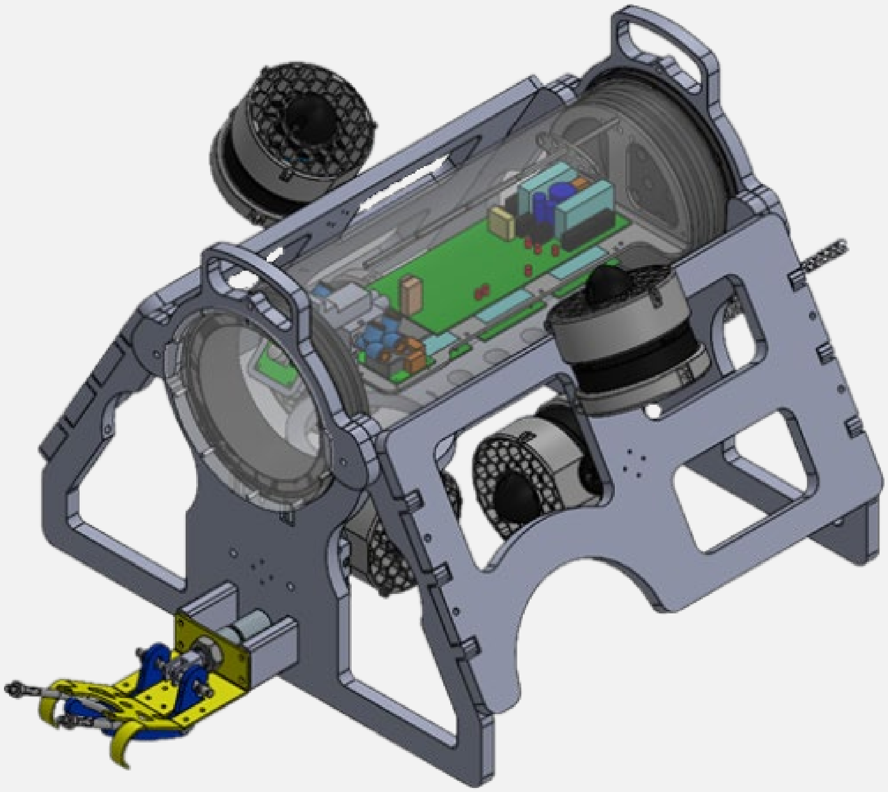
VX Industries

Long Beach City College

Long Beach, CA, USA



Viking Drakkar ROV

VX Industries Employees

Name	Position	
Guadalupe Vasquez	Chief Operations Officer	1st Year
Nick Zartman	Chief Design Engineer	1st Year
Robert Anderson	Electrical & Support	1st Year
Remi Ayon	Electrical & Support	1st Year
Tony Melena	Electrical & Support	1st Year
Ismael Torres	Electrical & Support	1st Year
Candice Martinez	Electrical & Support	1st Year
Danny Vasquez-Alverez	Design & Fabrication	1st Year
Humon Moeen	Payload & Floater Design	1st Year
Jaime Monterrosa	Floater PCB Layout	1st Year

Mentor: Scott Fraser

20 MATE ROV World Championship

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1. TEAMWORK

1.1. Team Bios

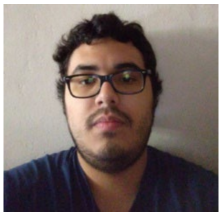
Robert Anderson - Robert and his wife Thaworn owned and operated restaurants for over 34 years. Their restaurants: a thriving Thai restaurant, and a Jewish Deli, closed due to the Covid shutdown. Broke but never starving, Robert returned to Long Beach City College, taking electrical classes and became a member of the LBCC Viking robotics team. Robert's training in electricity, electronics, and programming recently landed him a job in Building Automation Systems, using cutting edge electronics and software to turn buildings green and healthy. He always wanted to make a robot and is happy to be a part of the Viking Industries team

Remedios Ayon Jr (Remi), I'm twenty-nine years old. I am currently working as an electrician for a solar panel company. I've been in the construction industry for almost ten years, starting off as a laborer in the petroleum industry. This is my last semester at LBCC, graduating with an A.A. in Electrical Technology. The ROV club has been the highlight of my studies and academic experiences.

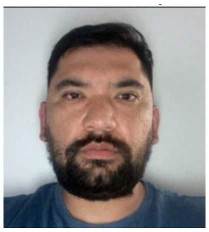
Candice Martinez - As I have no previous experience in courses in underwater robotics. I have always looked to challenge myself in learning new but, also challenging projects. In joining this project at LBCC, being a nontraditional college student, simply do not have enough time to take detailed robotics courses that might get beyond a surface-level introduction course at other universities. I was looking forward to developing strong skills and experience in design and fabrication, micro-controller programming, and circuitry that will maybe allow me to develop this into a potential career in robotics and being a future electrician. I became passionate about the intersection between engineering, and marine science and the intersectionality across my interests since childhood. In the past, I've been especially drawn to robotics (ROVs, AUVs, UAVs), especially with the Titanic discovery by the Marine explorer Robert Ballard and the high contributions to Oceanography he made during his oceanographic career. I think LBCC VX Industries classes provide a great opportunity for all students like myself to perform technical work in robotics and electrical technology.

Jose Melena (Tony) has been working in the steel manufacturing industries for over 14 years. It was through the steel industry that Jose, got the opportunity to work with robots. His tasks were to learn and operate as well as troubleshoot, program, and execute the proper procedure of an industrial FANUC paint robot through his old employer. It was through this exposure that Jose, got inspired to learn more about robotics. He enrolled in Long Beach City College to pursue a degree in the Electrical Technology Automation Technician program. Through enrolling in the program Jose, got the opportunity to work with the underwater ROV for the school and be part of the MATE 2022 competition held this summer at Long Beach City College. Jose currently works as a robotics shop technician for a robotics company where he fabricates, troubleshoots, and programs robots in a diverse field.

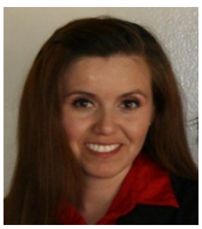
Humon Moeen - This is my first year participating in the MATE ROV competition (or any robotics competition for that matter). I first became interested in robotics after working on a lunar robotic construction project as an intern at NASA Ames Research Center. After earning a bachelor's degree in civil engineering, I began taking robotics classes at Long Beach City College to learn more about robotics design and operation. Currently, I'm working as a construction materials test technician, and I will be pursuing a master's degree in mechanical engineering at USC this fall. In the future, I hope to use the skills I developed from this competition to develop robots for exploration and construction in extreme environments such as in space or underwater.



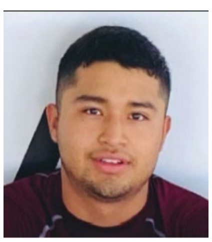
Jaime Gerardo Fernandez Monterroza - I am currently a student in “Electrical Technology, Automation Technician” program and one of my main goals are to obtain at least my Associate Degree or if I have the opportunity and ability to obtain a Bachelor of Electrical Engineering. Finally, my contribution to this project is to help in the creation of the printed circuit board “LBCC FLOATER 2022” and it was a nice experience.



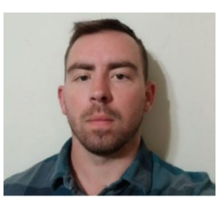
Ismael Eddie Torres – Born 1984; Current Title: Sr. Agent Compliance Reviewer / Sr. Compliance Quality Assurance Analyst Background in Regulatory Anti-Money Laundering compliance and Risk Assessment for Financial Institutions. Looking for a career change and studying to break into the electrical industry. Current educational focus is on the existing cross sections between where High Voltage and Automation electricity exist. After LBCC, I aspire to complete an Electrical Engineering Program and will endeavor to complete this goal. I enjoy detailed work and problem solving and I’m always looking for challenging opportunities to allow me to transition into the industry.



Guadalupe Vazquez - I have a BA in Business Management Information System from California State University, Long Beach. Due to lack of experience in Business Management in 2018, I applied for a Construction Solar Corp fellowship thru a non-profit organization where I worked for two years. Working as Solar Installer encouraged me to learned more about electricity and this was exciting news to my dad because he is an electrician as well. My dad has been my greatest supporter. Due to the Covid-19 Pandemic, the company I worked as a solar installer reduced the work hours and I had no choice than to look for another job. Changing to a new job allowed me to continue going to school and currently I am working for a homecare company to help patients with special needs. This semester I will be graduating from LBCC with my Associate Degree in Electrical Technology, Automation Technician. Being part of the Robotics Class has been a great learning experience and I am thankful for this opportunity.



Danny Vasquez-Alverez - During the pandemic, I was let go from my job as a server, then shortly after I dropped out of school, and nearly got evicted from my house. I decided to go back to school and plan my education progression with my counselor. On that day my life turned around, fast forwarding to 2022, I have had finish my general education, got a job as an electrician apprentice, shortly after finishing the first semester of the Electrical Program. I join the ROV team by coincidence, a buddy of my spoke great things about Scott Fraser, I checked him on YouTube; and saw his passion for teaching. I thought to myself, “I got to take his class”, short story long, I took his class to personally experience “Fraser Show” and now I’m building a ROV.



Nickolas Alexander Zartman - Born 1989 in Ely Nevada, grew up in southeast Ohio in the Appalachian foothills. Moved, at the age of 18, to Reno Nevada to attend University of Nevada, Reno to study political science (Did not finish,). Moved to Long Beach in 2015 and enrolled at LBCC. I am getting 2 Associate Degrees, one in Mechanical Design and one in Engineering. I intend to transfer to CSULB, majoring in Mechanical Engineering. Currently working as an AIT (assembly, integration & testing) technician at Terran Orbital, also enlisted as a Sergeant in the Marine Corps Reserves.

1.2. Project Management

Long Beach City College-VX Industries Company is a company run by Long Beach City College students with the goal of learning new environmentally friendly technologies. LBCC has participated in the MATE ROV since 2004. This year company members are made up of 1st year team members. Through the development of this project, team members develop skills such as critical thinking, collaboration, engineering design, inquiry skills, soldering, creativity, and problem solving.

Scheduling and Planning

A project timeline was developed in Excel to stay on track with our project. Most of our team members are full time employees at companies outside of VX Industries and group meetings was one of our biggest challenges in this project. Communication was established thru the Slack application. To maintain group collaboration and communication, announcements and messages were sent out to the team via Slack and emails. Slack application allows team members to receive messages, post designed files, photos, and schedule meetings. Good communication and collaboration skills contribute to the success of our project. When team members communicate effectively with each other, they were able to collaborate well and work together to reach our team's goals. Good communication within a team allows for better exchange of ideas and cooperation amongst team members.

Team Meetings

Morning and Evening meetings were created for team members to work on this project at their available schedule. Morning meetings were held Wednesdays from 10:00am to 1:30pm, Friday meetings from 6:00pm to 9:30pm and Saturday meetings from 1:00pm to 3:30pm. For safety reasons, there was always at least two team members working at each meeting. Proper PPE was required at all times. Team members must wear safety googles, gloves, long sleeve shirt, pants and closed toe shoes. Zoom meeting were also created to accommodate team members who were unable to be present for a particular meeting. Most Zoom meeting occurred during the development of the design process of the frame prototype, power supply boards, and the language coding process.

2. DESIGN RATIONALE

2.1. General Design

The overall goal when designing the Viking Drakkar **(Figure 1)** was to prioritize simplicity and robustness without sacrificing the ROV's ability to execute the required tasks efficiently and reliably. We aimed to keep components simple and easily manufacturable in order to minimize the chance of system failures and reduce costs.

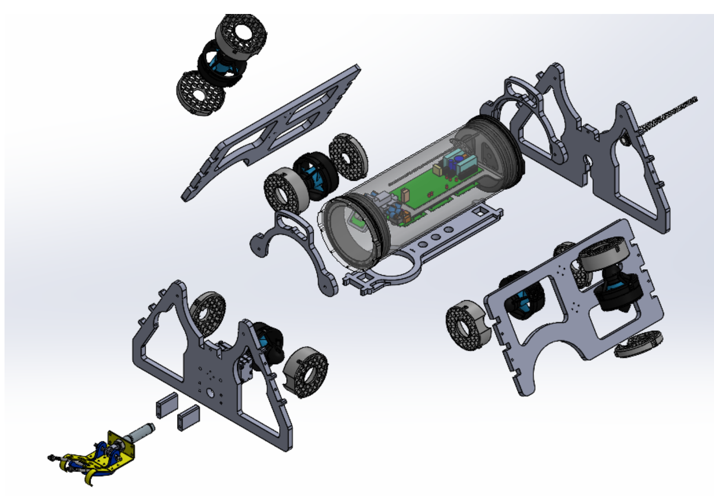


Figure 1: *Exploded view of the Viking Drakkar ROV*

Early on, we decided to use only 4 to 5 thrusters in order to maximize the utilization of thrust provided by each thruster when moving forward, backward, or crabbing. By using fewer thrusters to achieve movement, we reduced cost, power draw, and the amount of electronics that must be accommodated in the tube. Our vertical thrusters are mounted at a 60-degree angle, increasing stability when moving vertically and also provides for small crabbing movements. Further information on thruster design can be found in **Section 2.5.**

We aimed to keep the ROV easily manufacturable with the shop tools available to us at Long Beach City College. Our frame was designed to be easily cut out of a sheet of neutrally buoyant High-Density Polyethylene (HDPE) using a CNC router. In line with our, "keep it simple" philosophy, we aimed to minimize the part count and developed a frame design that only contains 5 pieces. Using our CNC router, this frame can be cut from a single sheet of material with only one repositioning during the process **(Figure 2).** Slots and tabs were added to the frame to simplify the assembly process.

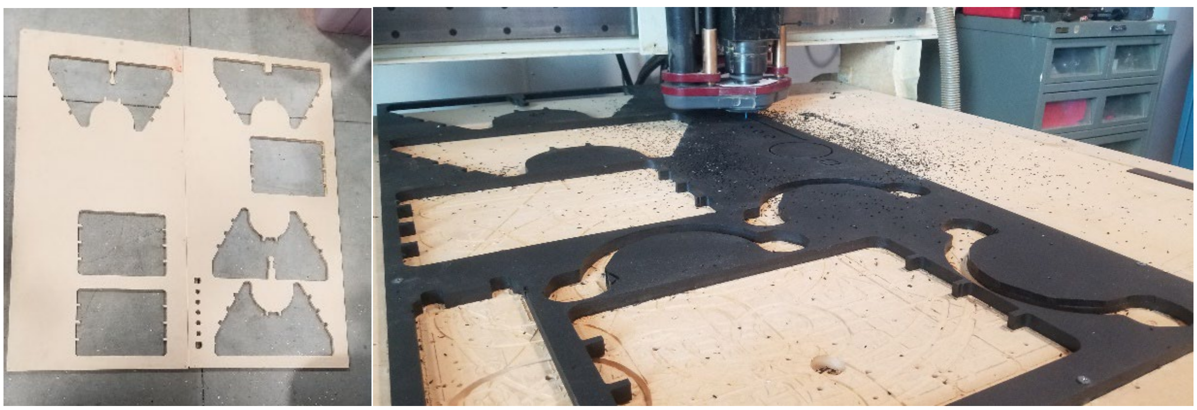


Figure 2: *Frame cut from single sheet of pressed wood (left) and HDPE (right) using CNC machine.*

Water flow was a consideration in every stage of the design process. We maximized water flow through the ROV frame by cutting away material that may block flow without compromising the strength and rigidity of the frame (**Figure 3**).

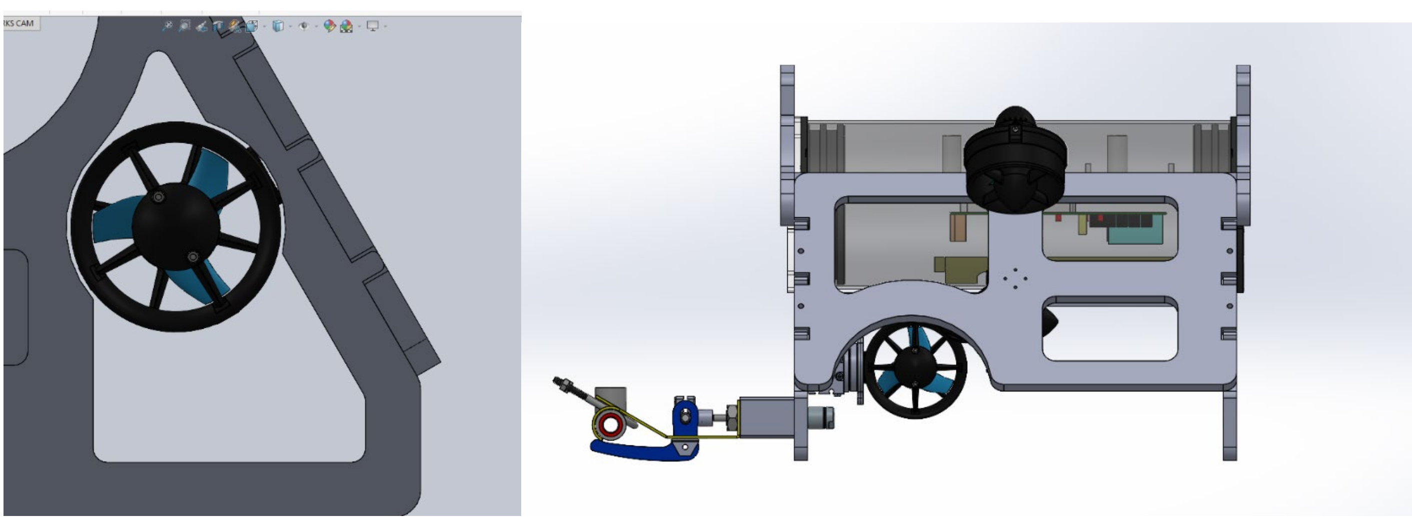


Figure 3: *Areas where holes were added to ROV frame to allow for water flow.*

2.2. Innovation Highlights

Rotating Thruster

The Viking Drakkar features a thruster mounted on a pneumatic rotary actuator (**Figure 4**). The rotary actuator allows a single thruster to provide thrust in both the horizontal and vertical direction, thus enhancing the ROV's maneuverability without the need for additional thrusters. In the horizontal orientation, the ROV is able to crab left and right; in the vertical orientation, the ROV can change pitch and has increased vertical thrust. Further information on the ROV's thruster system can be found in **Section 2.5.**

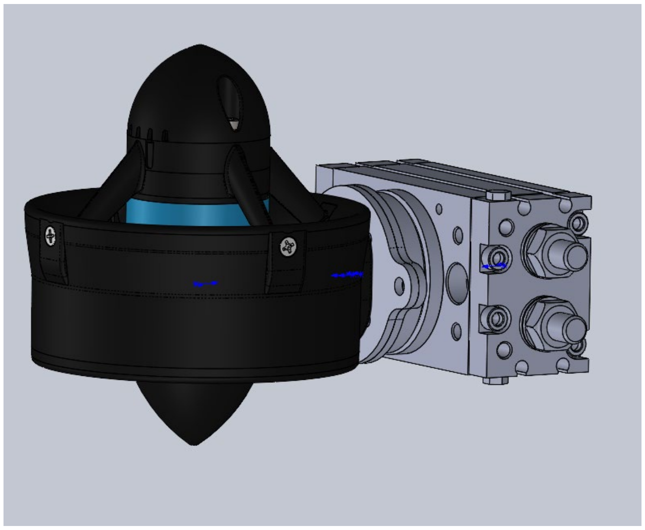


Figure 4: *CAD model of thruster mounted on pneumatic rotary actuator.*

Single End Effector for All Tasks

In order to maintain a simple design, VX Industries has combined all of our manipulator task requirements into a single end-effector **(Figure 5).** The Viking Drakkar's pneumatic gripper is able to clamp onto a variety of shapes as well as pull pins. By using a single gripper ROV operations are simplified, and material requirements are reduced. Further information on the ROV's gripper design can be found in **Section 2.7.**

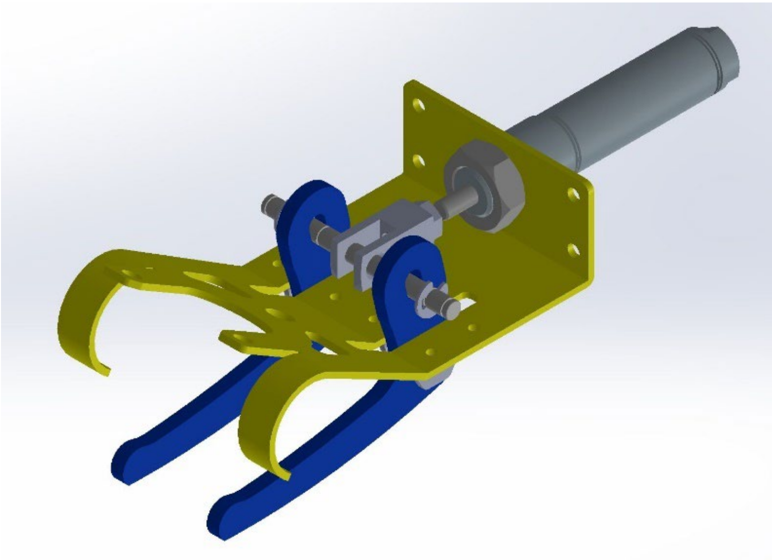


Figure 5: *CAD Model of Viking Drakkar Gripper*

2.3. Design Evolution

When designing the Viking Drakkar, our team brainstormed together and considered several design options. Throughout the process, we repeatedly asked ourselves, "is the simplest way to achieve our goal?" After settling on a design, we prototyped it, found areas where it could be improved, and redesigned. The Viking Drakkar went through three major design iterations described below **(Figure 6).**

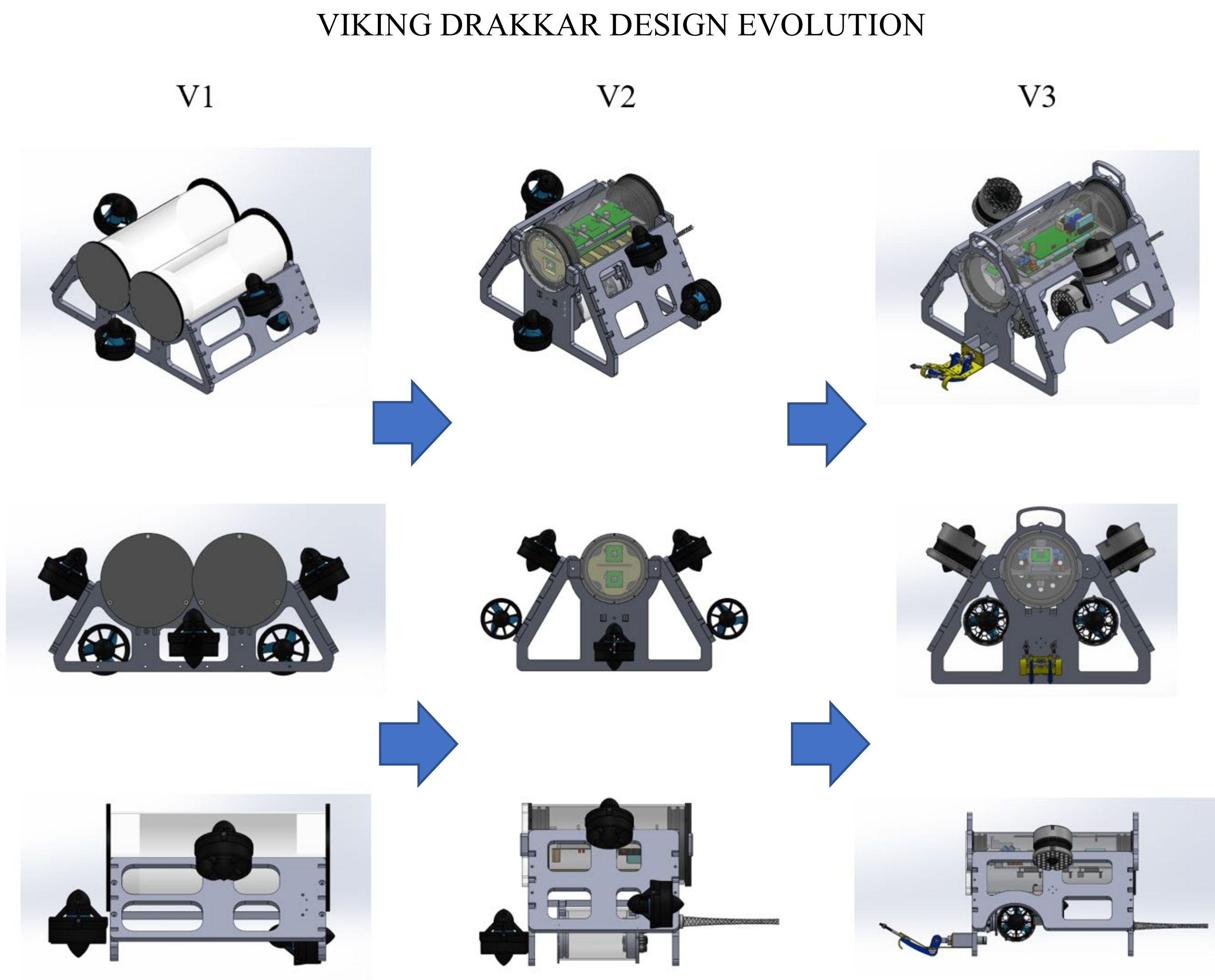


Figure 6: *Design evolution table for the Viking Drakkar.*

Version 1

In our initial design we envisioned two separate tubes situated side by side, one to house the electronic while the other to hose the pneumatics **(Figure 6)**. After progressing further in the design of the pneumatics system we realized the tube volume was much larger than needed and required a degree of weight symmetry or balancing between the two tubes. Also, this design was less than ideal as it would have caused the ROV to be extremely positively buoyant and close to the maximum weight limit from ballasts required to maintain neutral buoyancy. We also cut out a prototype frame from pressed wood to begin testing fit and identify any assembly issues **(Figure 7).** During the assembly of the first wood prototype, we realized that drilling holes into the frame by hand was causing our frame to be misaligned and required to be filed down to fit properly. To alleviate this issue, we modeled a custom drilling jig for our frame and 3D printed it to assist in the assembly process.

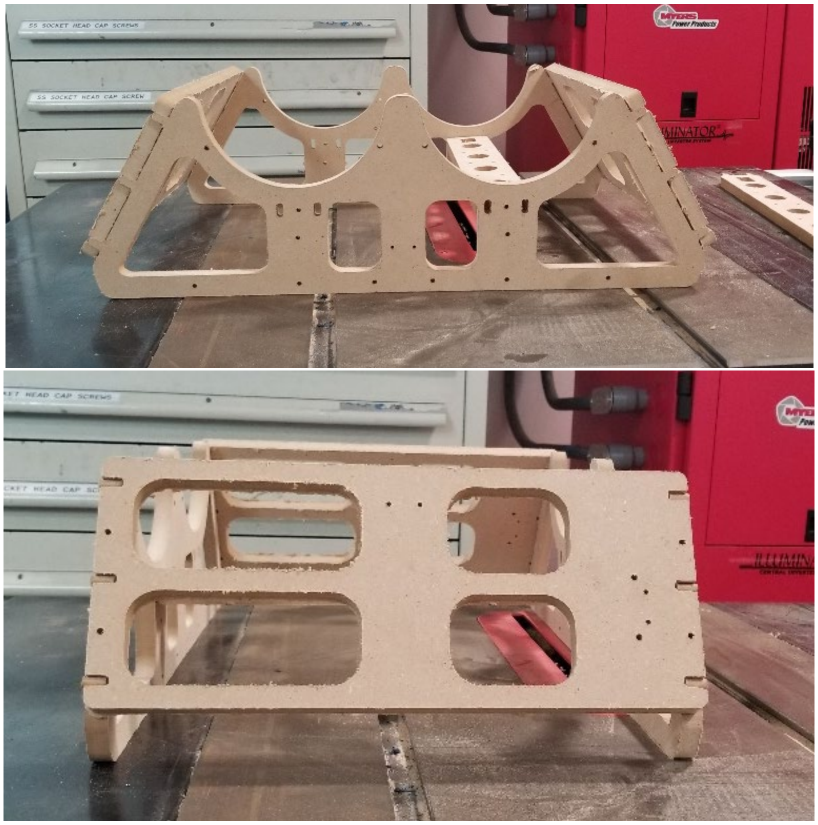


Figure 7: *Initial frame prototype for of the Viking Drakkar V1.*

Version 2

For the second version we decided to go with an over-under orientation of the tubes with a smaller pneumatics tube below the larger electronics tube. This solved the balancing issue and reduced our overall buoyancy. Having solved most of the major problems we decided to move forward with building the first functioning ROV prototype **(Figure 8).** Our goal when building this prototype was to test the ROV's maneuverability in water. As such, a pneumatics tube was not added to this ROV, and the gripper design was not finalized. During our testing, we found that the ROV would pitch upward when thrusting forward due to the moment applied by the forward/rearward thrusters, which were mounted toward the rear of the vehicle. This would be solved in the next version of the ROV.

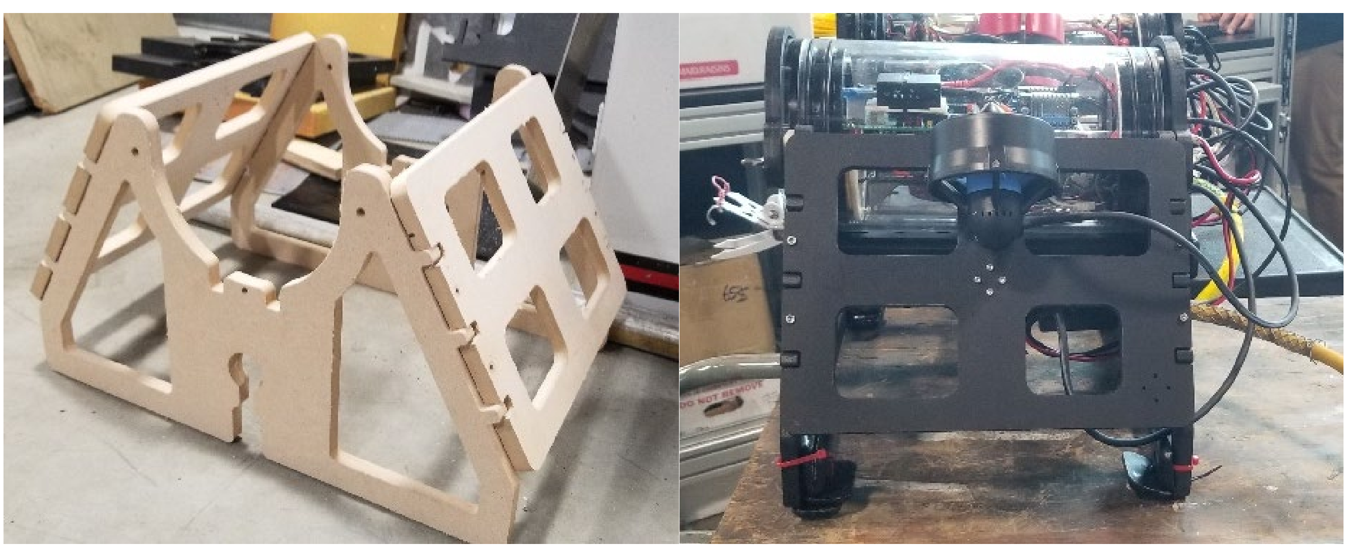


Figure 8: *Viking Drakkar V2 pressed wood frame prototype (left) and assembled ROV prototype (right).*

Version 3

For the final version of the Viking Drakkar (**Figure 6**), we moved the forward thrusters to the center of the ROV to prevent them from applying torque and raising the nose of the vehicle. Having finalized the gripper and pneumatics systems, we realized that we could fit the pneumatics into the main tube if it was lengthened by 4 inches. This meant we could consolidate everything into one tube, allowing for more space below the ROV and fewer areas where the ROV could leak.

2.4. Control/Electrical Systems

Inside the Viking Drakker, we have 5 major electrical components: the Arduino Mega for control, pneumatics, thrusters, visual aide, and power distribution (main circuit board) **(Figure 9).** All circuit boards were design, tested, and assembled in house. The design of the circuit boards we used were EagleRay and SeaMate circuit boards. We used the company Digi-key Electronics to order our parts for assembling the circuit boards. When assembling the circuit boards, our group of teammates, with minimal experience in soldering, managed to systematically solder the components from smallest to biggest. For example, we started with resistors, then capacitor, diodes, mosfets, all the way to power converters. This process made it easier to assemble and allowed us to modify and fix problems found in the process.

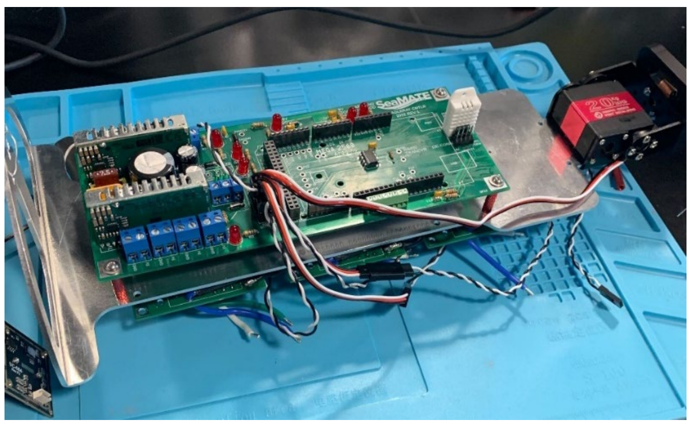


Figure 9: *ROV electronics*

In the main circuit board, you can find our power converts from 48V to 12V, then to 9V, and finally to 5V. From the main circuit board, at 48V, we can distribute power to our thrustor, at 12V, using 4 EagleRay circuit boards. We scaled down from 12V to 9V to power our Arduino. At 12V, our Arduino Mega could function without a problem. The concern when using 12v instead of 9v; was the heat that would be created. Our goal was to keep the inside of our ROV at a maximum temperature of 26.6 degrees Celsius or less. This was accomplished by mounting our circuit boards to a metal plate, using it as a heat sink **(Figure 10).** This allowed heat to then be transferred into the water. Lastly, our pneumatics circuit was mounted separately from the main circuit; we used a 48V to 24V convertor to provide power for the pneumatic valves. To control the pneumatics, we connected them to the signals from the Arduino Mega.

Figure 10: *Heat sink for ROV electronics.*

Our tether is composed of 12 wires; sized at 24 AWG. Six of those wires are in parallel for the 48V positive and the other six are in parallel for the 48V negative. Also inside the tether is a CAT 5 shielded cable for our USB Extender. The USB Extender which helped us get higher speed signals at a longer distance. At both ends of the tether, we used a custom black box as a strain relief and cable termination. It was designed and fabricated in house using SOLIDWORKS and a 3D printer. To safely waterproof it, we used epoxy to seal it and prevent short circuiting the electrical system (**Figure 11**).

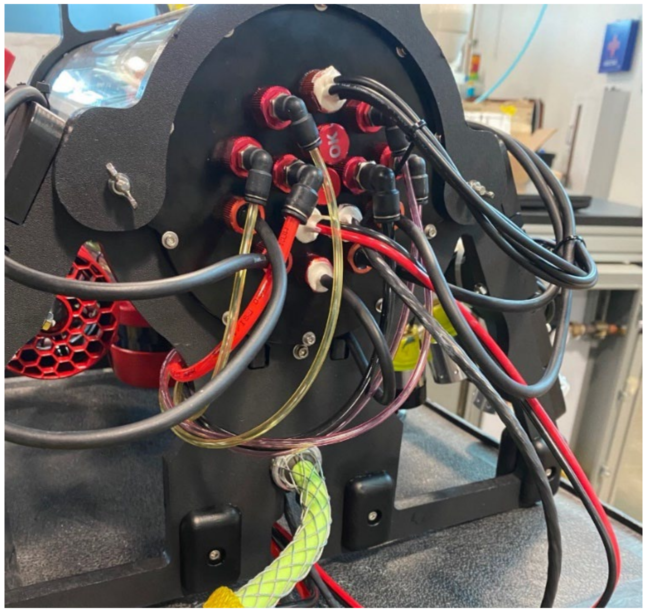


Figure 11: *Sealed electrical connections*

To control our thrusters and pneumatics valves we used LABVIEW control program that was originally provided by SeaMate. We made modifications to support the pneumatic valves controlling our gripper, as well as to controlling our thrusters for crabbing motion. We hypothesized that programing our thruster to have a crabbing motion instead of zigzagging back and forth motion would allow us to pilot the ROV more effectively and efficiently in sideward motions. When we practiced the required tasks in the pool, we found that our hypothesis was correct and that we saved time when utilizing the crabbing function. Lastly, we mounted our thrusters in the opposite direction of the SeaMate model, allowing us to increase thrust in the forward and upward directions. We again modified LabView to handle the direction changes.

2.5. Propulsion

For our propulsion system we used the Blue Robotics T200 series thrusters (**Figure 12**); the T200 thruster is a staple in the MATE ROV competition and must be used. The decision we now had was how and where to implement the thrusters in our build. While brainstorming, there were two different paths we considered when deciding how the Viking Drakkar's controls would operate. The team first contemplated using horizontal vectored thrusting to control the rotation of the ROV. This would have allowed for a more controlled rotation along its central vertical axis but contained a major drawback. Though the ROV's thrusting would be highly functional, it would demand six to eight thrusters, which, consequently, required a higher current demand and more space allocated for thrusters and their associated electronics. The Electronic Speed Control (ESC) units would have required us to add a second control tube or to make the current tube larger. We ultimately decided against horizontal vectored thrusting for the ROV as the main goal with our ROV is to get most functionality and reliability out of as simple and small of a physical package as possible. Instead, we decided to use only five (5) thrusters to control the ROV's movement within the pool.

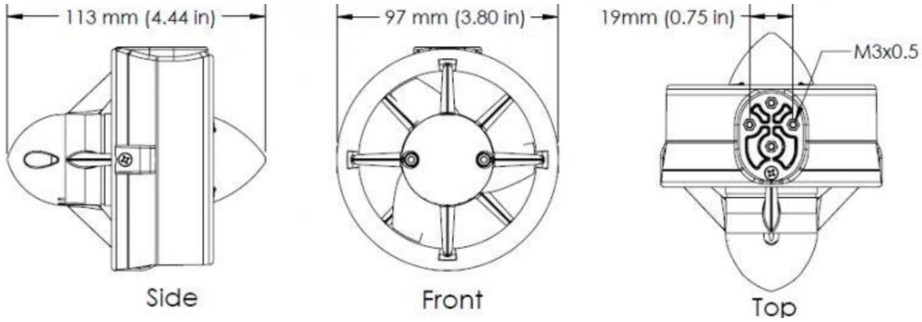


Figure 12: *Blue Robotics T200 series thruster drawing*

Two (2) thrusters control the vertical movement and some crabbing movements. These two are located on opposite sides, port and starboard, outside of the frame and are installed angled inward towards one another. Two thrusters control the yaw movement of the ROV; these are installed inside the frame and do not interfere with the vertical thrust. The final 5th thruster is to control crabbing movement of the ROV (**Figure 13**). The fifth thruster is our alternative solution to horizontal vectored thrusters. The 5th thruster allows for horizontal movement of the rover in port and starboard directions for more precise control of the ROV when completing tasks. In the event that the payload is too demanding for the ROV, the 5th thruster can rotate 90-degrees using a pneumatic actuator and will assist by adding additional lift right under our gripper. This not only helps lift heavier loads but also allows the ROV to maintain balanced movements when carrying such a load.

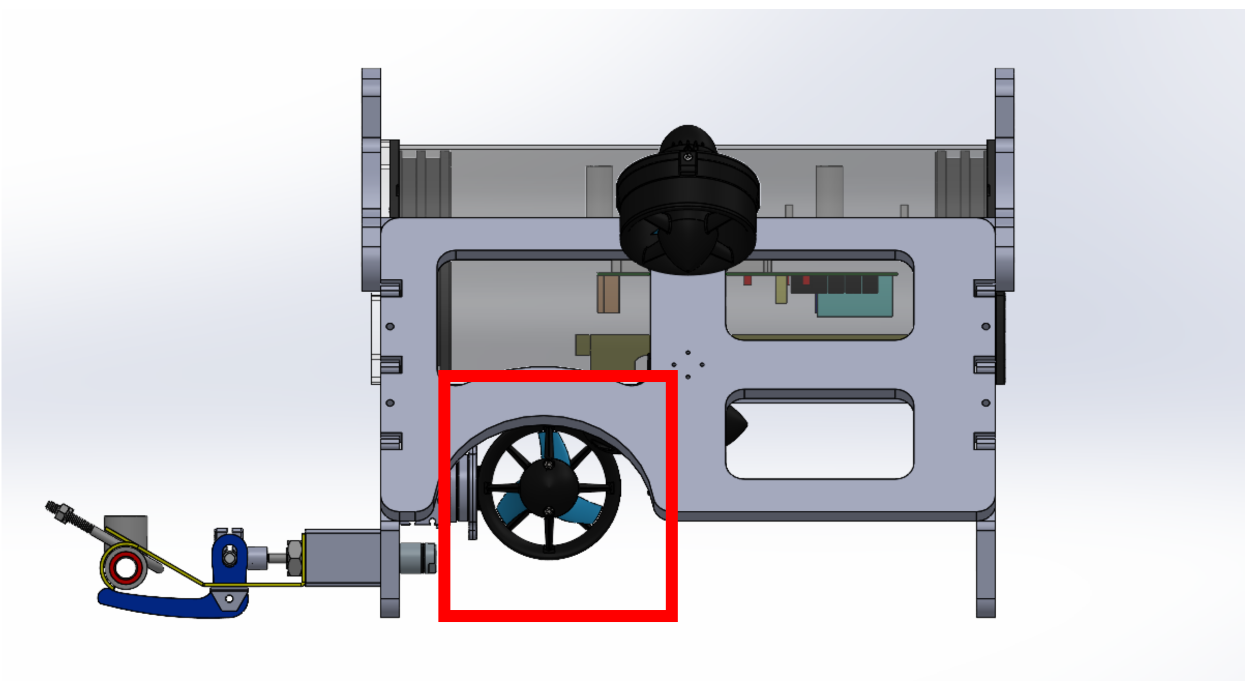


Figure 13: *Rotating thruster for crabbing movement boxed in red.*

Our thruster electronics are found into the control tube where both the ESCs and the power supplies connected. We are using three 12v power supplies for the thrusters, each protected by 20a fuses. The power supplies are mounted directly onto a metal plate frame within the control tube to act as a heat sink, which helps to dissipate the heat within our control tube. Two of the power supplies each operate one vertical and one horizontal thruster. The 3rd power supply operates only the 5th crabbing thruster. This configuration allows us to evenly draw power from two separate power supplies when thrusting forward/backward or vertically.

2.6. Buoyancy and Ballast

The Viking Drakkar frame is made from High Density Polyethylene (HDPE) and as such is naturally buoyant. Our control tube contains 8.70 liters of volume within it and provides a substantial 8.7 kg of buoyancy. This provided a positive buoyancy for our machine. Our goal was to maintain a neutral state of buoyancy. In order to accomplish neutrality, we added several ballasts which will ensure the unit remains neutrally buoyant and easy to control. Each ballast is 5.72cm x 3.74cm x 1.05cm and weighs approximately 191g. To accomplish our goal of maintaining neutral buoyancy a total of 15 ballast are used for a total of 2.86kgs ballast weigh. We first zip-tied ballasts to the ROV frame to test their effects on control and later mounted them directly onto the frame using bolts. Twelve (12) ballasts are mounted to the lowest corners of the ROV frame and three (3) are mounted to rear center of the ROV near the tether (**Figure 14**). This mounting configuration ensures a stable and balanced weight distribution. Achieving our desired buoyancy is an integral part of maintain stability when controlling the ROV in the water and allows for predicable feedback and control for the driver.

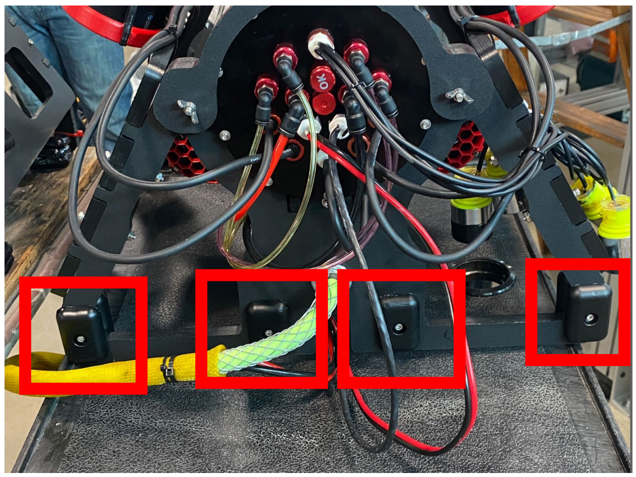


Figure 14: *Ballasts (boxed in red) added to the ROV frame.*

2.7. Payload and Tools

End Effector

Rather than designing and manufacturing multiple payload tools, the Viking Drakkar uses a single end effector (gripper) to achieve all the tasks outlined by the MATE competition (**Figure 15). ** When designing the gripper, our team listed every prop shape and orientation present in the competition. We then considered which gripper features would best be able to manipulate the props in a controlled manner and subsequently combined those features into a single end effector. Before manufacturing our gripper, we tested its functionality and sizing in SOLIDWORKS using models of the MATE competition props (**Figure 16**).

Figure 15: *Picture of the ROV gripper.*

The body of the gripper was fabricated out of sheet metal in the Long Beach City College metal shop. The body features a hooked end that can be laid onto the horizontally oriented PVC pipes present in the competition as well as the handle of the vertical profile float we designed. A 3.3 cm gap was left in the middle of the end of the body to allow the ROV to grip directly onto tee fittings and cross fittings. Furthermore, space was left between the hooked ends to allow the gripper to grab onto U-bolts.

The fingers of the ROV are cut from a sheet of plastic and are operated by a single linear pneumatic actuator. The fingers featured a pointed end to allow the ROV to scoop morts from the floor like a spatula as well as a bump to firmly grasp onto a variety of objects. In order to increase visibility and clearly see the fingers and props, holes were added to the body of the gripper. These holes can also be used to hook onto and pull out the metal pins in the competition.

Cameras

The Viking Drakkar utilizes 5 cameras to provide an ample view of the ROV's surroundings. A camera mounted inside the cylinder gives a close-up view of the gripper allowing the pilot easily see the objects they are manipulating. This camera placement was first tested for its field of view in SOLIDWORKS and was later adjusted for distortions caused by water **(Figure 16).** The camera is a wide angle USB type camera and is mounted using a 3D printed mount. Four more cameras are mounted to the ROV to provide views to the side, below, and above the ROV. This allows us to complete transects and mapping in a variety of orientations. The outer cameras our housed in scuba diving flashlight casings and sealed with epoxy. They cameras were originally planned to be mounted onto the frame using a 3D printed mount we designed (**Figure 17**); however, we decided to purchase off-the-shelf mounts due to time constraints and a need to troubleshoot our camera mount prototype.

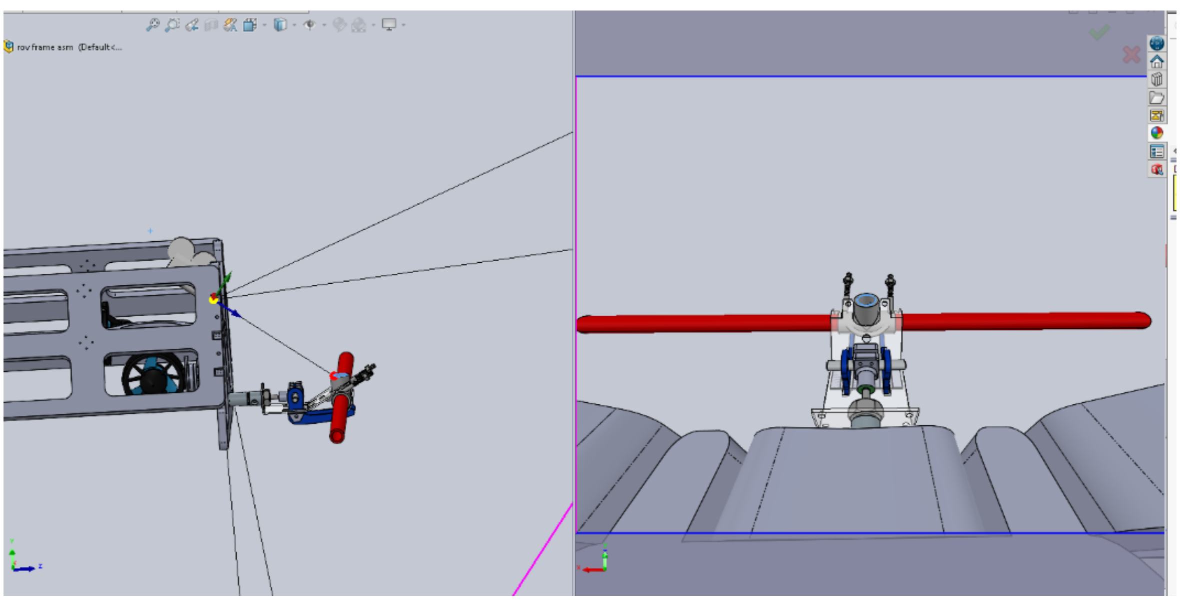


Figure 16: *Testing the position of the gripper camera and its ability to grab objects using SOLIDWORKS.*

Figure 17: *CAD model of 3D printed camera mount prototype*

2.8. Build vs. Buy, New vs. Used

When developing the Viking Drakkar, we aimed to design and manufacture as many components as possible in order for our team to learn, gain experience, and create parts that are custom tailored to our needs. However, at times, designing and manufacturing parts was unfeasible due to the time, cost, or machinery required to do so. In these cases, we opted to reuse parts from previous years, a practice that is more sustainable and cost effective than purchasing new parts. Purchasing new parts was a last resort for our team.

Highlights of components VX Industries built this year include the following:

- ROV frame was designed and manufactured from HDPE sheets in house
- All circuit board assemblies were soldered and assembled in house
- Electronics heat sink was designed and manufactured from sheet metal in house
- Gripper assembly was designed and manufactured from sheet metal/plastic in house
- Cylinder camera mount was designed, and 3D printed in house
- Thruster shrouds were designed, and 3D printed in house
- Printed Circuit Board (PCB) for the vertical profile float was designed, soldered and assembled in house. The actual circuit board was manufactured by a professional company.
- End caps and the internal frame for the vertical profile float was designed and manufactured in house
- Various other small components were designed and manufactured in house

A full list of purchased, reused, and donated parts can be found in **Section 7**.

Provided by SeaMate

As part of the SeaMate Grant for Community Colleges, we were able to use the following items from them to get us started.

- A blank Control PCB for the Arduino Mega
- Blank 48V to 12V 20A power supply PCBs for the Thruster Supplies
- 75 Feet of donated tether
- A starter program in LabView for control

VX Industries Float

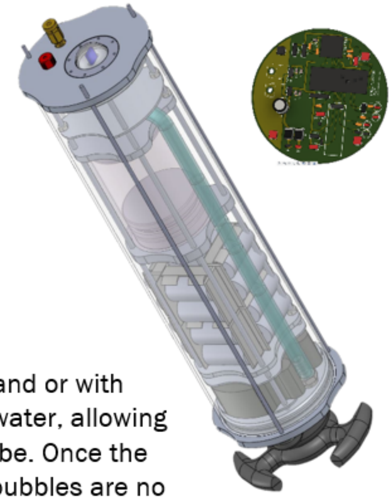
June 2022 • MATE ROV Competition

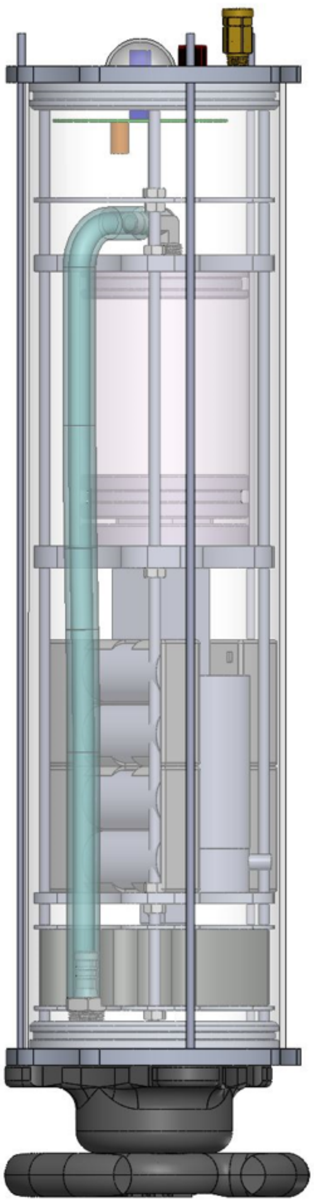
Photo by Anthony Powell (antarcticimages.com)

MATE ROV 20 World Championship

Design Summary:

A vertical profiling float is used to take scientific measurements at various depths in the ocean. Once deployed in the ocean, our float takes advantage of Archimedes' Principle of Buoyancy to complete several vertical profiles and uses sensors to collect valuable scientific data along the way. Our float design focuses on safety, simplicity, and reliability.





Float Operation:

The float can be deployed in bodies of water by hand or with an ROV. First the float is held upside-down underwater, allowing water to fill the internal cylinder through a vinyl tube. Once the cylinder and tube are filled with water and rising bubbles are no longer apparent, the float is released and will sink to the ocean floor. While underwater, sensors located at the top of the float collect data such as depth and temperature. After reaching the ocean floor, the float ascends to the surface and sends the collects data to your device through Bluetooth. The float then completes another vertical profile and sends the second batch of data.

Buoyancy Engine Design:

The float uses a unique "syringe" design to ascend and descend in water. By filling the float cylinder and tube with water, the weight of the float increases, thus overcoming the buoyant force and causing the float to sink. The float utilizes a Printed Circuit Board designed in house. While sinking, the float periodically takes depth measurements. When the float reaches the ocean floor and no longer senses a change in the depth, a linear actuator moves the piston and pushes water out of the cylinder. This decreases the float's weight and allows the buoyant force to ascend the float.

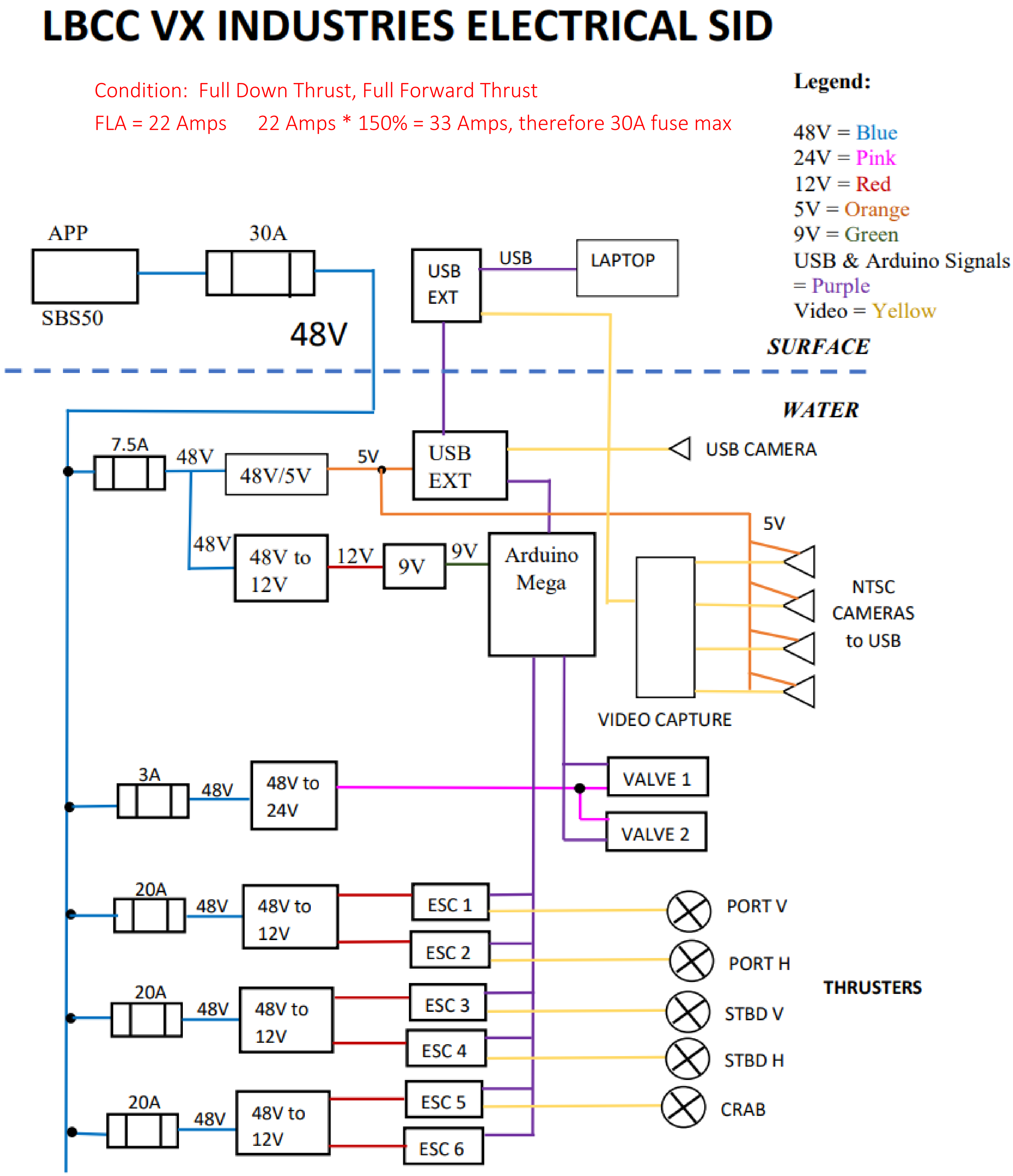
Safety Considerations:

Safety is our first and foremost priority when designing the float. The alkaline batteries are secured in place using battery holders that are strapped down inside the float. A 2.5 cm diameter pressure relief plug is included on the bottom end cap in case of pressure build up inside the float. The power supply does not exceed the 12 VDC and 6 amp maximum specifications and a 7.5 amp fuse within 5 cm of the battery terminal.

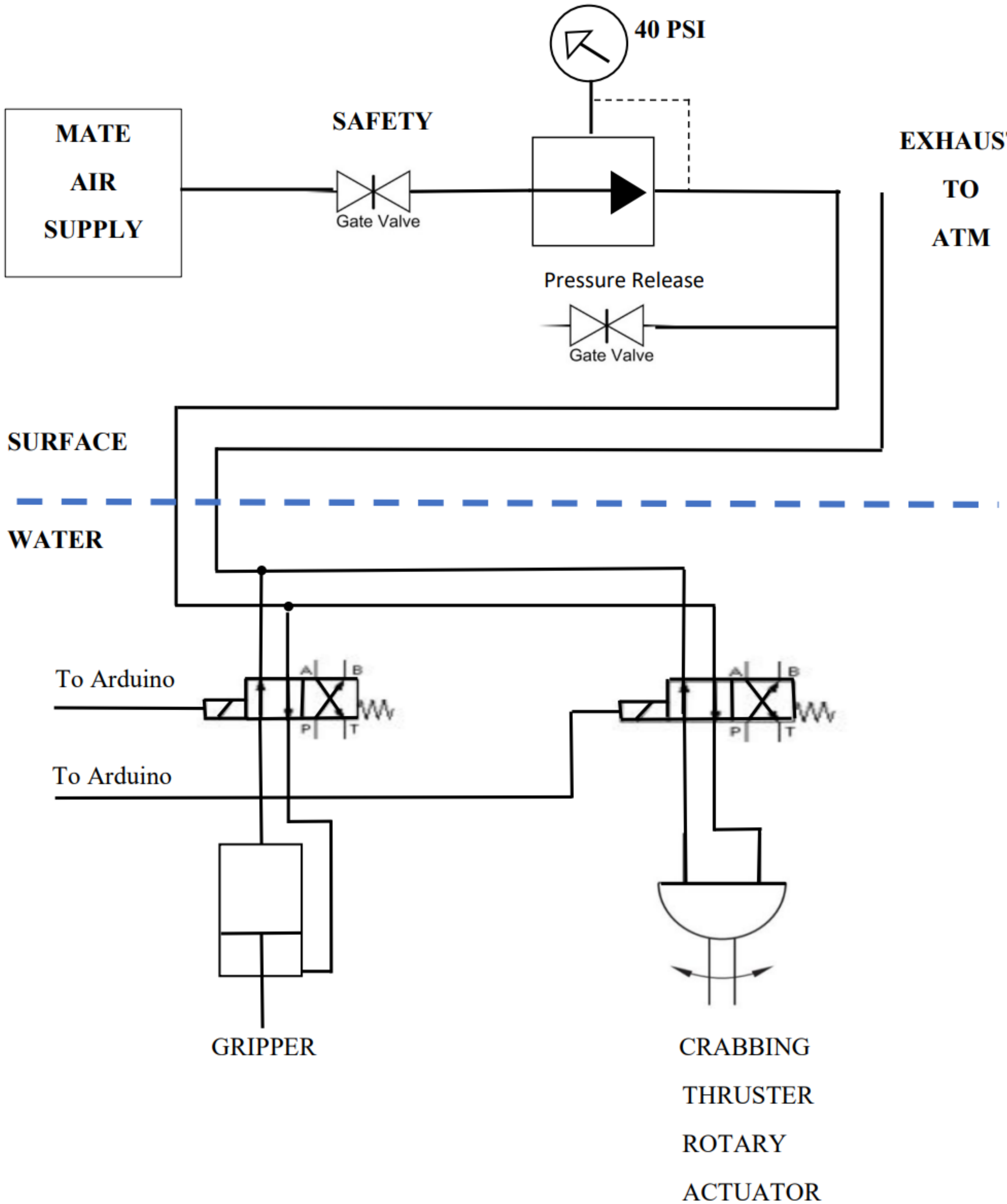
Specifications:

Max Diameter:	18 cm	Battery Type:	8 Alkaline D Cells
Total Length:	67 cm	Fuse Type:	7.5 amps
Cylinder Volume:	10,100 cm	Controller:	Arduino Nano

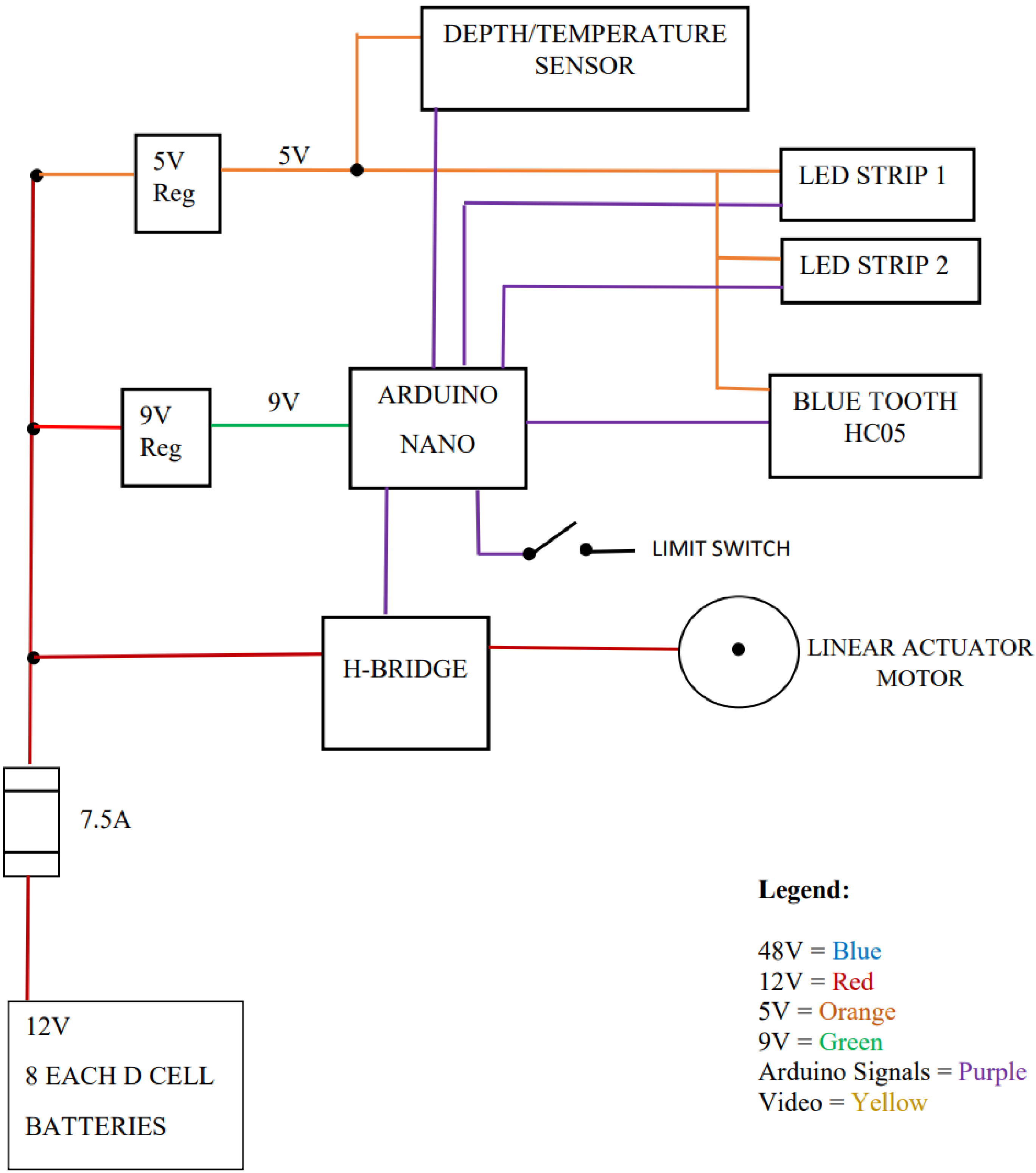
4. System Integration Diagrams



LBCC VX INDUSTRIES FLUID POWER SID



LBCC VX INDUSTRIES FLOAT (NRD) SID



Legend:

48V = Blue
12V = Red
5V = Orange
9V = Green
Arduino Signals = Purple
Video = Yellow

5. Safety

5.1. Safety Philosophy

Long Beach City College-VX Industries Company strives to maintain a safe workplace environment for all team members. This year's team members are all new so extra care was taken to ensure everyone understood and practiced all safety procedures. Project safety was crucial to the success of this project. Proper PPE was required at all times, team members were not allowed to participate in any activity if proper PPE was not worn. Team members must wear safety goggles, gloves, long sleeve shirt, pants and closed toe shoes. Our team developed a Job Safety Analysis that all members must follow.

All team members received proper training from our mentor before operating any equipment. Our team received safety and operations training in the following areas: general electrical hazards, tripping hazards and lab procedures, soldering of power supplies and circuit boards, use of power and hand tools, use of shop equipment (3D printer, CNC router, laser machine, bandsaw, sander, drill press, etc.), ROV cylinder leak testing, and pneumatics systems safety. Our team took the Fluit Power quiz with a 100% score. This passing score allows our team members to use MATE-approved hydraulics or pneumatics on our ROV. Team members were trained on how to safely operate the ROV and eliminate potential hazards through clear communication. Frequent safety meetings were held to remind team member of proper safety procedures.

5.2. Safety Features

Our "Viking Drakkar" ROV safety features includes thruster shrouds to cover each thruster which were painted in red to prevent injuries caused by the spinning blades of the thruster (**Figure 18**). Grip handles were incorporated in our ROV to designate a safe place for team members to hold onto the ROV and to minimize the chance of the ROV falling onto feet or others. All sharp objects have been eliminated or covered to eliminate cutting hazards. Fuses were incorporated in every subsystem and all electronics are housed in acrylic tube.

Figure 18: *Thruster shrouds designed to prevent injuries caused by thruster blades.*

5.3. Safety Procedures

Safety checklist for construction and operation

Tether Setup:

- ❑ 1. Unroll the tether.
- ❑ 2. Keep the control box six feet away from the pool.
- ❑ 3. Safely plug the tether into the control box.
- ❑ 4. Secure the strain relief of the control box to prevent it from possibly becoming disconnected.
- ❑ 5. Notify each team member of the tether location.
- ❑ 6. Connect the airline to the ROV.
- ❑ 7. Connect the air supply
- ❑ 8. Connect the strain relief to the ROV.

Tether Disconnect:

- ❑ 1. Make sure all power if off.
- ❑ 2. Safely unplug and disconnect the tether from the control box.
- ❑ 3. Disconnect the airline from the supply and ROV.
- ❑ 4. Roll up the tether neatly.

Deck Pre-Run Checklist:

- ❑ 1. Check electrical power connections.
- ❑ 2. Check that cameras are working properly and there are no obstructions
- ❑ 3. Make sure all waterproof seals are secure.
- ❑ 4. Check the thrusters to see if there are working and with no obstructions.
- ❑ 5. Check the grabber to see if its properly functioning.

Deck checklist:

- ❑ 1. Proceed with the tether set up protocol.
- ❑ 2. Connect the power supply and turn on.
- ❑ 3. Power up the ROV.
- ❑ 4. Test the ROV Vertical Trusters, Horizontal Trusters, and Rotating Truster.
- ❑ 5. Test the grabber tool
- ❑ 6. Test the camera views on the Deck Screens.
- ❑ 7. Gently place the ROV in the water.
- ❑ 8. Deck team members signal "Ready" to the ROV pilot.

Post-Run Checklist:

- ❑ 1. Turn of power at the Control Box.
- ❑ 2. Turn off the power supply
- ❑ 3. Turn off the Pneumatics Supply
- ❑ 4. Bleed the Pneumatics using the pressure release valve
- ❑ 5. Follow the tether disconnect protocol.
- ❑ 6. Dry the ROV and set it safely on the cart.
- ❑ 7. Clean up the work area of all materials, props, supplies and leave your area clean.

6. Testing and Troubleshooting

Though ongoing testing and troubleshooting is a key part of the design and manufacturing process, it plays such an important part that some brief examples are worth mentioning. Well defined goals and objectives often produce several alternative designs. Each of these can be tested and further refined and altered until the best design is selected. Unanticipated problems are revealed, and new, novel approaches become evident, making for a somewhat complicated process, but it is all worth it as it produces the best, simplest, and most robust solution.

The gripper design is a good example. The design team came up with a number of different designs, and each was tested to see how well it could perform each of the particular tasks in this year's challenge. Grasping, releasing, pulling, carrying, pushing, and moving, fish, marine growth, ghost nets, sections of pipeline, and precision docking, all had to be done in a fast and efficient manner. The current design was arrived at through the making of prototypes, testing and refining, and more testing. The final design uses a pneumatic linear actuator, custom milled and shaped stainless steel, and plastic. During further testing in the water, it was found that the gripper was having trouble pulling the pins that hold many of the props, so another refinement was made, a stiff wire was added to the top of the gripper to make that specific action faster and easier (**Figure 19**).

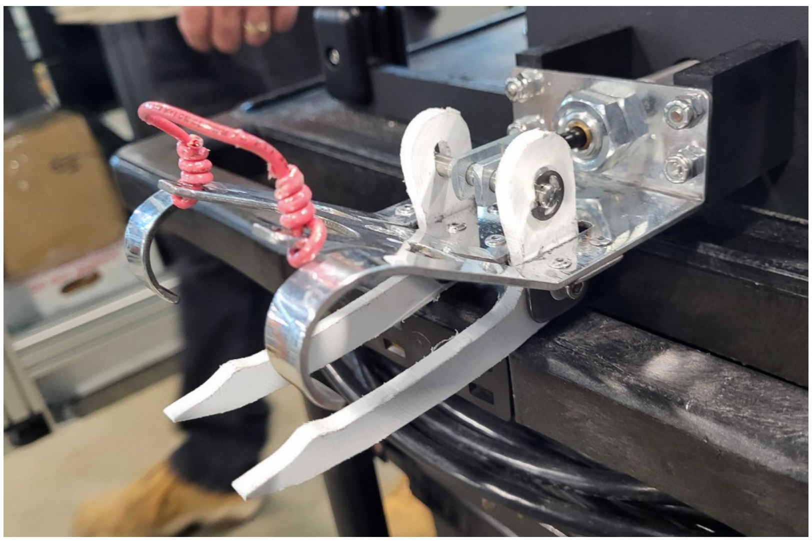


Figure 19: *Wire added to top of gripper for pin pulling.*

Leak testing is another area that demanded through testing and troubleshooting. Robust leak prevention was built into the design from the very beginning, with double O rings and O ring grease, clamping, sealing, and pressure relief, all a part of the design requirements. If a leak occurs, and water floods the electronics tube, it will potentially destroy all the electronics, and we may not have time to recover before the event. So, leak prevention was a high priority. We did extensive testing with the ROV electronics enclosure under both vacuum and pressure. A leak under vacuum was detected and we switched to low pressure air to help locate the leak. The final assembly was tested to 34.5 Kpa (5 PSIG), enough to find leaks, yet low enough to ensure personnel and equipment safety. Once pressurized, each of the potential leak points was tested with "Big Blue," a non-toxic solution used to find leaks in the HVAC industry. Big Blue forms a cone of fine bubbles at the source of even the smallest leak. Our leak was located and fixed. Even with the most careful design work and thorough testing, problems do happen, in which case, troubleshooting, correction, and more testing saves the day.

Heat generated by the electronics is another force that needs to be addressed. The electronic devices contained in the control cylinder generate heat that can push the internal temperatures beyond the tolerance of those devices. During our tests, the internal temperature did not exceed 80° C, well within the operating specs of the devices. Part of our design was to mount the electronics to an aluminum plate that acts as a heat sink. The voltage regulators are mounted with a thermal paste to transfer the heat to the heat sink. The heat sink is mounted to the machined aluminum rear bulkhead, that releases the heat to the water. We did explore active heat removal methods but, in the end, the passive heat sink proved to be very efficient, and an active heat removal system was unnecessary.

From our earliest design concepts, we fabricated a prototype ROV **(Figure 20).** We used the protype to test and refine every part of our machine. It was a lot of work, but it proved to be an invaluable step in the process. Testing the prototype ROV in the water, we found that we could increase upward and forward thrust by simply changing the way the thrusters were mounted. We implemented those changes in the final version of the ROV and it proved very successful. When we initially hooked up the new ROV to the control computer, we realized that we needed to make changes to the software (written in LabView) that controls the thrusters. Through testing, troubleshooting, and altering the code, we were able to get the ROV responding to controls, exploring, and working each of the tasks as designed.

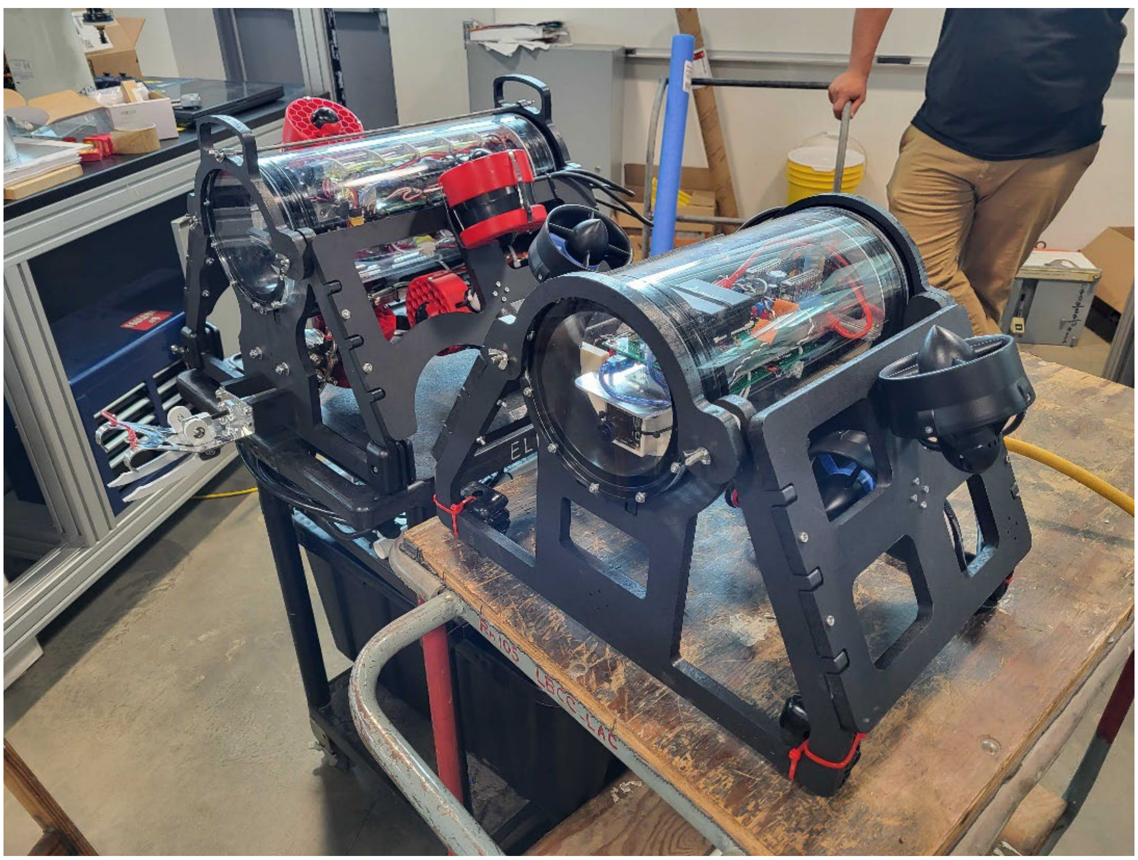


Figure 20: *Viking Drakkar Final ROV (left) and version 2 prototype (right).*

7. Accounting

Our ROV was developed using a combination of reused parts from previous ROV teams, new parts, and donated parts. A list of a costs for purchased, reused, and donated parts is included below in **Table 1.** Travel expenses for this year's competition were negligible due to the competition being held at our home campus (Long Beach City College).

Table 1: List of ROV component sources and cost

Item	Quantity		Description	Price/Ea	Cost	Source	New	Reused	Donated
1	1	ea	2'x4'x1/2" HDPE Sheet	$ 100.43	$ 100.43	N	$ 100.43	$ -	$ -
2	1	misc	Stainless Hardware	$ 25.00	$ 25.00	N	$ 25.00	$ -	$ -
3	5	ea	BlueRobotics T200 Thrusters & ESC	$ 236.00	$ 1,180.00	D	$ -	$ -	$ 1,180.00
4	1	ea	24"x24"x0.1" 6061 Aluminum Sheet	$ 86.97	$ 86.97	N	$ 86.97	$ -	$ -
5	1	ea	BlueRobotics 6" enclosure with endcaps	$ 423.00	$ 423.00	D	$ -	$ -	$ 423.00
6	1	ea	ePlastics 6" plastic cylinder	$ 194.26	$ 194.26	N	$ 194.26	$ -	$ -
7	2	ea	USB Cameras	$ 34.25	$ 68.50	N	$ 68.50	$ -	$ -
8	4	ea	NTSC Cameras	$ 37.55	$ 150.20	R	$ -	$ 150.20	$ -
9	1	ea	Pneumatic Assembly	$ 130.52	$ 130.52	R	$ -	$ 130.52	$ -
10	14	ea	Pneumatic Fittings	$ 1.05	$ 14.70	N	$ 14.70	$ -	$ -
11	1	ea	25 ft 5/32 Pneumatic tubing - yellow	$ 7.50	$ 7.50	N	$ 7.50	$ -	$ -
12	1	ea	25 ft 5/32 Pneumatic tubing - red	$ 7.50	$ 7.50	N	$ 7.50	$ -	$ -
13	75	ft	Tether	$ 5.00	$ 375.00	R	$ -	$ 375.00	$ -
14	150	ft	Pneumatic air line 1/4"	$ 0.36	$ 54.00	R	$ -	$ 54.00	$ -
15	1	ea	Avstar USB Extender	$ 59.99	$ 59.99	N	$ 59.99	$ -	$ -
16	1	ea	Pneumatic Regulator	$ 189.75	$ 189.75	R	$ -	$ 189.75	$ -
17	1	ea	Pneumatic Gate Valve	$ 15.23	$ 15.23	R	$ -	$ 15.23	$ -
18	2	ea	Pneumatic Surface Control Valves	$ 24.56	$ 49.12	R	$ -	$ 49.12	$ -
19	1	ea	Pneumatic Controls Surface Case	$ 12.99	$ 12.99	R	$ -	$ 12.99	$ -
20	75	ft	Yellow Expandable Sleeving	$ 0.67	$ 50.41	R	$ -	$ 50.41	$ -
21	1	ea	Aluminum Cord Grip	$ 23.81	$ 23.81	N	$ 23.81	$ -	$ -
22	1	misc	wire, heat shrink, glue	$ 35.00	$ 35.00	N	$ 35.00	$ -	$ -
23	4	ea	AMPS handlebar mounting pedestal for ca	$ 12.95	$ 51.80	N	$ 51.80	$ -	$ -
24	6	ea	BlueRobotics Cable Penetrator Blank	$ 5.00	$ 30.00	N	$ 30.00	$ -	$ -
25	5	ea	3d Printed Thruster Shrouds	$ 18.75	$ 93.75	R	$ -	$ 93.75	$ -
26	1	ea	Seamate Controller Circuit Board	$ 25.00	$ 25.00	D	$ -	$ -	$ 25.00
27	3	ea	Seamate 48V to 12V power supply	$ 15.00	$ 45.00	D	$ -	$ -	$ 45.00
28	1	ea	Electronic components for Controller	$ 57.95	$ 57.95	N	$ 57.95	$ -	$ -
29	3	ea	Electronic components for Power Supply	$ 16.79	$ 50.37	N	$ 50.37	$ -	$ -
30	1	ea	Circuit board for 24V Valve Control	$ 5.00	$ 5.00	N	$ 5.00	$ -	$ -
31	1	ea	Electronic components for Valve control	$ 17.23	$ 17.23	N	$ 17.23	$ -	$ -
32	1	ea	Circuit board for Floater Control	$ 5.00	$ 5.00	N	$ 5.00	$ -	$ -
33	1	ea	Electronic components for Floater	$ 9.25	$ 9.25	N	$ 9.25	$ -	$ -
34	1	ea	2ft x 6" polycarbonate tube for floater	$ 86.88	$ 86.88	R	$ -	$ 86.88	$ -
35	2	ea	12"x12"x1" HDPE for Floater	$ 40.34	$ 80.68	N	$ 80.68	$ -	$ -
36	1	ea	12"x12"x1" HDPE for Floater	$ 30.77	$ 30.77	N	$ 30.77	$ -	$ -
37	1	ea	6"x6"x2" HDPE for Floater	$ 46.68	$ 46.68	N	$ 46.68	$ -	$ -
					$ 3,889.24		$ 1,008.39	$ 1,207.85	$ 1,673.00
				Tax	$ 398.65		$ 103.36	$ 123.80	$ 171.48
				Total	$ 4,287.89		$ 1,111.75	$ 1,331.66	$ 1,844.48

8. Acknowledgements

We would like to thank the following individuals and organizations for their support:

- Scott Fraser: our Mentor, Instructor, Role Model, and LBCC MATE Reginal Coordinator. This team wouldn't have been able to do it without you!
- Long Beach City College for their support of the students, our ROV team, and the electrical program as a whole.
- The MATE Center for organizing this event and being an excellent source of information for the marine technology community.
- Seamate for their generous donation of thrusters, endcaps, circuit boards, and power supplies.
- SOLIDWORKS for providing student licenses to our team

9. References

1. Mate ROV Competition Website: https://www.materovcompetition.org/
2. Blue Robotics T200 Thruster Website: https://bluerobotics.com/store/thrusters/t100-t200-thrusters/t200-thruster-r2-rp/
3. Arduino software IDE Website: https://docs.arduino.cc/software/ide-v1/tutorials/Windows
4. McMaster-Carr Fittings: https://www.mcmaster.com/535OK82
5. Degitkey Parts: https://www.digitkey.com/
6. PCB Board Layout and Fusion 360 Support: https://www.autodesk.com/products/fusion-360/resources