ABS (Acrylonitrile-Butadiene-Styrene)
model of the Seawolf V

Seawolf V

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(Assistant Pilot, Precision Machining, Drafting)
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Gage Pinson (Engineering, Fundraising)
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Mentors:
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Mr. Wes Burkett (Drafting)
Mr. Carey Williamson (Electronics)
Mrs. Celeste Williamson (PR)

Seawolf Underwater
Robotics Engineering
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A. Abstract

The 2016 request for proposal (RFP) calls for a Remotely Operated Vehicle (ROV) capable of exploration on Jupiter's Europa and in the deep water environment of the Gulf of Mexico; efficient in design, construction, and operation; and light-weight/compact enough to ship affordably. Space travel today is being conducted by private companies, not just NASA; so justifies the RFP in which Seawolf Underwater Robotics Engineering (S.U.R.E.) has thoroughly fulfilled.

S.U.R.E. is an education/technology company headquartered in Wesson, Mississippi, United States of America. Our nine-member company focuses on physics, drafting, precision machining, electronics engineering, mechanical engineering, and business/entrepreneurship in order to deliver superior products and services. S.U.R.E.'s talented company members work rigorously as a team within a safe working environment to further technology and use education as the vehicle to drive progress in the future.

Seawolf V is S.U.R.E.'s 2016 effort to meet current demands for a vehicle capably equipped with state-of-the-art, reliable technologies to explore Europa and the deep waters of the Gulf of Mexico. Our company utilizes the latest technologies to create our vision including Computer Numerical Control (CNC) milling machines; National Instrument's LabVIEW, AutoCAD, and SolidWorks software; in-house 3D printing; and countless other advanced technologies. With an attention to detail in design and materials, use of state-of-the-art technologies, and superior teamwork and leadership, Seawolf Underwater Robotics Engineering is proud to present Seawolf V: the best ROV to explore and conduct research on Jupiter's Europa and in the Gulf of Mexico.

Figure 1: S.U.R.E. Company members (l to r) Front: Blake Pryor, Lauren Westrope, Kevin McCone (Mentor), Reginald King; Back: Carey Williamson (Mentor), Colby Phillips, Thomas Westrope and Gage Pinson.
Not Pictured: Charles Miles, Wes Burkett (Mentor)
Photo credit: Celeste Williamson (Mentor)

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B. Design Rationale:

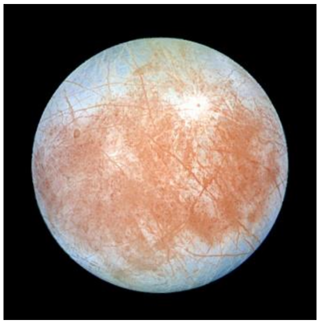

Figure 2: Jupitor's Europa.

1. Overview:

The work behind Seawolf V can be categorized into three important phases: conceptual, design, and machining. These processes were completed in order and in close collaboration to produce our superior product.

2. Concept:

An early design included a Manta ray shaped ROV with a more-wide-than-tall form factor. Much thought was put behind this design because it would eliminate a large amount of water resistance and increase control. One company member wanted to do a hub cap design and another member suggested a Star Trek Enterprise style ROV. Ideas were flowing, CAD drawings were being created, edited, and demonstrated daily. The creative genius spirit of S.U.R.E. was being throttled to the fullest. When MATE released the 2016 competition manual, we had to go back to the drawing board because none of these designs would work for the 2016 RFP. Seawolf V's design includes an enclosure tube (E-tube) as the central design element due to the size constraints placed on our ROV's intended use which includes the economically-reasonable transportation of Seawolf V to Jupiter's Europa. Instead of building a frame with all the components attached including the electronics enclosure box (E-box), we would build an ROV as a tube and mount everything to the tube. This has proven to bring innovative ideas into designing Seawolf V with at least half the size and weight of Seawolf IV while maintaining the high quality reputation for which S.U.R.E. is known.

3. Design:

Our talented drafting members took this concept of a cylindrical electronics enclosure tube (E-tube) serving as the central structure and added to and cut the tube to fit components within computer software including SolidWorks and AutoDesk's AutoCAD. Three outside ribs were added to the tube to add support and provide mounting holes for the legs and thruster mounts. Thirty-three mounting holes are drilled from the ribs. Two smaller, separate topside ribs (with one hole drilled into each) are placed on the top of Seawolf V to allow for future manipulation of components, however the current configuration features a carrying handle. On the bottom of the E-tube is a bulkhead boss spotface mount. A spotface is a flat area machined onto a round surface to make connectors flush, which makes Seawolf V's electronics enclosure tube both more challenging to design and manufacture. Four legs connected with *¼"-18 x 1 ¾"** bolts (two bolts per leg) serve to suspend the tube when Seawolf V is resting on a surface. For support of the legs, a thruster controller is mounted in between both pairs of legs with four bolts. Carbon fiber

Figure 3: Miniature 3D model of Seawolf V.

*S.U.R.E. uses U.S. Customary bolts because they are more affordable and are more easily available for purchase in our area.

rods were initially selected to use as skids, but during the buoyancy testing of Seawolf V we found the vehicle needed weight added to achieve neutral buoyancy. Stainless steel rods were interchanged to add weight and has resulted in a superior, stable handling experience when piloting Seawolf V.

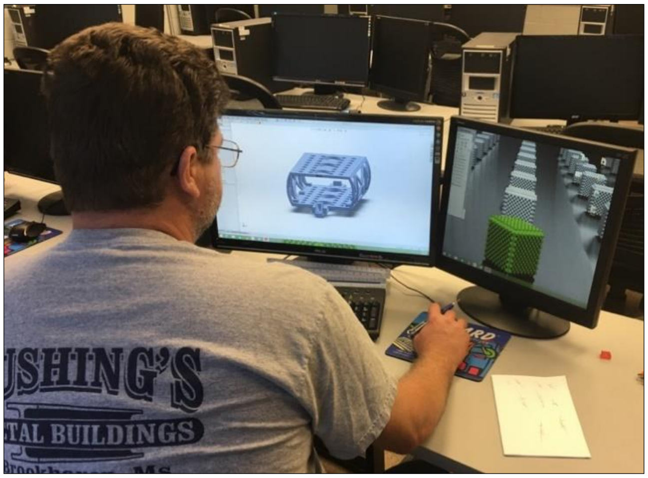
Figure 4: Company member designing E-rack.

Within the E-tube is a custom, in-house designed and printed electronics mounting rack (E-rack). This rack includes two built-in camera mounts that are mechanically able to pan and tilt when controlled by servo controllers. The E-rack was designed with convenience in mind so the internal electronics could be easily extracted from the tube in one piece. The mounting rack is designed in a multi-layer form to allow for the stacking of electronics boards. Also, the mounting rack provides added structural support to the depth pressure the enclosure tube is able to withstand. Enclosing the tube are two acrylic domes measuring 0.3175 cm thick, 17.78 cm in diameter, and 8.89 cm in depth with a 0.635 cm lip. Thirty-two ¼”-18 x 3”* bolts mount Seawolf V’s dome onto the tube with rubber O-ring gaskets in between for proper sealing.

Because the 2016 MATE competition offers bonus points for ROVs that fall under the size constraints of 58 cm, 64 cm, 70 cm, and 85 cm diameter holes, Seawolf V was designed to fall under this RFP size constraint of 58 cm. MATE is also providing bonus points to teams’ ROVs that fall under 17.0 kg, 17.01 kg to 19.0 kg, and 19.01 to 22.0 kg weight dimensions. Seawolf V falls between 17.01 kg and 19.0 kg making it a wise economic choice when considering expensive outer space shipping costs. Trimming Seawolf V with weights and adjusting the skid materials from carbon fiber to stainless steel in order to achieve neutral buoyancy put us over the 17.0 kg threshold, so we balanced our project with proper buoyancy and a lightweight design. We decided to go slightly over the RFP weight limit due to an accounting for our aimed effort to design and construct a structurally sound and stable ROV in the unknown environment of Jupiter’s Europa.

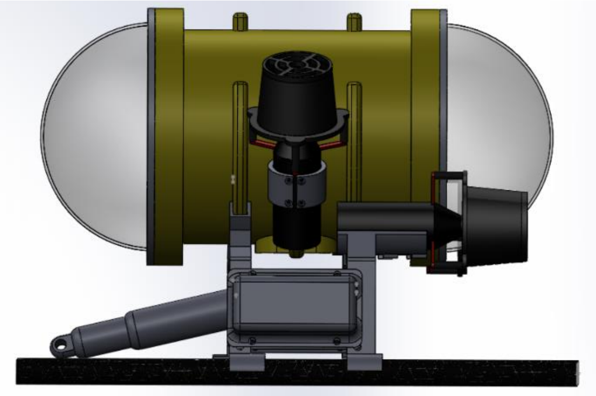
Figure 5: complete drawing of Seawolf V in AutoCAD.

4. Physics:

We chose High Density Polyethylene (HDPE) as the material from which we milled our frame. HDPE is extremely flexible in that its physical form is very easy to work with and once milled yields a strong and dynamically capable product. HDPE can be operated in extreme temperatures (120°C to -100°C) making it a conscious choice to construct an ROV from, which is intended to be sent into the frigid temperatures of Jupiter’s Europa where factors of expansion, contraction, and brittleness/rigidity must be considered.

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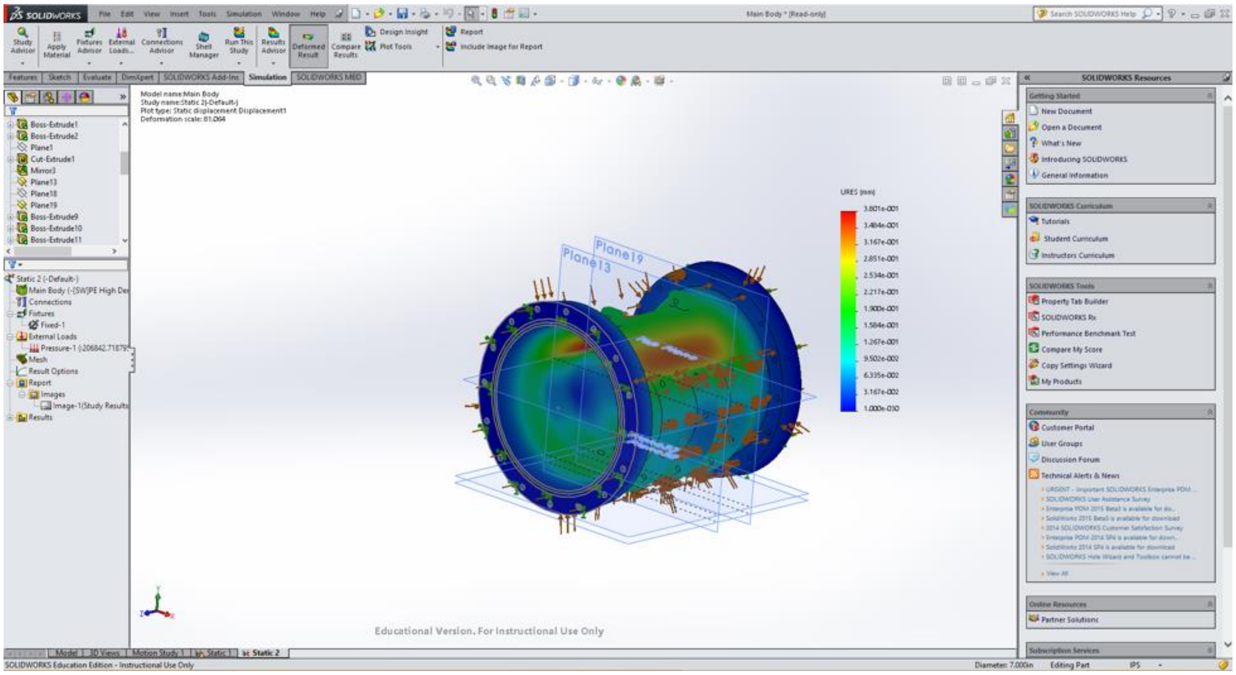
*S.U.R.E. uses U.S. Customary bolts because they are more affordable and are more easily available for purchase in our area.

Figure 6: Solidworks test conducted to determine the center of mass of Seawolf V. The point just below the E-tube is Seawolf V's center of mass.

HDPE's light weight and almost neutrally buoyant characteristics also served as important factors in the Seawolves' decision to use it in Seawolf V's design because these characteristics reduce stress on the thrusters and structural integrity of the compact design. The cylindrical design with the ribs also arose as a physics solution to issues by increasing the structural integrity of the E-tube in terms of deformation due to pressure stress at deep depths. Once we added the ribs, the displacement was significantly reduced in SolidWorks stress simulations. Proper buoyancy was an initial issue that arose after we had completed assembly of Seawolf V. We calculated the initial buoyancy before beginning design work; the buoyancy was determined using SolidWorks as well as the center of mass. Our calculations suspected that we had too much buoyancy. After testing, we exchanged our carbon fiber rods for stainless steel rods to add weight and lower the center of mass to increase stability. Overall, Seawolf V's design has yielded a high quality underwater piloting experience with top-caliber handling and stability.



Model name:Main Body
Study name:Static 2(-Default-)
Plot type: Static displacement Displacement1
Deformation scale: 81.064

Figure 7: SolidWorks pressure test on Seawolf V's E-tube.

5. Machining:

Figure 8: Company member milling E-tube.

S.U.R.E. is fortunate to have a second year machinist on the team who has previous experience with machining ROV parts and other precision machined related tools. The two steps prior to the process of machining (the conceptual and design processes) must be physically possible to machine. This is where engineering issues come into play. Can what I imagine in my head and design in computer software be physically machined and work properly? Is it feasible? What strengths and weaknesses will have to be counteracted? All of this must be examined, edited, and approved by engineers and machinists who will ultimately take the design from the concept and 3D computer renderings and shave from raw materials the finished product. Seawolf V has been constructed using the most efficient machining methods including the Computer Numerical Control Mill (CNC mill) and MasterCam software. S.U.R.E. first considered melting left-over high density polyethylene (HDPE) from past projects to mold into a cylinder. One of our creative engineers experimented with this idea and the results were rather disappointing, but it was something for us to learn from. We proceeded to purchase a tube that is 25.4 cm long from flange to flange, 22.86 cm in outside diameter, and 17.78 cm in inside diameter. A manual lathe was used first to trim down a shape from the HDPE tube to achieve the initial outside and inside diameters. The tube was then applied to a five axis mill/router. Once the body was machined from this method, the material was placed on a three-axis machine to drill out the holes and flanges. Our first manufacture of the tube resulted in a major defect; too much material was milled from the primary wall of the outside diameter. This caused concern about the pressure the tube could experience during missions. The fixture that was made for locating the tube on the five axis machine was incorrectly located (perhaps even .1 inch or 2.54 millimeters). After this issue, a second tube was milled out with close attention to proper dimensions and proper machine use. The result was the superior Seawolf V electronics enclosure tube seen today.

6. Electronics:

Our ROV’s surface components include a Microsoft Windows 7 laptop running National Instrument’s software LabVIEW 2014 connected to a network router via ethernet jack (RJ45). The router communicates with a 4-channel video decoder (AXIS P7701) connected through a DVI to VGA converter which then

Figure 9: Company members inspecting Seawolf V's software response status before launching.

connects to a television displaying video playback from the two 2.1 mm wide angle lens, SD cameras equipped on Seawolf V. Utilizing our video encoder and decoder, the video playback is automatically displayed on the television in up to four windows at one time; however, because we only have two cameras connected in the current configuration only two windows of video playback are displayed. The LabVIEW software controls our four Crust Crawler 400HFS-L thrusters, two cameras (pan and tilt on both) and a linear actuator (the device which controls the movements of the manipulator) via an XBOX controller. The orientation of the ROV can be viewed through the software due to the communication of the Sparkfun Razor IMU (includes a gyroscope, magnetometer, and accelerometer) which can measure 9° of freedom. The software is highly flexible in that it can easily be reprogrammed to fit the needs of missions.

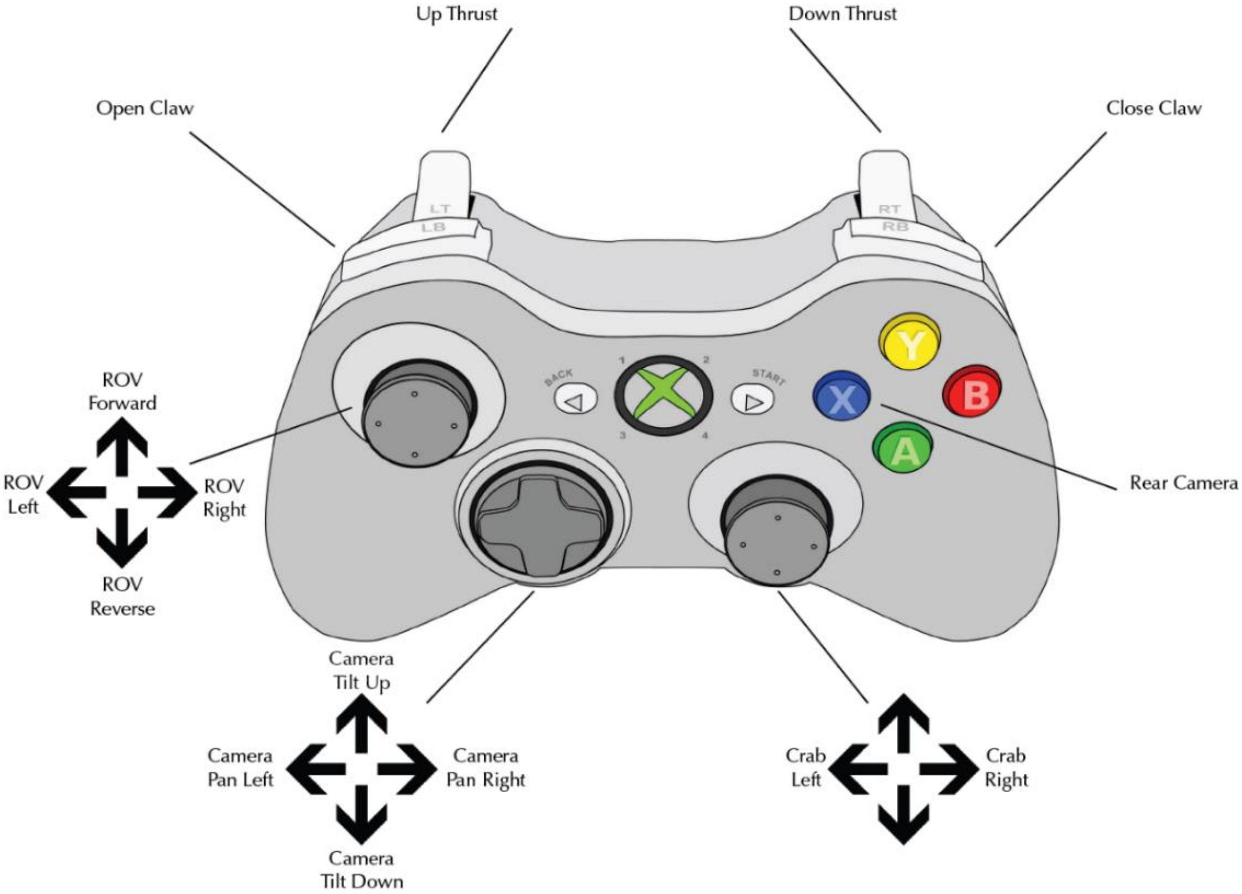


Figure 10: Labeled XBOX controls for Seawolf V.

Where Seawolf V's tether connects to the 48V power supply, a 30A slow-blow fuse is utilized to protect the ROV from power failures. Seawolf V's tether includes three cables: Ethernet, power, and ground. The tether connects to two Subconn micro-circular bulkhead connectors on the underside of the cylindrical electronics housing of Seawolf V; the two connectors are power and ethernet. Concerning the other bulkhead connectors, two connectors provide power and communication to the thrusters and thruster microcontrollers. Having four microcontrollers (one for each thruster) on the exterior of the ROV provide great benefit in that heat dissipation on the outside of the ROV is much easier to achieve than inside the electronics housing, preventing system failures due to overheating. The vertical and horizontal thrusters on one side of the ROV share a connector and the opposite vertical and horizontal thrusters share a connector as well. An additional bulkhead connector provides power and communication to the linear actuator. Two bulkhead connectors are designated for the future addition of an exterior camera and exterior lighting system. Seawolf V is equipped with two more spare bulkhead connectors in the case that future equipment may be added, providing flexibility to the adaptation of our ROV. Because the size constraints placed on the RFP designs, of Seawolf V's onboard electronics posed a unique challenge in designing within this compact theme. The interior electronics systems include the primary motherboard, video encoder board, 12V and 5V DC-DC step-down converters, a temperature sensor, and a water pressure sensor. The Automation Direct PTD25-10-0015H water pressure sensor measures the water pressure outside of the tube to formulate a depth measurement which can be used on the surface to assist in piloting. To monitor onboard temperatures, a Tmp35 analog temperature sensor is utilized. Four Hitec HS-65HB Mighty Feather micro servos (two for pan, two for tilt) angle the cameras for optimal viewing experience. The servos operate at 5V with stall torque at 2 kg/cm. Our cameras are mounted on custom, in-house designed and printed mounts.

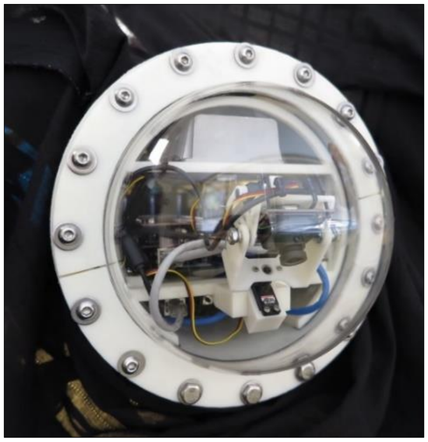


Figure 11: One of Seawolf V's cameras installed inside E-tube on E-rack camera mount with functions of pan and tilt operated by servos.

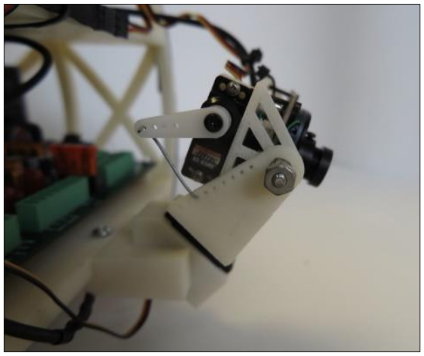


Figure 12: One of Seawolf V's cameras mounted on S.U.R.E. custom in-hour camera mounts

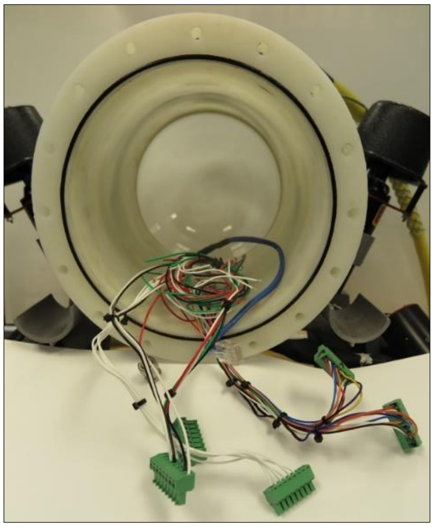


Figure 13: E-tube prior to installation of E-rack.

Seawolf V Motherboard Fabrication

Figure 14

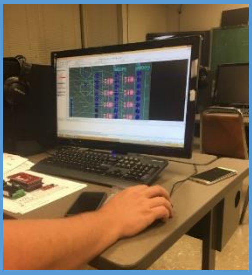


Figure 15

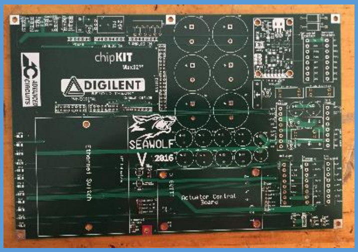


Figure 16

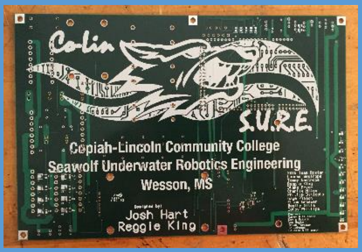


Figure 17

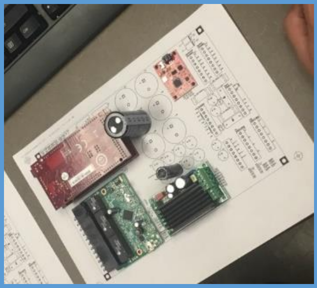


Figure 18

Figure 19

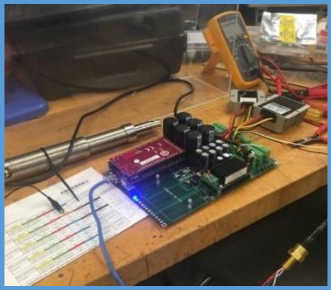


Figure 14: Designing the motherboard.
Figure 15: Top of printed motherboard, unpopulated.
Figure 16: Bottom of printed motherboard, unpopulated.
Figure 17: Testing component alignment prior to installation on the motherboard.
Figure 18: Populated Seawolf V motherboard.
Figure 19: Testing motherboard and DC to DC step-down converters before installing other systems.

Our in-house designed motherboard serves as the primary device which communicates with all devices on the ROV. Our goal this year was to include as many components on one board as possible to fit Seawolf V's electronics components within a highly compact enclosure. The motherboard includes the Digilent Max32 chipKIT input/output connection, temperature sensors, the Ethernet switch (the main portal of communication), actuator control board, four 5V switching circuits, four 12V switching circuits, three 12V camera outputs, 48V power supply input, Razor input/output connection, water pressure sensor input, H-bridge output, six large 6800 μF 63V filter capacitors, and eight medium 560 μF 63V filter capacitors (for voltage conditioning). Also included on the motherboard are eight detachable Wurth connectors. These connectors

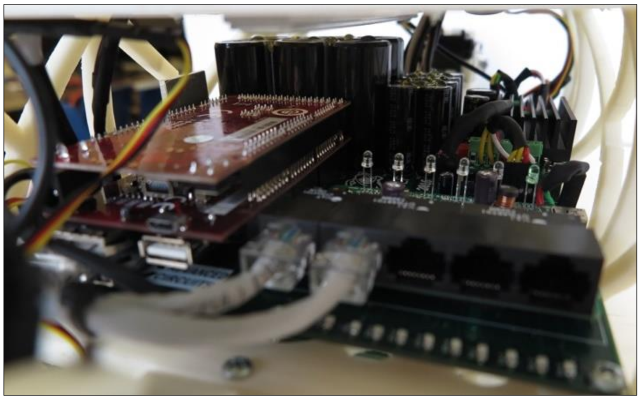


Figure 20: Motherboard and stacked system boards mounted onto E-rack.

are the primary connections to any components which are not directly soldered onto the board including connections to the bulkheads, camera servos, water pressure sensor, internal lighting of the tube, and to the DC-DC convertors. These provide quick interconnect to the motherboard. The 3A H-bridge output is included for future DC motor control of mission specific tooling. Header pins and cables connect devices including the Razor chipKIT, ethernet switch, actuator control board, water pressure sensor device, and the temperature sensors. Twelve status indicator LEDs are installed on Seawolf V's motherboard (8 for the switching circuits and 4 for the power supply) to display Seawolf V's operation readiness when powered on. Overall, Seawolf V's electronics systems have been precisely engineered for optimal performance. Serious time and thought was spent to ensure the electronics systems could fit inside a small enclosure and operate without failure. The product of this effort has proven to yield a high quality ROV electronics system which is highly capable to explore and complete missions to Jupiter's Europa and the Gulf of Mexico. Please refer to Appendix 1 to view the Seawolf V's System Interconnection Diagram (SID).

Figure 21: DC - DC step-down converters shown with detachable Wurth connectors

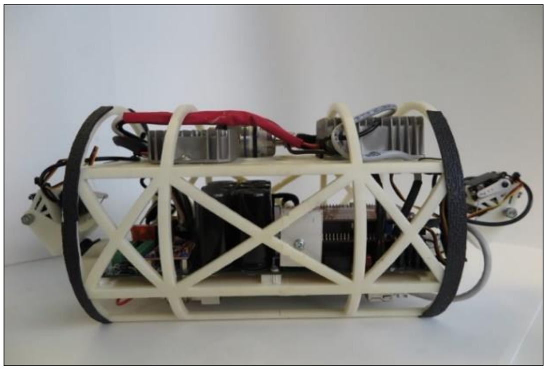


Figure 22: Side view of the populated E-rack

7. Thrusters:

For transportation, Seawolf V is equipped with four Crust Crawler 400HFS-L thrusters which operate at 4.54 kgf max burst thrust and 2.72 kgf normal operation thrust. S.U.R.E. spent much energy and discussion in appropriately selecting these thrusters with the thought in mind "do more with less." The previous generations of Seawolf utilized Seabotix BTD150 which operated at 2 kgf forward and reverse thrust, making the Crust Crawler thrusters a powerful upgrade in thrust output for Seawolf V. The Crust Crawler thrusters utilize a high efficiency brushless design which is partly why the thrust values are greater than that of the Seabotix thrusters, operating at a max burst power of 400W over the Seabotix's 100W. The

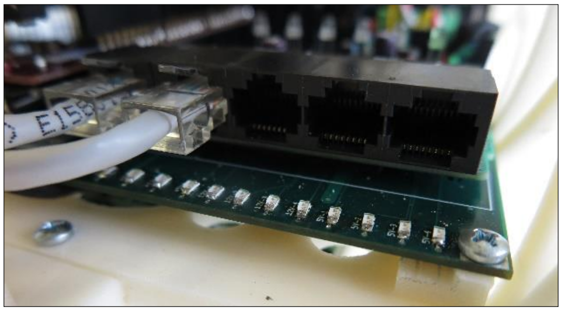


Figure 23: LED status indicators on motherboard.

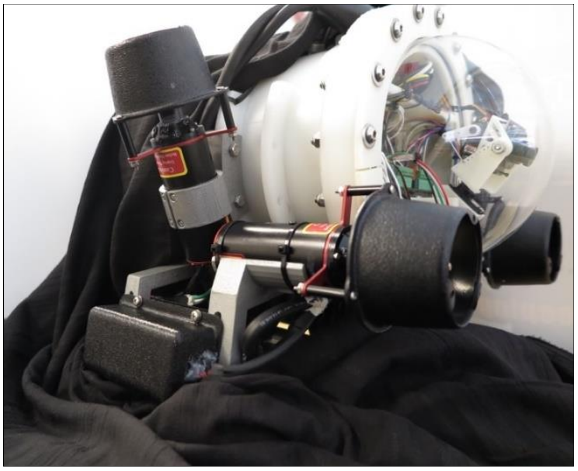


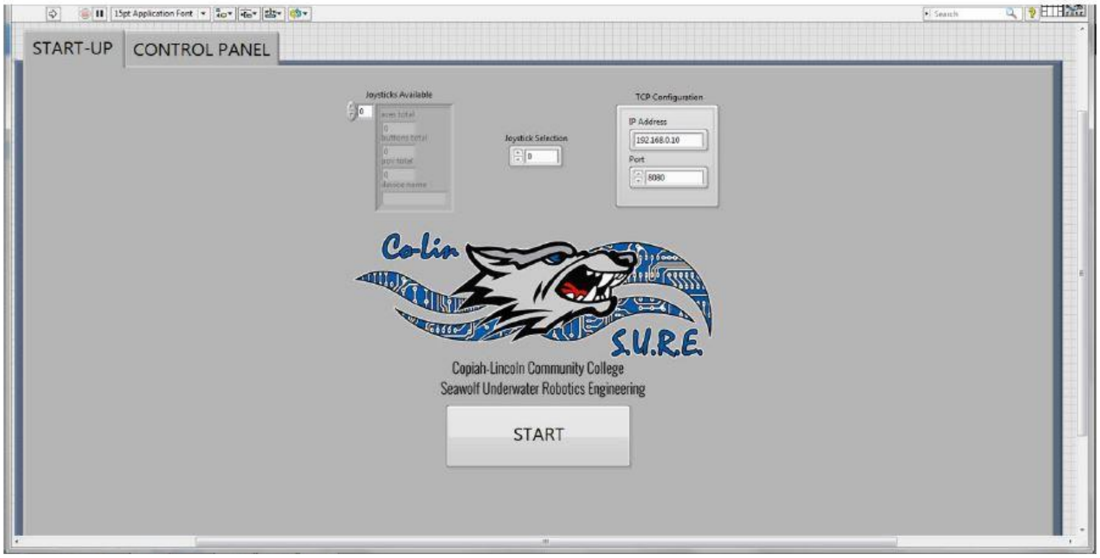
Figure 24: Installed thrusters and controllers

Crust Crawler thrusters equipped on Seawolf V operate at 48V and are limited to 4A for normal use. Overall, a significant performance increase has been observed on Seawolf V with the addition of the Crust Crawler 400HFS-L thrusters.

C. Software:

Seawolf V continues to utilize the reliably proven National Instruments LabVIEW software. This software employs a user friendly Graphical User Interface (GUI), making it easy to adjust commands yet complex enough to handle the control inputs of Seawolf V's electronic systems. LabVIEW allows Seawolf V to be operated with a laptop computer by which the computer conducts the bulk of data processing quickly which is preferable to putting the stress on the onboard microcontroller. Ultimately reasoning the difference in CPU performance between Seawolf V's microcontroller and the piloting computer, communication and performance is significantly increased by placing the majority of the processing workload on the piloting computer and LabVIEW software.

Within one of the sub VI's is the code which commands Seawolf V's Auto Hover function. In the case that Auto Hover is not selected, the ROV's vertical thrusters are controlled by the XBOX controller during which all thrusters rotate at the same speed. When Auto Hover is selected, it examines the depth value from the water pressure sensor and attempts to maintain that value. If the value increases or decreases, the thrusters will output accordingly to reposition Seawolf V at the appropriate depth. Please refer to Appendix 2 to view the Software Flow-Chart and Appendix 3 for the Software/ROV Troubleshooting Checklist.



Joysticks Available: 0
axes total: 0
buttons total: 0
povs total: 0
device name:

Joystick Selection: 0

TCP Configuration
IP Address: 192.168.0.10
Port: 8080

Figure 25: Our front panel controls startup screen. At this screen, one can select an available controller to drive with, connecting to the IP address that is assigned to the chipKIT microcontroller

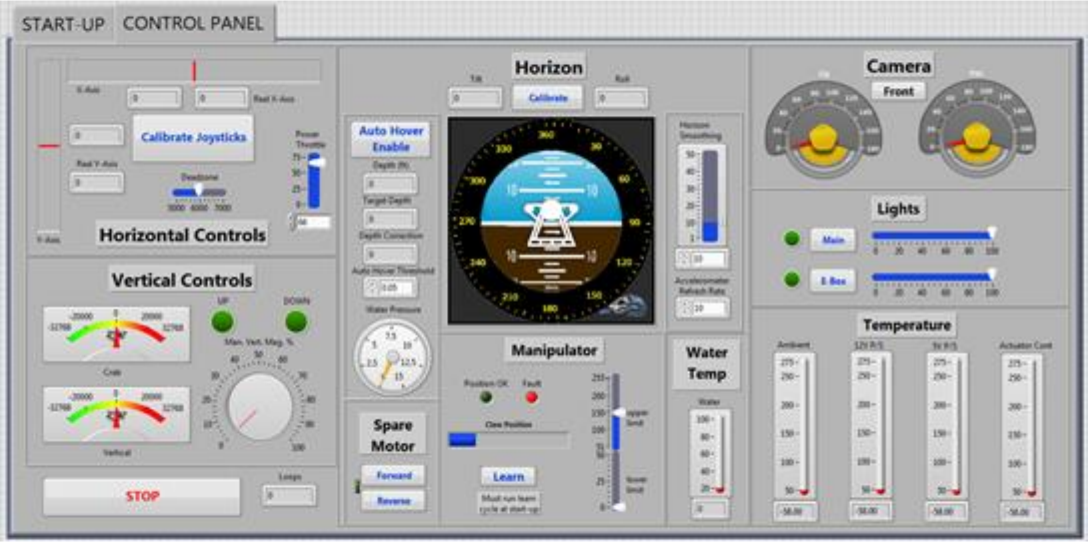


Figure 26: The front panel once communication is complete. Provided is the controller values for the thrust, camera servo positions, water pressure/depth/ temperature, temperature readings for DC-DC converters, ambient temperature, and a horizon indicator representing the orientation/position of Seawolf V.

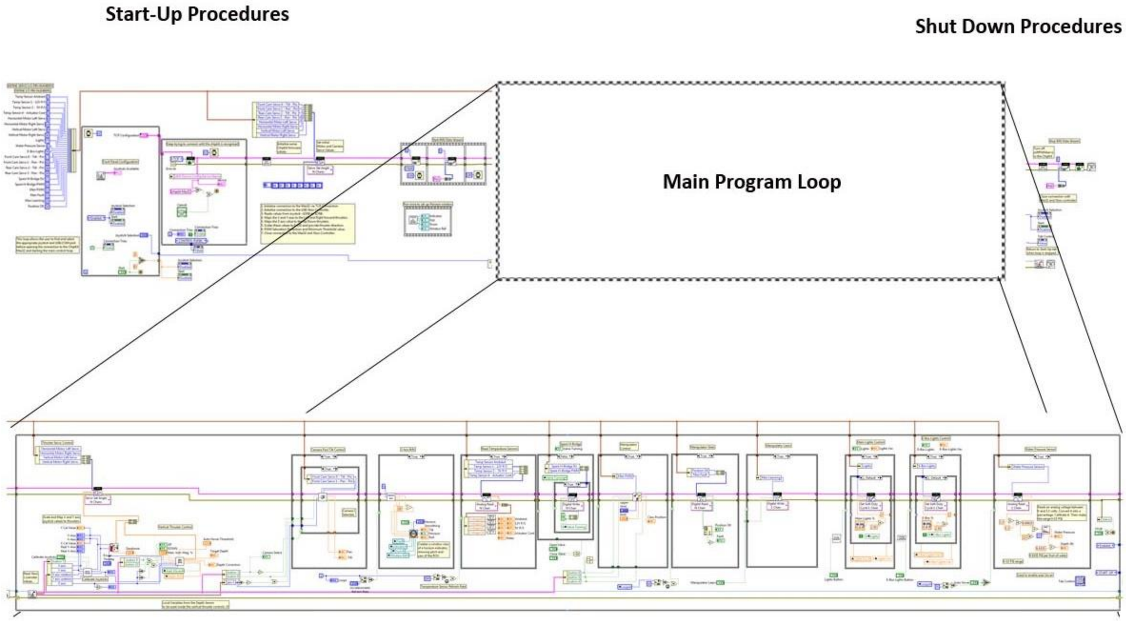


Figure 27: SURE's block diagram in LabVIEW software which ultimately controls Seawolf V. Each small sub VI contains additional code.

D. Tooling:

1. Temperature Sensor:

A simple analog temperature sensor was chosen to be installed on the exterior of Seawolf V to measure the temperature of specific water vents located on Europa. The chipKIT microcontroller relays temperature data to the pilot computer.

2. Water Pressure Sensor:

The water pressure sensor installed on Seawolf V measures the depth at which Seawolf V is located underwater. The water pressure recorded by the sensor is converted to a depth reading within the LabVIEW software. Seawolf V's Auto Hover feature within the software communicates with the depth reading to maintain vertical location. This greatly assists when piloting Seawolf V in deep water environments.

3. Actuator and Manipulator:

In the past two generations of Seawolf, S.U.R.E. has utilized a hydraulics system to power the mechanical manipulator which has performed superiorly within the environments the ROVs were designed for. Because Seawolf V is designed with space exploration in mind, we felt that an electronic power manipulator via a linear actuator would be better suited to operate in the thought-to-be harshly frigid temperatures of Jupiter's Europa with factors of expansion, contraction, and brittleness/rigidity in mind. Seawolf V is equipped with a Concens LA35 linear actuator which has a 400 N load capacity, 50 mm stroke, 16 mm/s speed, and Hall sensing technologies for position data. The actuator communicates with a C2-20 advanced actuator controller board that offers multiple control function and operates with less than 20% ripple effect. Seawolf V's manipulator is an in-house design and print utilizing AutoCAD and 3D printed ABS plastic. A three claw design was agreed upon for ultimate simplicity and function. Due to weight constraints, the one-degree axis was chosen to be utilized in the design of the manipulator. The third claw was added to the design because the manipulator does not rotate 360°. The manipulator's claws are laser cut from stainless steel.

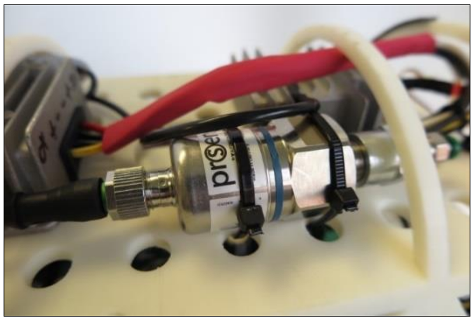


Figure 28: Water pressure sensor

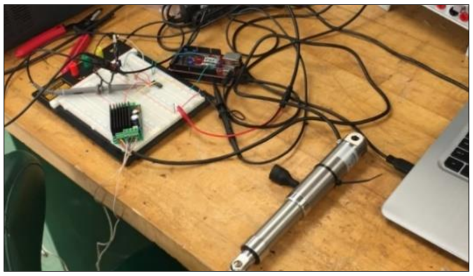


Figure 29: Testing the Concens linear actuator's Hall sensing technology.

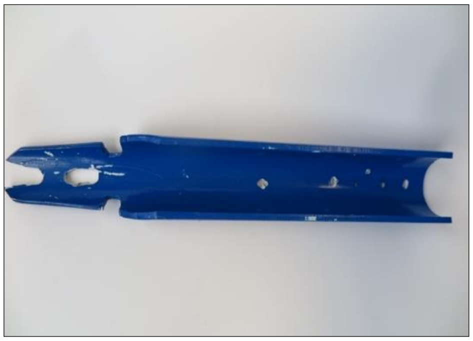


Figure 30: Milled PVC Thomas tool (T-tool) used on the rear side of Seawolf V to assist in mission work.

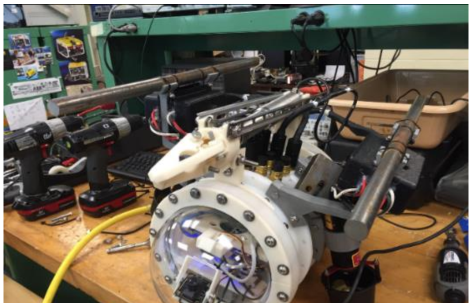


Figure 31: (ROV inverted) custom in-house 3D printed manipulator installed. Also shown are the bulkhead connectors.

E. Safety:

Our company members underwent proper safety training before beginning design, manufacturing, and testing Seawolf V. The Seawolf Company's safety officer Colby Phillips met with Copiah-Lincoln's Workforce Training Specialist Randy Castilaw to schedule a series of safety training sessions to take place over the 2015-2016 year. Colby Phillips also undertook one-on-one training under Mr. Castilaw and studied the Occupational Safety and Health Administration's (OSHA) safety manuals, further discussing coherence with OSHA's workforce standards. After meeting with Mr. Castilaw, Colby would return to company headquarters and announce the training sessions the company would undertake and review proper safety procedures. The company scheduled five sessions including Slips, Trips, and Falls (one hour duration); Electrical Safety (thirty minutes duration); Personal Protective Equipment (PPE) and Hand Tool Safety (one hour duration); Adult Cardiopulmonary Resuscitation (CPR) and Automated External Defibrillators (AED, one hour duration); and Adult First Aid (two hours duration).

Figure 30: Company members undergoing safety training session.

Slips, Trips, and Falls covered how to treat the body in the case of a slip, trip, or fall and how to prevent these accidents. Flip flops and other open toed shoes are not permitted within the work environment. The primary safety precaution to take in preventing accidents is keeping the workplace environment clean and free of safety hazards. Electrical Safety reviewed proper safety techniques when working on electrical components including being careful when working over live circuits and live wires, wearing proper personal protective equipment, and being sure that electrical components are powered off before beginning work. Personal Protective Equipment (PPE) and Hand Tools analyzed wearing the proper clothing within the work environment including lab coats, gloves, goggles, steel toe boots, and Hazmat suits. Proper hand tool procedure included basic rules to follow, but most importantly it related that keeping the work environment clean and tidy is the best preventive for accidents when using hand tools. Adult Cardiopulmonary Resuscitation (CPR) and Automated External Defibrillators (AED) reviewed what to do in the situation that a company member collapses into unconsciousness and if his or her heart stops beating. Mouth-to-mouth resuscitation (with and without a mask) was demonstrated and

Figure 31: Company member demonstrating proper eye protection

practiced using a prosthetic manikin. Adult First Aid included basic first aid procedures to undergo in the case of accidents and bodily damage including proper sterilization, treatment, and equipment usage.

Co-Lin’s Seawolf V is painted using water resistant techniques using the colors orange, yellow, and grey to provide a visual safety feature. From distances and up close, Seawolf V is highly visual allowing swimmers, fish, and other underwater vehicles to see Seawolf V easily. Seawolf V’s LED indicators within the enclosure tube light up when Seawolf V safely powers on. Thruster shrouds are installed in front of the propeller shafts and painted yellow for safety. The company does not require two or three people to transport Seawolf V as it did to transport Seawolf IV. One person can handle it safely, provided the ultra-portable and compact design. Seawolf V also includes a carrying handle at the top of the electronics enclosure tube for easy lifting and carrying. The machine is under eighteen kilograms, making it safe to transport by means of one fully-grown adult. Safety is extremely important at S.U.R.E. Each team member has been thoroughly mentored on using proper safety techniques; careful thought was put into the inclusion of safety features included in Seawolf V’s design. Please refer to the Safety Check-List in Appendix 4.

F. Experience Reflections:

"Through my time at Co-Lin, the MATE robotics competition has been one of my most enjoyed experiences. I must thank Carey Williamson and Kevin McKone for starting this program and working so diligently to make it all possible. I look forward to this year's and next year's!" Reginald King (pilot, electronics engineering)

Reginald King (Pilot, Electronics Engineering)

Figure 35: Reginald King completing his pre-pilot protocol.

Figure 34: Blake Pryor and the Seawolf V team look over a draft of the tech report.

I have family that work for one of the world’s largest ROV companies. It is of course unfeasible for me to go to work with them…However, I have learned so much about what they do from the collaborations and work I have completed at the Seawolf company. A year ago I was very unSURE of myself when talking about the components of the ROV, though I could fully explain them in written word. Being a member of this great company has made me so much more SURE of myself in both my individual and teamwork professional skills.

Blake Pryor (CFO, Technical Writer, English)

“Adequate pool time is perhaps the most important time before competition…”
Dr. McKone (Physics Mentor)

Figure 32: Dr. Kevin McKone hosting interested parties inside S.U.R.E. headquarters.

Figure 33: Thomas Westrope is demonstrating how the E-tube and domes are water tight.

“This year has been a challenge for me, a challenge that has once again provided me with fantastic learning opportunities. I am very grateful for our company members and the MATE organization.”
Thomas Westrope (Assistant Pilot, Precision Machining, Drafting)

“Two years at S.U.R.E. has pushed me in challenges above what I could have imagined. I have learned innumerable things about the world around ROVs and simultaneously earned confidence in my work. S.U.R.E.’s exceptional teamwork and leadership is key to success!”
Lauren Westrope (CEO, PR, Drafting)

Figure 33: Lauren Westrope displays Miniature 3D model of Seawolf V.

Figure 35: Charles Miles attaching the acrylic domes to the E-Tube.

Being on the Robotics Team has been an amazing experience for me. The process of starting with an idea, seeing that idea become a draft, and that draft becoming an actual product is astounding. I have learned how teamwork is essential to success and how much you learn from failure rather than triumphs.
Charles Miles (Missions Facilitator, Engineer, Electronics)

G: Issues/Lessons Learned:

1. Machining errors— The initial milling of Seawolf V's E-tube yielded an unsatisfactory product. The machine milled out too much material from the outside diameter of the tube. This caused concern about the amount of depth pressure the E-tube could withstand, and after running simulations in SolidWorks we learned that Seawolf V's E-tube would fail after traveling a certain distance within our goal water resistance level. The fixture which was created for locating the tube on the 5-axis machine was incorrectly located, perhaps even one-hundred thousandths of an inch (.1 inch or 2.54 millimeters) too much. We then re-ordered the same cylinder of HDPE we ordered previously and began the milling process (round two) with careful concentration in not repeating the error we previously made. This result was the highly durable E-tube we originally envisioned.

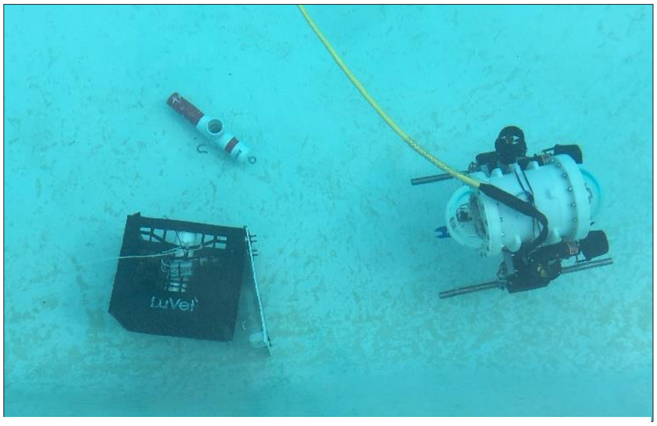


Figure 36: The completed Seawolf V is equipped with stainless steel skids to achieve proper buoyancy.

2. Buoyancy— Our initial calculations proved that we might have issues with buoyancy before trimming Seawolf V with weights. The design team worked with this in mind and attempted to counter this with modifications in the software before the machining process began. When Seawolf V's assembly was completed and testing began, we found that we had a positively buoyant device. The design we originally agreed upon utilized hollow carbon fiber skids mounted to the bottom of the legs. Initially, S.U.R.E. thought it could add weight to the ROV by adding weights inside the skids, but then if the weights were not balanced properly within the skids it might add a teeter-tottering effect. The team researched, calculated and then concluded to use stainless steel rods cut to the proper length and weight to trim out Seawolf V, keeping the machine's design clean and simple without weights zip-tied onto the sides of Seawolf V.

3: Future Improvements— Seawolf V is the best design S.U.R.E. has ever created in terms of portability and cost effectiveness. With regard to improvements, of course there are things that could be improved. Perhaps higher quality cameras could be installed, a higher quality manipulator could be designed and printed, and more efficient architecture building processes could be utilized in the design of the electronics board. With humans, *error is always present* regardless of who designs a product and how much money is used to construct a product. S.U.R.E. knows this just like major tech companies such as Apple, Samsung, and Microsoft know this. It is our unique collaboration in making conscious choices when faced with these issues that sets S.U.R.E. apart from the rest. Six members of the company will be moving on after this year, while only three members will be returning. Recruiting new company members will be a challenge in the future, something the returning members will have to improve on. Fundraising and outreach is another area that could be improved on. The Seawolves' success in the 2015 competition garnered much attention on social media and in the local press, though 2016 has been a challenge to involve more of the community. A radio interview was scheduled prior to the 2016 competition with the intention to create a following movement within our community. The Seawolf company has scheduled a post-competition follow-up interview with SuperTalk Southwest Mississippi, WQRO 102.1. S.U.R.E. is constantly working with the local press to keep the local community updated. S.U.R.E. also operates a Facebook page at https://www.facebook.com/colinseawolves with regular updates. In addition to our outreach efforts, S.U.R.E. has contacted rocket/spacecraft industry leader SpaceX for a quote of how much it would cost to send Seawolf V to Jupiter's Europa; however, there has been no reply. Considering our hard work, involving the community is a challenge we have met but could improve on in the future. Please refer to Appendix 5 to view our e-mail to SpaceX.

H. Budget and Project Costing:

1. Budget Overview: S.U.R.E. began meeting in August 2015 to discuss planning for the 2016 MATE ROV competition. The company had about $3,500 in its account. One of the major purchases S.U.R.E. members agreed on was the purchase of new thrusters. Seabotix BTD150 thrusters have been utilized since Seawolf I. The first Seawolf ROV included four; by Seawolf IV, eight Seabotix thrusters were utilized. These thrusters were a wise investment considering they had been utilized for four years. However, the way to progress is not to remain stagnant, resting on top of tradition or legacy. S.U.R.E. budgeted $3,200 from its account to purchase new Crust Crawler 400HFS-L thrusters and thruster controllers which would add superior mobility and efficiency to the Seawolf line. This left S.U.R.E. with $300 in its account. Rigorous outreach and fundraising was planned early on. Included is a chart of the budget we planned on in August 2015; these are the estimations we made at the beginning of the year. The project costing demonstrates S.U.R.E.'s successful budget planning and efficient team work for the 2015-2016 fiscal year.

2. 2015-2016 S.U.R.E. Budget Table

Month designated for purchases/fundraisers	**Items/material/fundraisers**	**Amount budgeted**	**Account balance beginning at $3,500**
August	4 Crust Crawler 400HFS-L thrusters & 4 Crust Crawler thruster controllers	-$3,200	$300
September	HS robotics event, sale of concessions at Co-Lin	+$500	$800
October	Co-Lin Homecoming refreshments	+$100	$900
October	HS robotics "Screamage" concessions at Co-Lin	+$300	$1,200
November	Purchase ROV materials	-$500	$700
December	Mission props	-$250	$450
January	Donations/grants	+$7,500	$7,950
January	Electronics materials	-$750	$7,200
February	Purchase company uniforms	-$1,500	$5,700
March	Martial arts competition fundraiser	+$750	$6,550
April-June	General costs	-$100	$6,450
May	Collection of Co-Lin candy sales	+$500	$6,950
June	Travel/lodging costs to MATE competition in Houston	-$3,500	$3,450
Ending Budget Balance			$3,450

3. 2015-2016 S.U.R.E. Project Costing Table

type	source	item	quantity	price	total	account balance
Beginning Balance						**$3,500**
purchase	Crust Crawler	400HFS-L thruster	4	$599.00	$2,396.00	$1,104.00
purchase	Crust Crawler	Phoenix EDGE HV-60 thruster controller	4	$199.00	$796.00	$308.00
fundraiser	First Robotics	Selling concessions	NA	NA	$497.00	$805.00
fundraiser	Homecoming	Selling concessions	NA	NA	$61.00	$866.00
fundraiser	Robotics “Screamage”	Selling concessions	NA	NA	$401.00	$1267.00
purchase	Nationwide Plastics	2x9” HDPE tube	1	$159.00	$159.00	$1,108.00
purchase	Ace Hardware	Misc.	NA	NA	$98.45	$1,009.55
donation	Concens	LA35 linear actuator	1	$500.00	NA	NA
donation	Concens	C2-20 actuator controller board	1	$200.00	NA	NA
donation	Georgia-Pacific	Monetary donation	NA	NA	$5,000	$6,009.55
purchase	Automation-Direct	Water pressure sensor	1	$125.00	$125.00	$5,884.55
purchase	Amazon.com	Hitec 33065 SHS-65HB Servo	6	$21.53	$129.18	$5,755.37
purchase	Amazon.com	2.1mm lens wide angle mini cameras	3	$14.99	$44.97	$5,710.40
purchase	Newegg.com	Hubbell cable support grip, bus drop	2	$21.36	$42.64	$5,667.76
purchase	Newegg.com	Resin splice kit	2	$49.64	$99.28	$5,568.48
purchase	Mouser Electronics	NA	1	$126.60	$126.60	$5,441.88
purchase	Mouser Electronics	chipKIT Max32	1	$49.50	$49.50	$5,392.38
purchase	Mouser Electronics	chipKIT network shield	1	$54.99	$54.99	$5,337.39
purchase	B&H Photo & Video	Axis comm. 4-channel video encoder	1	$254.15	$254.15	$5,083.24
fundraiser	David Higgs martial arts club	Selling concession and admission	NA	NA	$401.00	$5,484.24
donation	David Higgs	Monetary donation	NA	NA	$300.00	$5,784.24
donation	anonymous	NA	NA	NA	$5,000.00	$10,784.24
Re-purchase	Nationwide Plastics	2x9” HDPE tube	1	$159.00	$159.00	$10,625.24
purchase	Seal Group	O-ring	6	$2.50	$16.05	$10,609.19
purchase	NA	Acrylic domes 1/8”x7”x3.5”	2	$34.50	$69.00	$10,540.19
purchase	T-Tommy’s	First order of company uniforms	20	NA	$204.60	$10,335.59
donation	Tim Jones	Monetary donation	NA	NA	$100	$10.435.59
donation	Co-Lin Foundation	Monetary donation	NA	NA	$1,000	$11,435.59
fundraiser	Co-Lin candy sales	Selling candy	NA	NA	$704	$12,139.59
purchase	MATE	Registration fee	NA	NA	$250	$11,889.59
purchase	Holiday Inn	Competition lodging	NA	NA	$2,737	$9,152.59
purchase	Co-Lin	Travel	NA	NA	$600	$8,552.59
purchase	T-Tommy’s	Formal shirts and t-shirts**	26	NA	…	…
donation	API Wesson, MS	1.5 inch* diameter stainless rods	2	$100.00	$200.00	NA
donation	ExxonMobil	Monetary donation	1	$3,000.00	$3,000.00	$11,552.59
Final						**$11,552.59**

*S.U.R.E. uses U.S. Customary bolts because they are more affordable and are more easily available for purchase in our area.

**Billing is incomplete at the time of this publication.

4. Project Costing Overview Table

	Amount	Subtracted from Beginning Balance
Beginning Balance	$3,500	$3,500
Donations (Monetary)	$14,400	$17,900
Donations (Materials)	($900)	NA
Fundraising	$2,064	$19,964
Purchases	-$8,411.41	$11,552.59

5. Conclusion: As seen from the numbers, S.U.R.E. had a very successful year in budgeting. The primary difference between the 2014-2015 and the 2015-2016 years is the difference in how much we spent on travel to the MATE competition. In 2015, we spent around $10,000 in international travel expenses. In 2016 we will spend less than $3,400. Thoughtful planning went into fundraising. Two of the fundraisers we were successful at the semester before turned out to be unsuccessful the next semester. Our candy sales around the career-technical campus yielded $700. This is incredible considering how little amount of work went into restocking and collecting the money. Generosity has been high this year as well with over $12,100 donated in a combination of capital and capita.

I. Acknowledgements:

Brookhaven Country Club—For the use of their pool for testing before competition. Having adequate pool time and facilities is key to being well prepared for competition.

Marine Advanced Technology Education (MATE) Center—For providing a safe competition medium for students to study marine technologies and in turn help them prepare for the real-world work environment through healthy competition.

Copiah-Lincoln Community College—For providing S.U.R.E.'s healthy learning environment and supporting us through innumerable means.

Georgia-Pacific, Monticello division—For taking interest in our local education company and supporting financially and through encouragement.

Figure 37: Fundraising at Co-Lin martial arts competition.

Howard "Bo" Johnson— (Copiah-Lincoln Community College Precision Machining Technology Department Head) For contribution to the club by opening up your machine shop so that we can use the machines to build our ROV's frames and other supporting systems.

SeaTrepid— Supporting us with materials, through encouragement and providing us with a filming location.

ExxonMobil— Supporting us financially.

I55 Engineering— Providing use of their 5-axis mill.

Canvas Next Door Restorations— For painting Seawolf V and previously painting Seawolf IV's syntactic foam.

Josh Hart— (former S.U.R.E. CEO & Pilot, electronics 2015) for help and mentoring on 2015-2016 electronics boards.

Tim Jones (former S.U.R.E. tether manager, electronics 2015) for supporting us financially and helping with fundraising during the 2015-2016 year.

J. Special Thanks:

Dr. Ronald E. Nettles II—Copiah-Lincoln Community College President

Dr. Jane Hulon—Copiah-Lincoln Community College Vice President of Instructional Services

Mrs. Jackie Martin—Copiah-Lincoln Community College Dean of Career-Technical Education

Dr. Jill Logan—Copiah-Lincoln Community College Dean of Academic Instruction

Mr. Brian Turnage— Copiah-Lincoln Community College Electronics Instructor

Figure38: The Georgia-Pacific Foundation donated $5,000 to SeaWolves Robotics Team. Making the presentation was Doug Hoy, Georgia-Pacific Monticello LLC Public Affairs/Communications (third from left). Pictured l to r: Brent Duguid, Assistant Dean of Career, Technical & Workforce Education; Jackie Martin, Dean of Career, Technical & Workforce Education; Hoy, Dr. Jane Hulon, Vice President of Instructional Services; David Campbell, Executive Director of the Co-Lin Foundation/Alumni Affairs; and Dr. Jill Logan, Academic Dean.

K. References:

LABVIEW HACKER. (2016) *LabVIEW hacker.* http://www.labviewhacker.com/

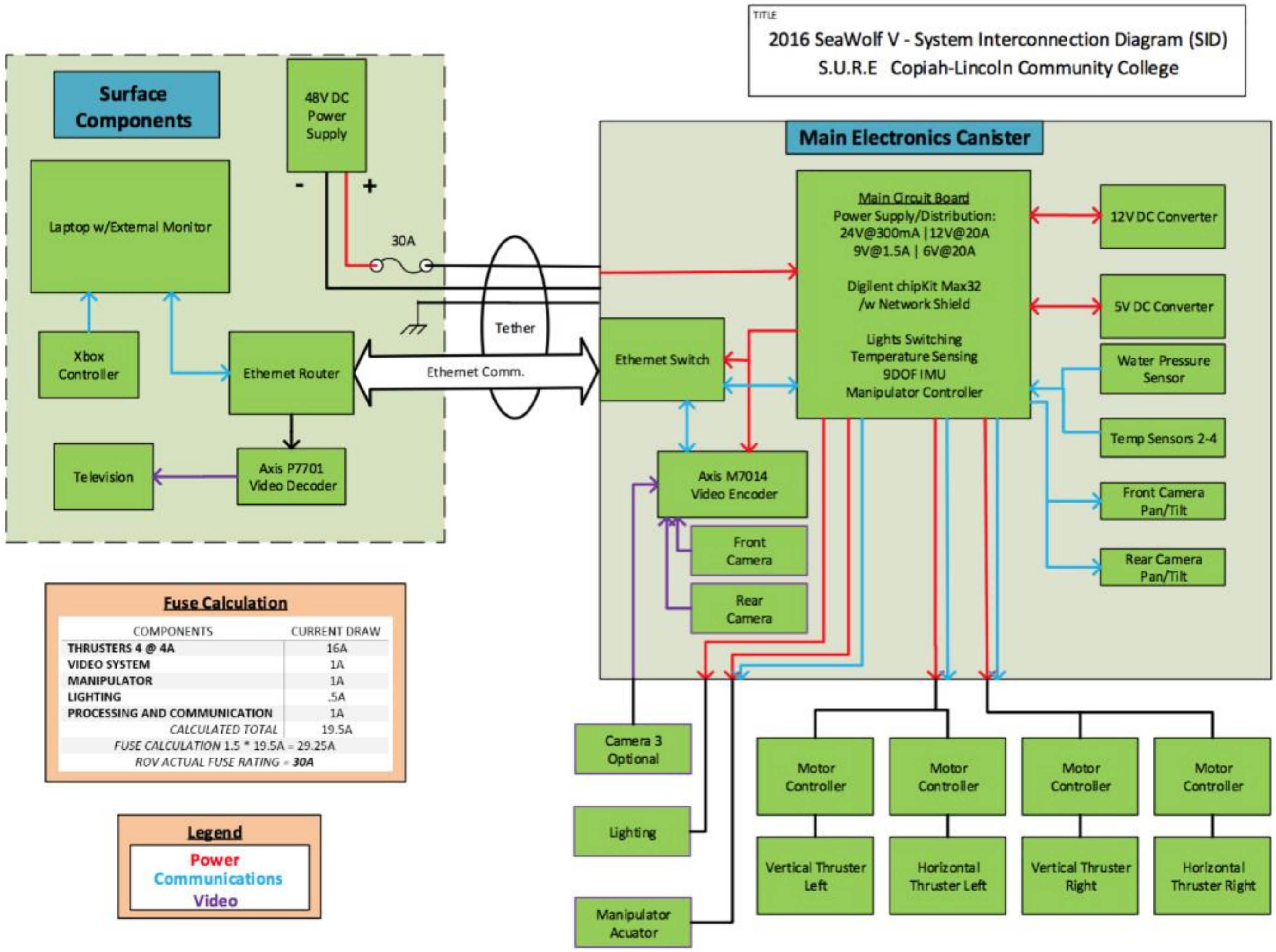
MATE. (2016). *Marine Advanced Technology Education.* http://www.marinetech.org/

CRUSTCRAWLER. (2016) *CrustCrawler Robotics.* http://www.crustcrawler.com/products/urov2/index.php

SEABOTIX. (2016) *Seabotix.* http://www.seabotix.com/products/pdf_files/BTD150_Data_Sheet.pdf

L. Appendices

Appendix 1: Seawolf V's System Interconnection Diagram (SID).



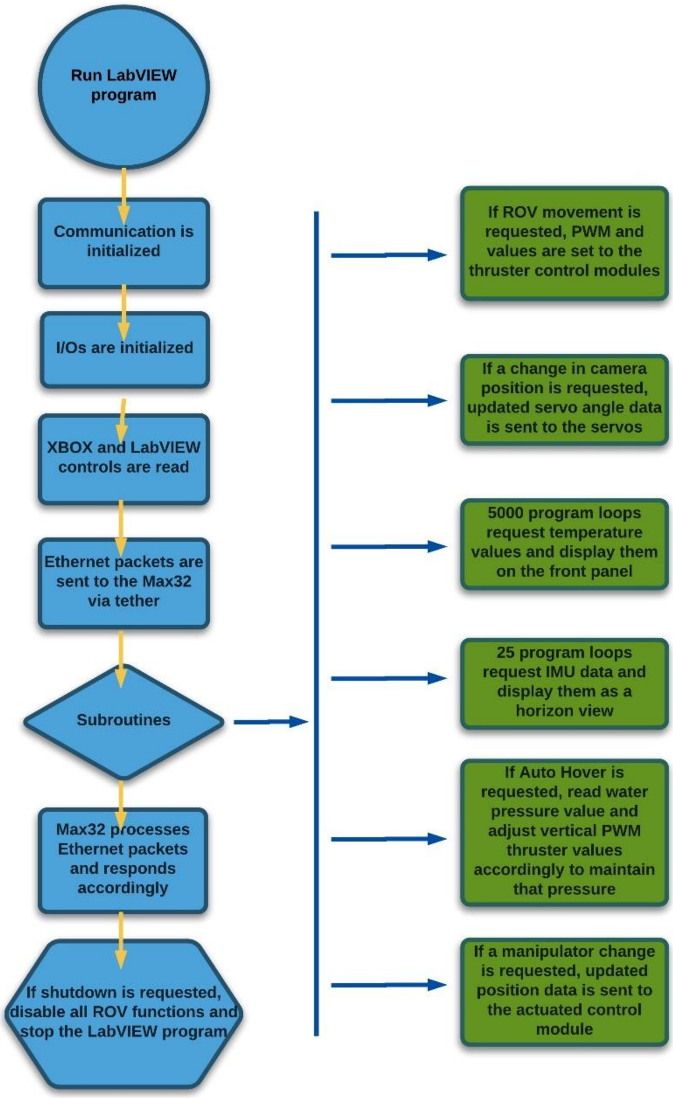
Fuse Calculation

COMPONENTS	CURRENT DRAW
THRUSTERS 4 @ 4A	16A
VIDEO SYSTEM	1A
MANIPULATOR	1A
LIGHTING	.5A
PROCESSING AND COMMUNICATION	1A
CALCULATED TOTAL	19.5A

*FUSE CALCULATION 1.5 * 19.5A = 29.25A*

*ROV ACTUAL FUSE RATING = **30A***

Appendix 2: Software Flow-Chart



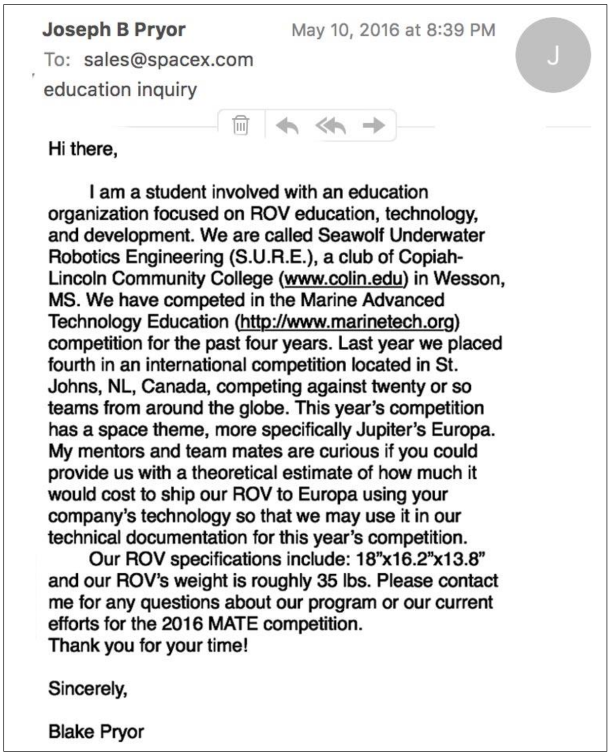
Appendix 3:
Troubleshooting Checklist:

1. If program freezes:
    a. Change windows and end the main program.
    b. Close LabVIEW.
    c. Restart Safety Checklist procedure starting with step 11.
2. If ROV fails to communicate:
    a. Turn off power supply.
    b. Close LabVIEW.
    c. Restart Safety Checklist procedures starting with step 9

Appendix 4: Safety Checklist

1. All company members put on safety glasses.
2. Check work areas and ROV for any hazards (sharp edges, untidy cables, wet/slippery areas).
3. Inspect ROV's electrical systems and connections for water proofing.
4. Inspect strain relief on tether.
5. Inspect 30A power supply fuse.
6. Connect tether to 48V fused power supply.
7. Power up the laptop, monitor, and ensure the charger is connected to the laptop.
8. Connect XBOX controller.
9. Turn 48V power supply on.
10. Listen for audible thruster beep and check for illuminated LEDs.
11. Start LabVIEW and open the main program.
12. Listen for single audible thruster chime to indicate operation readiness.
13. Designated company member launch ROV into water.
14. Poolside members check for bubbles that indicate leaking.
15. Once procedures are completed, ROV is ready for mission tasks.

Appendix 5:
Outreach to Space Research Company



Joseph B Pryor May 10, 2016 at 8:39 PM
To: sales@spacex.com
education inquiry

Hi there,

I am a student involved with an education organization focused on ROV education, technology, and development. We are called Seawolf Underwater Robotics Engineering (S.U.R.E.), a club of Copiah-Lincoln Community College (www.colin.edu) in Wesson, MS. We have competed in the Marine Advanced Technology Education (http://www.marinetech.org) competition for the past four years. Last year we placed fourth in an international competition located in St. Johns, NL, Canada, competing against twenty or so teams from around the globe. This year's competition has a space theme, more specifically Jupiter's Europa. My mentors and team mates are curious if you could provide us with a theoretical estimate of how much it would cost to ship our ROV to Europa using your company's technology so that we may use it in our technical documentation for this year's competition.

Our ROV specifications include: 18"x16.2"x13.8" and our ROV's weight is roughly 35 lbs. Please contact me for any questions about our program or our current efforts for the 2016 MATE competition.
Thank you for your time!

Sincerely,

Blake Pryor