2016

The Corporation of Offshore Reconnaissance & Polar Submersion

Company Associates

Chief Executive Officer- Esmeralda Castillo ‘18
Chief Operations Officer & Head Engineer- Ryan Ramos ‘18
Chief Financial Officer- Daniel Benavides Jr. ‘18
Head Software Engineer- Omar Arredondo Martinez‘18
Safety Officer- Noah Johnson ‘18
Pilot & Public Relations Officer- Omar Bravo ‘18
Government & Regulatory Affairs- Briana Olivarez ‘19

Mentor

Faculty Advisor- Mr. Romeo Valdez

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

Table of Contents

Appendices

Abstract

The Corporation of Offshore Reconnaissance & Polar Submersion (C.O.R.P.S.) is an innovative company specializing in finding solutions to real-world marine technology problems. Our company has designed a first-of-its-kind, remotely operated vehicle (ROV) that can operate in the harsh environments of both the ocean and outer space. In February of 2016, we were approached with the task of designing a ROV that would be sent to Europa, one of Jupiter's moons, and into the Gulf of Mexico. The ROV must perform numerous tasks including: measuring the temperature of Europa vent water, measuring the thickness of Europa's ice crust, collecting samples of oil and coral in the Gulf of Mexico, identifying conditions of local flora colonies, recognizing and accumulating mission essential equipment, and repairing a decommissioned wellhead.

Our ROV, Admiral, is a product of innovation from the initial success of our first product, Brigadier. The Admiral is constructed of polyvinyl chloride pipe (PVC) and a thermoplastic polymer known as acrylonitrile butadiene styrene (ABS plastic). The frame holds two 1/4" CCD Flush Mount Waterproof cameras, a TC1502 temperature probe connected to a Labquest 2 Interface System, four propellers, and a HawkEye Digital depth sounder. Secured to the top of the frame is an approximately twelve meter tether that connects to the control system. This system is entirely encompassed in a watertight Pelican 1560 Case with foam and holds a 19" Insignia LED TV and all of our sensor displays. Together, these attributes create Admiral, an exemplary ROV that is ready to explore.

Left to Right: Ryan Ramos, Omar Arredondo, Esmeralda Castillo, Omar Bravo, Briana Olivarez, Daniel Benavides Jr. & Noah Johnson

Company Mission

The Corporation of Offshore Reconnaissance & Polar Submersion is a corporate business that is in the process of becoming one of the most innovative companies in the world. This is our first year working together as a company, and to ensure our success, we plan to complete

the requisite tasks on one of Jupiter's moons, Europa and in the Gulf of Mexico. Although there are other corporations that seek to achieve the same goal, the components of the Admiral and its control system will exceed the performance of competing organizations. 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 will make history and produce Europa and the Gulf of Mexico's most resourceful navigator.

Design Rationale

Frame

The main constraint we took into consideration when designing and building the Admiral's frame was size. Unfortunately, our prior product, the Brigadier and its tether was not able to fit inside our 48 cm diameter ring constraint. In response to this aspect of the first product, The C.O.R.P.S. has made major design improvements in order to create the Admiral. Now, our product is approximately 2.7 kg lighter than Brigadier and is less than half the size. Due to the reuse of the motors from before, this new condensed frame increases the Admiral's total acceleration and maneuverability.

The frame of the Admiral is made of a combination of polyvinyl chloride pipe (PVC) and a thermoplastic polymer known as acrylonitrile butadiene styrene (ABS plastic). Most of the PVC pipe and ABS plastic used for the frame is ½"; however, one significant part of the ROV does not follow this dimension. In the lower, central area of the Admiral, ¾" PVC pipe makes up the collection device. Two distinctive features of our current product are the components made with ABS plastic. All four of the Admiral's motor housings and its camera mount are manufactured in-house and were designed specifically for this product. With the aid of a 3-D printer, the Admiral showcases a uniquely designed camera mount and four motor housings that create a distinct ROV.

The picture to the left shows the basic frame of The Admiral without any attachments.

Overall, the Admiral's compact and light structure allows for a more effective and reliable product, especially when considering the location of its subsystems. Our product's frame holds the mounts for the motors, ballast tanks, cameras, depth sounder, temperature probe, and collection device, all still staying within our size constraints. There is a total of four motors in two separate sets on the lower sides of the ROV. The first set of motors, located in the interior of the Admiral, are angled slightly to not only allow the ROV traverse up and down, but to also "crab" left and right. The second set of motors, located at the exterior of the Admiral, are mounted horizontally giving the ROV the ability to rotate and move backward and

forward. The ballast tanks are held by 4 plastic conduit clamps located on opposite sides at the top of the Admiral. These positions further help us achieve neutral buoyancy, maintain a consistent velocity underwater and distribute balance throughout the ROV.

The two cameras are mounted at the front of the ROV and face opposite directions. On the original design of the Brigadier, the cameras were set in one place. The C.O.R.P.S. collaborated and decided to improve upon this design and implement a pan and tilt system into the Admiral's frame. This system is made of a combination of AB plastic and FTC robotics materials and provides the Admiral with 360˚ view. The depth sounder is located in the back of the ROV and is facing in such a way that isolates it from any objects in order to generate accurate data. The temperature probe is powered by hydraulics and is located above the depth sounder. The collection device is in the lower, central area of the Admiral, slightly protruding toward the front of the ROV. Please see Appendix C for the Admiral in CAD Software.

Ballast System

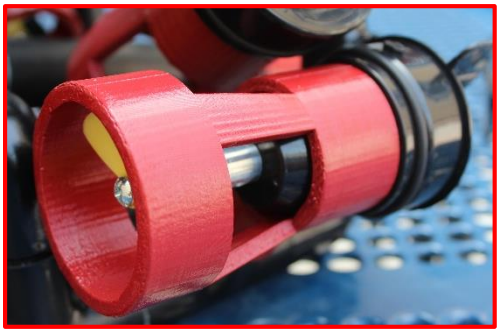
The Admiral's ballast system is equipped with a pair of 2-in diameter PVC pipes, approximately 34 centimeters long, located on the top port and starboard sides of the ROV. These specific pieces of PVC contain a negative buoyancy of -18.581 g/cm. They are air tight sealed with "Oatey regular clear cement" and were left to dry for a total of 24 hours to ensure maximum efficiency. These two pieces of PVC allow our ROV to achieve neutral buoyancy and maintain itself with the help of a buoyant wire wrapped around the inside of the tether. On the Brigadier, buoyancy was created by thick flotation devices wrapped around the exterior of the tether. Although this aspect of the ballast system functioned well, it consumed too much space when wrapping the tether around the ROV for transportation. Admiral's new and improved ballast system is monumentally more efficient and will perform without problem.

The method we chose to accurately calculate the necessary buoyancy was gathered from a worksheet from the MATE website at "Mate Summer Institute 2014". The exact formula that was used was Fb=M/18.581. "Fb" is essentially the amount of buoyancy needed for the Admiral to be able to float just under the surface of the water, and still be able to keep itself from sinking to the bottom. "M" is the mass of the ROV in what is known as "dry weight", that being what is hovering without any water in or around it. The C.O.R.P.S.

In the process of extracting that information, the company enacted the use of what is known as a "Vernier Dual Range Force Sensor." With this, any object that hangs from the hook attached to the sensor is accurately weighed. This sensor is vital to the operation because it allows objects to be placed in and under any surface and is necessary for efficiently calculating buoyancy. Ultimately, the accurate calculations gathered with the sensor allowed the company to equip the Admiral with just the right amount of air to achieve perfect equilibrium.

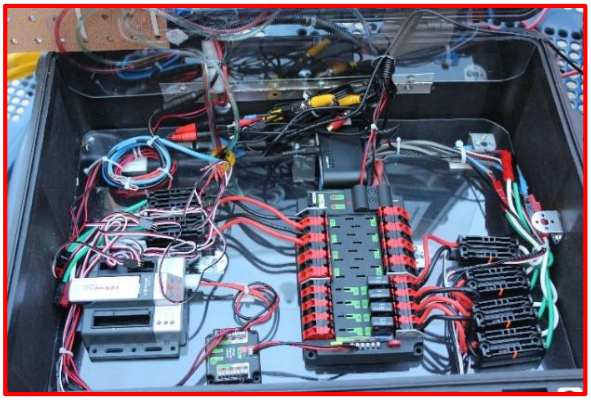
Motors

The Admiral contains a total of four Johnson Bilge 1000 GPH motors that each have a 5 amp. fuse with max amp. draw of 3.2 amps. These motors- located in two separate sets on the lower sides of the ROV- , are encased in ABS plastic motor housings that were manufactured with a MakerBot Replicator 2x 3-D printer. These red motor housings ensure the safety of others whenever they come within the vicinity of the propeller blades.



The picture above portrays our 3-D printed motor housing.

The propellers themselves are attached to the motors with Loctite, a water-proof adhesive specifically designed for metal parts. With the Loctite, the propellers function at maximum efficiency and generate enough force to maneuver the Admiral underwater. Essentially, the combination of the position of the motors on the frame and their programming are what allow the Admiral to move at all. The two separate sets of motors are located on the interior and exterior of the Admiral and provide the ROV with the ability to move in different ways. The first set of motors are angled slightly so the Admiral can traverse up, down and "crab" to either side. The second set of motors are mounted horizontally onto the frame so the Admiral can rotate and move backward and forward.



These two pictures portray our featured components inside of the Control System.

Control System

The C.O.R.P.S. Admiral's control system is completely encased in a Pelican 1560 case and consists of an incredible, interconnected electrical design. All of the subsystems and wires from the control system are connected to the ROV by a tether approximately 12 meters long. The two different types of materials used throughout the tether and in the control system are the clear vinyl tubing and Fathom Tether. The two strands of clear vinyl tubing are used to control the movements of the temperature probe and the collection device. The four strands of Fathom Tether are used to neutralize the buoyancy of the completed tether connecting the Admiral to its control system.

The Admiral and all of its components are powered through our control system. The control system begins with a power distribution board located in the middle layer of the control system. This power distribution board has multiple wires that connects to each of the four motor controllers. These motor controllers aren't only connected to a single component, but they are also wired to a vex cortex, the brain of the control system. Although this aspect of the control system may seem complicated, these are the essentials needed for movement in the ROV. Atop of the control system is the location for the hydraulic system. Since there are two attachments that depend on hydraulics for movement, the company came to a consensus to color the hydraulic fluid with food coloring. By coloring the fluid, we are now able to differentiate the hydraulic syringes between the temperature probe (red fluid) and the collection device (black fluid).

Subsystems & Attachments

Cameras

Cameras are essential to the product's success on Europa and in the Gulf of Mexico. Without the cameras, there would be no way to navigate the Admiral or know what is happening in action. The cameras on the ROV act as the company's eyes when performing the numerous tasks and play a crucial role. Our product features two ¼" Closed-Circuit Display (CCD) Flush Mount Waterproof Rear View Cameras. Both of these cameras are waterproofed using EnviroTex Lite and are mounted in a 1 ½" PVC ring. EnviroTex Lite protects the camera from becoming damaged by allowing us to apply a thick coat of liquid around it.

The C.O.R.P.S. Admiral utilizes two cameras that are mounted onto the frame in a creative way. Instead of having two cameras mounted at separate positions on the ROV, the way they were on the Brigadier, the company decided to mount the cameras directly next to each other. Since we changed the design, the cameras are now located in the center of the ROV and use pan and tilt system that allows us to look in the direction of our choosing. The placement of the cameras gives us the opportunity to see where the Admiral is heading and to be aware of the ROV's surroundings at all times.

Depth Sounder

The depth sounder is a Norcross Hawkeye product. Luckily, very few adjustments were needed; however, the adjustments that were made were definitely necessary. For example, the depth sounder's original wires were too short to match the length required for the tether, so in turn, the C.O.R.P.S. had to work together to extend the wire to 12 meters. The depth sounder is mounted on the exterior back of the Admiral. Initially, we were planning to keep the location of the depth sounder based on where it was on the Brigadier, but this placement was too close to the motors. The constant disruptions of the motor vibrations caused the company to receive inaccurate readings during our missions. With its new location, the depth sounder is able to gather more accurate and consistent readings than before. The sensor display is located on the bottom left of the lid, allowing the driver to see it as easily and to collect reliable information at

a moment's notice. . To mount the display, we drilled through the back of the control system and screwed it in securely. This was to ensure that it will never fall off or cause any harm to the driver or damage the electronic components beneath it. With the use of a hack saw we removed any excess to produce a more aesthetically appealing product. The depth sounder was initially set to detect distance in terms of feet, however due to the fact that MATE requires distance in SI units, we reprogrammed it to measure distance in terms of meters. Conveniently enough, the depth sounder contained the capabilities of changing to the specified settings in SI units, saving us time during the mission.

Temperature Probe

The sensor that we used on the robot is a Vernier Temperature Probe that connects to a LabQuest interface module. Since the Temperature Probe wire was significantly shorter than the wires in the tether, we had to extend them. An amazing feature of the Probes is that it can measure temperatures ranging from-40°C to 135°C. The entire length of the Probe is 15.5 cm long and is located on the inside of the back right of the Admiral. It is enclosed in PVC pipe direct between the tether and the claw. This PVC pipe is connected to a hydraulic line that functions to lower the probe into the right location to gather calculations. The hydraulic line is joined to a syringe that lowers the temperature probe and raises it back up. This specific component of the Admiral has fluid colored red to be easily identified. In the Gulf of Mexico, the temperature probe will be used to measure the temperature of the water coming out of the vent.

The picture above showcases our hydraulic powered temperature probe.

Collection Device

The collection device is basically a claw located directly in the bottom center of Admiral. It is connected to two ¾" PVC three-way connectors (T-connectors) with one in the middle of the claw to limit how far the claw can go down. This extension directly branches off the bottom back part of the ROV frame. Between the two three-ways there is a 4½" Piece of PVC and on the outside of the three-way is another 4½" piece of PVC which connects to a 90° angle. Under the main claw, there are two pieces of PVC that are built to stop the claw and support the oil sample as we bring it to the surface to collect it. The claw is lifted and lowered by a hydraulic line which contains water that is dyed black. This color helps the company distinguish between the hydraulic line that is used to power the

The Admiral's hydraulic powered collection device.

collection device and the hydraulic line used to lower the temperature probe. In the Gulf of Mexico, the collection device will collect two oil samples and return them to the surface to be analyzed.

Financial Report

Total Product Price

Product Name	Quantity	Unit Price	Total Price
Pelican 1560 Case with Foam (Black)	1	$159.37	**$159.37**
Hawkeye Digital Depth Sounder	1	$109.99	**$109.99**
19" Insignia TV	1	$79.99	**$79.99**
Wattmeter	1	Salvaged	
Power Distribution Panel	1	$204.99	**$204.99**
Victor SP	6	$59.99	**$359.94**
Voltage Regulator Module	2	$44.99	**$89.98**
Vex Arm Cortex-Based Microcontroller	2	$249.99	**$499.98**
VEXnet Joystick	1	$149.99	**$149.99**
VEXnet Key 2.0	1	$39.99	**$39.99**
Circuit Breaker, 20 Amp	4	$4.99	**$19.96**
Everbuilt 1-1/16 in. x 12 in. Bright Nickel Continuous Hinge	1	$5.97	**$5.97**
Lexan 24in. x 18in. x 093in. Polycarbonate Sheet	2	$20.98	**$41.96**
Clippard Air Power Storage Tank	1	Salvaged	
VIAIR Air Compressor	1	Salvaged	
BLUE 95A PUR 1/4 x .160 x 50 FT Pneumatic Tubing	1	Salvaged	
Pipeman's 3/4"/ 19mm 100 ft. Expandable Braided Sleeve	1	$36.85	**$36.85**
Clear Vinyl Tubing 1/8" Diam. PK/50	2	$12.50	**$25.00**
Fathom Tether: length 75m	1	$250.00	**$250.00**
HS-646WP Waterproof Servo (Standard Size)	4	$43.00	**$172.00**
Johnson Bilge Pump 1000 GPH	4	$36.99	**$147.96**
1/4'' CCD Flush Mount Waterproof Rear View Camera	2	$9.76	**$19.52**
10 cc/mm syringe 10-pack	1	$4.45	**$4.45**
PVC (Conduit Clamps, L's, T's, etc.)		$57.25	**$57.25**
Miscellaneous (Zip-Ties, Screws, Couplers, Extra Wires, etc.)		$36.82	**$36.80**
Total			$2,511.94

Travel Expenses

Regional Competition	Cost
Gas to Houston	$256.45
Food Cost	$1,500.00
Lodging	$855.00
Total	$2,611.45

International Competition	Cost
Gas to Houston	$256.45
Food Cost	$1,620.00
Lodging	$1,323.00
Total	$3,199.45

Total Travel Expenses	$5,810.90

Total Expenses	
Category	Cost
Total Product Price	$2,511.94
Travel Expenses	$5,810.90
Grand Total	$8,322.84

Budget

Originally, the C.O.R.P.S. received all of its funding through a $5,250 grant provided by the Harlandale Independent School District (HISD). This grant allowed our company to purchase all of the necessary equipment and materials to build Brigadier, the first product we competed at regionals with. By the end of the project, the C.O.R.P.S. had a total of $683.79 left in the budget. In preparation for the international competition, the C.O.R.P.S. received another grant that was utilized for the expenses that came with creating the Admiral. This second grant amounted to $4,000 and left the company with $927.16 in our budget.

Safety

Company Philosophy

The C.O.R.P.S. works to ensure the safety and integrity of the group as a whole. Together, we worked to design and construct a ROV product that is as safe as possible. This was completed by ensuring the robot does not have any sharp edges, exposed wires, or faulty fluid power systems. In the event of a safety issue, our company is trained on how to handle their problem and will use precaution in taking the appropriate steps. 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 worst and four being the best.

Potential risks	Consequences	Seriousness	Probability	Prevention
Fingers caught by propeller	Possible laceration to the finger	3	1	Ensure robot is off when touching or carrying the robot.

Water leak in electrical case/ Hydraulic lines disconnecting	Can cause fire or short circuit the different product 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 in one small area	3	2	Always ensure ROV is off and always work in pairs
Pneumatic Bladder busted by hazardous object	Harm or injury from the object that penetrated the bladder	2	2	Ensure the Bladder does not get close to or touch any sharp objects in or out of water
Entangled inside product tether	Can trip/fall if mobility is limited	2	3	Keep tether wrapped in one area and always be aware

The Safety Officer for The C.O.R.P.S. is Noah Johnson. He ensures the company is following all safety regulations in an orderly manner. His constant reminder to wear gloves and safety goggles helps keep the entire company safe during the construction and testing of the ROV. Also, Johnson is always present to supervise and advise in situations where an employee would be working with potentially dangerous materials.

Reflections

Challenges

Technical- Our main challenge that shaped the entire design of the Admiral was finding a way to mount all of the attachment and subsystems to the product, while still remaining in the 48 cm diameter size limit. The frame was constructed in a unique shape that allowed for all of the smaller components to be included in the design without overpowering each other, a major improvement from Brigadier. Another issue the company encountered was buoyancy. When the ballast tanks were too large, we expanded the pipe's diameter and shortened its length. This ensured the ROV wouldn't lose its buoyancy and remain within the size range.

Lastly, the entire company had trouble with constructing the tether. After a total of 5 hours, we were able to work together to cut the right length of wires, fill it into the rope, and wrap it in tape and pool noodles. In general, our design was adjusted numerous times throughout the M.A.T.E. season, but has ultimately become the best possible product the C.O.R.P.S. could produce.

Interpersonal- This year the C.O.R.P.S. Company worked extremely well together, but not without a few mishaps. A significant obstacle that individuals face when working with others towards one goal is communication. In the very beginning, some struggled to stay

focused on our common goal, and time management issues had to be sorted out. We found this lack of focus and time management concerns resulted from lack of communication, so we implemented consistent checks with one another. Some of those checks were formal, such as team meetings; others were less formal, but equally important check-ins with one another. A simple, "What are you working on? How are you doing?" went a long way to keeping us all on track. In the end, consistent communication and support for one another was the key to our ultimate success.

Lessons Learned

Throughout this entire experience for MATE 2016, the C.O.R.P.S. has learned many important lessons, including:

1. Wires must be properly spliced- The design of the ROV is always crucial to its performance but the company learned to appreciate the electrical aspect of the product. First, the power wire must be connected to the ground wire. If the power is supplied to the wires with no emergency counter measures, improperly spliced wires can short circuit or crash the entire control system. We cannot afford to lose because of the quality of spliced wire.
2. The length of wires is important to the amount of current flowing to the ROV- When we first completed the Brigadier, all of the motors were sputtering. The company brainstormed to find the source of the problem and eventually turned to our mentor for advice. He mentioned that the longer the wires are, the more delay is present in the moving current. Knowing this, when we were constructing the Admiral, the C.O.R.P.S. chose to shorten the tether from 15 meters to 12 meters. This challenge ultimately made each associate aware of how each component in the ROV can affect each other.
3. Communication is essential to success- All employees have their own specific job titles, but can still do more than one type of task. Due to this fact, the company learned that communication is extremely important. If we hadn't worked in sync, the amount of work finished wouldn't be as great. With so many different components of the competition to work on, communication was necessary to ensure someone was always putting in all of their effort. In the process of preparing for internationals, the C.O.R.P.S. developed a MATE wall. This featured two calendar posters that held all of the member's task deadlines, printed e-mails from the regional competition coordinator and different schedules that would affect the company member's time together.
4. The Hawkeye depth sounder has to be mounted in a specific way- Originally, the Brigadier featured the Hawkeye sounder mounted

above one of the ROV motors. This placement is what cost the company points when we performed at the regional competition, because the vibrations from the motor were interfering with the sounder's readings. When we built the Admiral, the company was successful in mounting the depth sounder in such a way that was isolated from the rest of the attachments. This taught each of the individuals on the company that since there are multiple attachments and subsystems on the Admiral, each one must be capable of functioning properly on its own before it can function for the entire ROV.

Experience Evaluation

Overall, the entire C.O.R.P.S. and all of its members enjoyed the energy of the regional competition at the Neutral Buoyancy Lab. After our product presentation, we went straight into our first product demonstration and experienced ROV difficulties. In the time we had before our second demonstration, we all worked together to fix the problem and were very pleased with the product's performance. Unfortunately, there was an error in the final score Excel spreadsheet so the C.O.R.P.S. was not going to advance to internationals. Approximately one week later, our mentor received an e-mail explaining the error and passed the news onto us. All of the members were absolutely thrilled to have had a second chance at competition and began working immediately.

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.

Esmeralda Castillo, C.E.O.

"My first year working with M.A.T.E. has definitely been very eventful and I'm so grateful I have this amazing team to work with. After the regional competition, I'm definitely looking forward to competing against other companies at internationals. "

Ryan Ramos, C.O.O. and Head Engineer

"This is a very hands-on competition and what I love the most is that I always have something to work on. I appreciate the fact that all of the companies are expected to take the entire competition seriously because that prepares us for real-world situations."

Daniel Benavides, C.F.O.

"M.A.T.E. has brought me closer to very smart people, helped me develop important work ethics and increased my knowledge of building. My favorite part of the regional competition was analyzing the oil chromatograph data and learning about other company ROVs."

Omar Arredondo, Head Software Engineer

"I have learned a great deal from my time in M.A.T.E. and I know I have more to learn in the years to come. Although we were approached with

multiple obstacles at regionals, I really enjoyed how the entire company came together to win first place."

Noah Johnson, Safety Officer

"It has been a fun experience so far and I'm looking forward to continuing to compete alongside the C.O.R.P.S. members. If it weren't for the M.A.T.E. competition I would've never experienced amazing teamwork or had the opportunity to meet other companies that understand what we go through."

Omar Bravo, Pilot & Public Relations Officer

"This is my second year competing and I'm enjoying it a lot more because the company is reliable and understanding of others. At competition there was a lot of pressure, but I know we performed the best we could."

Briana Olivarez, Government & Regulatory Affairs

"It has been an unforgettable adventure. I can't wait until next year!"

Future Innovation

Product Improvement

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. In short, the company went over all the aspects of the Brigadier we could improve upon and in turn, created the Admiral. Now that we have designed and constructed an innovated ROV, we are content with the work we have put into our product. After long discussions within the company, we concluded that the following list contains different aspects of the Admiral that can be improved even further upon:

- Frame- The design of the frame is entirely PVC pipe. If we could find a thinner, less dense, equally sturdy material to construct the ROV out of, the product performance would be enhanced tremendously. We would have more room to work with the individual subsystems inside the frame and would still be able to become successful.
- Tether- To have a more appealing product appearance, we would combine the two separate tethers into one.
- Bladder- To add an emergency retrieval system to the Admiral, the C.O.R.P.S. would implement a bladder into the design of the ROV. On the Brigadier, we did have a bladder; however, we lacked access to a vacuum. If we could improve upon the Admiral, we would invest in a vacuum and utilize the air compressor that is already installed onto the control system.

References

S.T.E.M. Early College High School: Mr. Valdez, Mrs. Janie & The Deep Dive Project

MATE Center: Competition Manual, Buoyancy PowerPoint, Triggerfish kit, Forums, Former Tech Reports

Autodesk 2014: 3-d Modeling Software

Excel: Spreadsheet for Financial Report

NorCross Marine Products, Inc.: Boat Mount Digital Depth Finder Installation Manual

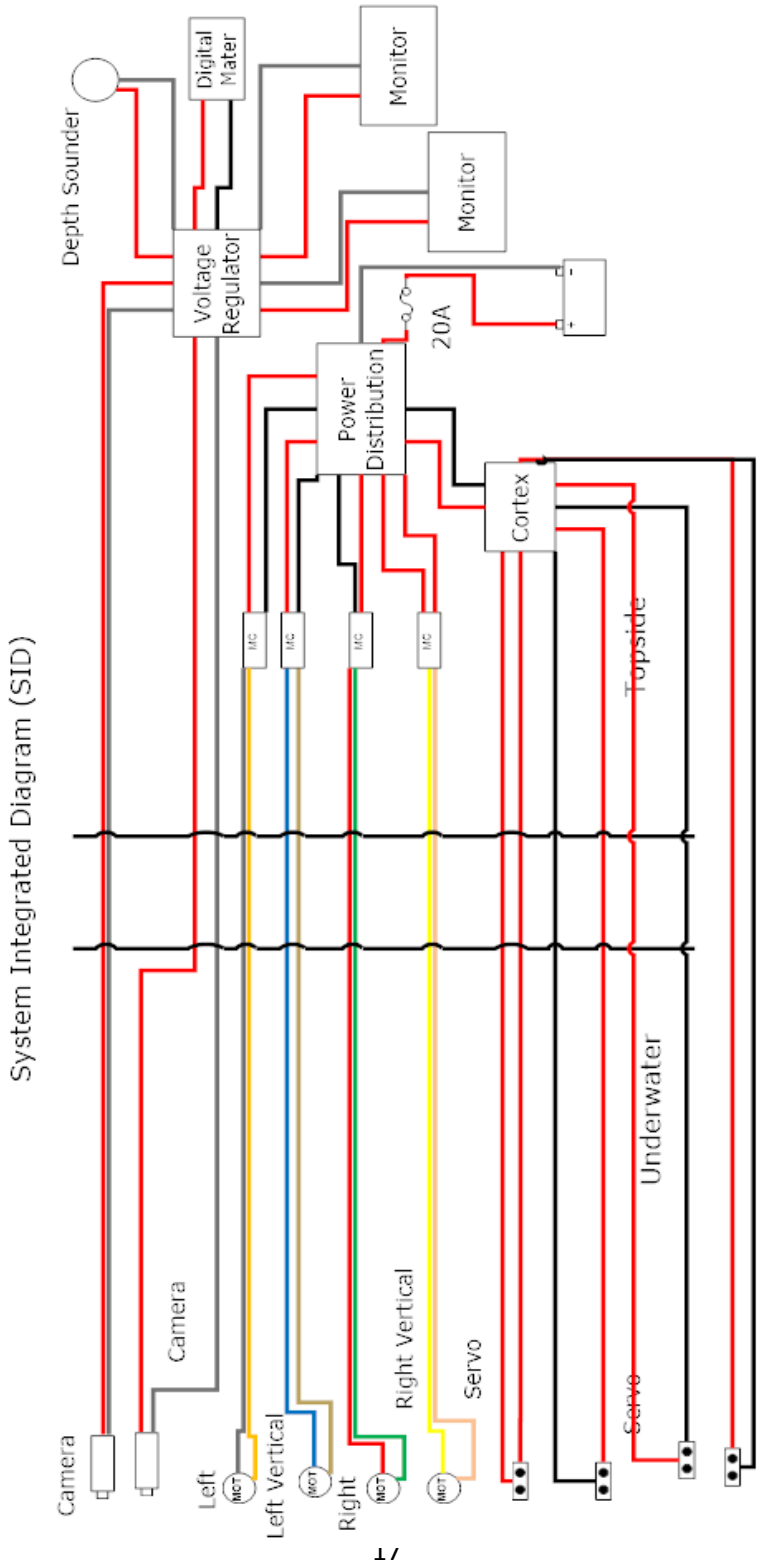
Acknowledgements

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.
- **Mr. Romeo Valdez** for your endless support, expertise, and patience. You're our most cherished teacher, inspiring mentor and fearless leader.
- **NASA** for hosting the regional and international competition in their Neutral Buoyancy Lab
- **The M.A.T.E. Center** for accepting our design and for organizing a competition that creates an environment to thrive in.
- **The Deep Dive Project**, our outstanding sister company, for always having our back throughout this entire 2016 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!

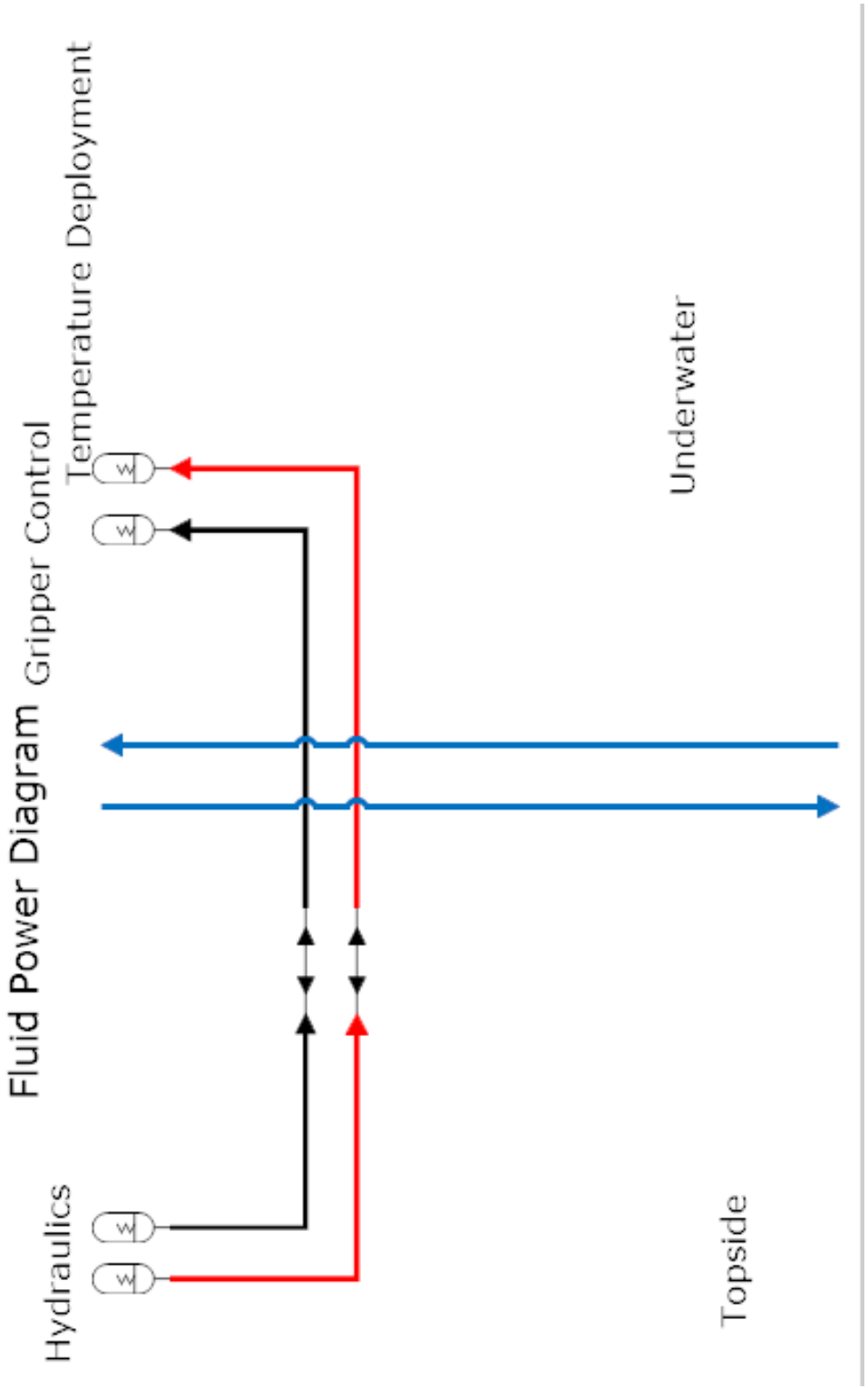
Appendix A

System Integration Diagram



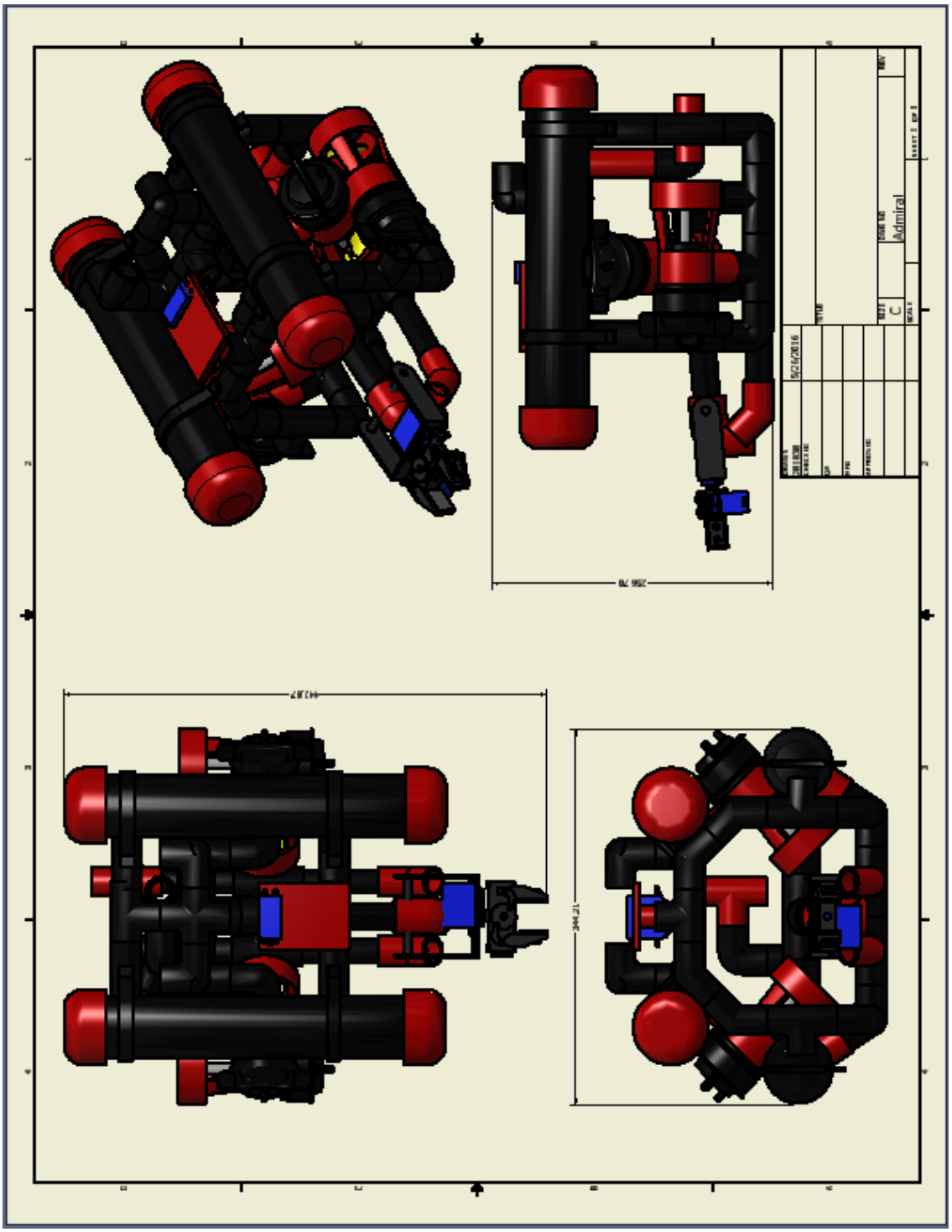
Appendix B

Fluid Power Diagram



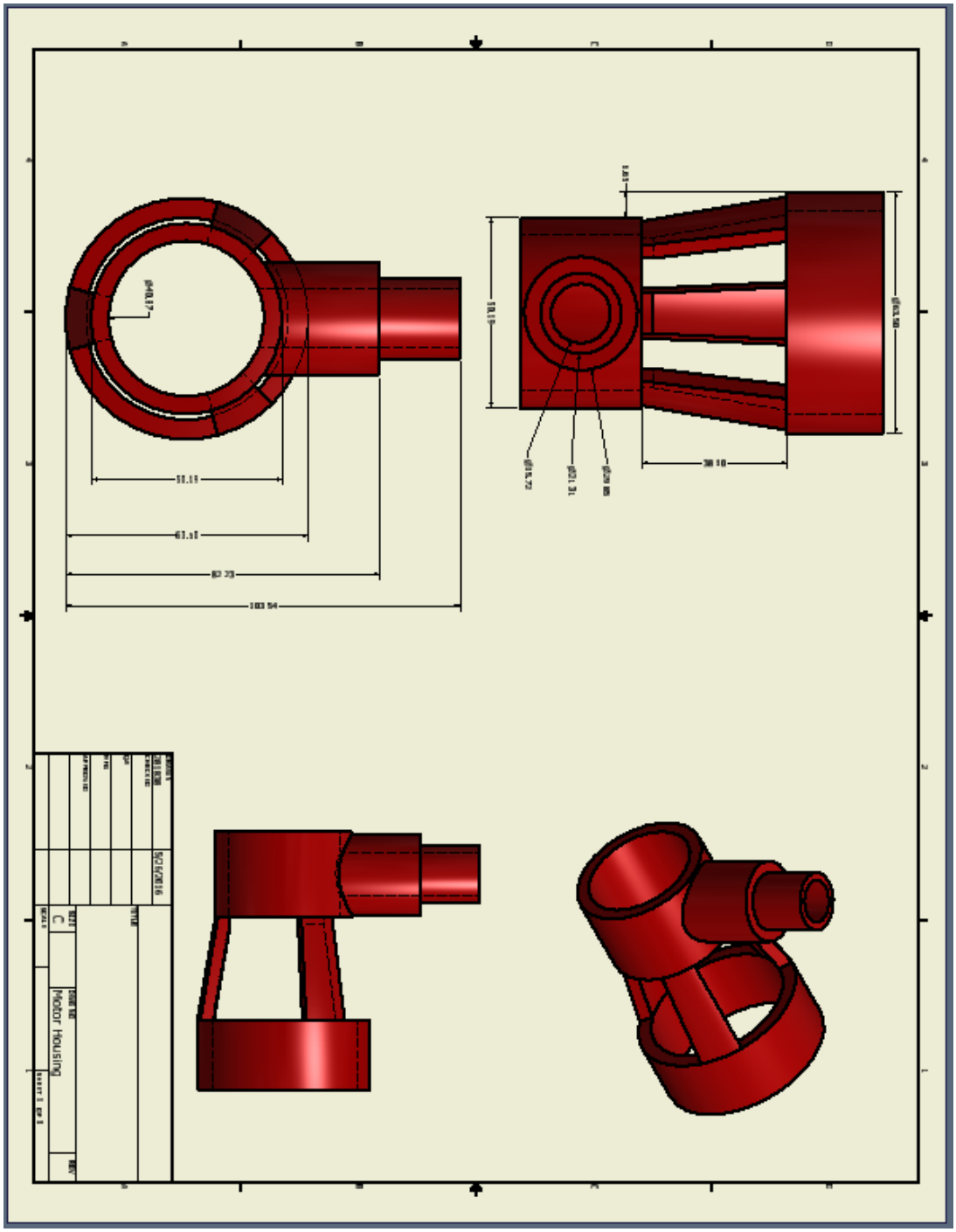
Appendix C

ROV IDW File



Appendix D

Motor Housing IDW File



Appendix E

Servo Mount for Camera Pan and Tilt IDW File