Natalie Rodriguez
Chief Executive Officer

Haley Craton
Chief Operations Officer

Bri'Ana Goodwin
Chief Technology Officer

Riley Leblanc
Chief Compliance Officer

Hector Arciniega
Engineer

Jorge Trevino
Engineer

Kyle Nixon
Engineer

Matthew Uristegui
Engineer

Sara Malloy
Mentor

MAXIMUS

Dickinson Gators Engineering, Inc.

Technical Report

Dickinson High School | Dickinson, TX USA

Abstract

Dickinson Gators Engineering, Inc. (DGE) is a company of 8 students based in Dickinson, TX, USA, which specializes in the design and construction of underwater Remotely Operated Vehicles (ROV). The DGE team has produced a custom ROV, Maximus, which meets all requirements for proposal.

Maximus features the latest high-tech technology. Utilizing innovative technology, Maximus frame is constructed from carbon fiber tubing that is lightweight, but extremely durable. This ROV can effectively remove a ghost net from midwater as well as remove floating debris from the surface and bottom using its claw. The ROV has a claw that operates on a pneumatic actuator that is more compact and allows for dexterous, precise operation. Maximus has the capability to propagate corals onto reefs by removing a coral fragment from the nursery structure and out-planting to a designated location on the reef. Finally, Maximus is able to position itself at five locations around the subway car on an artificial reef using three cameras that are attached on the top and bottom of the claw as well as the right side of the ROV structure, giving the ROV a wide range of views to perform the many different tasks of the challenge.

DGE is proud to present the Maximus as it's most advanced, intuitive and modular ROV to date. The DGE team is confident in its ability to provide these professional services to the MATE Center and aims to continue developing innovative products and solutions for years to come.

Table of Contents

Company Profile

Dickinson Gators Engineering, Inc. (DGE) is a part of the Career and Technical Education (CTE) department of Dickinson High School (DHS), located in Dickinson, Texas, USA. The company was established in 2015. We have previous experience with other student competitions such as the VEX Robotics Challenge. This proven track record helps the company be successful at completing this project on schedule and within the established budget.

The company is led by an executive board that has final authority on every element of the project. The executive boar has the company's CEO, Natalie Rodriguez and COO, Haley Craton. In the event of conflicting elements, the company would look to their CTO, Bri'Ana Goodwin. The main consultant for this project is our faculty member, Sara Malloy who has worked with the Marine Advanced Technology Education (MATE) program in various roles since 2013. The organizational structure is referenced in Figure 1. Each member contributed to more than one area which allowed the project to stay on time and budget.

Our fully integrated engineering department oversees the technical requirements and the construction of the ROV prototype. Team members each have a unique skill set that allows them to contribute to the project. Each chief officer has a specific function to oversee. Our Chief Compliance Officer was primarily responsible for ensuring that all specifications and restrictions were enforced on the ROV design and development. Our Chief Technology Officer was primarily responsible for developing our navigation and control systems. Our Chief Operations Officer was primarily responsibility was operational protocols and safety. Our Chief Executive Officer was primarily responsibility for our systems engineering approach as well as overseeing the financial management of the company. Our engineers were responsible for drafting, designing and prototyping specific components such as the claw and thruster attachments. The engineering team also integrated the designs into the Remote-Operated Vehicle (ROV). Additionally, the entire team is responsible for public relations and community outreach.

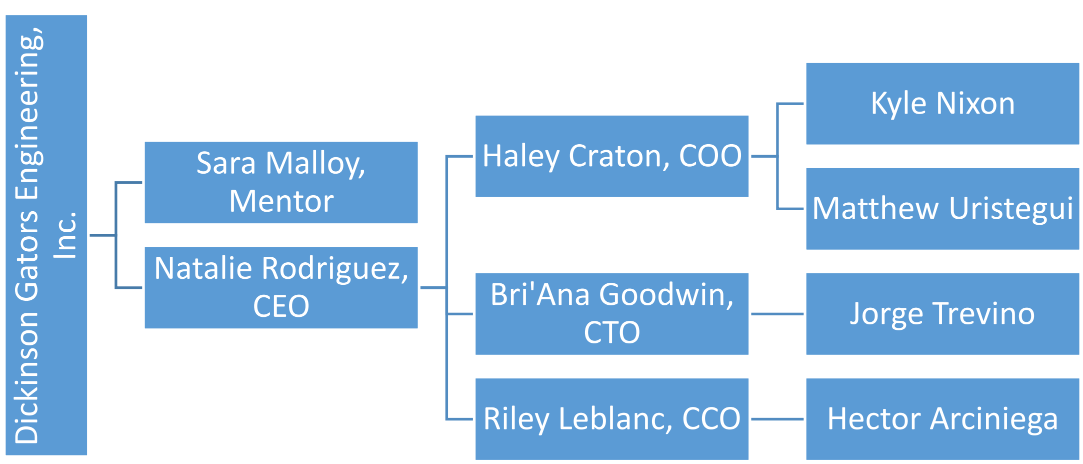


Figure 1 – Dickinson Gators Engineering Inc. Organizational Structure

Project Management

The project management of the Maximus ROV started during the end of the VEX Robotics Challenge season in January/February 2021, although the manual was distributed to the team members in December 2020. Based on interest and performance during VEX, the executive board was named by our faculty mentor. The team quickly worked to read the manual, research MATE and successful ROVs (from previous competitions) and begin the brainstorming process.

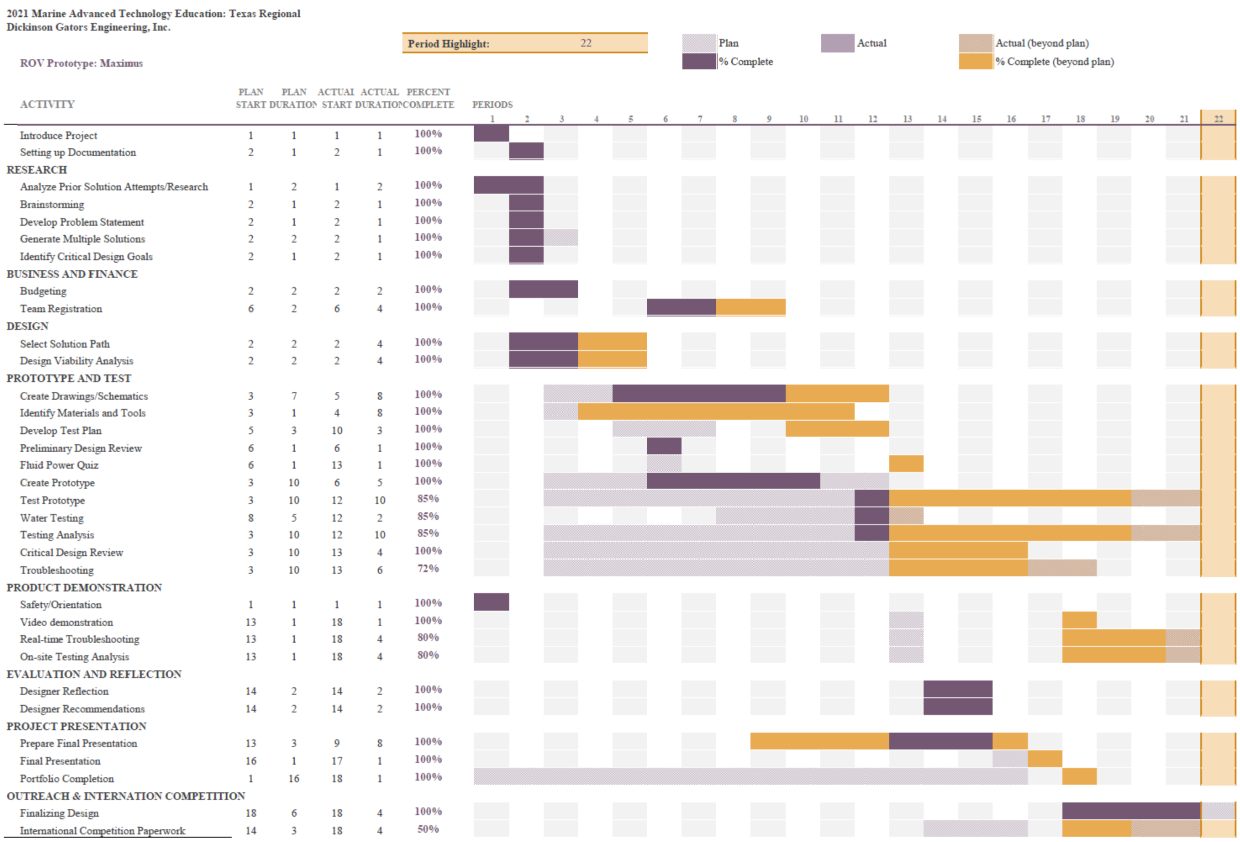
DGE’s initial conversations about this project started on January 30, 2021 during a VEX Remote Skills competition with Clemson University. Starting on February 1, 2021, the team met during their Robotics I & II class period of the school day and did so until the day of the video demonstration in late May 2021. The company started staying after school in February 2021, in which members of the team were required to show up to a majority of the practices or they would not be able to participate in the regional competition. Members of the team were also required to be University Interscholastic League (UIL) eligible in their classes in order to participate in the Texas Regional Competition of MATE.

To accomplish tasks people were often divided into smaller working groups. This allowed for more tasks to be done in a smaller amount of time. At the end of each week, the groups came together to discuss what they accomplished and documented it in weekly reports. In those same weekly reports, we would also plan what would be accomplished in the next week. This encouraged us to keep moving and push towards our goal of being in the pool by the beginning of April.

Schedule

Based on previous experience, one tool we used to keep the project on schedule is Gantt chart. The team brainstormed a list of activities that would need to be completed during this project. A snapshot of the Gantt chart is below in Figure 2. Then, we projected the timeline in the plan start and duration columns. Because of the length of this project, we decided the periods should be in week segments. The Gantt chart is a living document and as the project progressed, the actual start and duration was filled in. The next column is for the percentage of work completed. This allowed the entire team to see the project at a glance to make sure their responsibilities were on schedule.

A complete Gantt chart for this project can be found in Appendix A. The highlighted column is featuring Week 22, which is the week of the technical documentation due to the International MATE Competition.



ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Introduce Project	1	1	1	1	100%
Setting up Documentation	2	1	2	1	100%
RESEARCH					
Analyze Prior Solution Attempts/Research	1	2	1	2	100%
Brainstorming	2	1	2	1	100%
Develop Problem Statement	2	1	2	1	100%
Generate Multiple Solutions	2	2	2	1	100%
Identify Critical Design Goals	2	1	2	1	100%
BUSINESS AND FINANCE					
Budgeting	2	2	2	2	100%
Team Registration	6	2	6	4	100%
DESIGN					
Select Solution Path	2	2	2	4	100%
Design Viability Analysis	2	2	2	4	100%
PROTOTYPE AND TEST					
Create Drawings/Schematics	3	7	5	8	100%
Identify Materials and Tools	3	1	4	8	100%
Develop Test Plan	5	3	10	3	100%
Preliminary Design Review	6	1	6	1	100%
Fluid Power Quiz	6	1	13	1	100%
Create Prototype	3	10	6	5	100%
Test Prototype	3	10	12	10	85%
Water Testing	8	5	12	2	85%
Testing Analysis	3	10	12	10	85%
Critical Design Review	3	10	13	4	100%
Troubleshooting	3	10	13	6	72%
PRODUCT DEMONSTRATION					
Safety/Orientation	1	1	1	1	100%
Video demonstration	13	1	18	1	100%
Real-time Troubleshooting	13	1	18	4	80%
On-site Testing Analysis	13	1	18	4	80%
EVALUATION AND REFLECTION					
Designer Reflection	14	2	14	2	100%
Designer Recommendations	14	2	14	2	100%
PROJECT PRESENTATION					
Prepare Final Presentation	13	3	9	8	100%
Final Presentation	16	1	17	1	100%
Portfolio Completion	1	16	18	1	100%
OUTREACH & INTERNATION COMPETITION					
Finalizing Design	18	6	18	4	100%
International Competition Paperwork	14	3	18	4	50%

Figure 2 – Gantt chart for Maximus

At the beginning of the project, we looked into underwater robotics basic concepts such as buoyancy, stability, and ballast. We became systems experts in those areas, which ultimately helped designate the roles and responsibilities of the team. Then, we gathered and compiled information about past MATE competitors; both their accomplishments and failures. Each team member was assigned a 2019 world championship Ranger class team. During a team meeting, we discussed positive and negative feedback about each team's prototype. Next, we came up with a design plan that had a mixture of all the positive feedback from past competitors and some of our original ideas to come up with our current design.

Next, we spent several days reviewing the manual and tasks. Before any idea came to fruition, DGE members were required to brainstorm ideas and come up with concept sketches individually. We would then present the sketches to each other and take the best parts of each sketch and incorporate it into a group concept sketch. This allowed for different viewpoints to come together to make the best design for our ROV. As a group we took the best parts of each sketch and used them in our final sketch.

Engineering Design Rationale

To make the designing and building of Maximus possible, DGE is rooted in the engineering design process from Project Lead the Way (PLTW). First, we clearly defined the problem as stated in the Ranger class manual. After brainstorming and developing our solution, we started gathering up the materials and began our prototype with the general structure and continued with the details of the design. To solve the obstacles we often encountered in the building of Maximus, we talked as a team and came up with the best solution based on expert recommendations with systems engineering oversight.

Our goal for this ROV was simplicity and accessibility. One of the first decisions that we had to make was whether we wanted the ROV to have slight positive or negative buoyancy. This was the biggest decision as it directly impacted all of the design choices that remained. We determined that it would be easier to float than it is to sink.

The design changed during the building process. Since we had an established budget, we had to keep the cost at a minimum. We made our ROV using used parts, spent money to buy only needed parts to minimize the cost. This makes our ROV as cost efficient as possible. When it came to building the Maximus, we made sure our ROV was small and compacted to fit in the size constraint to maximize bonus points. We made our ROV light so we can move through the water, as well as earning the weight bonus.

Building the structure was our first priority, at the same time as looking into control systems to have an understanding of how we were going to make Maximus move. After the structure was built, we decided that the next logical step was propulsion along with the manipulator. Obstacles were encountered, but extra time was spent, and we were able to catch up with our planned timeline.

Innovation

DGE is always looking to be innovative in our designs because innovation drives higher functionality while reducing costs. The first innovation that we incorporated into vehicle design was using carbon fiber tubing for the structure. Traditionally, we would have used ½-inch PVC because of availability. Comparing the weights of a 15.25cm length of ½-inch PVC to the same length carbon fiber tubing, the PVC weighs 37 grams, while the carbon fiber tubing weighs 17 grams. This greatly reduced the overall ROV weight to help ensure the weight bonus. Because these tubes were donated, it also allowed us to keep our costs to a minimum.

Our school has a rapid prototyping capability, making 3D printed parts readily available and cost efficient. This is a simple and available means of achieving a support system outside of our ROV structure. In order for us to 3D print the parts, we utilized SolidWorks 2020 software and our Dremel 3D45 3D Printer. Our 3D printed components consist of Polylactic Acid, most commonly known as PLA filament, which is a polymer made from renewable resources and is best suited for its strength.

Problem Solving

As problems arose during all phases of the project, they were dealt with using a logical, standard method with which all employees of Dickinson Gators Engineering, Inc. are familiar. The process is as follows:

1. Identify the issue and its underlying cause. Eliminate all other possible factors and distill the issue to its simplest form.
2. Isolate the issue and test one component at a time to confirm where the problem is located.
3. Evaluate possible fixes and implement the best option, depending on cost, time and simplicity.
4. Monitor the solution and ensure that the issue has been resolved completely.

This method has proven to be very effective in troubleshooting our design, manufacturing, testing and all other types of problems.

Systems Approach

DGE incorporates the design process at each stage of development and believes in simplifying the design without forfeiting functionality. To accomplish this, we use a top-down comprehensive solving process which is applied sequentially through all stages of development to help us stay organized with our work. Our team was divided into small sub-teams so each group could work independently on a module of the ROV. Since each section was focused on a specific task we had to have good communication, so every system could work together as a whole.

One of the sub-teams was ROV structure and electrical systems, which focused on the manipulator and the outer structure of the ROV. This team communicated to the control team, as the two are directly connected. The integration between structure and control is vitally important for piloting Maximus.

The structure and electrical system sub-team had to communicate with the buoyancy and ballast team to make sure the buoyancy tanks were built sufficiently for ROV stability. Integration between subsystems is crucial to the success of Maximus. Each system relies on the other to successfully complete the defined tasks.

Vehicle Structure

As previously discussed in the innovation section, DGE, Inc. is always looking to be innovative in our designs because innovation drives higher functionality while reducing costs. Maximus structure is made from carbon fiber tubing. This greatly reduced the overall ROV weight (under 15kg) to help ensure the weight bonus.

During the initial design meetings, the team discussed potential shapes for the structure. After our research into underwater concepts and previous competitors, the team decided to build a symmetrical shaped vehicle in order to maintain balance during mission tasks.

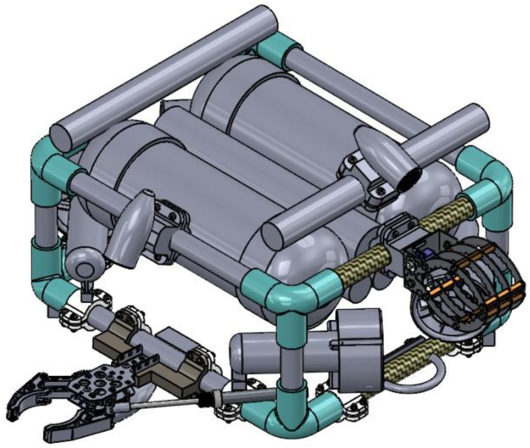


Figure 3 –Maximus ROV
(CAD Assembly)

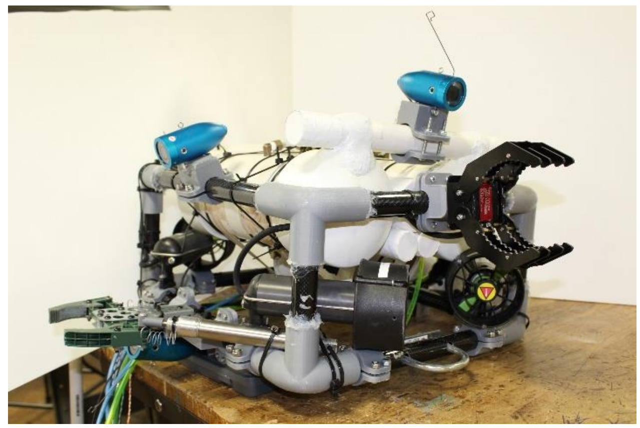


Figure 4 –Maximus ROV
(Full Assembly)

In order to be awarded the size bonus, we measured the length and height of the thrusters. Taking into account our ballast system, we determined the size of the ROV to be 45cm x 35cm x 20cm. This should ensure that Maximus is well within the sizing bonus of 60cm. The CAD assembly is shown in Figure 3. The full assembly is shown in Figure 4.

Parts and Materials

A list of parts and materials used in construction of the Maximus is below:

Qty	Description	Qty	Description
4	SeaBotix BTD-150 Thrusters	3	Aukfa underwater fishing camera
7	25mm carbon fiber tubing	3	17.78cm display monitors
3	Cat6 cables, 13.72m	1	Lexan polycarbonate sheeting
1	Pneumatic actuator	1	SeaHorse SE-1220 Protective case
4	PLA Plastic Spools (205m)	4	Solenoids

In addition to the parts and materials above, Anderson power poles, zip ties, silicone, epoxy, electrical tape and miscellaneous screws, nuts and bolts were used.

Vehicle Systems

Component and material selection had a major impact on Maximus' design. Since we did not use standard size pipes, the team designed customized clamps. They were designed using SolidWorks 2020 and 3D printed for perfect sizing. In addition, using rapid prototyping 3D printing, we were able to refine the design and readily print the components needed. The required filament was already in inventory, allowing for cost reduction and shortened production timeline. These clamps became an integral part of the ROV design and were used on thrusters, cameras and claw components.

Clamp Attachments

In order to accomplish the type of movements for Maximus, thruster placement is vital. As we previously mentioned, we used carbon fiber tubing for the ROV structure frame. Because these tubes are not standard sizes and we had made a functional decision not to screw into the carbon fiber tubing (for buoyancy) and would need to design a clamping mechanism to attach the thrusters to our frame.

Figure 5 – 3D Printed Thruster Clamp

The final version of the thruster clamp design worked perfectly. We shortened the measurement on the x-axis so they wouldn't pop out, alleviating the problems from the first version of the design. The clamp's arc measurement was changed to 12.99mm to make the arc smaller, thus alleviating the problem from the second version of the design.

The 3D printed prototype, shown in Figure 5 measures 64.94 x 18.32 x 30mm. The clamps edge was filleted by 10.00mm and the edge between the arc and the face where the holes are is filleted by 5.00mm. The thickness of the clamp is 5.50mm on the sides and the thickness of the arc is 7.04mm.

The first 3D print of this thruster clamp was printed with 20% infill level. After making adjustments on the structure, some of the clamps started to crack at the weaker points of the print. In the reprint, the infill level was increased to 50% to increase the sturdiness of the thruster. The overall mass of the clamp is 8 grams. A total of 4 clamps were used on each thruster. The type of bolt we used to attach the clamps was 8-32*¾ machine screws. This is a lightweight, yet elegant design that has secured our thrusters to the structure frame of Maximus.

Camera Clamps

The basis for both designs came from the thruster clamps. In order to accommodate the second part (as seen in Figure 7), the first part needed minor adjustments. The first part measures 64.94 x 18.32 x 50.00mm (this is a slight increase on the Y and Z-axis). The SolidWorks rendered drawing of part 1 can be seen in Figure 6.

The modification for the camera clamp (part 2) is more pronounced. This component measures 64.94 x 35.5 x 50.00mm. The thickness of both pieces is 5.50mm on the sides.

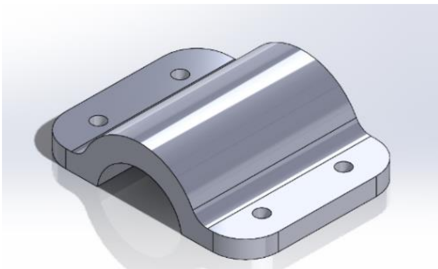


Figure 6 – CAD Drawing of Camera Clamp Part 1

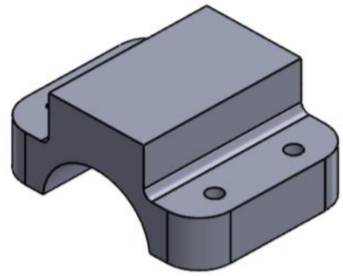


Figure 7 – CAD Drawing of Camera Clamp Part 2

Each camera is positioned in the middle of the carbon fiber tubes of the ROV structure. One camera is placed above the claw and one camera is placed below the claw. The top claw camera provides the primary visual for the ROV and claw manipulators. The camera below the claw helps to determine the proximity of Maximus to the mission tasks components (for example, placing the coral fragments into the designated areas on the coral reef). The third camera is placed to show the U-bolt that is used as a back-up system for the ghost net. In addition, utilizing the clamps allow us to easily adjust the camera's positioning as needed for task completion.

Developing these clamps allowed the team to place the thruster clamps exactly where we wanted in order for Maximus to be fully mobile and able to adjust to surrounding environments. The camera clamps and being able to attach a camera to any side of the ROV frame. Both of these are examples of how the design evolved to meet the mission specifications.

Being able to 3D print these components, saved us both time and money while increasing the ROV efficiency. These clamps give the ROV flexibility to accommodate a variety of tools and adaptability. This makes Maximus the ultimate ROV for completing mission tasks.

Control/Electrical System

DGE's main focus on the electrical systems was to make sure every wire was perfectly sealed, and every possible trouble spot was secured. To be able to accomplish this we used multiple layers of electrical tape, liquid and spray electrical tape. We took equal precautions for our control box to minimize potential hazards.

Control Box

We designed a control box for our ROV, based on the accessibility and simplicity of the controls and the ease to contain the electronic components. Our control box is the housing for our monitors, analog switches, power distribution module and the wires for the tether. The case in which we house everything is a Seahorse case that is 60.96cm x 38.1cm x 25.4cm. For ease of use, the case housing is lightweight and portable.

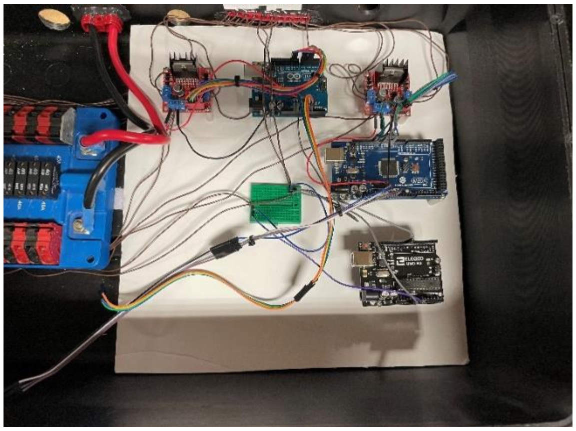


Figure 8 – Arduino Control Layout

A piece of Lexan was used to cover the power distribution module as well as the electrical components. If any issues do occur we can easily look inside without taking anything off. Three portable DVD players were also attached to the inside of the control box to allow us to view the cameras attached to the robot.

Control System

In previous years, we always started out with the intent to develop a fully functional control system, but in the time crunch, we opted for using toggle switches. Although the toggle switches worked, it made piloting the ROV very challenging. To tackle this challenge, we dedicated two individuals whose sole responsibility was to get a working control system that gave us better control, functionality and maneuverability.

When we first started brainstorming ideas for the control system, we thought of using Arduino boards, joysticks, and buttons to have better control over the ROV. Arduino is a rapid electronic prototyping platform composed by the Arduino board and the Arduino IDE (software). Arduino hardware and software is extremely accessible, flexible and offers a variety of digital and analog inputs. This open-source project is easy to use and runs in standalone mode. Arduino is a great tool for developing interactive objects, taking inputs from a variety of switches and controlling a variety of lights, motors and other outputs. This makes the use of Arduino in ROV control and navigation a viable option.

Most importantly, we decided to have the Arduino boards on the surface (in the control box) in order to avoid getting any water near our control system and rendering it useless. From the tether via Anderson power poles, there was a wire connected to the motor controller. The motor controller was connected to the power distributor and the Arduino Uno, which was connected to a joystick that, when moved along the y-axis, made the thrusters move. The layout for this setup is in Figure 8.

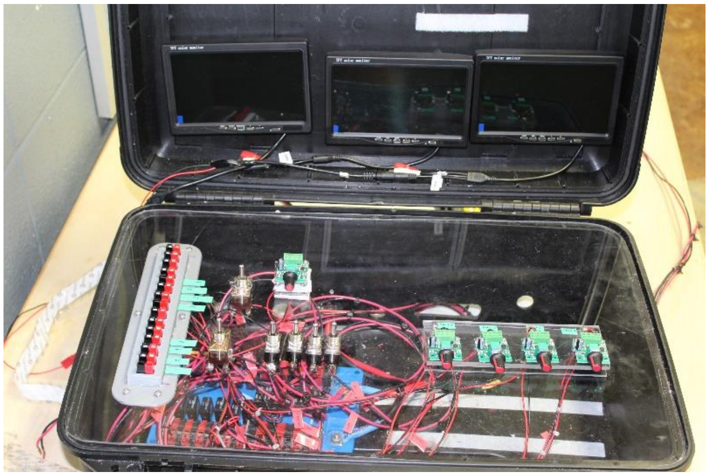


Figure 9 – Control System Setup

Connecting the Arduino boards to the thrusters through the tether, we found that power degraded over the length of the tether which was not enough to power the thrusters. To alleviate this problem, we tried a different method of connecting the Arduino Uno board. We tried to connect the Arduino Uno directly to a 12-volt, 40 amp fuse on the power distributor. When we tried this, the board started to smoke and left the chip on the Uno board with irreversible damage.

With a 12-volt battery and a 40 amp current, we had an estimated resistance of 0.3 ohms. With this resistance and current, we calculated the power traveling through the circuits to be 480 Watts. Through the control system, there were a total of 3 Arduino boards; two Unos and one Mega. One Uno powered the servo and the other Uno and the Mega powered two thrusters each. Theoretically, when all boards are connected to the power distributor, each board would get 4-volts of power. With a few more hours of research to figure out why the boards couldn't power the thrusters, we found that each board requires 7-12 volts of electricity each. With this information, we saw that the 12-volts battery was not enough to power all three boards at the same time. After investigating many different options, the control system was the only item keeping us from water testing. In order to expedite that testing, we made a control system with four 6-prong analog switches that have an on-off-on capability to control our thrusters, 1 on-off-on switch to control the buoyancy system and 1 on-off-on switch to control the claw actuator. By using Anderson Power Pole connections, we are able to separate the tether from the control box. This makes transport much easier.

To give the cameras power, we connected them through Anderson Power Poles, so we are able to disconnect the tether from the control box. Outside the control system, we used audio-visual connections to connect the three cameras that are on the ROV to monitors that we have secured to the lid of the control box using Velcro. The control system setup is pictured in Figure 9.

To give the vertical claw's power, three wires from a Cat6 wire dedicated to the claw servo. In the current configuration, the claw Cat6 cable is using 3 wires, leaving an additional 5 that could be used to expand capabilities of Maximus. These wires are connected to a servo tester in the control box for operations. The remaining four camera wires provide power, AV input signal and connection to the monitors.

Tether

The tether is made up of Cat6 cables that is 11.2776 meters in length, which is more length than required for the product demonstrations allowing us flexibility in our approach to each of the props. The rationale for the tether is to keep it small and light but supply sufficient power to all the necessary areas such as thrusters and cameras. The Cat6 has eight small copper wires inside the casing, with this we are able to attach multiple thrusters and cameras dependent on the needs of the ROV design. The tether is composed of seven separate cables (2 Cat6, 3 camera wires, 2 pneumatic) and two air tubes (to supply air to the claw and the buoyancy system. Two of the Cat6 cables provide power to the four thrusters on the ROV, one cable for every two thrusters. The remaining three camera wires provide power, AV input signal and connection to the monitors.

Tether management is very important in ROV operations. DGE protocol for working with the tether is inclusive of the entire product demonstration. Because the tether is connected to our control box, it is very important to keep it secure at all times. During set up, the tether must be movable, untangled and extended for the start of the operation. From there, it will depend upon the communication between the tether manager and the pilot. The tether manager is responsible for maintaining strain relief on the surface as well as underwater. At the conclusion of product demonstration, the tether must be untangled and wrapped in an organized manner.

Propulsion

There are two primary propulsion options; bilge pumps or thrusters. Based on previous experience, we determined that thrusters are a more effective means of propulsion. Working with Ashtead Technology Offshore Inc., we previously procured four SeaBotix BTD-150 thrusters due to their efficiency. These thrusters have a strong output of 67.57 FT/LB of continual thrust. The depth rating of 150 meters is more than efficient for the depth that we will be competing at for the different tasks we have to achieve. Each of the four thrusters are shrouded, have warning labels and guards. Additional manufacturer information about the thrusters can be found in Appendix D.

Figure 10 – Thruster Placements

We went through countless designs and suggestions on where the placement should be. This initial decision drove our design for thruster placement. After we figured out the placement for the thrusters, we mounted them to PLA 3D printed clamps as described in the vehicle systems section. The reason we chose to mount to 3D printed clamps is because it's light, easy to move, and easily mounted. More information about the thruster clamps can be found in the 3D printed parts section under vehicle structure.

We decided to place the thrusters on each corner, (two facing left direction, and two facing the right direction) as seen in Figure 10. This layout for thruster placement allows Maximus to easily maneuver in the water and utilize the maximum efficiency of the thrusters. It works well in ROV movements. We used one Cat6 cable for every two thrusters, which allowed our tether to be lighter.

Buoyancy and Ballast

According to the Archimedes principle, any body completely or partially submerged in a fluid at rest is acted upon by a buoyant, upward force. The magnitude of which is equal to the weight of the fluid that is displaced. Using this principle as guidance, we designed a buoyancy and ballast for Maximus as seen in Figure 11.

The buoyancy system that we used on Maximus is a variable ballast tank using pneumatic pressure. We started by estimating the weight of Maximus at 7.35Kg to come up with the size of the tanks used for the ballast system, which is 4-inch PVC pipes. The reason for this is because the PVC pipes can hold 4.92L of air in conjunction with the volume of the carbon fiber tubing which holds 7.42L of air and can produce 12.34Kg of lift. The formula used to calculate the volume of the cylinders was $\pi r^2 l$.

Using these calculations, we were able to determine how much air is required when the ROV is only partially submerged (volume of the fluid displaced is equal to the volume of the part of the body that is submerged). Mathematically, we were also able to determine how much air is needed if the ROV was completely submerged (volume of fluid displaced is equal to the volume of the body).

Figure 11 – Maximus' Ballast Tanks

By using pneumatic solenoids, we are able to inject air into the 4-inch PVC tubes, and the holes at the bottom of the tube help the water to escape. There is one solenoid on each tube to allow air to escape when required for operations. The hose that connects Maximus to the surface supplies air to the tube injectors. The ballast tanks are supported by their own aluminum cradle and attached to the robots via zip ties. On the electrical side, we are using a simple analog switch, to reduce the chances of failure.

Payload and Tools

Maximus' payload and tool designs are essential for completing the required tasks as outlined. These items are vital components to be able to interact with the underwater environment while allowing the pilot to have clear vision of the surroundings. This ROV can effectively reduce plastic pollution in waterways, can assist in monitoring coral colonies as well as out-planting coral fragments into a reef and help maintain healthy waterways.

Cameras

There are many commercially available cameras. After researching several available options, we decided to we decided to purchase and test a Zettaguard ZBC-100 waterproof night vision HD CMOS 170° viewing field car rear view backup camera with a universal mount. This camera is cost effective ($9.00 USD each) and already some level of waterproofing. Unfortunately, these cameras could not withstand the multiple uses underwater and began to fail.

Next, we decided to reuse three SS-Aquacams, which are completely waterproof. These cameras were used in the product demonstration during the Texas Regional MATE Competition. Since their original purchase in 2016, these cameras have been reused on multiple ROV and we worked to fix the broken wiring/pieces to make them usable parts again. These cameras began to have connectivity issues while others distorted the images.

After additional researching, product analysis and testing, the team purchased three Aukfa underwater fishing cameras. Each camera comes with a 2.54cm display and the item weighs 0.545kg. Each camera measures 8.89cm x 3.81cm x 3.81cm and offers depth and temperature sensors. Additional manufacturing information about the cameras can be found in Appendix E. All of these features are in line with our design concepts to keep Maximus as small and lightweight, while increasing efficiency.

The cameras are mounted on the ROV to provide three points of view. A camera above the claw is mounted to the top tube in the front of the ROV. A camera is mounted to the bottom of the claw mechanism. The third camera is placed to show the U-bolt on the right side of the ROV. The video line plugs easily into portable DVD players which are cost effective and rechargeable – allowing us to carry less wiring.

Claw

After reviewing mission tasks we determined a claw was the more efficient component rather than a hook or a U-bolt due to the fact that it can be mechanically manipulated in order to complete mission task.

Figure 12 – MATE 2019 Sea Dragon's Claw

The original inspiration for the claw came from a past MATE competitor in 2019, the Sea Dragons (as seen in Figure 12).

Version 1 (v1) was driven by a servo motor rather than a linear actuator, which was more cost-effective since we had plenty of servos at our disposal (seen in Figure 13). The original servo motor was a SpringRC SM-S4303R servo motor. Our servo motor, as well as our backup motors, had to be waterproofed. First, all moving parts of the servos were covered in marine grease. Then the seals of the servo were coated in silicone. Unfortunately during prototype testing, it was determined that the arms of the v1 design did not adequately secure the coral fragments due to the lack of grip and power.

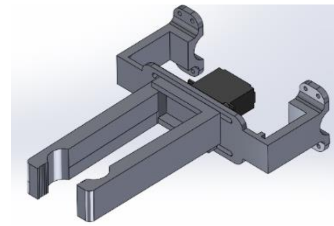


Figure 13 – Maximus'

Although we could have increased the infill of the 3D printed components, in the evaluation of our solution, the team opted for a design with a mechanism with a greater mechanical advantage.

The next version (v2) was an in-house VEX Cortex claw (see Figure 14). This claw uses a metal 12-tooth gear (driver) in combination with a 31-tooth gear (driven) giving the claw a 1:2.58 gear ratio. After this decision, we attempted to use our v1 servo with the v2 of claw and a custom shaft we 3D-printed. After a few tests, we discovered that the shaft was too fragile. We decided to switch to a VEX 3-wire servo to increase compatibility between parts. The v2 claw began to function as intended. However, during prototype testing, we discovered a design flaw in the VEX 3-wire servo. Due to the internal rotating shaft allowed water to penetrate and flood the servo.

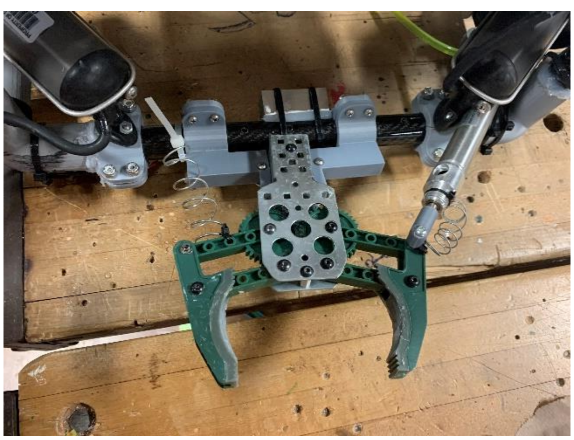


Figure 14 – Maximus' Horizontal Claw

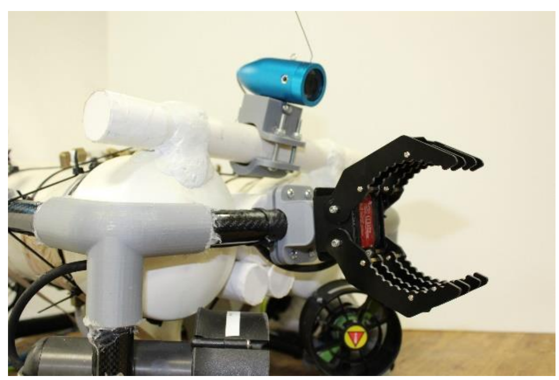


Figure 15 – Maximus' Vertical Claw

The v2 claw functions worked well to complete mission tasks and the team decided to generate alternative solutions to overcome the flooded servo issue. To power the claw, we are using a pneumatic actuator. To operate this, we are using a one-way solenoid to supply 40psi to the outgoing side of the pneumatic actuator. Instead of using air pressure to force a down-stroke, we are using spring on the claw itself. The claw is secured to the carbon fiber tubing through a 3D printed cradle that attaches using clamps.

After prototype testing with the props, we realized that a horizontal claw had some deficiency for certain tasks. After generating concepts, the team decided to add a vertical claw to the ROV structure. Claws operating in both horizontal and vertical makes our product demonstration run more efficient. The vertical claw is a Hiwonder Mechanical Robot Arm Claw/Gripper with a waterproof servo (as seen in Figure 15). With our final designs of the claw, Maximus effectively removes a ghost net from midwater as well as floating debris from the surface and bottom with the horizontal claw. Maximus has the capability to propagate corals onto reefs by removing a coral fragment from the nursery structure and out planting to a designated location on the reef. Finally, Maximus is able to position itself at five locations around the subway car, giving the ROV a wide range of views to perform the many different tasks of the challenge.

Underwater operations must be as efficient as we can make it. Every second the ROV is the water, there is potential for issues to arise and we may not always have the immediate opportunity to retrieve the ROV. This can be costly in both time and money. In the unlikely event that the claw mechanism fails, we have a U-bolt attached to the frame. The U-bolt serves as a back-up redundant system that is capable of easily removing the tent stake from the ghost net. If the primary claw is working, the U-bolt can be omitted without any loss of function.

Non-ROV Device

Figure 16 – Pascal Non-ROV Device

Pascal, Maximus' non-ROV device, is a deployable device that can go inside of a 6-inch drain pipe to pick up a sediment sample to analyze for contaminants. We used a 3-inch diameter PVC pipe and cut it to 15.24 cm in length to ensure stability. We are using gearhead motors and propellers to create thrusters. The propellers were designed in SolidWorks 2020 and 3D printed using PLA.

To control Pascal, we are using four motors. One is in the vertical position which provides thrust in the upward direction. Two motors are forward facing thrusters at the front of the device to provide forward thrust and to be able to turn with differential forces. The last thruster is on the rear of the device, providing reverse thrust. In combination, the pilot can move Pascal to any position needed using potentiometers that are wired by power and ground. We mounted a camera in the bottom front center of the PVC pipe, giving ample vision to complete the task. In order to pick up the payload, we are using a hook mounted on the top front center of the PVC pipe.

In-House vs Outsource, New vs Used

Dickinson Gators Engineering, Inc. bought the parts that would take too long to build. Our approach to building versus buying is build what we can and buy the rest. We come from a Title I school and we have a limited budget for student projects. DGE's CEO and mentor helped secure a charitable contribution from a local business, BP Texas City Chemical, which is designated to Dickinson High School's Engineering and Robotics program. The majority of these funds help support student competitions (such as VEX and MATE) and senior capstone projects.

We also bought components that are needed to build parts of the ROV. For example, the thrusters and underwater cameras, which were commercial-off-the-shelf items. Our team did not have the resources or expertise to build these items from scratch. Since we had most of the major components, like the thrusters, in the shop from previous MATE teams, we had to fix any broken components to make them usable parts again.

Outside the cost of the thrusters, we were allotted $2,560 within the approved vendors for our school district. Using cost-benefit analysis, we would determine if buying commercial-off-the-shelf items were more beneficial than spending the time and money to create them ourselves. We have about $297 remaining in the budget because we were able to use resources in the engineering shop such as Lexan, PLA plastic and miscellaneous supplies.

For our more expensive parts, such as the thrusters, we chose to reuse them from the 2019 team. We chose to reuse the old components because they are expensive and it was fiscally impossible to purchase new ones with our budget. Looking at our cost-benefit analysis, we determine it was a better use of our limited budget to purchase some new parts that were necessary like the Arduino boards components, in attempts to build a more sophisticated control system. These team decisions helped the creation of Maximus to be the most cost-effective vehicle possible. In addition, we were able to secure donations like the carbon fiber tubing, which allowed our ROV to be more lightweight while not impacting the budget for the project.

System Integration Diagram

The complete ROV SIDs is below and a copy will be provided during the product presentation. A complete electrical Systems Integration Diagram (SID) for this project can be found in Appendix F. A complete pneumatic Systems Integration Diagram (SID) for this project can be found in Appendix G. A complete non-ROV device Systems Integration Diagram (SID) for this project can be found in Appendix H.

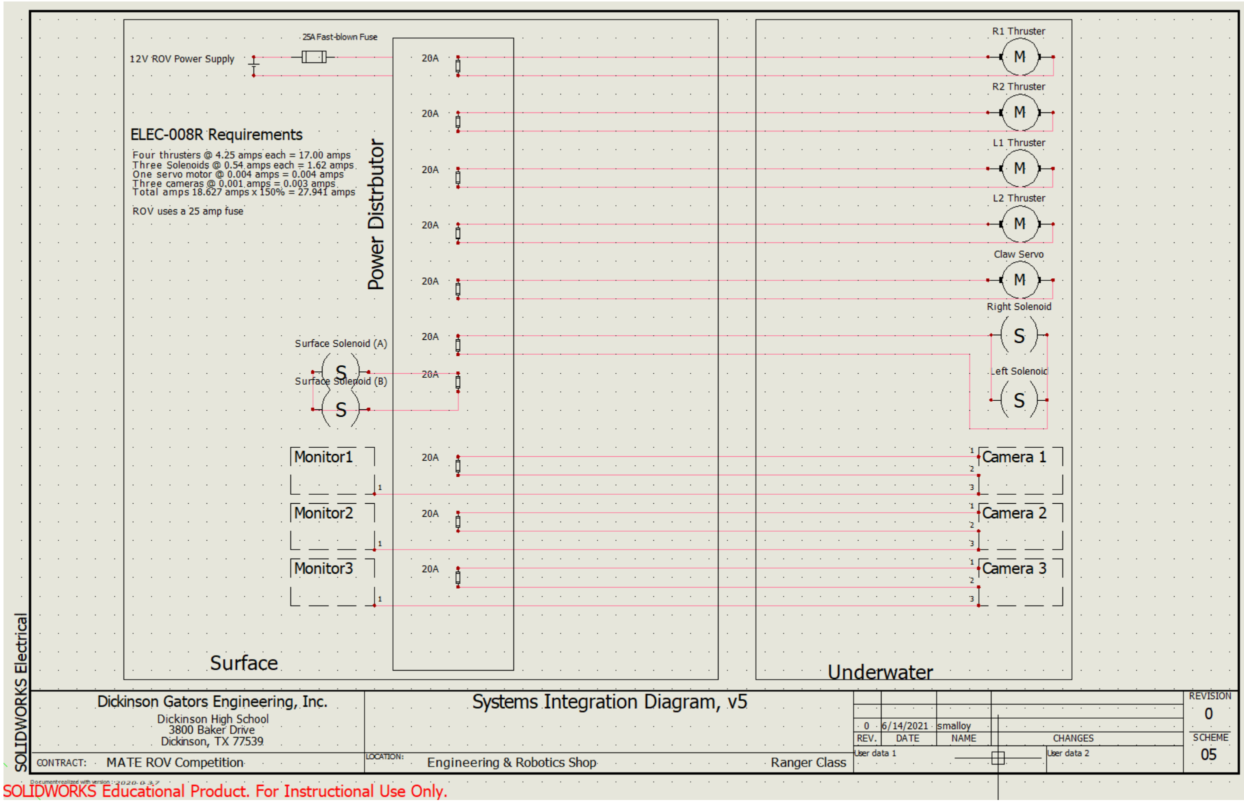


Figure 17 - Systems Integration Diagram, Electrical

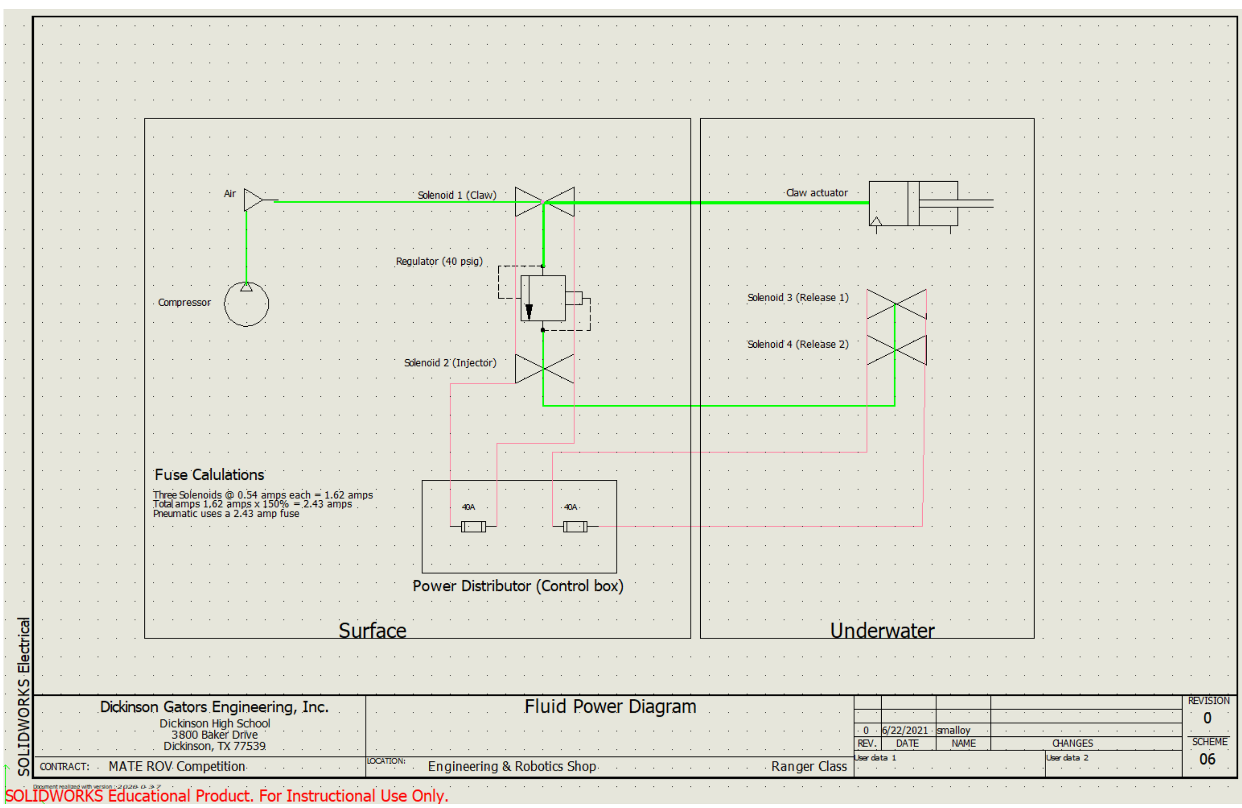


Figure 18 - Systems Integration Diagram, Pneumatics

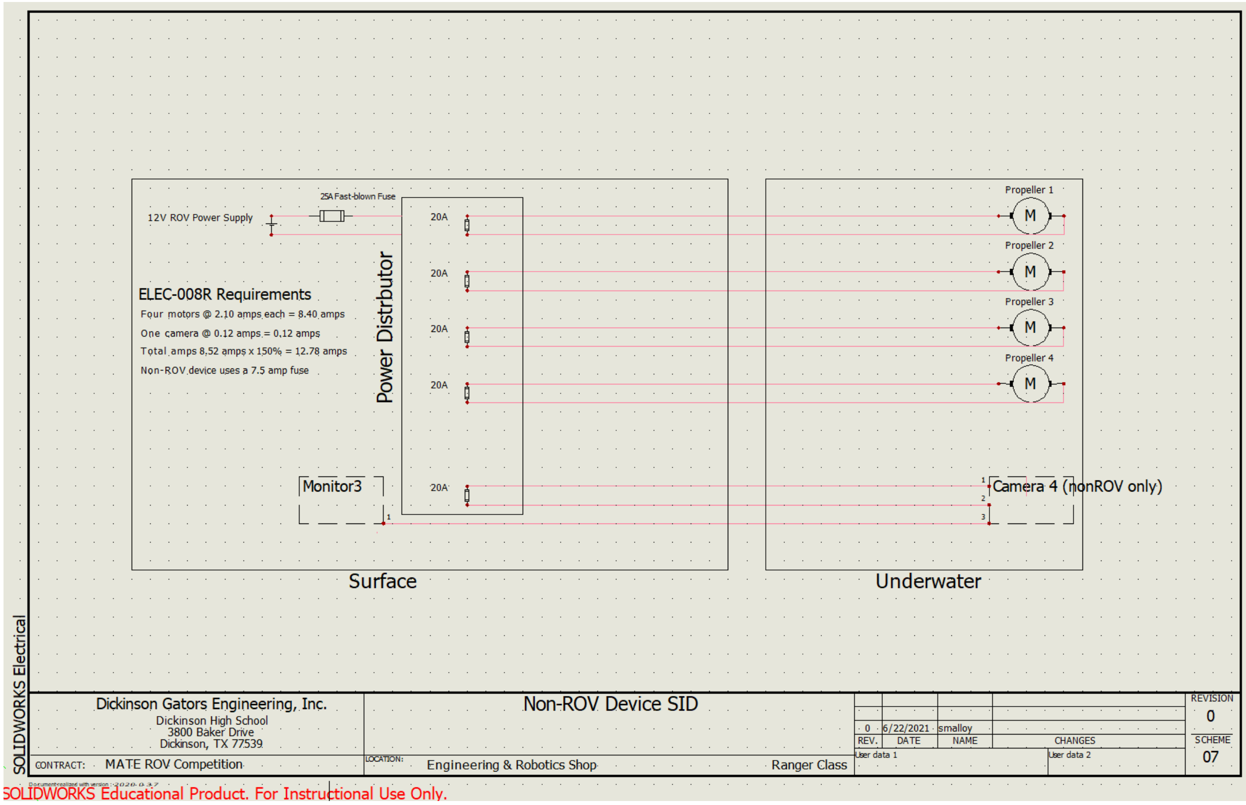


Figure 19 - Systems Integration Diagram, Non-ROV Device

Safety

Dickinson Gators Engineering, Inc. takes extra precautions to assure that our ROV is as safe as possible. In order to guarantee the safety of the craft and its personnel, Dickinson Gators Engineering, Inc. has taken a number of safeguards to prevent both electrical and mechanical damage. We worked hard establishing a protected area for our company. As a relatively new team, we've understood that we must be very aware of our surroundings to maintain an efficient working environment.

Safety is number one priority at DGE. Before using anything that may be a risk we make sure to identify all the dangers that could cause injury to protect our workers and clients. We take special precaution to make our ROV safe for underwater tasks and maintenance. We believe that accidents can and will be minimized by taking all the necessary precautions, which is why we follow "The Golden Rules" of the shop at all times to ensure the safety of our members and provide a safe environment to generate ideas.

DGE Engineering & Robotics Shop Safety Rules:

1. Safety glasses must be worn!
2. Always work with a partner
3. No long hair or long sleeves unless it is pulled up or tied up
4. No wearing jewelry or watches while working with shop equipment

5. Closed toe shoes or boots only
6. Ultimately YOU are responsible for your own safety!

The rules include the basics such as members must have closed toe shoes, long pants, and long hair tied back at all times in the shop. Everyone must wear safety glasses when operating power tools or soldering. As we proceeded to build our ROV we didn't want to fry wires so we coated layers of the tether with liquid electrical tape, solid electrical tape, and spray adhesive electrical tape. Our servos are coated with silicone to ensure no water seeps through to destroy our equipment. Anderson Power poles were used to reduce electrical shortage chances. Maximus has individual fused - electrical lines to help identify any electrical problems better.

Mechanical elements and safety precautions consist of shrouded thrusters to help prevent from cutting our fingers when running tests in and out of the water. The shrouded thrusters are labeled with a warning sticker provided by the manufacturer. Maximus edges were all rounded, leaving no sharp edges that can cause a damage components or cause serious injury. This helps prevent us from cutting ourselves or wiring when handling the ROV in/out of water.

Safety Procedures

- Wear the proper PPE (personal protection equipment)
- Have on close toe shoes
- Hair up/long sleeves rolled up
- No hanging clothing or jewelry
- Clean work area
- No horse playing
- Having knowledge of what tool you are using before using it

Operational Safety Protocols

As you might imagine, operating electricity under water is difficult and requires operations safety protocols that need to be in place. Each item in our protocol must have a green/GO rating before proceeding to the operational checklist. If any of these items are yellow/CAUTION or red/NO-GO, the team is not cleared to operate Maximus. This happens before the ROV is cleared for the pool deck.

- ☐ Wires are loose in control box (visual)
- ☐ Switch overheating (touch/visual)
- ☐ Wires exposed (visual)
- ☐ Tether is tangled (visual)
- ☐ If any components are loose (touch/visual)
- ☐ Pneumatic leaks (touch/auditory)

If all above components are green/GO, the team can begin the operational safety checklist. This checklist is to be completed during the 5-minute set-up period.

- Structural frame is intact
- Make sure all components are secure
- Check for any exposed wires on ROV, tether or internal/external control box
- Check for working controls/switches
- Make sure all components are connected to control box correctly and securely
- Tether is movable, untangled and extended for start of operation
- All components in correct starting position
- All components are functional (checked one at a time)

Once the operational safety checklist is complete, the team is ready to begin water testing or product demonstration. At the completion of water testing or product demonstration, the team will complete the below checklist for their 5-minute demobilization period.

- Return ROV to base/home
- Disconnect external electrical from control box
- Remove ROV from water and tilt for drainage
- Disconnect all components from control box
- Manually turn off DVD players
- Recoil tether

Testing and Troubleshooting

The Dickinson Gators Engineering, Inc. believes that only testing and troubleshooting can allow us to improve and refine our design for the Maximus. Our testing phase was split into surface and water testing.

Surface Testing

During the construction phase, we tested various components to ensure that our work was on point. After the initial frame construction, we worked with multiple configurations of component placement. We wanted to ensure that the ROV was carrying a balanced load so that it would not be off-center when maneuvering. To keep the ROV balanced, we also tested the symmetry of the ballast tanks.

One of the major areas that were tested prior to water testing was the wiring. At the beginning of this project, we were taught basic soldering skills, which the majority of the team had never done previously. During the wiring of the thrusters and claw, we wanted to verify the soldering was successful and our components were in working order. After the ROV components were complete, we also had to work with the analog switches to ensure they were wired correctly before the components were connected into the control system.

As discussed throughout the claw section, we tested many servos and claw configurations before water testing. On the buoyancy system, we made sure that the air flow in the solenoids was working as expected. Surface testing is a requirement before components come into contact with the water.

Water Testing

At different stages of construction, our company underwent testing at the Dickinson Civic Association Pool or private residence. Each test provided information that helped refine the design of the ROV and improve the functionality. There were some times where we would not have an air compressor, or would forget essential material to complete our test, we made sure we added these essential materials to the packing list to make sure the same mistake didn't happen twice.

The first time we underwent water testing, we determined there were balance issues because Maximus' tanks did not fill up at the same rate. To overcome this balance issue, we sealed the joints, and added more ballast tanks to keep it at equilibrium. After research, it was decided that drilling holes to flood the carbon fiber tubing would make it easier to maneuver. These tests helped us perfect each fault our ROV came across. There were also connection issues that are be addressed in the troubleshooting section.

The team used the pool time to practice familiarizing with the control system, or making sure the cameras were at a good angle. Once our pilot was determined, pool time was used to practice manipulating the props for product demonstration as well as the efficiency of the team for ROV setup and demobilization.

Troubleshooting

The initial issue we ran into was our control box. When we tried plugging in all our components, we realized that the Anderson power poles were too close together causing too much tension between each. To make our setting up more efficient and fast, we created a 3D printed power pole housing block module, designed in SolidWorks and picture in Figure 20.

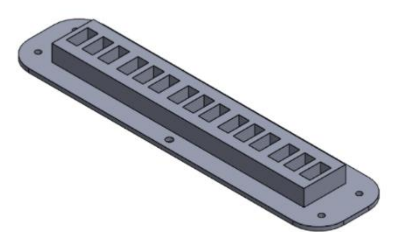


Figure 20 – CAD Drawing of 15-position Power Pole Block

The ROV we have built has gone through a various number of problems. Our troubleshooting method is to isolate components and test in order to find the root cause of the issue. DGE made multiple prototype claws before deciding on the final claw design. When we realized that 3D printed material was not going to be efficient, it was decided that we were going to use a VEX Cortex claw. Our first prototype helped us decide what essential components needed to have our claw, such as strength, enough tension to grip the props, size, and flexibility.

After the first pool practice, we noticed that the movement of Maximus was not what we wanted it to be. The ballast tanks were not sealed properly causing the ROV to sink; therefore, we sealed the PVC in caps on the tanks with silicone so the water only had one path to flow making it easier to operate. The outer structure tubes were not sealed properly causing Maximus to be heavier, thankfully our buoyancy system was capable of lifting 1.7Kg more than the ROV's weight, which meant we did not have to worry about the water it took on. In order to prevent more water getting in, we added more silicone to ensure the seal.

We also noticed a balance issue, since it was sinking faster on the left side than the right side. In order to fix this, we tried to get the center of gravity as low as possible, and the center of lift as high as possible creating a pendulum effect. In order to achieve this, we added counter weight to the lowest part of the robot. To make it extra efficient we added two more ballast tanks, one is 2.54cm x 33.02cm and a 5.08cm x 33.02cm.

Challenges

Time management was a major challenge for this team. The initial release of the MATE ROV Ranger class manual was in late 2019. Due to the COVID pandemic, the 2020 team was not able to begin this project. The 2020 team consisted of all high school seniors, who graduated. When the revisions were released for 2021, we formed a new team. This team is mostly juniors and we started looking at the manual in late January 2021. However, due to our commitments with the VEX EDR program, we did not get to start focusing on this project until February 2021. During this time, we were not in school for one-week during the winter storms, another week during March as well as State and Advanced Placement testing. Some team members hold part-time jobs outside of school and all team members carry a full rigorous academic load. Our entire company team members are also involved in additional extra-curricular activities, which mean attending practice before and after school in addition to UIL competitions as well as multiple honor societies that require community service hours throughout the school year.

One of the main challenges faced through the process of building Maximus was our control box. From the beginning, we were stuck on what to use to have precise control over our ROV. When we researched past MATE teams, we discussed many options that could potentially be used. As a team, we ultimately decided that Arduino boards and the Arduino IDE software would be the best, most available option for our control system. When working with the Arduino boards, we faced many problems along the way including power decreasing over the length of the tether and having trouble finding the right components that are compatible with the Arduino boards. With time running out, we decided to use toggle switches to control the thrusters and, although they aren’t the easiest to use to control our ROV, our pilot had many hours of practice that eventually made the ROV easy to control.

The claw was another challenge that took us a lot of effort to overcome. Through many trials and errors, we went through many different prototypes and designs as well as servos. When trying to use VEX components on the claw, the servos were not compatible with Arduino boards, so we had to use a VEX V5 robot brain along with a VEX bumper switch. With this method, the servos that we used flooded constantly, so we decided to try conventional servos that were connected to potentiometer, but we could not get this method working. Finally, we decided to use pneumatics to control the claw.

Lessons Learned

If the MATE program has taught us anything, it is that some things are not as simple as they seem. Wiring a complex control box also proved to be complicated. We noticed with our control box, there were plenty of times we had the controls backwards, one of our thrusters not working, leaving us to strip the wire and reattach the power poles.

While coding, our programmers learned how to manage their time better. At the beginning they would spend a lot of time on one task making it hard to complete other tasks that also required to be done within a certain time limit. Our CEO learned that delegation is important when leading a project and she also learned that sometimes a simple solution is just as great as a complex one and it takes less time. With this project, we learned how to organize our materials, ideas, budget and time.

In the process of building Maximus, our company developed two different skill sets; technical and professional. This project strengthened technical skills such as drafting, soldering, using microcontrollers, and electronic basics. All these skills are useful as we continue to pursue our technical education and are transferable across all types of projects and competitions.

This project also strengthened our professional skills such as communication, leadership, teamwork, learning and adaptability skills. These skills are important for communicating and working with groups and individuals in our future careers. These skills are also beneficial for the ability to solve problems and make good decisions. Team members can carry the experience gained to their future careers, and personal endeavors. In the future, we plan to apply the skills we developed this year to the challenges that are presented next year in the classroom and beyond.

Future Improvements

During water testing, we have noticed that the not all the thrusters have the same power level. We would recommend that the wiring/thruster power issues be researched and resolved. For future enhancements, we would like to work on the control box of the ROV (lovingly referred to as Susan Darlin'). Currently, our pilot uses toggle switches to maneuver the ROV's thrusters, buoyancy system, and claw manipulator. The team would like to upgrade to Arduino Boards and joysticks for more accurate control of the ROV and this will be the primary goal as we continue in the MATE program.

Reflection

The most rewarding part of this experience was being able to complete an engineering design project from start to completion. This project was challenging and even though our team has robotics experience, this project is on a whole different level. We had to push ourselves everyday - whether it was to learn building electrical circuits, researching potential solutions or technical writing, we had to apply professional skills to document a design process to established standards. This is an engineering experience that is so valuable as we continue to pursue our education.

Being able to travel to Johnson City, Tennessee and meet people from other countries is an experience that not all students will have the opportunity to have during their high school career. When we found out we were getting to represent Texas at the 2021 World Competition, we realized that all of our hard work and extra hours have paid off.

We have learned a lot about marine technology and numerous disciplines in engineering such as mechanical and electrical. It also gave us practical usage of soldering skills that we can transfer to other aspects of our lives. Looking back, we wish we had started pool practice sooner in the schedule and on a much stricter schedule, to force the practice required for driving our ROV more consistently. Also, we think it would have been a good idea to split up the work to have more than two people on every aspect of the ROV so there would be more and better ideas for every piece of the ROV.

Accounting - Budget

As previously mentioned, the CEO and mentor worked on keeping the team on budget. We are dividing this section into a budgeting and cost accounting section as noted below.

Budgeting information is what we proposed to spend on the components. As previously mentioned, Dickinson High School is a Title I school and we are extremely lucky that our industry partner helped fund this project. The limitations of the budget are outlined below in Figure 21. A complete budget chart for this project can also be found in Appendix I.

Budget

			Reporting period	
School Name:		Dickinson High School	From:	1/30/2021
Instructor/Sponsor:		Sara Malloy	To:	8/10/2021
Income				
Income at start of project (if any)				
Source				**Amount**
BP Texas City Chemicals Grant				$ 1,325.00
DHS CTE Program				$ 4,000.00
Expenses				
Category	**Type***	**Description/Examples**	**Projected Cost**	**Budgeted Value**
Structure	Donation	Structure framing	$ 150.00	$ 150.00
Structure	Donation	Ballast Solenoids	$ 70.00	$ 70.00
Structure	Purchased	Misc supplies	$ 300.00	$ 300.00
Structure	Purchased	PLA Plastic for 3D printing	$ 100.00	$ 100.00
Electronics	Re-used	4 SeaBotix Thrusters	$ 3,800.00	$ 3,800.00
Electronics	Purchased/Re-used	Control boards, wiring, etc	$ 100.00	$ 100.00
Electronics	Donation	Waterproof cameras	$ 500.00	$ 500.00
Electronics	Re-used	Servos actuator	$ 25.00	$ 25.00
Electronics	Re-used	SeaHorse Control Box	$ 155.00	$ 155.00
Travel	Purchased	Team Registration, Fluid Power Quiz	$ 325.00	$ 325.00
Travel	Purchased	Travel to World Championship	$ 4,000.00	$ 4,000.00
***Items must fall into one of the following:**				
Purchase - defined as items that will be purchased new or services paid for.			Total Income:	$ 5,325.00
Re-use - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.			Total Expenses:	$ 4,825.00
Donation - defined as equipment, materials, and time that were contributed to your company.			Total Expenses-Re-use/Donations:	$ 4,700.00
			Total Fundraising Needed:	$ 500.00

Figure 21 – Maximus Budget

Cost Accounting

BP Texas City Chemical donated funds, which is designated to Dickinson High School's Engineering and Robotics program. The majority of these funds help support student competitions and senior capstone projects. Our mentor budgeted funds for general supplies and Dickinson High School's CTE program previously paid for our thrusters and cameras in addition. The actual breakdown of materials is below in Figure 22. A complete project costing chart for this project can be found in Appendix J.

PROJECT COSTING

School Name:	Dickinson High School	Reporting period From:	1/20/2021
Instructor/Sponsor:	Sara Malloy	To:	8/10/2021

Funds Date	Type*	Category	Expense	Description	Sources/Notes	Amount	Running Balance
10/30/2020	Cash donated	General		General supplies, Team Registration, Fluid Power Quiz	Funds donated by BP Texas City Chemicals	$ 1,325.00	$ 1,325.00
3/1/2021	Purchased	General	Competition	Team Registration, Fluid Power Quiz	Funds donated by BP Texas City Chemicals	$ (225.00)	
6/23/2021	Purchased	General	Competition	World Championship Team Registration	Funds donated by BP Texas City Chemicals	$ (100.00)	
11/2/2020	Purchased	Hardware	Structure	Dremel 3D45 PLA filament	Used for corner joints, clamps, claw, etc.	$ (101.04)	
3/1/2021	Purchased	Hardware	Props	1/2-in PVC, Tee joints, prop supplies	Used for props	$ (301.96)	
3/2/2021	Re-used	Hardware	Propulsion	Seabotix BTD-150 Thursters (at market value)	Used in main ROV propulsion system	$ (3,800.00)	
3/9/2021	Parts donated	Hardware	Structure	Six carbon fiber tubes (~50cm each)	Used in ROV structure	$ (150.00)	
3/12/2021	Parts donated	Electronics	Control System	Arduino control boards, joysticks, jumper wires	Used in control system	$ (218.00)	
3/23/2021	Re-used	Hardware	General	Marine grease, silicone, zip ties	ROV construction	$ (13.33)	
3/23/2021	Re-used	Hardware	General	Servos	Servo motors used in claw prototypings	$ (56.56)	
3/29/2021	Parts donated	Hardware	Navigation	Zettaguard ZBC-100 Waterproof Cameras	Used in navigation system	$ (120.64)	
4/5/2021	Re-used	Hardware	Control System	Seahorse case	Used in control system	$ (154.98)	
4/6/2021	Re-used	Electronics	Control System	Wiring	Used in control system	$ (129.97)	
6/7/2021	Parts donated	Hardware	Structure	Replacement cameras and claw servo	Replacement parts	$ (422.13)	
6/25/2021	Cash donated	Travel	Competition	Team shirts	Student Activity (polos), LeBlanc (tshirt)	$ 167.00	
6/28/2021	Purchased	Travel	Competition	Marketing Display printing/mounting	DHS CTE Program	$ (100.00)	
8/1/2021	Cash donated	Travel	Competition	Travel to/from TN (Worlds)	DHS CTE Program	$ 4,096.00	
8/1/2021	Purchased	Travel	Competition	Rental vehicle to/from TN (Expedition)	Bay Area Auto Rental	$ (1,059.12)	
8/1/2021	Purchased	Travel	Competition	Hotel to/from TN, ETSU Residence Hall	Country Inn, Tru Hilton, Governerns Hall	$ (2,055.00)	
8/1/2021	Purchased	Travel	Competition	Estimate meal allowance	DHS CTE Program	$ (882.00)	
						Total Raised	$ 10,453.75
						Total Spent	$ (10,056.73)
						Final Balance	$ 397.02

*Items must fall into one of the following:
Purchased - defined as items that are purchased new or services paid for.
Re-used - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to your company. Do NOT include items given to your school for general use.
Cash donated - defined as funds contributed to your company. Do NOT include funds given to your school for general use.

Figure 22 – Maximus Project Costing

Acknowledgements

We would like to recognize the following organizations for their generous support:

- Dickinson High School
- Dickinson Independent School District
- DISD Education Foundation
- BP Texas City Chemicals
- Ashtead Technology Offshore
- Dickinson Civic Association Pool
- Bryan and Casey Schoen
- The LeBlanc Family
- MATE II

The contributions and financial support from these organizations made it possible for our company to remotely attend the Texas regional MATE competition. We hope to represent our community at the International MATE ROV Competition in August 2021.

References

Anish, et al. “A Detailed Explanation on How to Operate a Ship's Ballast System.” *Marine Insight*, 29 Dec. 2020, www.marineinsight.com/guidelines/a-detailed-explanation-on-how-to-operate-a-ships-ballast-system/.

Britannica, T. Editors of Encyclopedia (2020, May 29). *Archimedes' principle*. *Encyclopedia Britannica*. https://www.britannica.com/science/Archimedes-principle

By Kej605 - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27444282.

Contributor, TechTarget. “What Is Control System? - Definition from WhatIs.com.” *WhatIs.com*, TechTarget, 31 Dec. 2017, whatis.techtarget.com/definition/control-system.

“Delaware Bay.” Https://En.Wikipedia.Org/Wiki/Delaware_Bay, 4 Jan. 2021, en.wikipedia.org/wiki/Delaware_Bay.

DRBA. “About the DRBA.” Http://Www.Drba.Net/, 2018, www.drba.net/AbouttheDRBA.aspx.

Harrington Middle School. *HMS Seabots 2017 MATE Technical Documentation*. 2017, files.materovcompetition.org/TechReportArchives/2017/HarringtonMiddleSchool_HMSSeaBots_TechnicalDocumentation_2017.pdf.

“Introduction.” *Arduino*, www.arduino.cc/en/guide/introduction.

Marine Advanced Technology Education: ROV Competition Home. MATE. Accessed February 5, 2021. https://materovcompetition.org/

(n.d.). Retrieved May 06, 2021, from https://files.materovcompetition.org/TechReportArchives/2019/PTSTEMClub_SeaDragons_TechnicalDocumentation_2019.pdf

“Operations.” Underwater Robotics: Science, Design & Fabrication, by Steven W. Moore et al., Marine Advanced Technology Education Center (MATE), 2010, pp. 575–631.

SeaBotix: Teledyne. Web. Accessed February 8, 2021. http://www.teledynemarine.com/seabotix.

SeaBotix BTD-150 Thruster Data Sheet. Accessed April 7, 2021. http://ocean-innovations.net/OceanInnovationsNEW/SeaBotix/BTD150_Data_Sheet.pdf.

Sparkfun, B_E_N. *What Is an Arduino?*, learn.sparkfun.com/tutorials/what-is-an-arduino/all.

Systems Engineering Fundamentals. (n.d.). Retrieved April 17, 2021.

Underwater robotics At rmsst. (n.d.). Retrieved February 10,2021, from http://underwaterrobotics.wikidot.com/tool-safety

“What Is Buoyant Force? (Article) | Fluids.” *Khan Academy*, Khan Academy, www.khanacademy.org/science/physics/fluids/buoyant-force-and-archimedes-principle/a/buoyant-force-and-archimedes-principle-article.

FIGURES

APPENDIXES

Appendix A – Gantt Chart for Maximus

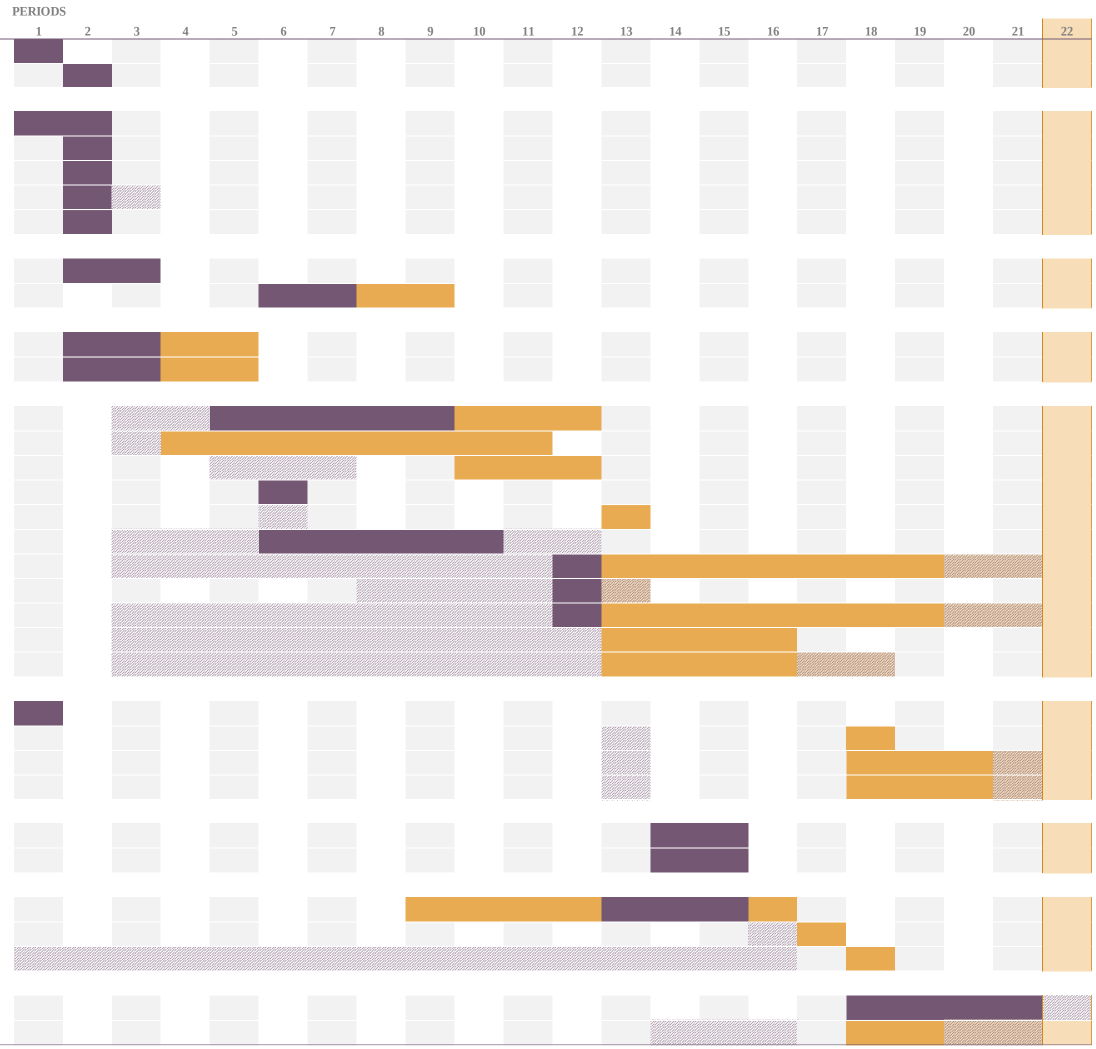
2021 Marine Advanced Technology Education: Texas Regional
Dickinson Gators Engineering, Inc.

Period Highlight: 22

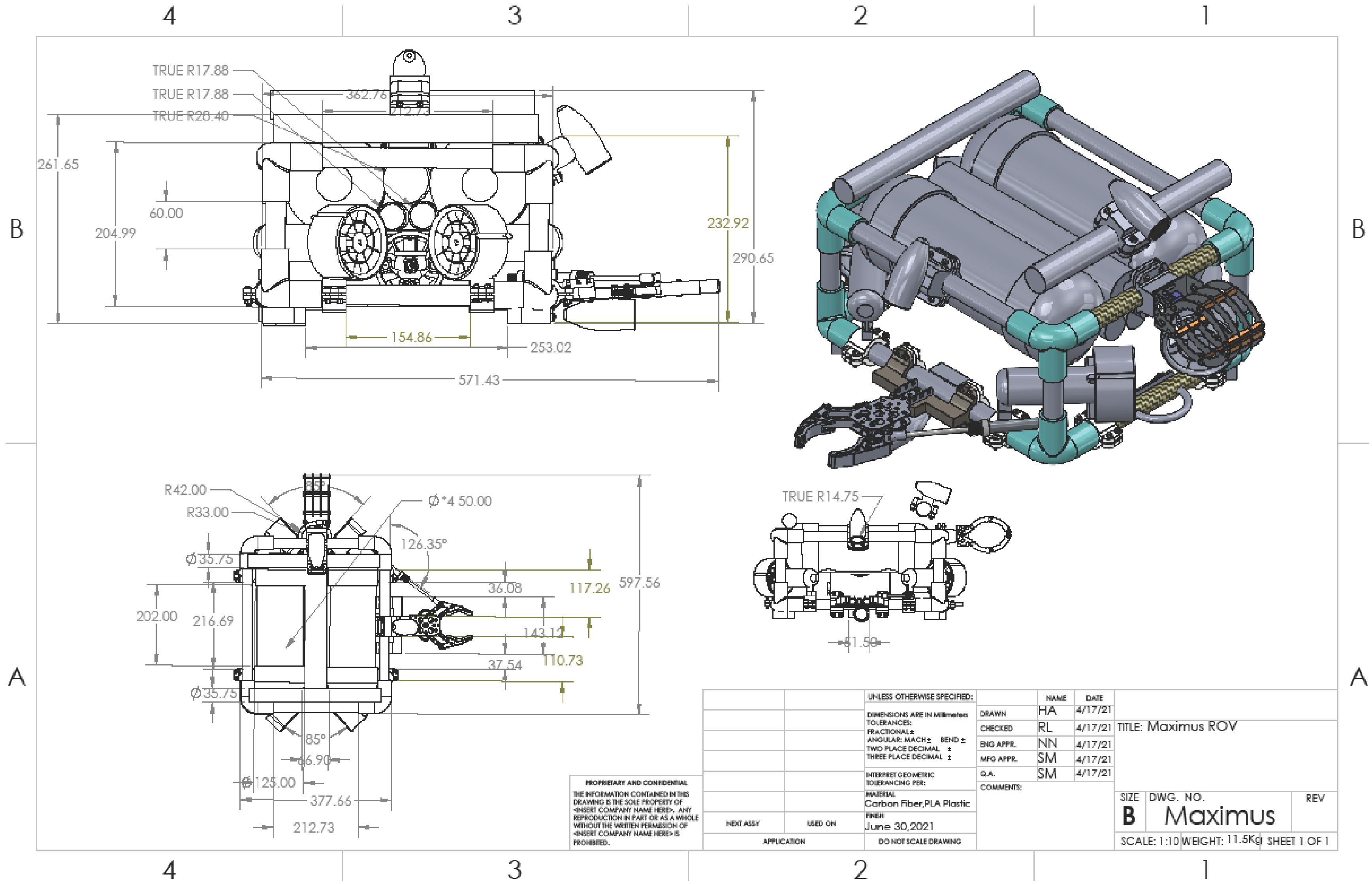
Plan | Actual | Actual (beyond plan) | % Complete | % Complete (beyond plan)

ROV Prototype: Maximus

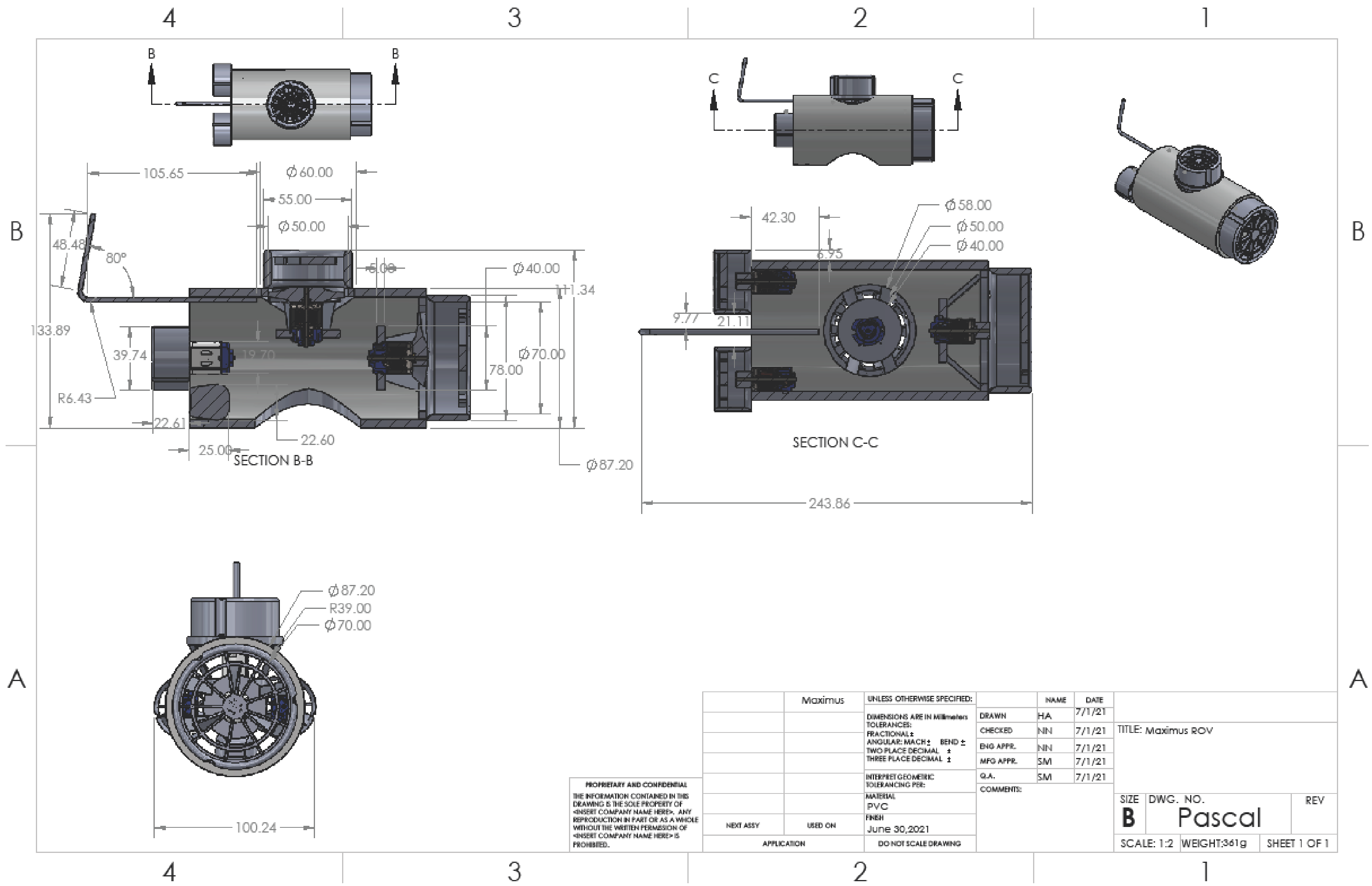
ACTIVITY	PLAN START	PLAN DURATION	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Introduce Project	1	1	1	1	100%
Setting up Documentation	2	1	2	1	100%
RESEARCH					
Analyze Prior Solution Attempts/Research	1	2	1	2	100%
Brainstorming	2	1	2	1	100%
Develop Problem Statement	2	1	2	1	100%
Generate Multiple Solutions	2	2	2	1	100%
Identify Critical Design Goals	2	1	2	1	100%
BUSINESS AND FINANCE					
Budgeting	2	2	2	2	100%
Team Registration	6	2	6	4	100%
DESIGN					
Select Solution Path	2	2	2	4	100%
Design Viability Analysis	2	2	2	4	100%
PROTOTYPE AND TEST					
Create Drawings/Schematics	3	7	5	8	100%
Identify Materials and Tools	3	1	4	8	100%
Develop Test Plan	5	3	10	3	100%
Preliminary Design Review	6	1	6	1	100%
Fluid Power Quiz	6	1	13	1	100%
Create Prototype	3	10	6	5	100%
Test Prototype	3	10	12	10	85%
Water Testing	8	5	12	2	85%
Testing Analysis	3	10	12	10	85%
Critical Design Review	3	10	13	4	100%
Troubleshooting	3	10	13	6	72%
PRODUCT DEMONSTRATION					
Safety/Orientation	1	1	1	1	100%
Video demonstration	13	1	18	1	100%
Real-time Troubleshooting	13	1	18	4	80%
On-site Testing Analysis	13	1	18	4	80%
EVALUATION AND REFLECTION					
Designer Reflection	14	2	14	2	100%
Designer Recommendations	14	2	14	2	100%
PROJECT PRESENTATION					
Prepare Final Presentation	13	3	9	8	100%
Final Presentation	16	1	17	1	100%
Portfolio Completion	1	16	18	1	100%
OUTREACH & INTERNATION COMPETITION					
Finalizing Design	18	6	18	4	100%
International Competition Paperwork	14	3	18	4	50%



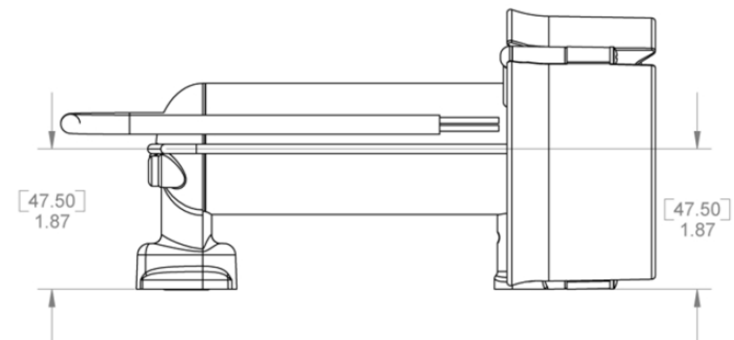
Appendix B – CAD Technical Drawing: Maximus

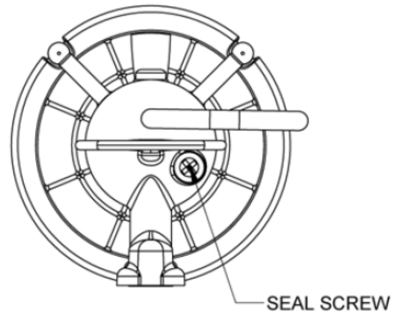


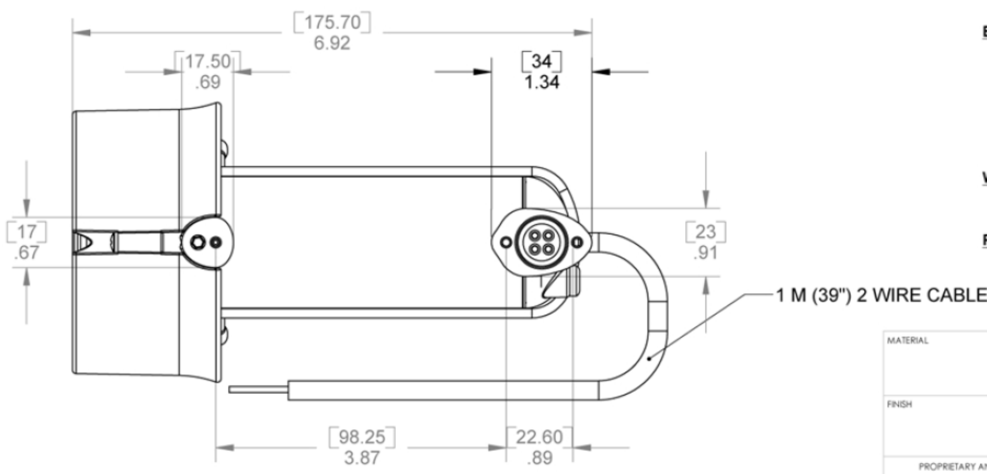
Appendix C – CAD Technical Drawing: Pascal



Appendix D – SeaBotix BDT-150 Thruster Data Sheet







BTD150 SPECIFICATIONS

DEPTH RATING

FRESH WATER:	150 METERS - 500 FEET

MOUNTING HARDWARE

QTY:	3 (INCLUDED)
TYPE:	SHEET METAL SCREW, PAN HEAD PHILLIPS, 316 SS
SIZE:	#6 X 3/4"
McMASTER P/N:	90184A152 (OR EQUIVALENT)
SEABOTIX P/N:	FN308

ELECTRICAL INTERFACE

VOLTAGE:	+19.1V DC ±10%
POWER:	110W MAXIMUM (DEPENDING UPON RPM OR DRAG)
MAX AMPERAGE:	5.8 AMPS (30 SECOND DURATION)
MAX CONTINUOUS AMPERAGE:	4.25 AMPS
CABLE:	39IN (1 M) 2 WIRE COLOR CODED

WEIGHT

IN AIR:	705 GRAMS
IN FRESH WATER:	350 GRAMS

PERFORMANCE

PEAK BOLLARD THRUST:	2.9 KGF (6.4 FT/LBS)
CONTINUAL BOLLARD THRUST:	2.2 KGF (4.85 FT/LBS)

MATERIAL	UNLESS OTHERWISE SPECIFIED:		NAME / DATE
	DIMENSIONS ARE IN INCHES	DRAWN	J Rodocker / 1JAN07
FINISH	TOLERANCES:	CHECKED	
	ANGULAR: MACH± 1° BEND±1° ONE PLACE DECIMAL ±.100 TWO PLACE DECIMAL ±.010 THREE PLACE DECIMAL ±.005	ENG APPR.	
PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF SEABOTIX INC. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF SEABOTIX INC IS PROHIBITED.© 2005 SEABOTIX INC.	125 DIMENSIONING AND TOLERANCING PER ASME Y14.5M 1994 & B4.3 1982 APPLY	COMMENTS: UNLESS OTHERWISE SPECIFIED BREAK ALL EDGES R/C 0.01 NO BURR ALLOWED. DO NOT SCALE DRAWING. ALL DIMENSIONS APPLY AFTER FINISH.	

SeaBotix Inc.
1425 Russ Blvd
Suite T112D
San Diego, CA 92101

TITLE: **Standard Thruster & 2 wire whip**

SIZE	PART NO.	REV
B	BTD150	A
SCALE: 1.5	WEIGHT:	SHEET 1 OF 1

Appendix E – Aukfa Portable Waterproof IP68 DVR Fish Finder camera with 1024x720p 7 inch HD Screen and 12 PCS White LED Ice Fishing Camera for Ice, Lake, Boat, Sea Fishing (50ft Cable) Manufacturing Information

Product description

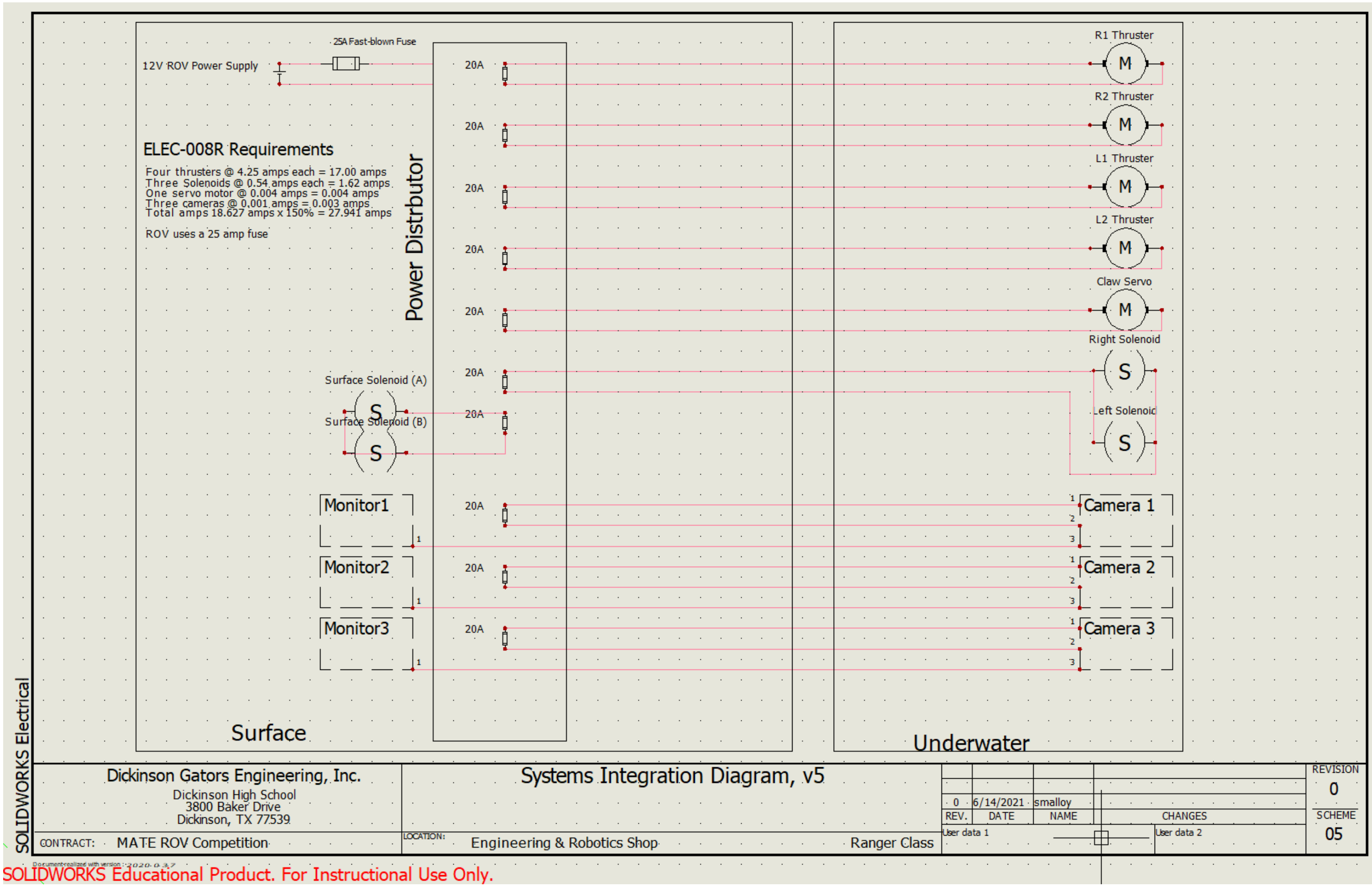
Features:

- Upgraded 7 inch color Screen - Aukfa fishing finder has newly upgraded 1000TVL camera and 7-inch 1024x720p color screen. It provide clearer images and brighter colors. This will give you a more unique and realistic underwater world. Note: there is no DVR.
- Waterproof IP68Camera – Aukfa underwater fishing camera has 12 adjustable white LED lights. It can be viewed from 130°Angle, so you can see fish in the dark water. It is made of imported waterproof material, which can effectively prevent water from entering the camera.
- 4500mAh Rechargeable Battery - The camera’s fish finding system features a powerful 12V 4500 mAh battery. It can be used continuously for 6-8 hours after fully charged, which meet your outdoor needs.
- Incredibly Convenient -The underwater fishing camera system comes with a durable suitcase, so you can easily carry it wherever you are and make sure the fishing camera is always on board or in your car. Besides, its screen is detachable and easy to carry around.
- Widely Used Occasions - Aukfa fish finder for fishing enthusiasts. It’s ideal for sea fishing, swimming, ice fishing, diving, lake fishing, snorkeling, inflatable kayak fishing, boat fishing, Underwater Ice Fishing, monitoring aquaculture, underwater exploration and other underwater adventures.

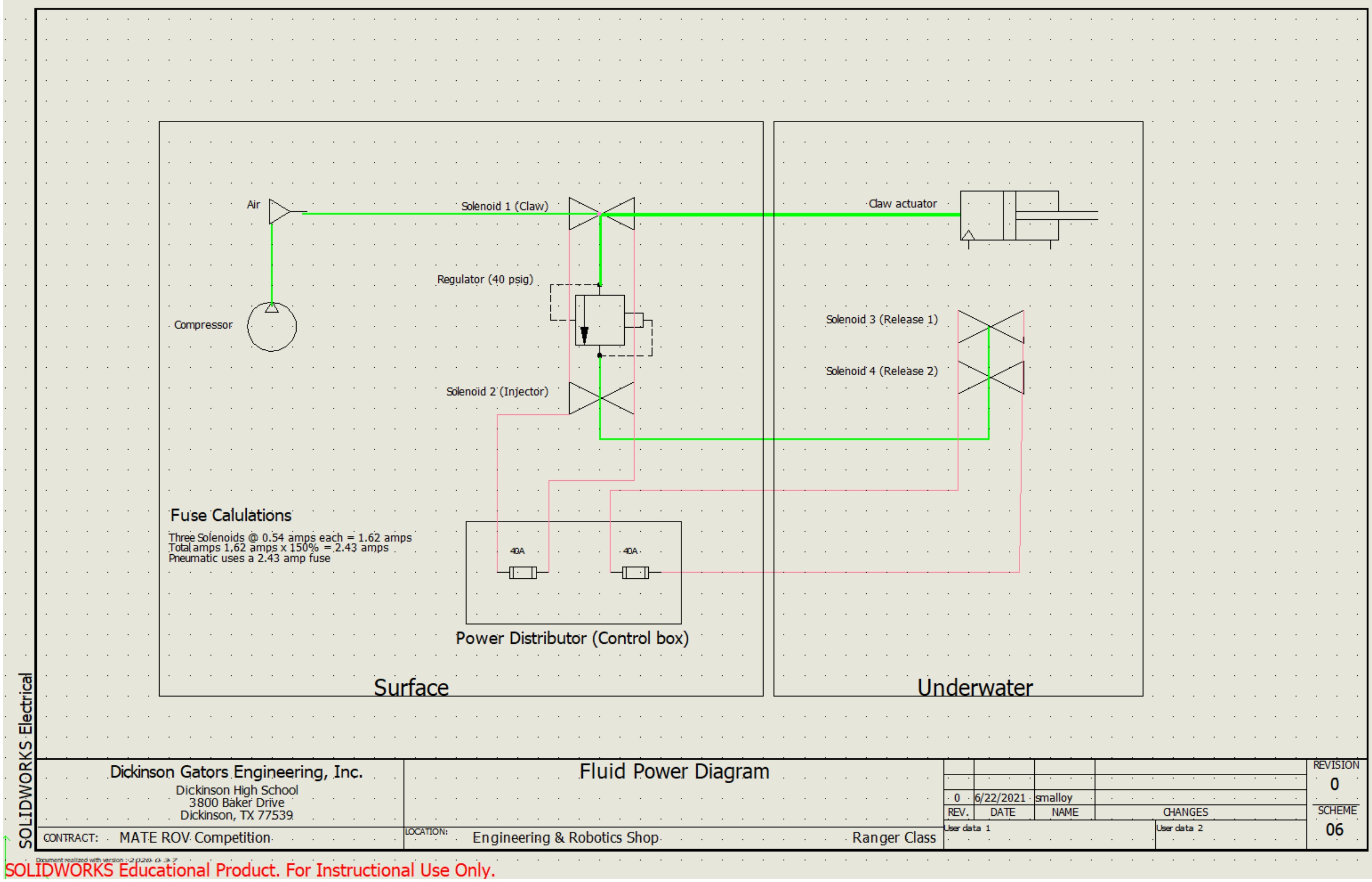
Technical Details

Item Weight	4.16 pounds
Product Dimensions	8.66 x 7.09 x 4.72 inches
Display Size	7 inches
Battery Life	8 hours
Voice Command	Buttons
ASIN	B0874LTN2D

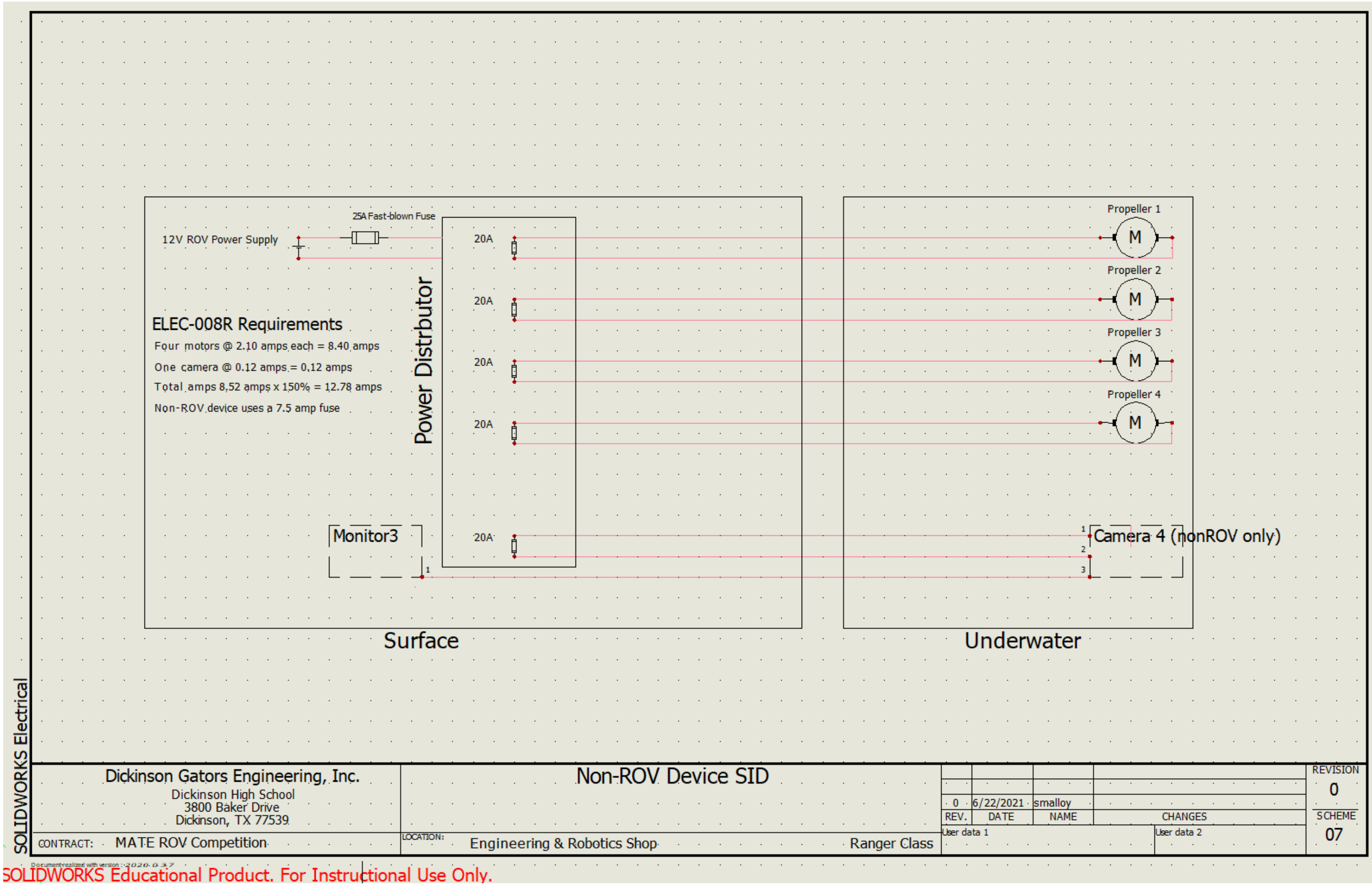
Appendix F – Systems Integration Diagram (SID)



Appendix G – Systems Integration Diagram, Pneumatics



Appendix H – Systems Integration Diagram, Non-ROV Device



Appendix I – Maximus Budget

Budget

		Reporting period
School Name:	Dickinson High School	From: 1/30/2021
Instructor/Sponsor:	Sara Malloy	To: 8/10/2021

Income				
Income at start of project (if any)				
Source				**Amount**
BP Texas City Chemicals Grant				$ 1,325.00
DHS CTE Program				$ 4,000.00
Expenses				
Category	**Type***	**Description/Examples**	**Projected Cost**	**Budgeted Value**
Structure	Donation	Structure framing	$ 150.00	$ 150.00
Structure	Donation	Ballast Solenoids	$ 70.00	$ 70.00
Structure	Purchased	Misc supplies	$ 300.00	$ 300.00
Structure	Purchased	PLA Plastic for 3D printing	$ 100.00	$ 100.00
Electronics	Re-used	4 SeaBotix Thrusters	$ 3,800.00	$ 3,800.00
Electronics	Purchased/Re-used	Control boards, wiring, etc	$ 100.00	$ 100.00
Electronics	Donation	Waterproof cameras	$ 500.00	$ 500.00
Electronics	Re-used	Servos actuator	$ 25.00	$ 25.00
Electronics	Re-used	SeaHorse Control Box	$ 155.00	$ 155.00
Travel	Purchased	Team Registration, Fluid Power Quiz	$ 325.00	$ 325.00
Travel	Purchased	Travel to World Championship	$ 4,000.00	$ 4,000.00

***Items must fall into one of the following:**

Purchase - defined as items that will be purchased new or services paid for.

Re-use - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.

Donation - defined as equipment, materials, and time that were contributed to your company.

Total Income:	$ 5,325.00
Total Expenses:	$ 4,825.00
Total Expenses-Re-use/Donations:	$ 4,700.00
Total Fundraising Needed:	$ 500.00

Appendix J – Maximus Project Costing

PROJECT COSTING

School Name:	Dickinson High School	Reporting period From:	1/20/2021
Instructor/Sponsor:	Sara Malloy	To:	8/10/2021

Funds Date	Type*	Category	Expense	Description	Sources/Notes	Amount	Running Balance
10/30/2020	Cash donated	General		General supplies, Team Registration, Fluid Power Quiz	Funds donated by BP Texas City Chemicals	$ 1,325.00	$ 1,325.00
3/1/2021	Purchased	General	Competition	Team Registration, Fluid Power Quiz	Funds donated by BP Texas City Chemicals	$ (225.00)	
6/23/2021	Purchased	General	Competition	World Championship Team Registration	Funds donated by BP Texas City Chemicals	$ (100.00)	
11/2/2020	Purchased	Hardware	Structure	Dremel 3D45 PLA filament	Used for corner joints, clamps, claw, etc.	$ (101.04)	
3/1/2021	Purchased	Hardware	Props	1/2-in PVC, Tee joints, prop supplies	Used for props	$ (301.96)	
3/2/2021	Re-used	Hardware	Propulsion	Seabotix BTD-150 Thursters (at market value)	Used in main ROV propulsion system	$ (3,800.00)	
3/9/2021	Parts donated	Hardware	Structure	Six carbon fiber tubes (~50cm each)	Used in ROV structure	$ (150.00)	
3/12/2021	Parts donated	Electronics	Control System	Arduino control boards, joysticks, jumper wires	Used in control system	$ (218.00)	
3/23/2021	Re-used	Hardware	General	Marine grease, silicone, zip ties	ROV construction	$ (13.33)	
3/23/2021	Re-used	Hardware	General	Servos	Servo motors used in claw prototypings	$ (56.56)	
3/29/2021	Parts donated	Hardware	Navigation	Zettaguard ZBC-100 Waterproof Cameras	Used in navigation system	$ (120.64)	
4/5/2021	Re-used	Hardware	Control System	Seahorse case	Used in control system	$ (154.98)	
4/6/2021	Re-used	Electronics	Control System	Wiring	Used in control system	$ (129.97)	
6/7/2021	Parts donated	Hardware	Structure	Replacement cameras and claw servo	Replacement parts	$ (422.13)	
6/25/2021	Cash donated	Travel	Competition	Team shirts	Student Activity (polos), LeBlanc (tshirt)	$ 167.00	
6/28/2021	Purchased	Travel	Competition	Marketing Display printing/mounting	DHS CTE Program	$ (100.00)	
8/1/2021	Cash donated	Travel	Competition	Travel to/from TN (Worlds)	DHS CTE Program	$ 4,096.00	
8/1/2021	Purchased	Travel	Competition	Rental vehicle to/from TN (Expedition)	Bay Area Auto Rental	$ (1,059.12)	
8/1/2021	Purchased	Travel	Competition	Hotel to/from TN, ETSU Residence Hall	Country Inn, Tru Hilton, Governerns Hall	$ (2,055.00)	
8/1/2021	Purchased	Travel	Competition	Estimate meal allowance	DHS CTE Program	$ (882.00)	
						Total Raised	$ 10,453.75
						Total Spent	$ (10,056.73)
						Final Balance	$ 397.02

***Items must fall into one of the following:**
Purchased - defined as items that are purchased new or services paid for.
Re-used - defined as items that were purchased in previous years. Amount MUST be listed as the current market value.
Parts donated - defined as equipment, materials, and time that were contributed to your company. Do NOT include items given to your school for general use.
Cash donated - defined as funds contributed to your company. Do NOT include funds given to your school for general use.