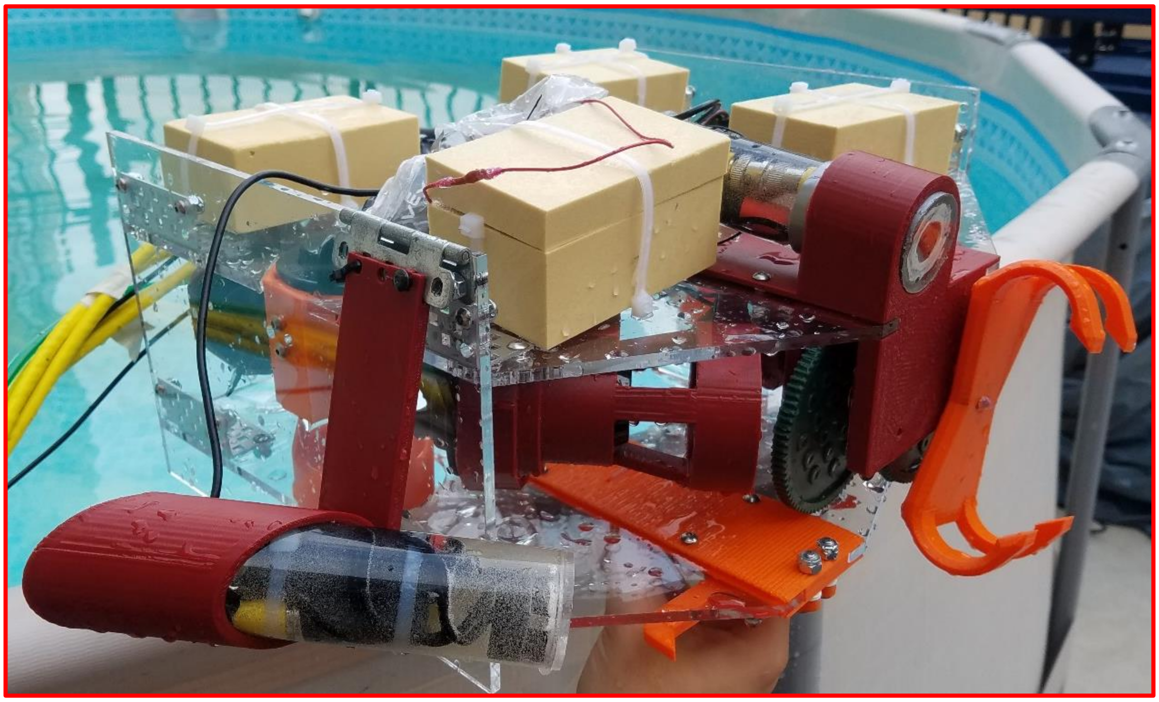
2017

The Corporation of Offshore Reconnaissance & Polar Submersion



Company Associates

Chief Executive Officer- Esmeralda Castillo '18
Chief Administrative Officer- Ryan Ramos '18
Chief Financial Officer- Daniel Benavides Jr. '18
Chief Operations Officer & Pilot- Noah Johnson '18
Chief Marketing Officer- Yamilett Pilar '18
Marketing Assistant- Jocelyn Chavez '20
Mechanical Engineer- Omar Arredondo '18
Software Engineer- Maximus Bermudez '19
Safety Officers- Emma Garza '20

Mentor

Faculty Advisor- Mr. Romeo Valdez

S.T.E.M. Early College High School
San Antonio, TX

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Abstract

The Corporation of Offshore Reconnaissance and Polar Submersion (C.O.R.P.S.) is an innovative company specializing in marine technology solutions. In December of 2016, we were approached with the task of designing a ROV that would operate in the Port of Long Beach, California. This ROV must perform numerous tasks including: installing a Hyperloop system, conducting maintenance on the port's entertainment facilities, collecting contaminated sediment samples, and locating and identifying cargo ship container contents.

Our ROV, Commander, is a product of innovation and is composed of 5.588 mm thick acrylic. The frame features a total of two 0.635 cm CCD Flush Mount Waterproof cameras, six motors, eight aluminum brackets and original ABS plastic attachments. Our control system is entirely encompassed in a Pelican 1560 case, contains a 48.26 cm Insignia TV and is connected by an 11 m tether. Together, these attributes create Commander, an exemplary ROV that is ready to perform.

Figure 1- C.O.R.P.S. Company Members

Company Mission

The Corporation of Offshore Reconnaissance & Polar Submersion is a corporate business that is in the process of becoming one of the most ground-breaking companies in the world. This is our second year working together and, using our experience from two successful product releases, we plan to complete the numerous asks regarding the Ports of Long Beach, California. Although there are other corporations that seek to achieve the same goal, all of the components of the Commander and its control system will exceed any level of performance they present. The C.O.R.P.S. is not only a company of success, but of talent as well. We hold an executive committee of the best employees that have been working hard for our clients. Together, we plan to make history and will produce a safe and efficient product.

Safety

Company Philosophy

The C.O.R.P. S's first priority is to ensure that we work together to promote a safe work environment, ensuring the integrity of the company and Commander. Through proper communication, the company was able to successfully construct the ROV, while following safety protocol. Our safety officer, Emma Garza, ensured all company members followed safety guidelines and informed us on how to safeguard the ROV against sharps edges, exposed wires or faulty fluid power systems. We enforce the rules of safety and are prepared to properly handle a safety hazard, should one occur. Although our product and clients are highly valued by all employees, the welfare of the company is of the utmost importance.

ROV Features

The table below depicts the risks associated with our product and methods to prevent them. The scale ranges from 1 to 4; one being the lowest and four being the highest.

Potential risks	Consequences	Seriousness	Probability	Prevention
Fingers caught by propeller	Possible laceration to the finger	3	2	Ensure ROV is off when touching or carrying the ROV
Water leak into ROV control system	Can cause fire or short circuit the different subsystem wires	4	1	False base created to prevent water from making contact with the electronics
Body part caught inside ROV frame	Injury from multiple subsystems	3	2	Always ensure ROV is off when working
Hydraulic line disconnects from syringe	Hydraulic fluid spills into pool, endangering the environment	4	1	Have the line securely connected to both ends of the syringe
Entangled inside product tether	Can trip/fall if mobility is limited	2	3	Keep tether wrapped in one area and always be aware

Table #1 - ROV Risk Analysis

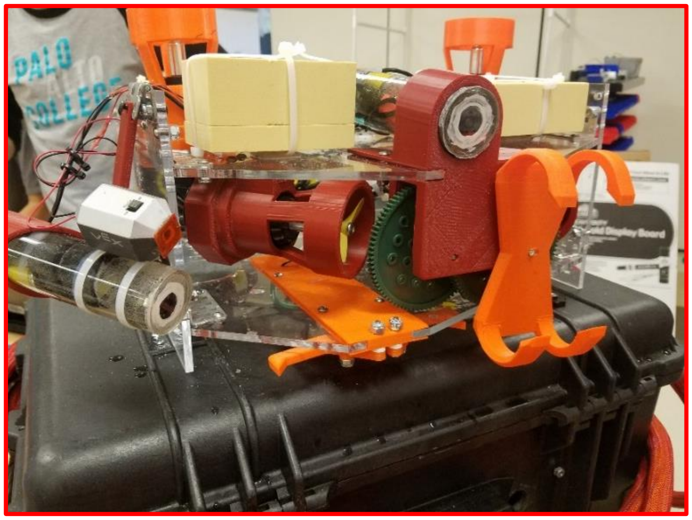
Troubleshooting

Troubleshooting has been a vital part of the creation and assembly of Commander. In order to design a product built for maximum efficiency, our pilot and safety officer worked together to develop a troubleshooting guide. The C.O.R.P.S.'s troubleshooting guide played a key role in ensuring that the ROV continued to function properly after each attachment was assembled. This guide was referenced throughout the Commander's entire building process in order to immediately identify and fix possible errors.

Design Rationale

Frame

The C.O.R.P.S. firmly believes frame material is a key aspect of creating a light, maneuverable and effective ROV. With our previous products, the company primarily used PVC to construct the frame; however, this year, we decided to utilize acrylic. This new acrylic design is a product of precision, affordability and efficiency.



The frame was developed using CAD software and gave us a clear perception on how the ROV would function with its components attached. These CAD models were continuously updated and changed as prototypes. After 3 renditions, the Commander was created.

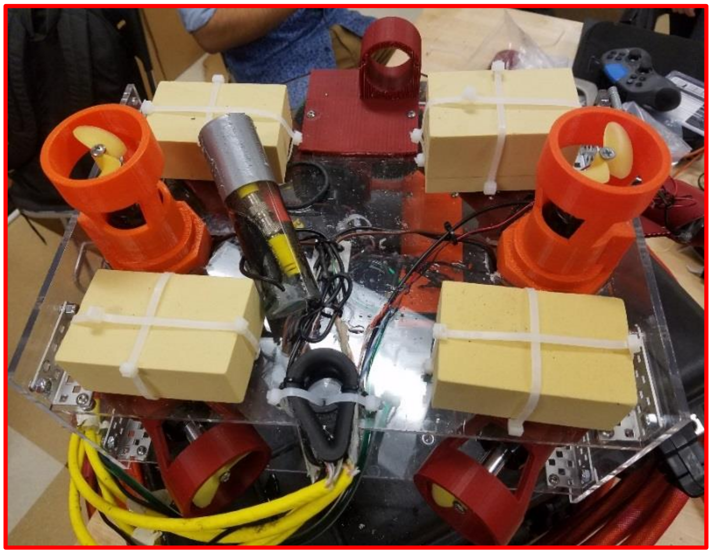
The acrylic was laser cut to exact measurements by 10-bit works, a non-profit business. Each incision made into the frame was measured to be an efficient use of space, while encompassing the various attachments. The thickness of the material is 5.588 mm. The frame is adjoined via eight aluminum brackets bolted down by 32 screws and nylon nuts. Wires are efficiently and neatly secured to the frame with numerous zip tie strain reliefs.

Buoyancy

The Commander's buoyancy system is composed of four sea foam rectangular prisms. They are located in the corners of the acrylic frame and evenly distribute the ROV's weight underwater. Each piece is approximately 10 cmx 6 cmx 4 cm. These four sections of sea foam play a pivotal role in achieving neutral buoyancy because they are precisely cut and spaced.

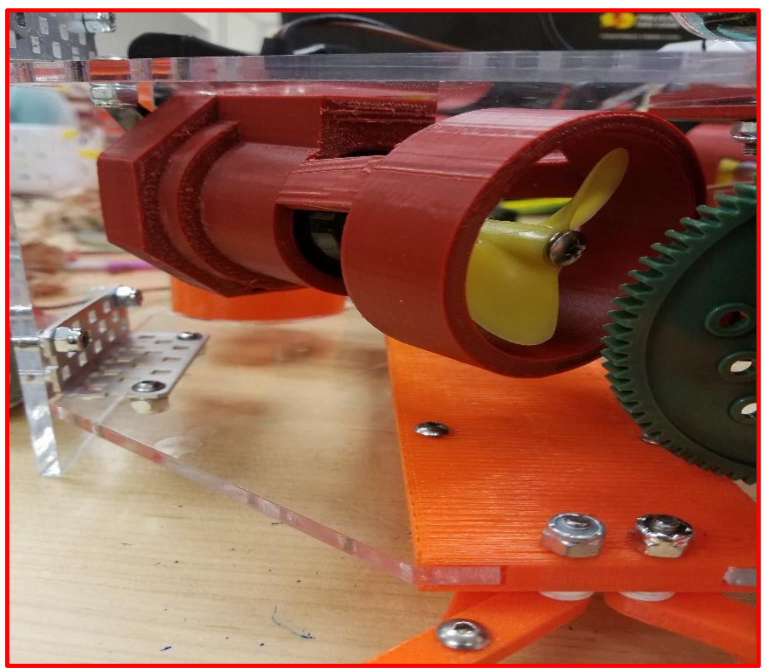
In order to make our buoyancy calculations, the company implemented the use of a Vernier Dual Range Sensor. This sensor allowed us to effectively collect each weight measurement by hanging the ROV on the sensor's hook. Collecting the weight of the ROV was a very important step in calculating buoyancy because it is the first variable need in our buoyancy formula: Fb = Wlbs/Vin^3.

This formula was gathered from the *MATE Summer Institute 2014* and has a total of three unknown variables: W, V & Fb. "W" is known as an ROV's "wet weight" and is the weight of the ROV when held about 30.5 cm under the surface of the water. Commander's wet weight is approximately 739.8g. "V" stands for the volume of the sea foam and, in total, amounts to 55.919 in^3 or 916.348 cm^3. "Fb" is essentially the amount of buoyant force needed for the Commander to be able to float just under the surface of the water. Using our wet weight and volume calculations and the formula, the amount of buoyant force our product has is approximately 0.873 N. Ultimately, this information allowed the company to equip the Commander with just the right amount of Seafoam to achieve perfect equilibrium.



Propulsion

The Commander's propulsion system allows The C.O.R.P.S. to navigate throughout the water efficiently and accomplish our tasks. This system is composed of two 1000 GPH Bilge pump motors and four 500 GPH Bilge pump motors, mounted on Commander's acrylic frame. The two 1000 GPH are mounted vertically specifically for ascending and descending in the water. One of each of these two motors are attached to the center of the port and starboard sides of our frame. The remaining four motors are mounted to the four corners of the ROV. These motors are all positioned the same way so that we would have enough forward and backwards thrust. The positioning of Commander's motors is essential for ROV maneuverability and efficiency.



The company decided to redesign the older shrouds from previous years. The length of the shrouds has been lengthened by approximately 0.15875 cm from their predecessors. The two vertical motors also have an enlarged outer diameter of 9.5 cm. The larger diameter was created for the purpose of encasing the newly customized 3D printed propellers.

The new propellers have the capability to produce the same amount of thrust in both directions, whereas the old propellers were only able to produce proper thrust in a single direction. The new shrouds are still capable of protecting the propellers as efficiently as the older models. Each shroud has a 2-lock and zip-tie system that properly secures them to the frame. On the octagonal face of every shroud are four holes specifically spaced and sized to tightly attach them in the areas that they were designed to be in.

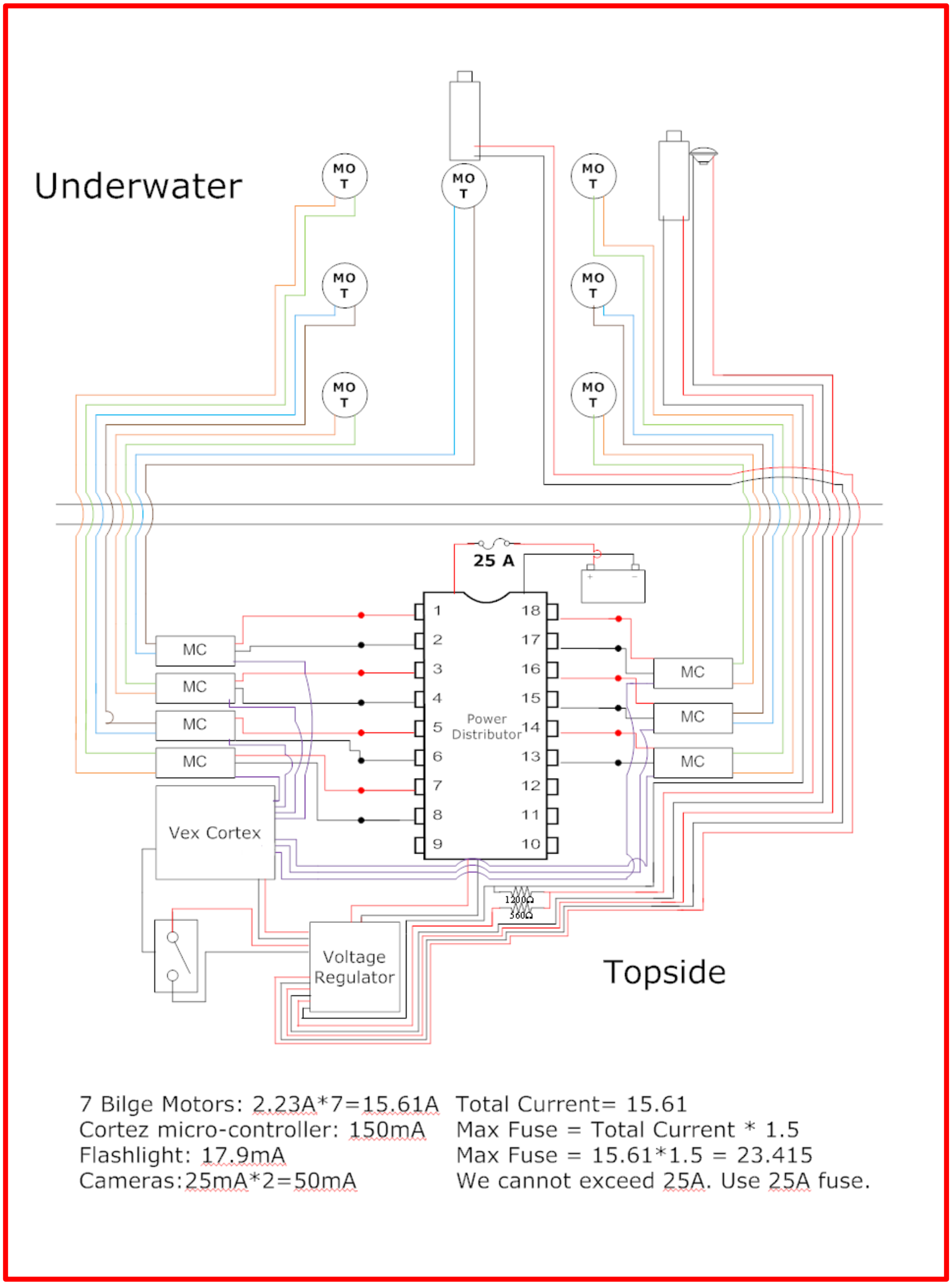
Control System

The Commander, along with all of its attachments, are powered through a VEX PRO control system located within a Pelican 1560 Case. This durable and lightweight system is divided into three layers, each serving a unique purpose**.** The first layer consists of a watt meter, a 19'' Insignia display, and a manual hydraulic control system. The second layer contains: a voltage regulator module, seven motor controllers, a power distribution board, a VEX robotics cortex, a video converter, and nine fuses. The last layer acts similarly to a false bottom and serves as a precaution in the event water breaches the system. As an added feature, the last layer contains surplus wiring to better organize the various electronics.

The Commander's electronics play a pivotal role in the functionality of the ROV and are essential to the completion of each task. Beginning from the first layer of the ROV is the 19 in'' Insignia display that allows the pilot to see the environment around the Commander. Next is the Watt Meter that displays the current and amperage that runs throughout the system. The most critical parts of the Hydraulic manipulator are the control system for the gripper. This is where the copilot is able to adjust the pressure of the gripper. In the second layer of the control system, where the most crucial aspect of the ROV the power distribution board is the heart of the control system powering all the aspects of the Commander. The board houses nine fuses for safety purposes.

From the main ports of the power expander is the seven motor controllers that send power and commands to the rotary manipulator and propellers. Also from the power expander is the voltage regulator that powers the remaining components of the Commander. From the voltage regulator the two cameras and courted are powered, these components are essential to the control of the ROV. Finally, there is the video converter which allows the pilot to have a view an alternate view of the secondary robot. At the third; later the Fan layer of the control system oils the false bottom which holds surplus wires from the ROV to maintain order on the following layers of the control system.

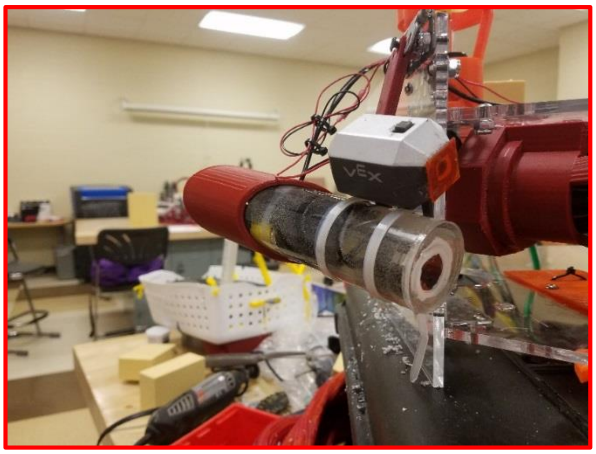
System Interconnection Diagram



Tether

The VEX PRO electrical system powers all the components of the ROV via the wires that run through the approximately 11-meter long tether. There are three different types of wires within the tether, including: camera wires, neutrally buoyant wires and ¼ inch vinyl tubing. The use of the two camera wires is to enable the pilot to (see) the environment around the Commander. The Mutually buoyant wires are made to carry power and commands from the control system to the pilot himself, most wires that power multiple ROV's are not naturally buoyant therefore adding drag to the ROV, but ours is naturally buoyant therefore it benefits the ROV in the way that it take always drag while still serving its main purpose of decreasing drag and carrying out the same functions as standard electrical wire. The vinyl tubing that is encased within the sheathing has the purpose of controlling the hydraulic manipulator located at the bow of Commander.

Cameras



The Commander features two 0.635 cm Closed-Circuit Display (CCD) flush mount waterproof rear-view cameras and are used to gain a strategic view of the surrounding environment during mission use. The camera wires are positioned around vital sections on the ROV and connect to the control system through the tether. The primary camera will be displayed on the Insignia LED TV on the lid inside the control system, while the secondary camera will be connected to the supplied secondary display. This allows for both cameras to be displayed simultaneously. Our camera mounts were specifically designed to complement the structure of the ROV by being compact and easy to manipulate.

Each of the two cameras are located at the bow of the ROV and are individually attached to uniquely designed 3D-printed parts. The primary camera is in the center of Commander and shares its mount with the rotary manipulator. This particular placement was chosen because it saves space and is cost efficient. The secondary camera is located on the starboard-bow of the ROV and is secured in a separate in-house manufactured 3D-printed part attached to the frame on a hinge. This camera is specifically angled to face the components on the bow of the ROV to provide a view of our rotary manipulator and hydraulic gripper. Our camera mounts were specifically designed to complement the structure of the ROV by being compact and easy to manipulate.

Mission Specific Tooling

Hydraulic Gripper

The hydraulic gripper is a 3D-printed, in-house manufactured attachment on the Commander that functions to retrieve sediments and clams at the Long Beach City Port ocean floor. It is a double jointed hooked manipulator built with nylon nuts, VEX robotics spacers and nonslip netting. This ABS plastic gripper is moved whenever syringe, located in the control system, is pushed down. This syringe is connected to the gripper through hydraulic fluid filled vinyl tubing. In order for the gripper to close, the joints must be brought to the front. The company designed the 3D part specifically to be able to be mounted on to the ROV with ease. We chose this design because we were familiar with hydraulics and knew how to smoothly integrate this into our newest product, Commander. The 3D-printed assembly is found on Appendix B.

Rotary Manipulator

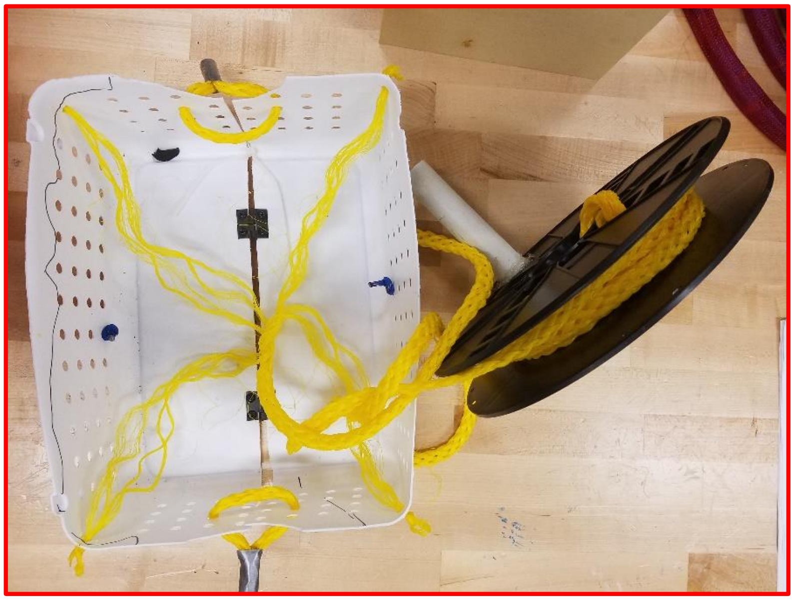
The rotary manipulator is one portion of a 3D-printed part that is located on the centralized bow of the Commander. This part was specifically designed to slide onto the acrylic frame, eliminating the need for drilling excessive amounts of holes into the material.

The actual manipulator is on a shaft that is moved by a gear train and powered by a 500 GPH bilge pump. The bilge pump was properly secured with a 2-lock and zip-tie design that prevents unexpected disconnection.

The rotary manipulator plays a pivotal role in the ROV's overall performance and was designed for the purpose of outputting efficient torque strength. Much time and effort was put into determining which design for this section of the ROV was going to be the most effective. This final piece was our best option yet, however our team's philosophy is that there is always room for improvement in any of our efforts.

Collection Device

The C.O.R.P.S. now employs the use of a 34.93 cm x 27.31 cm x 12.7 cm, white, Sterilite Ultra Basket as a collection device. It was chosen due to its relatively compact size and reasonable height so that it may efficiently contain each of the retrievable mission materials in a single trip. This will increase efficiency as the ROV no longer needs to transport each material to the surface separately.



The rim of the device has been removed in order to scale the underwater wall more easily. This prevents the collection device from tipping over and reduces friction against the underwater wall. The device has also been cut in half and secured along the center with hinges. The ability to compress the device ensures stronger compatibility during mission use. In each interior corner of the device are 195 g steel square weights. These are meant to ensure the device sinks evenly and reaches the sea floor at an efficient pace. There are four holes drilled into each corner so that the expandable, braided sleeve could be securely weaved through them. Alongside each strand, knots were made tying the edges of the device to prevent it from collapsing in on itself during its ascent to the surface. Each strand meets together approximately 30.48 cm above the top of the basket and continues along the 762 cm stretch to the winch. The winch is a component of the collection device and has a 20.32 cm PVC handle secured to it as a crank.

Raman Laser

The Commander features a simulated Raman Laser, in order to determine if there are contaminants present. This laser is essential to collecting samples and placing caps over contaminated areas. Our laser is currently a manually waterproofed VEX Flashlight that is located directly above the product's secondary camera. Waterproofing the flashlight was a learning experience for all company members and was achieved by our Pilot, Noah Johnson. He completed this process by filling the interior empty space of the flashlight with wax from a wax ring. Since the wax is in the interior of the flashlight shell, water is repelled from the internal circuit

Raman Laser secured to exterior of secondary camera.

board and LEDs. Overall, the flashlight consists of four white LEDs that are powered through the tether back to the control system. At the control system, the pilot operates the simulated laser through the VEX controller.

Financial Report

Value of Reused Items		
Item Name	**Est. Cost**	**Original Year**
Wattmeter	$9.26	2015
10 cc/mm Syringe 10-Pack	$4.45	2016
Everbuilt Continuous Hinge	$5.97	2016
Clear Vinyl Tubing 1/8" Diam.	$12.50	2016
1/4'' Rear View Camera (2)	$19.52	2016
Circuit Breaker, 20 Amp (4)	$19.96	2016
Spike H-Bridge Relay	$34.95	2016
Expandable, Braided Sleeve	$36.85	2016
VEXnet Key 2.0	$39.99	2016
Lexan Polycarbonate Sheet (2)	$41.96	2016
500 GPH Johnson Bilge Pump (4)	$75.76	2016
19" Insignia TV	$79.99	2016
Voltage Regulator Module (2)	$89.98	2016
VEXnet Joystick	$149.99	2016
Pelican 1560 Case	$159.37	2016
Fathom Tether: length 50m	$166.76	2016
Power Distribution Panel	$204.99	2016
Victor SP (6)	$359.94	2016
Total Salvaged Materials	**$1,512.19**	

General Expenditures	
Item Description	**Cost**
Laser Cutting	$30.00
PVC Pipe	$54.92
MATE Registration	$125.00
Total	**$209.92**

Travel Estimate	Cost
Travel to Regional	$256.45
Travel to International	$7,485.00
Lodging & Transportation	$5,197.50
Total	**$12,938.95**

ROV Build Expenditures	
Item Description	**Cost**
Sterilite Basket	$2.49
Subsea Buoyancy Foam	$12.50
Misc. Hardware	$32.48
OPTIX Acrylic Sheet	$36.73
1000 GPH Johnson Bilge Pump (2)	$67.20
ABS Filament (2)	$102.26
Total	**$253.66**

Total Salvaged	**$1,512.19**
Total Spent on ROV	**$253.66**
Total ROV Expenses	**$1,765.85**

Budget

This year's budget was an extension of last year's grant for the C.O.R.P.S., which was provided by Harlandale Independent School District (HISD). This grant allowed our company to purchase all of the necessary equipment and materials to build this year's ROV, the Commander. All of our money was spent according to what we need, and after much thought. The majority of the Commander's topside materials were reused, and we also salvaged some of the items that were used on the Commander. Thanks to our access to our school's 3D-Printer we were able to save money that would have been otherwise used on camera mounts, motor housings, and materials for the Commander's manipulators. We started this years' competition with $927.16 in our budget, and ended with $673.50 left. All the money for our travel was provided by our district's special activity fund.

The Company

Challenges

Technical- Our main challenge this year was learning how to work with acrylic. With all of our previous products, we used a combination of PVC pipe and ABS plastic. Although we used more ABS plastic for Commander, we didn't know how the acrylic was going to react to drilling holes for attachments. After numerous trials we were able to construct a unique shape, while remaining inside the 48 cm size limit. Another issue encountered was buoyancy. Rather than using ballast tanks, we decided to use Subsea Buoyancy foam. Since this was another product that we had never worked with, it took extensive research to successfully calculate, measure, cut and position the foam for Commander. In short, we overcame multiple design challenges this M.A.T.E. season, and have produced the best possible product.

Interpersonal- This year the C.O.R.P.S. went through an entire recruitment process involving an application and two phases of interviews. This ensured we would have new members that are passionate about robotics and would complement the company as a whole. Naturally, due to the diverse schedules of each of the 9 members, there were issues with communication and attendance. In order to solve this, we created a Project Management Board that contained a Gantt chart to monitor productivity and a "Reminder Section". Whenever someone was going to miss a meeting or had an important announcement, they would post it on the board and the company would review it before the end of each meeting. This system was successful in producing solutions for other problems encountered, as well.

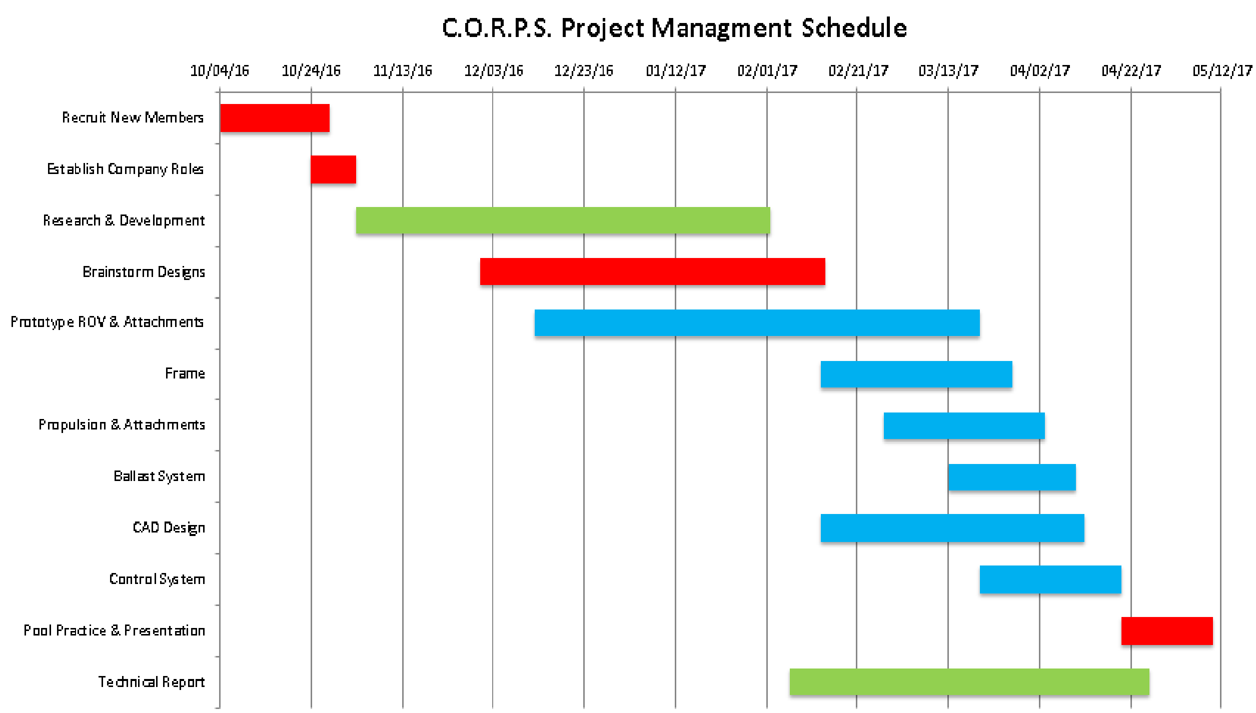


Table #2- The C.O.R.P.S. Project Management Schedule

Project Management

This year, the C.O.R.P.S. wanted to enforce a new strategy for time management and company organization. As previously stated in the interpersonal challenge section, our Management board guided the company throughout this entire season. We also used an hour log to keep track of everybody's hours and so we can manage our time to the best of our abilities. We made sure we had a set time frame for everything to be done so that none of us would be behind or off task. The colors on the graph indicate the type of work that was being completed. The red on the graph impacts all members of C.O.R.P.S. The green sections are specifically for our writing members. The blue is for our building members. With these guidelines and limitations, we were able to complete the ROV and Technical Report with enough time to edit and make any changes needed.

Lessons Learned

Throughout this entire experience, the C.O.R.P.S. has learned many important lessons.

1. <u>C.O.R.P.S. should always be prepared for anything-</u> The week of our regional competition, our C.E.O., Esmeralda Castillo, experienced a medical emergency and was unable to attend competition. This unfortunate situation taught the entire company the importance of communication in times of stress. Despite their leader's absence, everyone continued to work hard and, in the end, became stronger as team.
2. <u>UHMW is a better frame material than acrylic-</u> At our regional competition, one of our presentation judges approached us and asked why we decided to construct the frame using acrylic. After giving our reasons, he advised us to research a material called Ultra High Molecular Weight Polyethylene (UMHW). We learned that it was, in fact, a much more efficient material and are making plans to consider using UMHW for the 2017 MATE competition season.
3. <u>The shape of motor housing affects speed efficiency-</u> The same presentation judge from our regional competition also spoke to us about improving our motor housings. Originally, we had designed the housings to be angular and concaved along the inside. After our conversation with the judge, we learned that a completely circular housing shape would allow the water to flow through it from all sides. We redesigned all of our housings and, in the end, helped the ROV drive faster and smoother.

Experience Evaluation

In an attempt to give the entire company a moment of personal self-reflection over their experience in the C.O.R.P.S., we have collected statements from each employee.

<u>Esmeralda Castillo, C.E.O.</u>

"It's an honor to be able to compete in M.A.T.E. for a second year, especially with an even larger team. Throughout the recruiting, planning and building processes, I have loved every minute of it!"

<u>Ryan Ramos, C.A.O.</u>

"I've always looked towards my future instead of simply living day to day. Participating in M.A.T.E. Robotics has not only guided me towards my passion in Engineering, but also served to make me a better person."

Daniel Benavides, C.F.O.

"I enjoy M.A.T.E. because everyone in the company has something different to offer. Seeing everybody work their best on something that can benefit them, and others, gives me a good feeling about the future."

Noah Johnson, C.O.O. & Pilot

"Coming back for a second year to compete in M.A.T.E. is very exciting. This competition has broadened my view of my capabilities in robotics! Regionals was an awesome learning experience this year and I'm looking forward to competing at internationals again."

Yamilett Pilar, C.M.O.

"This was my first year in M.A.T.E. and I have met such hardworking and inspiring people who truly take robotics as a passion. I loved working with the people on my team because I got closer to them than ever before."

Jocelyn Chavez, Marketing Assistant

"Being in M.A.T.E. has inspired me to consider a job in engineering, also M.A.T.E. has led me to meet some of the most amazing people that I could ever meet during my high school experience!"

Omar Arredondo, Mechanical Engineer

"This year was very challenging, but I still learned a lot about the ROV through its driving systems and material usage. No matter how difficult the year was it was fun. My team has had some differences, but we always came together in the end and work things out."

Maximus Bermudez, Software Engineer

"Ever since I was young I've had a desire for building and designing, choosing an engineering school that has robotics competitions and a passion for engineering like me helps and pushes me to look forward for the future in an engineering field."

Emma Garza, Safety Officer

"This is my first year in M.A.T.E. and it has been a very fun and amazing experience. My favorite part of the regional competition was being able to see the other companies ROV's. All of this has made me realize how much I love working in robotics."

Future Innovation

Innovation is a strong priority of The C.O.R.P.S. and its values. As a company, we understand that there is always room for positive change in our product and its performance. After long discussions within the company, we concluded that the following improvement is crucial to our success next year:

- Top Motor Housings- the Commander cannot efficiently crab due to our two motor housings that are facing directly upwards. If we change our housing design to be vectored, we would have a more accurate, reliable, and efficient drive.

References

S.T.E.M. Early College High School: Mr. Valdez for his advice from years of experience with MATE

MATE Center: Competition Manual, Forums, Former Tech Reports

Amazon.com: Bilge Pump specs

Blue Robotics: Buoyancy Calculator

Autodesk Inventor 2016: 3-D Modeling Software

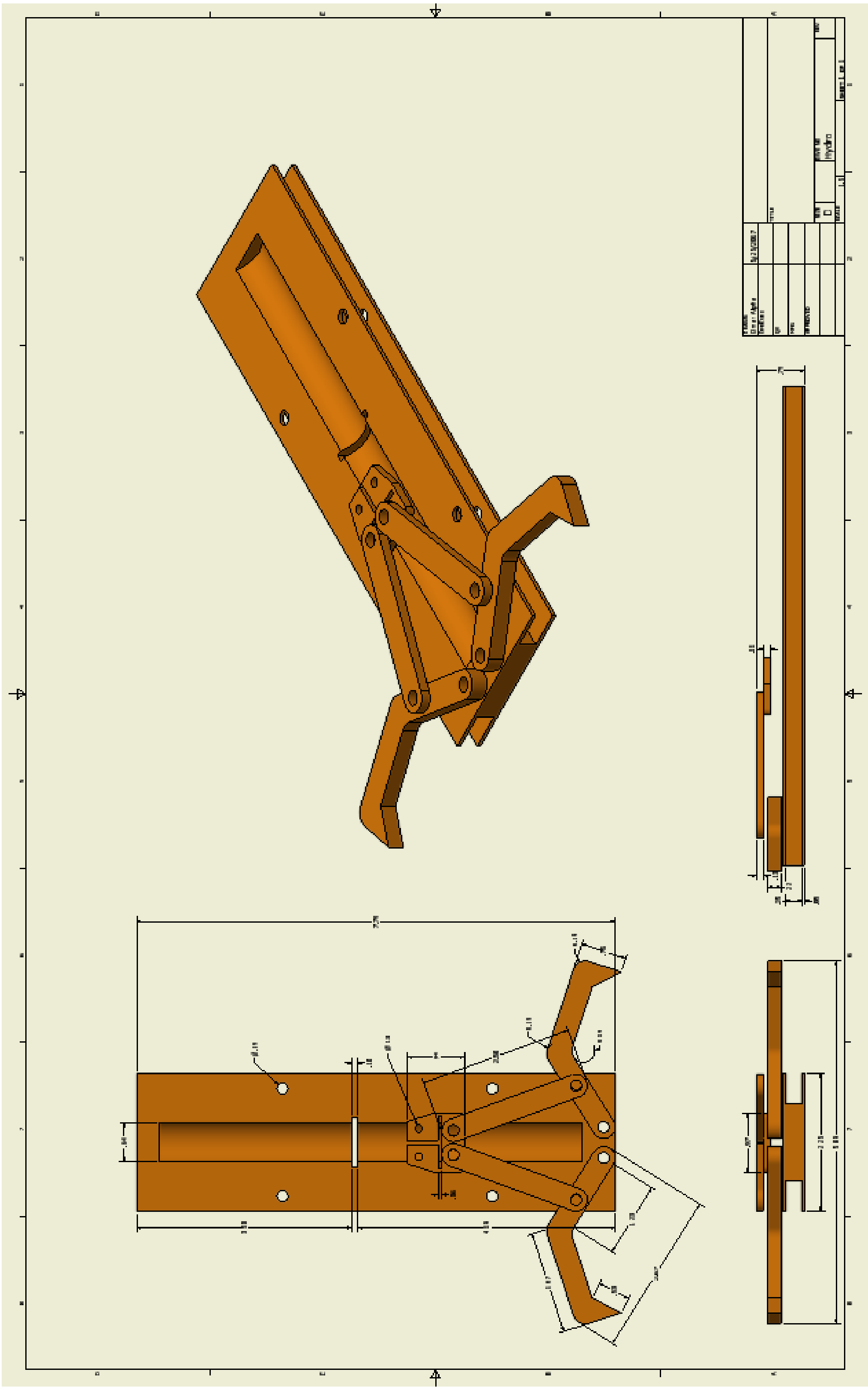
Microsoft Word: Charts for Financial Report

Acknowledgements

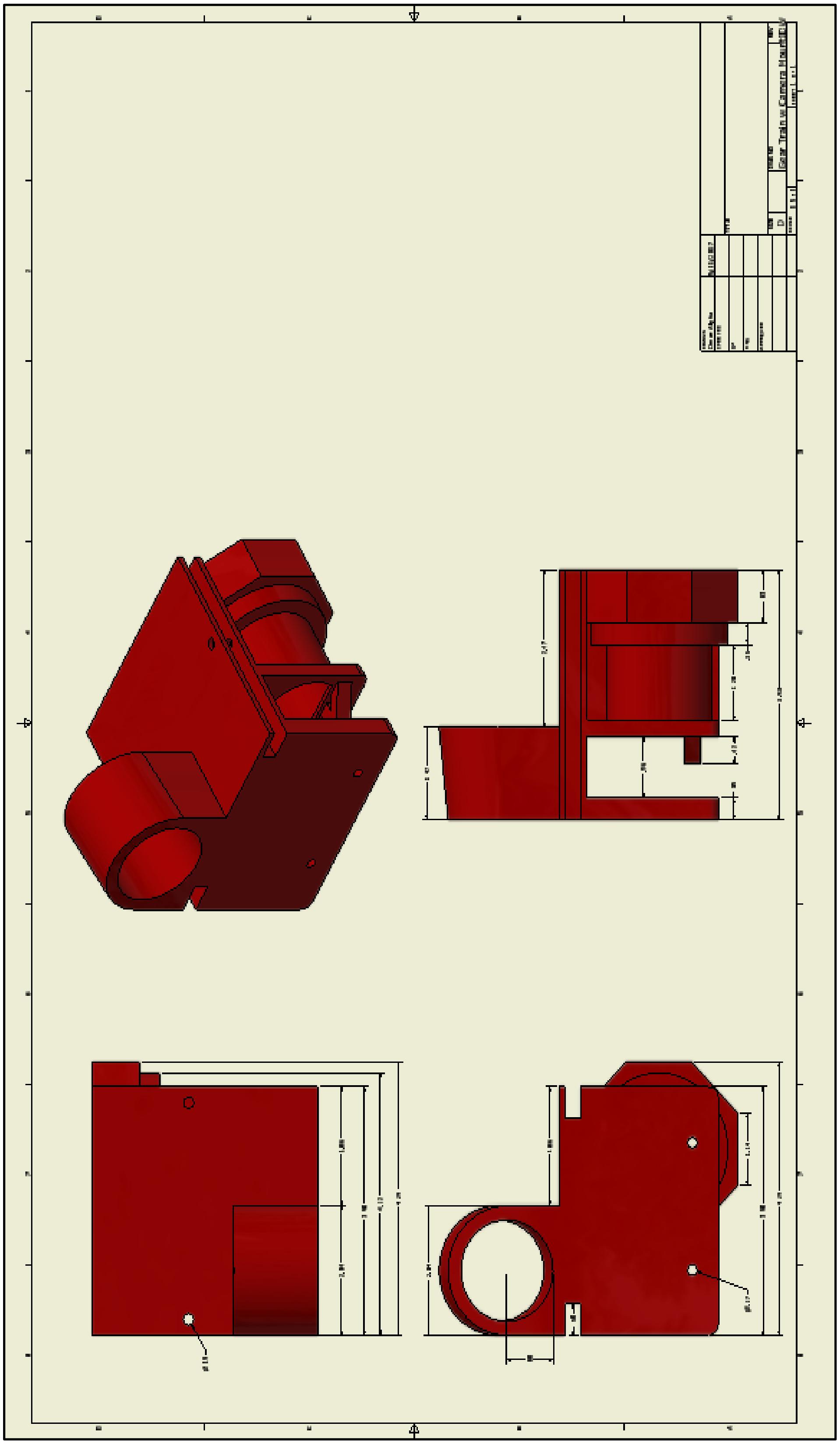
The C.O.R.P.S. Company is eternally grateful for all of those who played a role in our success and would like to recognize and thank each of the following organizations and individuals:

- **S.T.E.M. Early College High School** for exposing us to the world of robotics and providing the opportunity for us to compete again.
- **Mr. Romeo Valdez** for your endless support, expertise, and patience. You're our most cherished teacher, inspiring mentor and fearless leader.
- **Long Beach City College** for hosting the MATE 2017 International Competition
- **San Jacinto College Maritime Technology & Training Center** for hosting all of the MATE companies and the regional competition.
- **The M.A.T.E. Center** for accepting our design and for organizing a competition that creates an environment to thrive in.
- **10 Bit Works** for allowing us to use their facilities and teaching us how to operate the Rabbit Laser System.
- **The Deep Dive Project**, our outstanding sister company, for supporting us throughout this entire 2017 M.A.T.E. season.
- **The C.O.R.P.S. Families** for your continuous sacrifice throughout this project and your willingness to help us in any way possible!

Appendix A



Appendix B



Appendix C