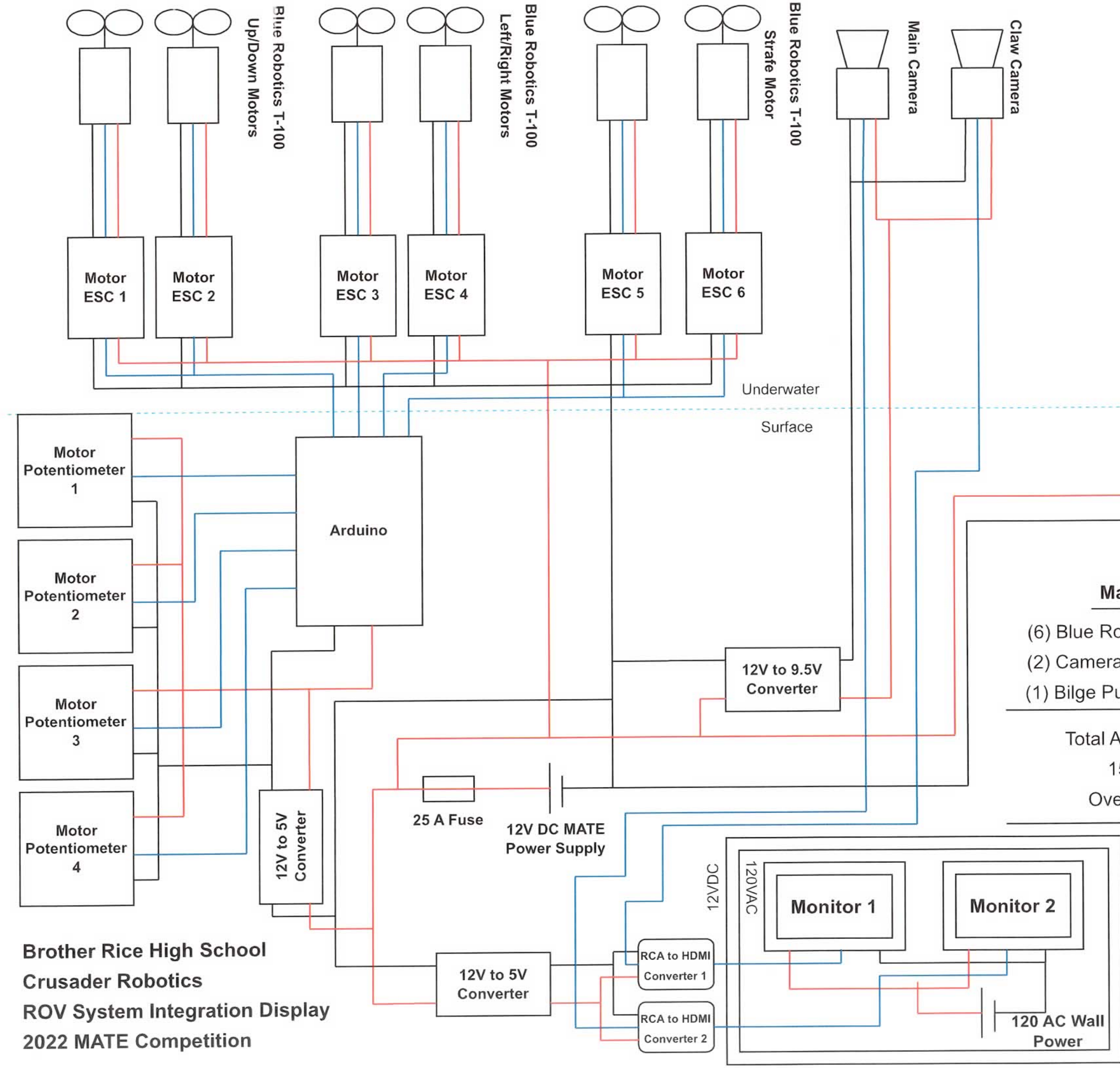


Single Hand Lift Bar



Tether Strain Relief

Appendix C



Brother Rice High School
Crusader Robotics
ROV System Integration Display
2022 MATE Competition

Maximum Current Calculations

(6) Blue Robotics T-100 6 x 2.5A = 15.0 A	
(2) Camera	2 x 0.1 A = 0.2 A
(1) Bilge Pump Motor	1 x 0.5 A = 0.5 A
Total Amperage	15.7 A
150% Overdraw	15.7 A x 1.5 = 23.6 A
	Fuse Used 25 A

Positive Wiring

Ground Wiring

Signal/Data Wiring

Appendix D

Job Safety Analysis

JOB TYPES	POTENTIAL HAZARDS	SAFE JOB PROCEDURES
ROV Setup	• Short Circuit • ROV Malfunction • Fire • Electrocution	• Follow ROV wiring labeling • Remove flammable materials • See "ROV Operation"
ROV Operation	• Fire • Electrocution • Short Circuit	• Remove flammable materials • Ensure surge protector is used and functioning • Ensure ROV fuse is functioning • Keep control box in dry location • Minimize splash and spray near control box • Ensure that control box is closed during operation

ROV Operation (cont.)	• ROV Malfunction	• Turn off ROV while opening control box or performing maintenance/adjustments
	• Pinch	• Keep hands and loose clothing away from claw
	• Cut	• Keep hands and loose clothing away from motors
	• Slip	• Wear grippy shoes • No loose clothing • Keep water on deck to a minimum
	• Trip	• Ensure tether "wrangler" is present • Minimize amount of tether on deck • Coil unused tether neatly • Be aware of surroundings
	• Drowning	• Wear life preserver when appropriate • Designate a "spotter" who keeps a head count of team members and assists team members when

ROV Operation (cont.)	• Muscle/joint injuries	leaning over the water • Do not operate the ROV in adverse conditions • Use proper lifting technique and/or team lift heavy objects
ROV Teardown and Storage	• Trip • Slip • Muscle/joint injuries • Electrocution • ROV Damage	• Properly coil and store tether after use • Grippy footwear • Avoid walking in standing water • Keep water on deck to a minimum • Use proper lifting technique and/or team lift heavy objects • Disconnect power supply first • Properly unplug, coil and store all ROV components and wires

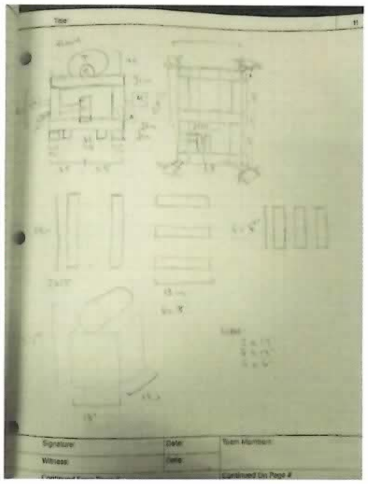
Appendix E

22-23 MATE ROV Budget for Crusader Robotics

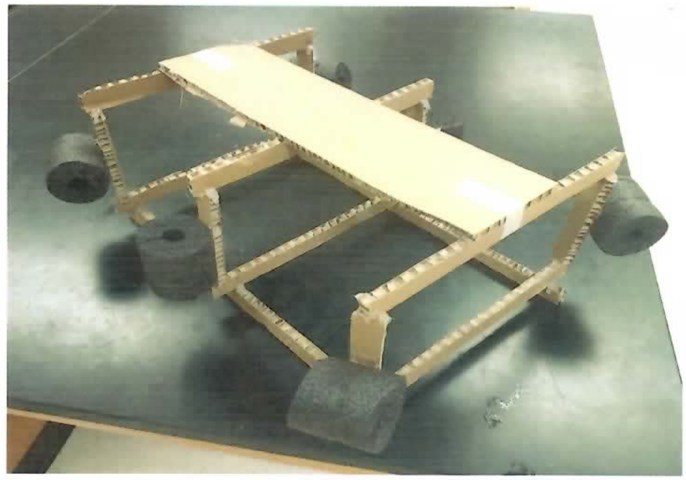
Item	Income	Debit
BRHS ROV Club Contribution	1200.00	
22-23 Sponsorship	0.00	
Blue Robotics Motor		230.63
HDPE		60.22
Prop Supplies 1		78.12
Prop Supplies 2		101.03
ESC's x 5		178.60
Cable penetrators/O-ring		29.89
Wago Connectors		31.15
MTW 12AWG Wire		50.00
Vinyl Cable Sheathing		46.87
MATE Entry Fee		250.00
ROV Poster		75.00
	1200.00	1131.51

Appendix F

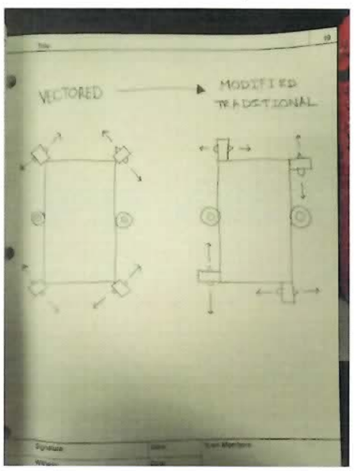
Planning and Strategy Documentation



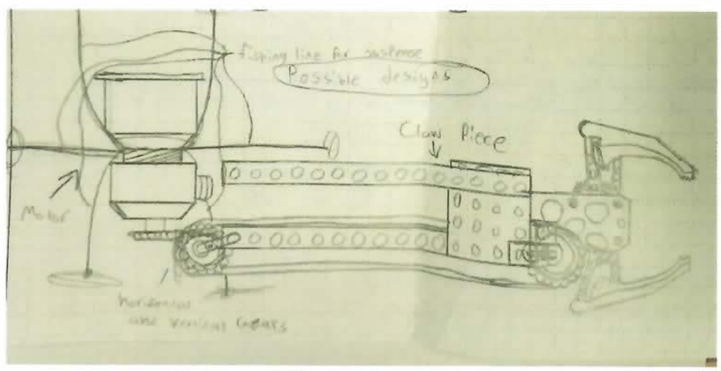
ROV Frame Blueprint



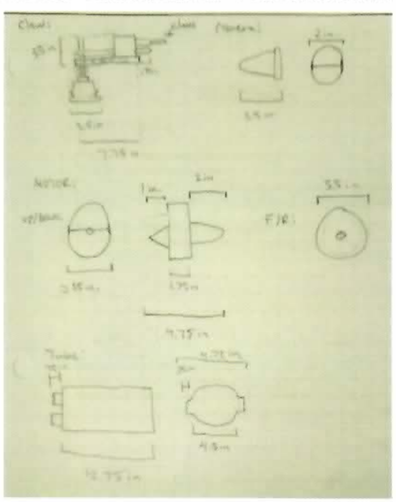
1:1 Scale Model



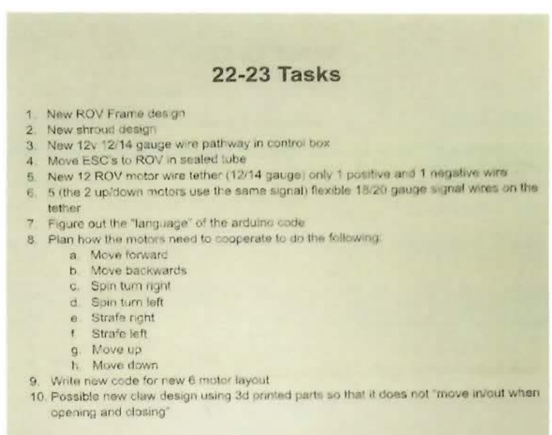
Motor Orientation Conversion Plan



Claw Assembly Brainstorm



ROV Attachment Spec Sheet



22-23 Tasks

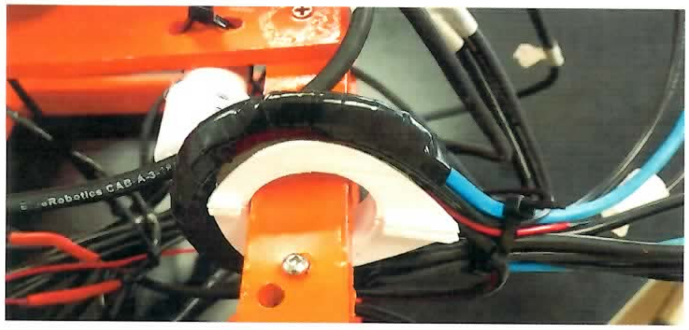
1. New ROV Frame design
2. New shroud design
3. New 12v 12/14 gauge wire pathway in control box
4. Move ESC's to ROV in sealed tube
5. New 12 ROV motor wire tether (12/14 gauge) only 1 positive and 1 negative wire
6. 5 (the 2 up/down motors use the same signal) flexible 18/20 gauge signal wires on the tether
7. Figure out the "language" of the arduino code
8. Plan how the motors need to cooperate to do the following:
   a. Move forward
   b. Move backwards
   c. Spin turn right
   d. Spin turn left
   e. Strafe right
   f. Strafe left
   g. Move up
   h. Move down
9. Write new code for new 6 motor layout
10. Possible new claw design using 3d printed parts so that it does not "move in/out when opening and closing"

List of Needed ROV Improvements

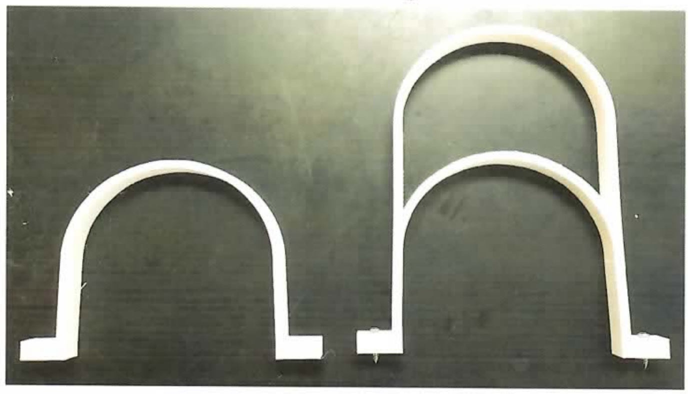
Research & Development

1. Motor Shroud Evolution

2. Tether Strain Relief

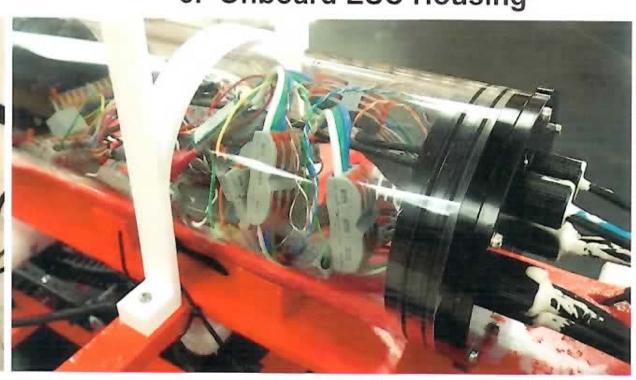


3. Tube Attachment & Single-Hand Lift Bar



4. Flexible Tether w/ vinyl sheathing

5. Onboard ESC Housing



R & D Breakdown

1. **Motor Shroud Evolution**
   The motor shrouding on our previous ROV designs was too large and bulky and significantly restricted the flow of water in and out of the motor. This restriction significantly reduced the speed and maneuverability of our ROV. The new shroud design restricts motor thrust as minimally as possible while still meeting safety requirements and being strong due to its spherical shape. 3D printing was the ideal method for speed of R & D, material strength and cost.

2. **Tether Strain Relief**
   Commercially produced tether strain relief couplings did not conform well to the size and shape of our ROV frame, so we designed and 3D printed our own that met our exact specifications and saved significant cost.

3. **Tube Attachment and Single-Hand Lift Bar**
   When commercial attachment solutions for the ESC tube again did not conform to our ROV's specific design, we used 3D printing to design a coupling to attach the ESC tube to the ROV. We later modified the tube attachment to be dual purpose by adding a to handle that allows for quick, easy and safe entry and exit from the water

4. **Flexible Tether with Vinyl Sheathing**
   Previous ROV designs used wiring that was too stiff. We collaborated with a local Electrical company to find a robust yet flexible wire to meet our needs. 12 gauge MTW wire met our needs perfectly, significantly increasing the flexibility and ease of use of the tether and allowing the ROV to move more freely in the water. MTW is a braided wire (flexible) that is covered in an extra flexible layer of insulation. Electricians use this unique wire in small spaces/boxes where solid or less flexible wire would kink and break. The Vinyl sheathing eliminated the need for most zip ties on the tether bundle and safely contained all the wires to avoid entanglement and trip hazards while the ROV is in operation.

5. **Onboard ESC Housing**
   Our previous ROV design used 10 separate 22 gauge wires (1 positive and 1 negative for each of the 5 motors) to power the ROV motors. This made for a larger and very inflexible tether bundle and also led to a loss of current, thereby reducing motor power, due to the wires heating up and not being able to handle the amp load of the motors. We moved the ESC's underwater in a sealed housing so that only 2 power wires (1 positive and 1 negative) were required to power all the ROV motors. This allowed us to use the appropriate gauge (thickness) of wire to handle the amp load and still retain tether flexibility. Inside the sealed ESC housing the power is distributed to all 6 ESC's and then sent out of the housing to each of the motors.