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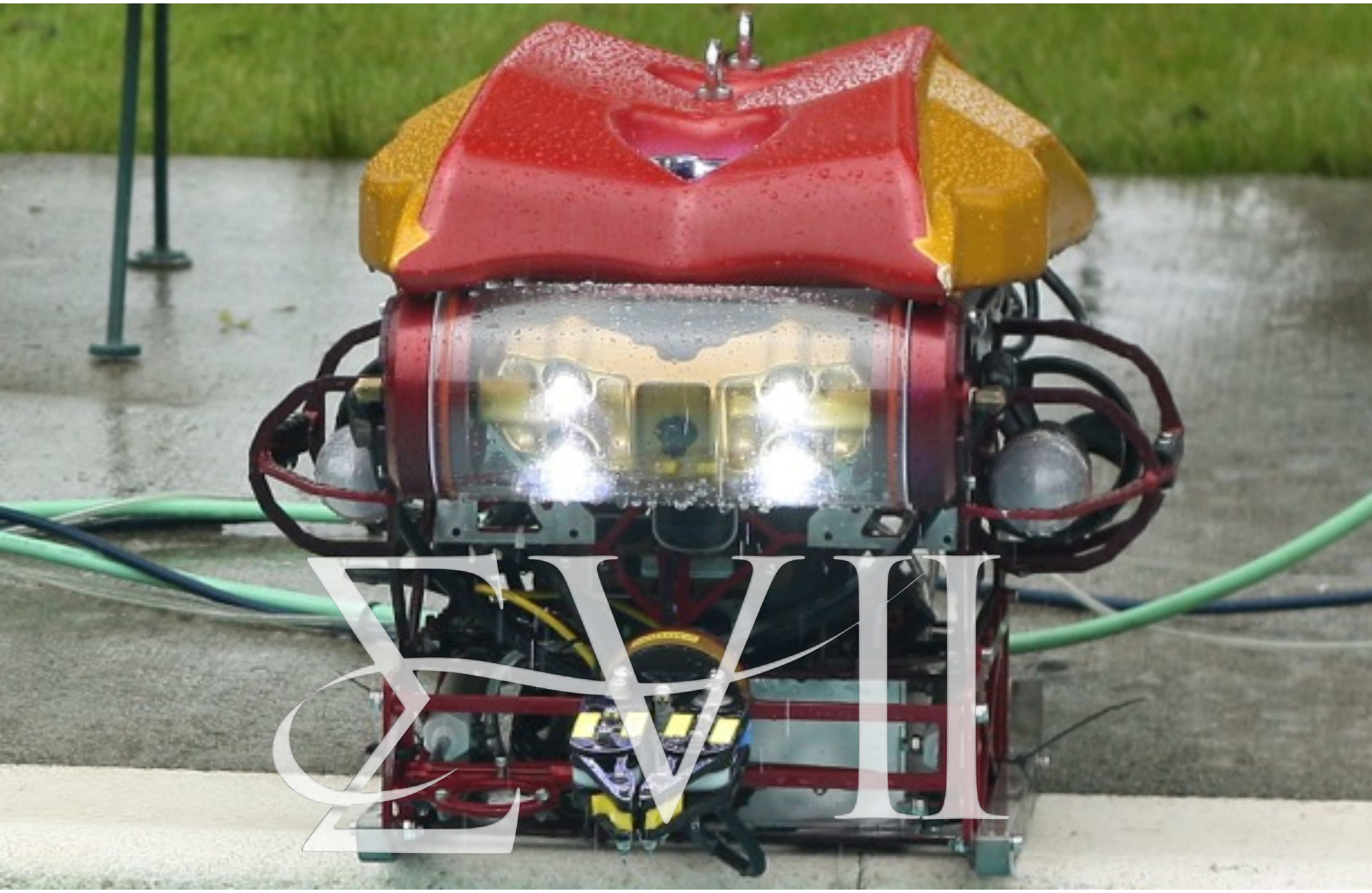

Technical Report 2014

Sea-Tech 4-H
Mount Vernon, WA

S.I.G.M.A. INC

Mentor: Peter Janicki

Supervisor: Lee McNeil

Michael Janicki	Chief Executive Officer /Systems Engineer
Matthew Atilano	Marketing Director / Mechanical Technician
Sierra McNeil	Chief Financial Officer
Madison Walkup	Technical Writer

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Abstract

Treacherous Thunder Bay, nick-named "Shipwreck Alley," is home to more than 50 known shipwrecks. These archeological treasures are under constant threat from extreme temperature changes, strong currents, invasive biological species and debris buildup. The National Marine Sanctuary located in Thunder Bay also contains sinkholes that emit superconductive ground water enriched with sulfates that encourage the growth of complex microbial mats. The dilemma lies in collecting information about the wrecks located in Shipwreck Alley before the valuable historical information is lost, while avoiding damage to the delicate microbial-rich environment.

Image 1: *Windiate*, a wooden schooner that went missing on Dec. 10, 1875 and was discovered in 1987. Photo by a NOAA archaeologist.

Our proposed solution to this problem is Project ΣVII, a Remotely Operated Vehicle (ROV) designed and built by Students for Innovative Global Marine Analysis Incorporated (SIGMA Inc.). Project ΣVII was designed by the team to address the problem in many facets, including the following:

- A rotating high definition (HD) camera, augmented by three auxiliary cameras mounted on the frame for identifying and exploring the contents of the wrecks.
- Electronic manipulator capable of collecting samples of the microbial mat and removing debris.
- Sensor designed to measure the conductivity of the groundwater in the sinkholes.
- Six powerful thrusters for propelling ΣVII from the surface to the wreck controlled by a hall-effect joystick and two linear slide potentiometers.
- LED lights to provide adequate visibility.
- Measuring equipment to record accurate dimensions of the wreck.

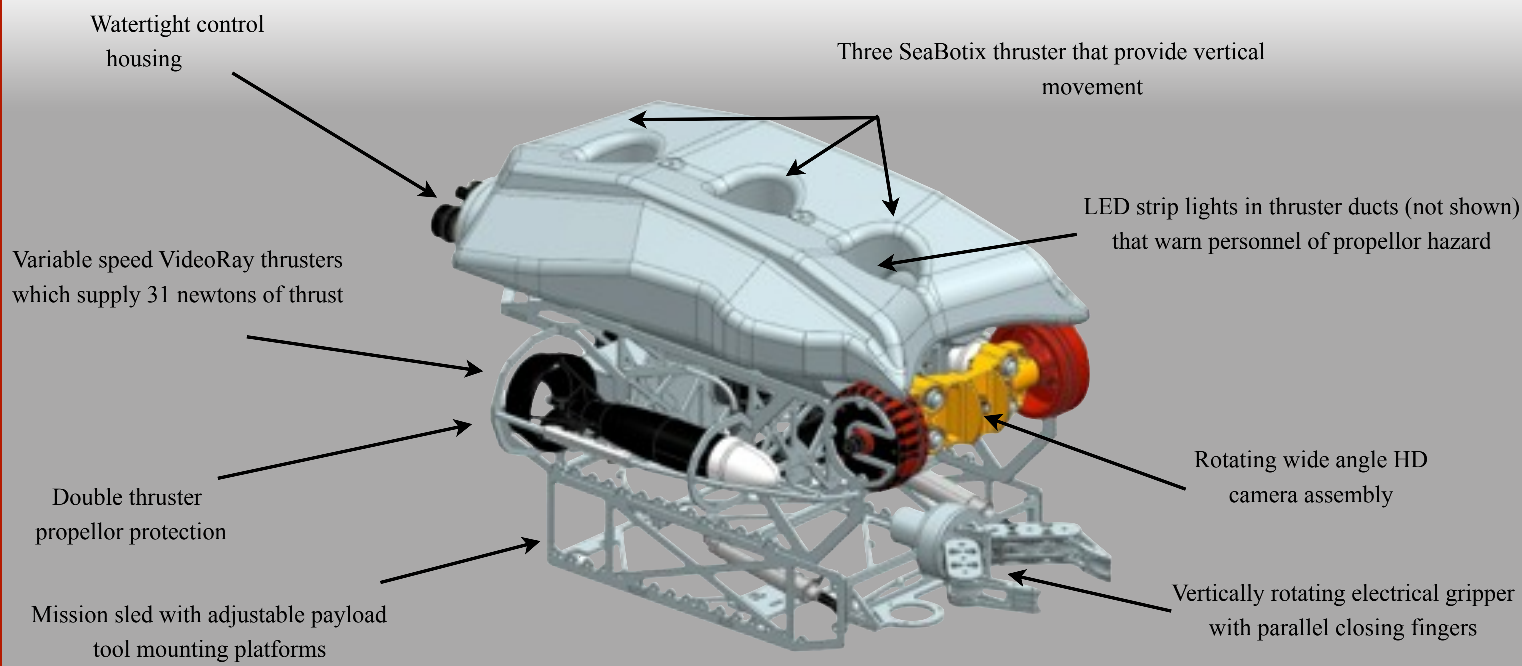


Image 2: CAD Model of ∑VII

SIGMA Inc. Engineers

Image 3: Team SIGMA

Staff Biographies

Michael Janicki

Company Role: Chief Executive Officer / Systems Engineer

Operation Role: Pilot

Michael is currently a 17 year-old junior enrolled at Skagit Valley College. As the CEO for the team, Michael managed the tasks and responsibilities for the rest of the team and kept the project on schedule. Additionally, he was the systems engineer and CAD modeling expert for the design process and oversaw the fabrication of ΣVII. With six years of experience building ROVs, he was well equipped to spearhead the engineering of the project. This is his third year of participating on the Explorer team and he plans on furthering his education by pursuing a Mechanical Engineering degree.

Matthew Atilano

Company Role: Marketing Director / Mechanical Technician

Operation Role: Mission Commander / Sensory Specialist

Matthew Atilano has participated in six regionally held competitions and three international MATE competitions. Leading the Sea-Tech 4H Ranger Class team to first place regionally two years in a row before he joined SIGMA was a rewarding accomplishment for Matthew. This year, his fifth year of involvement in Sea-Tech 4H, he has been faced with exciting new challenges that include competing at the Explorer level for a second year in a row, building a more complex ROV, balancing time between ΣVII project, and starting his freshman year at Washington Engineering Institute. Matthew plans to earn a degree in Mechanical Engineering.

Sierra McNeil

Company Role: Chief Financial Officer
Operation Role: Manipulator Operator
With seven years of experience building ROVs in the Sea-Tech and the MATE competitions, Sierra McNeil has polished strong leadership skills, a strong work ethic and love of ROVs. She has had the privilege of being the club leader's daughter, which has greatly increased knowledge and exposure to ROVs. At age 17, Sierra is currently a Senior in high-school as a home schooled student. In addition to her high school studies, Sierra is also attending Skagit Valley College as a Freshman through a Running Start program for high school students. She has plans to further her education at a University, using the knowledge and skill she has gained from Sea-Tech and the MATE Organization.

Madison Walkup

Company Role: Technical Writer
Operation Role: Mission Specialist / Tether Tender
Madison Walkup has been working on ROV projects with Sea-Tech 4H for six years. She has been an active member in Sea-Tech 4H, having acted both as team captain and club reporter in the past. This is her second year competing at the Explorer level. As a 18-year old sophomore at Skagit Valley College, Madison hopes to use the skills she has learned in Sea-Tech to help her accomplish her goal of majoring in Engineering.

Mission Statement

It is the Mission of Students for Innovative Global Marine Analysis Incorporated to provide a cutting-edge response to oceanographic challenges with ROV-related products and knowledge that fulfill engineering companies' and enthusiasts' wants and needs with a focus on safety. SIGMA's friendly, knowledgeable, and professional staff will help inspire, educate and problem-solve for it's customers.

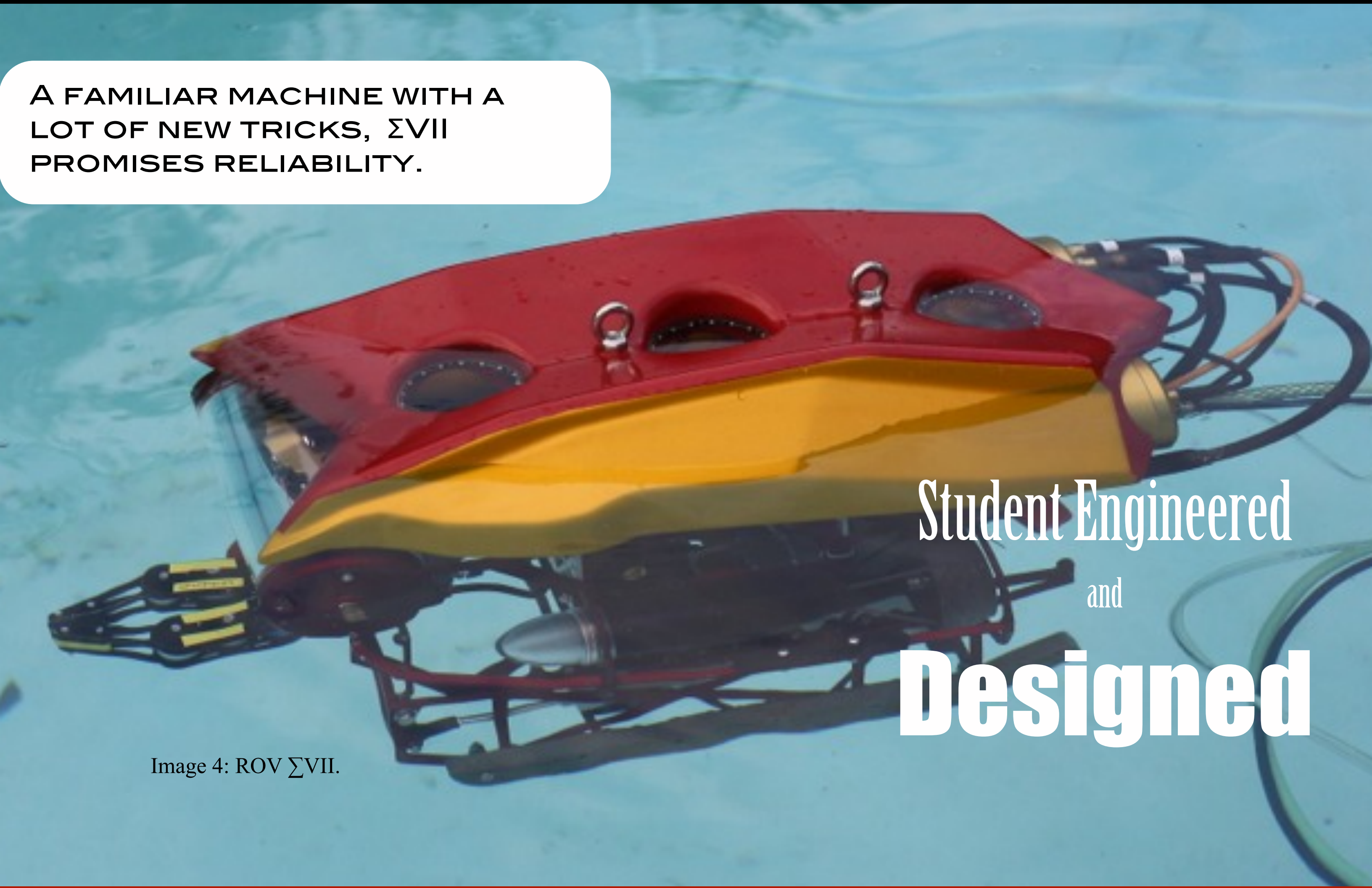
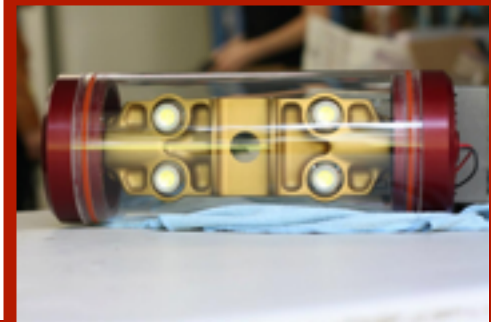


Image 4: ROV ∑VII.

Motivation

Mission Oriented

Project **Σ**VII is the new and improved model that was created by SIGMA in response to the challenge outlined by the client, the Marine Advanced Technology Education (MATE) Center in 2013. It has been redesigned with the majority of its components being new to perform multiple tasks involving research and recovery in the Thunder Bay National Marine Sanctuary in 2014.



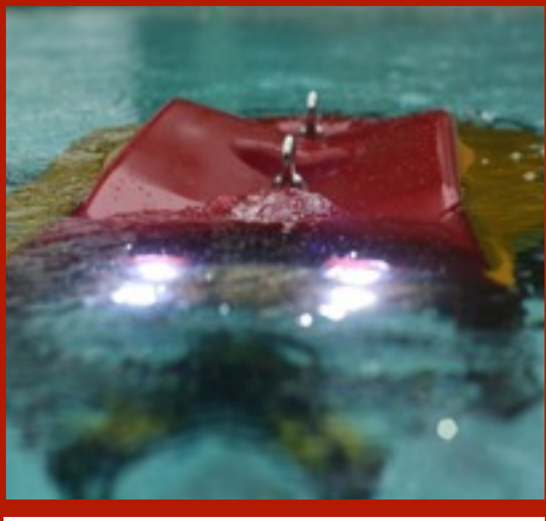


Image 5-7: LED lights for diver visibility and warning labels around moving parts are clearly indicated.

Safety Measures

Safety has played an integral role in the design and construction of project ΣVII in accordance with SIGMA's safety philosophy: *"safe staff equals an effective process."* Safety measures have been applied to every facet of ΣVII, from mechanical design to launch, and are specified in the following categories:

Mechanical Safety

Thruster guards were designed to prevent the exposed propellers from possible entanglement or unwanted contact, and safety labels identify all moving parts to clearly mark potential dangers. LED lights around propellers provide an additional warning to divers near the machine. Handles incorporated into the frame allow for safe launch and retrieval methods and were designed to be appropriately distanced from the thrusters. Also incorporated into the frame is a specially designed strain relief for the tether on the ROV. This keeps the electrical connections from being damaged and gives the members an easy method for removing the ROV from the water.

Electrical Safety

Electrical safety concerns have been addressed by ensuring that every subsystem within the control tubes on ΣVII were interfaced independently with their own fuse so if one component fails, the entire system will remain intact. The main power input is fused, and in the case of an emergency, a large red emergency shut-off switch which is located on the control box has the capability to cut all power to the machine.

Image 8: Team member safely machining aluminum with safety glasses.

Launch Protocol

When launching the machine, SIGMA follows a strict launch protocol to ensure the safety of both the SIGMA members and the ROV developed by SIGMA's top engineers (see Appendix III and IV).

Safety Lessons

One safety incident for SIGMA occurred while practicing the pool missions– a piece of sheet metal fell across the main power leads and made some sparks fly, startling the members. The fuses designed into the system prevented damage to ΣVII, but it gave SIGMA members a new appreciation for the necessity of safety while operating the machine. Due to this, the team now keeps the mission station clear of any conductive items such as tools or parts that could cause short circuiting.

Design Approach

The philosophy of SIGMA Inc. during the building and fabrication of ΣVII was that the machine needed to be capable of operating in harsh environments, similar to those in the Great Lakes, where the machine is designed to dive. These goals are why the motor controllers and thrusters on ΣVII were purchased from commercial suppliers. This is because the team recognized that their time was better spent designing the components, and the commercial parts would be integrated into the machine rather than "reinventing the wheel" with every part. Technology is able to advance as far as it does in the real world because we are able to build upon the accomplishments of others before us. A project such as building a motor controller is a yearlong project in and of itself, and the team needed to focus its attention on the rest of the machine. SIGMA designs custom ROVs that are easily serviceable with seamless integration of professional off-the-shelf hardware into the project when necessary to improve its performance, capabilities, and reliability.

The same mode of thinking was applied to the fabrication of the machine. SIGMA has chosen to utilize professional production processes, such as water-jetting and five-axis milling, similar to how a real world ROV company would tackle such a challenge. Every single part, component, and assembly on ΣVII was designed and/or integrated by SIGMA members. The majority of the complex metal parts themselves were machined by the team including the main camera housing, end caps for the control tubes, and the tooling. After designing the parts in CAD, SIGMA members participated and observed the cutting of the main frame on a water jet, had a few aluminum welds done on that frame, and machined the float on a mill under the supervision of professionals. All ΣVII design and system integration is the intellectual property of SIGMA Inc.

Technical Skills Acquired

For various portions of this project, the members of SIGMA found it necessary to learn many new technical skills to complete the project with a high level of professionalism. Some of these skills include the advanced understanding of UGS NX8.5, learning how to make electrical schematics from scratch on Express SCH, and also learning how to machine aluminum parts on lathes and 3-axis mills. These skills were acquired with the help of SIGMAs leaders and mentors, personal perseverance with online tutorials, and You-Tube videos. Lastly, the team was able to learn from machinists about safe operation of lathes and mills.

CAD Modeling

The production of ΣVII began with CAD modeling. The design was inspired by a desire for a strong righting moment, and versatile framework. It was carefully modeled by SIGMA members in UGS NX8.5. Over five hundred hours of detailed modeling went into the design, and with over a thousand solid bodies, fifteen main assemblies, and nearly a hundred sub assemblies, the design of ΣVII was finalized as a masterpiece of mechanical and systems engineering. Simulated assembly made it possible for SIGMA to detect design flaws and avoid unnecessary trial-and-error, along with allowing the team to brainstorm ideas for the best way to solve a certain task with the virtual representation of ideas. The 3D models made the building process streamlined and simple, with the added benefit of enabling SIGMA Inc. the use of a local sponsor's precision water-jet to cut ΣVII's frame. All portions of the CAD model were drawn by SIGMA. The CAD model of ΣVII assisted the company in making the fabrication process as accurate and simple as possible by enabling them to create the DXF files used to cut the frame on the water-jet with aid from a local sponsor's facility staff in the details and safety of the process.

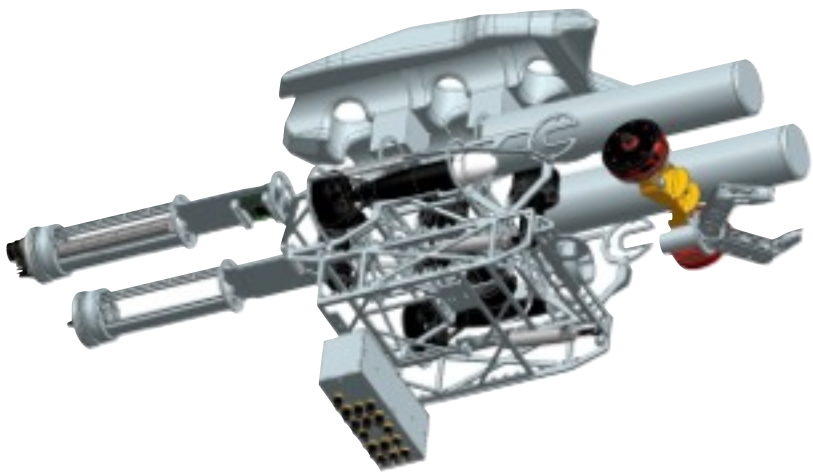


Image 9: Exploded view of ROV components, housings, float, and frame.

Structure

Frame

Project ΣVII is fitted with a sturdy 4.8 mm aluminum frame, that was originally fabricated for its predecessor, ΣVI. The frame was reused, but heavily modified to fit the needs of the new machine. The decision to retrofit the existing frame made it possible to save considerable cost and time for SIGMA Inc. Each section was cut on a water jet, then assembled by SIGMA Inc. members. It operates on a welded tab-and-slot system to reduce the amount of welding necessary and to provide easy assembly. The framework is lightweight yet structurally sound, making the machine easy to transport. This is enhanced by several convenient handles incorporated directly into the frame. Mounted on the bottom of ΣVII is a removable mission sled, which was designed for diversity with future clients in mind. The float is bolted to the upper part of the frame and is removable for serviceability. Multiple camera mounting points are incorporated throughout the frame should a mission require a different field of view. All of the aluminum framework was anodized to preserve the metal, which increases the longevity of the machine by avoiding corrosion.

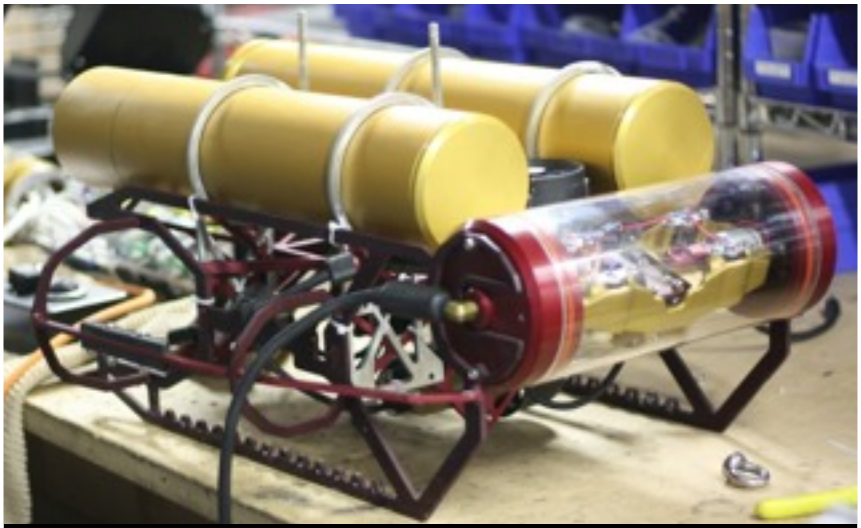


Image 10: Red anodized aluminum frame and gold anodized control tubes.

Mission Sled

The mission sled was also designed by SIGMA members on UGS NX8.5. It was cut from the same type of aluminum as the ΣVII frame and conveniently bolts to the lower portion of the machine with incorporated mounting holes for adding ballast. The sled was fabricated for project ΣVI, and SIGMA made a budget and time decision to reuse the existing sled on ΣVII. The versatility of the mission sled allows SIGMA the option of refitting project ΣVII to suit the needs of additional clients. The mission sled incorporates all of the mission tooling for ΣVII. The purpose of these tools will be discussed in detail in the Payload Tooling section.

Control Tubes

A new feature for ΣVII is the embodiment of an entirely new, on-board control system. The system is housed inside two 101.6 mm OD, 4.8 mm wall aluminum pipes that are each 570 mm long, that were cut and surface machined by the team. The tubes are sealed with custom-machined aluminum end caps with 9.5 mm o-ring grooves (see Appendix VII). The tubes are mounted on the top of the frame to allow for easy access and also to provide a strong righting moment with the water they displace (see Righting Moment). The controls themselves are mounted on an aluminum framework skeleton inside the tubes that were designed for ease of operation and maintenance. The framework for the controls is hard mounted to the rear end caps.

Image 11: Team member applies coat of paint to polyurethane float.

Righting Moment

A desire for a strong righting moment heavily influenced the design of project ΣVII. SIGMA achieved this through a balanced system of floatation and ballast. SIGMA designed an entirely new float for project ΣVII, machined from a block of high-density polyurethane foam. Once it was machined, SIGMA members sanded and then coated it with a heavy duty resin-based primer for increased durability. It was then painted and mounted at the top of the machine. The volume of the float was carefully calculated to give ΣVII neutral buoyancy. While maintaining the stiff righting moment, ballast is added to the lower portion of ΣVII. This creates maximum stability even at high speeds. Because of the balanced nature of the ROV, project ΣVII is able to lift heavy objects and maneuver with ease.


Image 12: Electrical manipulator utilized for multiple mission tasks.

Payload Tooling

Manipulator

Project ΣVII is capable of completing the majority of the tasks put forth by MATE with the aid of its student designed and built 24 Volts DC powered manipulator. The manipulator consists of a series of water-jetted gears and a worm drive. It operates via a high-torque planetary gear motor. The worm gear sets the other gears in motion, and forces the manipulator open and closed in a parallel motion. The gear motor is torque limited to avoid shearing the worm gear; and mounted to a pneumatically operated tilting base (see Appendix II for pneumatic system integration diagram). The manipulator is essential for the transportation of the various artifacts, opening the hatch on the shipwreck, as well as the removal of the debris and litter at the artifact site.

Conductivity Sensor

The conductivity sensor is comprised of two parallel electron plates of copper 10 cm long, separated by a centimeter with a rubber grommet, and attached to a firm handle for the manipulator to control. Wires are soldered to the electrode plates and are sent up their own designated tether to the surface. The reading for the conductivity sensor is simply taken with an Ohmmeter and then plugged into the equation: Conductivity/cm = 100/(Resistance x cross-sectional area). This equation was derived from an equation listed in *Physics for Scientists & Engineers, by Giancoli, Douglas C*. This equation gives SIGMA conductivity in Siemens per Centimeter. The only variable that must be measured during the mission run is the resistance because SIGMA will calibrate the cross-sectional area constant against the MATE organizations sensor.

Figure 1: Conductivity sensor schematic

Bio-mat Sampling Apparatus

SIGMA manages to retrieve the bio-mat sample with the use of a bundt cake mold placed over the top of the bio-mat container. The manipulator then simply scoops out the bio-mat which falls into the bundt cake mold, and is brought back to the surface for retrieval. This approach was chosen after much brainstorming and four main concepts were designed and tested. Three of these concepts were designed under the principles of pulling vacuum on the agar to attempt to remove it, but proved too difficult for the machine to remove without damaging the bio-mat container. The fourth sampler was effective in accomplishing this mission. A similar process was applied to the other tooling.

Photomosaic

SIGMA manages to accomplish the photomosaic task by running their video-feed from the monitors through a Digital Video Recorder (DVR), and then screen capturing the video collected and importing the screen captures into a photo-stitch software to create the photomosaic. This method was chosen because the SIGMA members deemed it the most efficient and affective method for creating the photomosaic after much brainstorming with ideas such as filming the screen with a camera.

Image 13: ΣVII's first successful photomosaic capture.

Additional Tooling

The observation and documentation of the shipwrecks do not require any additional specialized tooling, but SIGMA is very focused on short-term adaptability and has designed their machine as such. Some of these features include auxiliary cameras with easily modified mounting structures to accommodate many vantage points. Also, the team has designed a metric tape-measuring device mounted in the claw for measuring the shipwreck dimensions.

Propulsion

ΣVII is mobile by means of six thrusters. Fore and aft, or surge movement, is controlled by two brushed VideoRay thrusters. Vertical heave is controlled by three SeaBotix thrusters mounted in the center of ΣVII, and horizontal sway, as well as yaw is achieved through one SeaBotix thruster mounted within the lower center portion of the frame. The VideoRay thrusters have over a 2-1 thrust to weight ratio, and give ΣVII smooth and fast movement underwater. Their motor controllers are tuned for fast response, so there is no delay between deck side signal and movement of the machine. The SeaBotix thrusters each produces 21.6 newtons of thrust, and are equipped with a brushed motor housing, propellers, and kort nozzles. All of the thrusters are interfaced into the frame using mounting bars for easy removal and maintenance, and are guarded with both the kort nozzles and SIGMA's own frame design for extra safety. All potentially dangerous portions of the machine are thoroughly guarded by the frame of ΣVII.

Image 14: One of the two VideoRay thrusters that provides the horizontal movement for ΣVII.

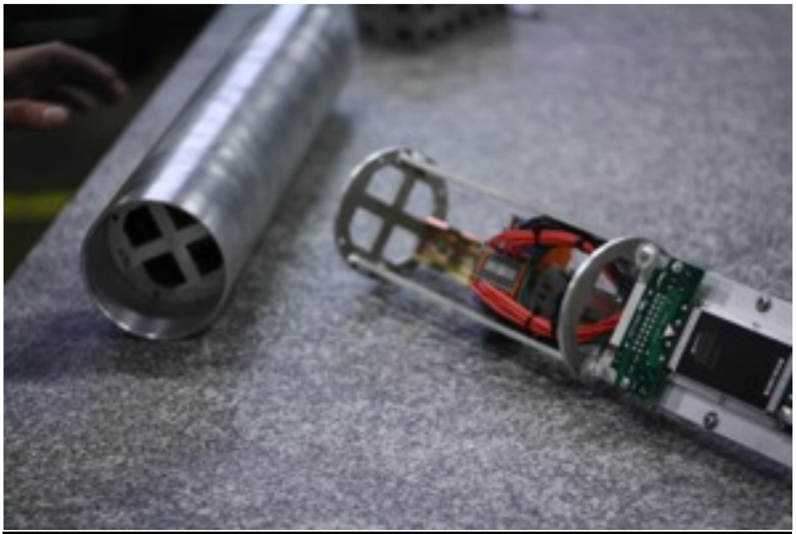


Image 15: New control housing skeleton and tube 1.

Electrical Subsystems

Housings

A new feature for ΣVII is the embodiment of an entirely on-board control system. In the design phase for the control housings, SIGMA looked to its many years of experience designing and fabricating watertight housings on ROVs to create housings that were incredibly robust, yet surprisingly simple.

The team spent nearly a hundred hours meticulously designing every detail for the control housings in CAD to be absolutely sure that there were no unaccounted obstacles, and that the housings would consistently prevent water leakage onto the delicate electrical components inside. The system the team designed incorporates all of the electrical components for

ΣVII inside two identically fabricated o-ring sealed aluminum tubes. The controls themselves are mounted on an aluminum framework skeleton inside the tubes, which is then mounted to the rear end cap. All of the electrical wires are connected to the rear end cap and are run through SEA CON waterproof electrical connectors, which are then routed to the auxiliary junction box. Both ends of the tubes are sealed with end caps custom-designed in CAD and machined by SIGMA members on a manual metal lathe. The o-ring groove tolerances are within 0.051 mm, which is better than the specified o-ring groove tolerances. Tube 1 houses all of the motor controllers and is where the tether inputs, while tube 2 houses the 48VDC/28VDC power converters and routes the power back and forth from tube 1.

Image 16: Team member wiring onboard controls on housing skeleton.

SIGMA has also learned from past experiences that it is very important for the controls to be easily accessible for easy debugging of problems. Therefore, since all of the hardware and electronics are mounted to the rear end caps of the tubes, SIGMA Inc. has the capability of removing the entire electronics system from ΣVII effortlessly for troubleshooting and maintenance. The brilliance of the system's design is that since all of the cables are routed through the rear end caps of the tubes, ΣVII can remain connected to the controls even when the electronics have been removed, which makes for incredibly easy problem solving and troubleshooting.

Controls and Hardware Only Approach

Project ΣVII embodies a simple design without compromising function or performance. Therefore, an analog hardware-only approach was selected to control ΣVII. SIGMA and its associates have utilized software to control machines in the past, and though this approach has some advantages, they are outweighed by added complexity. The hardware-only approach circumvents these issues by being simpler and more reliable than a software approach. The system utilizes three motor controllers, purchased from Dimension Engineering, which SIGMA custom-interfaced with the system. The first controller drives the fore, aft, and yaw of the machine, the second controls the vertical and side thrust, while the third is for the main camera vector motor and manipulator. The controllers utilize 0-5 Volt analog control signals for the operation. The second controller is set so that Signal 1, or S1, controls the vertical thrusters and S2 controls the real pitch directly. This control scheme is designed so that when the input is 2.5V, the output is set to stop; when the input is set to 5V, the output is set to full forward; and when the input is set to 0V, the output is set to full reverse. The system utilizes a 0-5V hall-effect joystick sourced from ETI Systems to control the fore, aft, left, right, and sway capability of ΣVII. Linear slide potentiometers are utilized for vertical control, camera vector, and the manipulator. The joystick and two of the potentiometers are mounted to a smaller control box, which is connected to the main control case by a cable for ease of operation. The 48 Volt power supply input is fused with a 30 amp slow blow fuse, as well as a large emergency off switch as a safety feature in case immediate shutoff of the machine's power is necessary. Additionally, each individual circuit is protected by appropriately rated fuses. For more detail on the electrical integration of ΣVII, please see Appendix I, *Electrical System Integration Diagram*.

Image 17: Human interface controller for ROV's thrusters and rotating camera assembly.

The human interface assembly is incorporated into a 1500 series Pelican case with a 432 mm LCD monitor hard mounted to the lid for camera display and the electrical interface wiring below in the main body. All of the tether input connections, main power input, 110VAC power input for the monitor, and emergency off switch are mounted on an aluminum interface plate that is mounted to the case. The pelican case and monitor were reused from previous years, which saved the team considerable time and money, but the interface assembly and wiring was completely redone for ΣVII.

Auxiliary Junction Box

When the team designed the control housings on ΣVII, they knew that there wasn't enough room on the end caps for all of the components on the machine to be directly connected to the tubes, so they designed an auxiliary junction box to account for this. All of the components on ΣVII including the six thrusters, four cameras, lights, manipulator, and cam vector motor are routed through the axillary junction box with the SEA CON connectors. (See next section) The box is constructed of 1.6 mm aluminum plate that was welded together on four sides, with the other two bolted on for internal access. The connectors and strain reliefs are routed through one of the bolted plates, and the wires are soldered inside. To

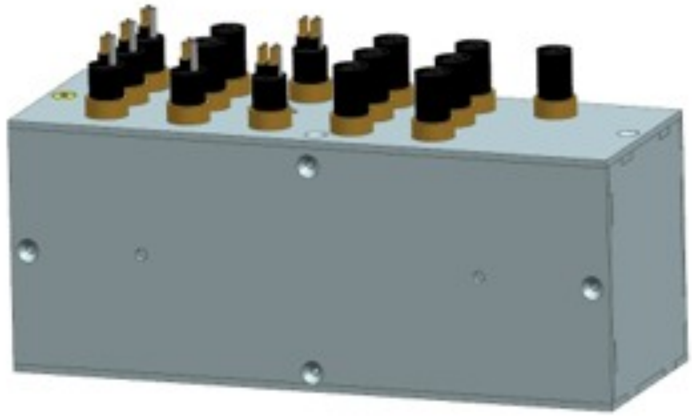


Image 18: Auxiliary junction box CAD drawing.

Image 19: SEA CON and Sub-Con connectors make individual components and the tether detachable from ΣVII.

prevent the wires from corroding, the team filled the box with a low-heat melt wax that can be removed in the event that a connection needs to be fixed or changed.

Connectors

In total, there are seventeen waterproof inline-to-bulkhead connections on-board ΣVII. These include the main tether input connectors, auxiliary junction box outputs, and the individual connectors for all of the electrical features on board ΣVII. On the surface side, the tether is split into two military-grade connectors; a 12-pin connector supplies power to project ΣVII, and an 8-pin connector supplies power to the cameras, lights, and also low voltage control signal for the on-board motor controllers. On ΣVII side, the tether is split into a 12-pin SEA CON connector and an 8-pin SEA CON connector in the same manner as the surface for simplicity. To ensure watertight connections, the SEA CON connectors were equipped with underwater cable terminations. This process was performed by SIGMA. All features of the machine have their own dedicated, waterproof connectors in order to provide the team with an easy assemble and disassemble of components.

Cameras

One of Project ΣVI's most prominent and useful features is it's color, wide angle 720 line camera with auto-focus. SIGMA can proudly claim that every single portion of the main camera housing was designed and fabricated by its team members. The camera housing was carefully modeled in CAD, then machined by its members from an aluminum billet. It is sealed within a 12.7 cm diameter acrylic tube complete with aluminum end caps, and rotates continuously by means of a slip ring and a planetary gear motor. Four 6-watt LED lights provide more than enough light to see even at great depths.

Image 20: Rotating camera assembly with HD wide angle camera and four LEDs.

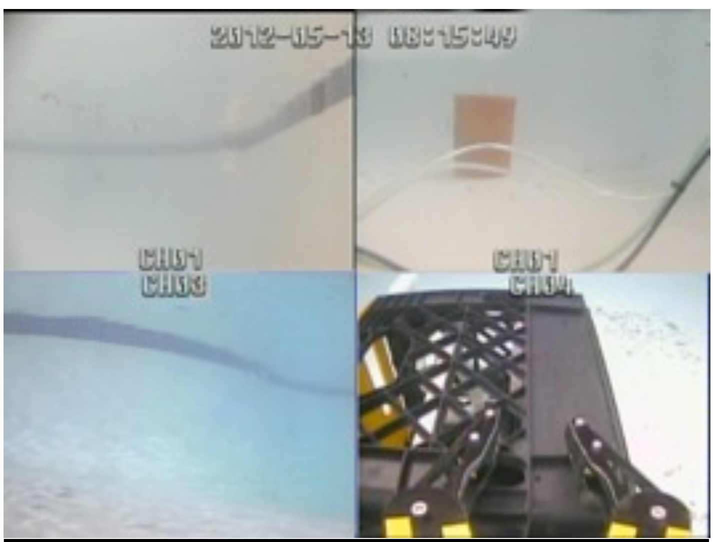


Image 21: Screen capture of multiplexer monitor display.

To provide multiple viewing platforms, three auxiliary cameras are mounted on the frame of ΣVII. Multiple mounts are incorporated into the design, so the location of the auxiliary cameras can be changed should the need arise. The auxiliary cameras have a 90 degree field of view, and provide high-definition color video. They are completely waterproof, using a method developed by SIGMA and its associate, Sea-Tech of Skagit Valley. The camera is mounted within a 3.8 cm square stainless steel tube, which is then filled with a potting compound. A silicon o-ring seals the camera's lens to an acrylic plate, and the back is fitted with a Delrin cap that allows the connectors to pass through. Each auxiliary camera is mounted via a dual-axis gimbal, allowing SIGMA to adjust their position for different viewing needs. Because of the multiple-camera reliance of project ΣVII, a multiplexer is used to reduce monitor space and provide a fast way to access the feed from each camera simultaneously. To achieve this, a 5-line multi-coaxial cable is incorporated into the tether that was graciously donated to the team by Igus Inc. This cable connects to the quad video multiplexer in the deck-side control box, which combines four video signals into one monitor signal. The fifth signal line in the cable is a spare in case of continuity issues, or an additional camera needed in the future.

Expenditure Summary*

Category	Fair Market Donated	2014 Company Cost	Re-used
Frame & Buoyancy	$4925.00	$0.00	$0.00
Propulsion	$1800.00	$0.00	$2662.40
Cameras & Sensors	$0.00	$218.31	$395.89
Tether	$1825.50	$35.90	$0.00
Controls and Console	$150.00	$1311.66	$378.13
Gripper & Mission Tools	$250.00	$5.52	$127.37
Fasteners	$0.00	$80.57	$0.00
Connectors:	$45.00	$0.00	$231.44
Engineering Documentation	$0.00	$75.33	$0.00
Estimated Travel Expenses	$0.00	$4400.00	$0.00
Total	$8995.50	$6127.29	$3795.23
		Total Project Cost:	$18918.02

*Please see Appendix V for a more detailed expenditure report.

Challenges

Interpersonal

SIGMA is comprised of dedicated student visionaries, but this comes with its difficulties. All SIGMA members are both full-time students, as well as working additional jobs. Because of this, scheduling meetings where all members would be available proved to be a challenge. SIGMA adjusted for this problem by staying in contact through email, phone, and setting up detailed task lists for each member to complete to aid in the completion of project ΣVII.

Technical

Because project ΣVII is a renovated version of an older model, project ΣVI, the infrastructure of the machine was in place at the beginning of the design process. However, there was very little documentation detailing the machine besides CAD, so SIGMA was forced to test each component to discover which ones were still operational. Because of this, SIGMA spent a notable amount of time fixing old hardware. To account for this issue and to prevent future complications, SIGMA spent a considerable amount of time putting together data sheets for all of its components and creating detailed electrical schematics that will make future troubleshooting or refitting more efficient.

Lessons Learned

Interpersonal

One of the lessons that SIGMA learned as a company was the importance of team management, especially when dealing with the busy schedules of its members. Because of the challenges in setting up frequent meeting times, the company was subject to miscommunications, which slowed the process of building project ΣVII. The team has decided that in future years a more effective and detailed schedule of events for time management will be put in place to both lower stress for the members and increase productivity.

Technical

Because SIGMA designed a new machine on top of the structure of an older model in the interest of cost, the challenges that were faced were completely different than the challenges that the company faced when designing an entirely new machine. Of the lessons learned through this process, the most prominent was the importance of not assuming that old hardware will work simply because it worked in the past. For example, when trouble shooting issues with the vertical thruster controls, the team spent a considerable amount of time trying to find an issue with the control circuits when in reality it was simply a bad potentiometer. In future ventures, SIGMA will provide better documentation for each project and assure that the specifications are correct for all components and test them before construction begins.

Teamwork

Building ΣVII was an enormous task. The team knew that it would have to be a team effort to get the machine built, the technical report written, and the other tasks completed. To accomplish this, SIGMA developed specific assignments for the design, the tech report, CAD modeling, and actual fabrication. Even though specific tasks were given to its members, and thorough schedules for the tasks implemented and managed by the team CEO, the team members were good about helping each other to get the tasks done as efficiently as possible. The team was able to stay on schedule for the duration of the year, but lagged a few weeks just before the Pacific Northwest Regional Challenge. SIGMA managed to get back on track with a lot of hard work and late nights before the regional challenge. Even though the design and fabrication of ΣVII was an immense task, and was completed with a remarkable level of professionalism, every portion and system of ΣVII was designed by SIGMA members, which gives SIGMA a very intimate understanding of the machine and how it was constructed.

Image 22: Team member writing out task assignments.

Troubleshooting

A large issue that the team had to troubleshoot was discovered when they pool-tested the machine days before the regional challenge. It had very little thrust; it seemed to not have enough power. The first thing the team did was test their main power source for issues. When they determined that was good, they marched down the line in the electronics and looked for bottlenecks in the power. When the surface side electronics were deemed to be accurate, they investigated the machine for issues. They found with a voltmeter that the power converters were only outputting around 20VDC, when they are rated for 28VDC. Upon further inspection, and after they had added up all of the motor amperages, they concluded that the

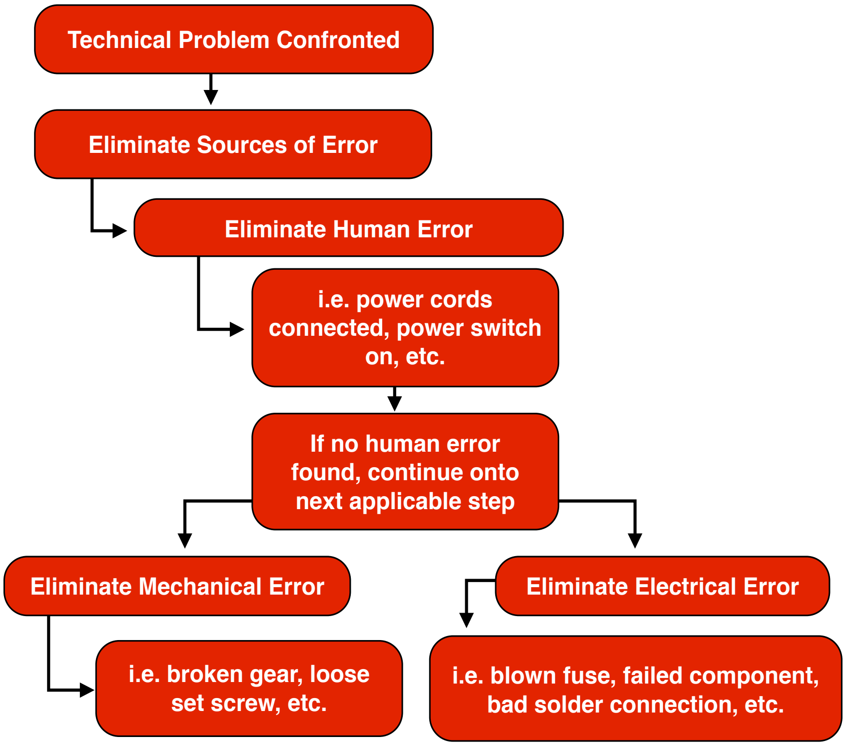


Figure 2: Troubleshooting flowchart process applied by team.

wires carrying the power between tube 1 and tube 2 had too much line loss and acted as a bottleneck for the required power. Under the tight time requirements just before the regional challenge, the team managed to fix the issue by boring up the holes that the original cable ran through and potting a much larger cable in strain reliefs to keep it from leaking. After this, the machine ran much better and the motor controllers had no issues with power output.

Future Improvements

In future projects, SIGMA would like to increase the max diving depth of their produced machines, and incorporate a single cable umbilical by moving away from their standard analog control system. To do this, SIGMA has begun the process of designing an onboard PLC incorporated system that requires only three control signal wires to the surface, which would run on 110VAC. In doing this, it would greatly reduce the line loss in the tether which would allow for the tether to be much longer, and the digital control would allow room for additional conductors in the tether for cameras. All cameras will be run as twisted pairs through the tether instead of a separate cable as it is now. The team would definitely have to consider the safety concerns with AC power, but with careful thought and design they could accomplish it. Through these improvements, SIGMA hopes to prepare their machines for better commercial outfitting.

Real World Application

Due to the fact that SIGMA created a robust and durable ROV, they had been approached and given the opportunity to take it out on several occasions for real world activities in both Puget Sound and Lake Washington in the Seattle area. Most prominent of these occasions is when the team was able to dive their ROV on the PBM Mariner – a WWII plane wreck – in nearly eighty feet of water. The team definitely plans to pursue these kinds of activities in the future and has actually been asked to assist in the documentation of three hundred and ninety unknown targets on the bottom of Lake Washington. SIGMA plans to do this after the MATE International Competition with their ROV.

Image 23: Project ∑VII in Lake Washington exploring the propellor of a WWII era plane wreck.

Personal Reflections

"Throughout the whole process of designing and building project ΣVII, I have felt challenged and inspired. Before working on ROV projects such as ΣVII, I was not sure what I wanted to pursue or who I wanted to become. Through Sea-Tech and through SIGMA I have a newfound passion that has helped me find myself and what I want to do as a long term career." — Madison Walkup

"The process of building and designing ΣVII has definitely cemented in my mind that I want to go into a career of mechanical engineering. I have always been interested in the technical fields, but this project has challenged me and pushed my limits to become a more knowledgeable and technically able individual. I have learned everything from CAD, to controls, to machining throughout this process and I wouldn't change it for the world." — Michael Janicki

"Every aspect of the design and fabrication of ∑VII has been a wonderful experience for me. I have been able to learn more about science, technology, math, and engineering. In addition, I have been able to learn how to effectively manage time, resources, and people. All these skills have furthered my overall goal of pursuing an engineering-related career. I have especially enjoyed meeting engineers who have dedicated their livelihood to making this world a better place to live." – Matthew Atilano.

"As I complete my seventh year building and competing with ROVs, I realize how much I have benefited from Sea-Tech and MATE. As a result of these programs, I have obtained an abundant knowledge in CAD, fabrication of ROVs, team management skills and many others. These new skills have helped craft and mold my desire of future accomplishments." — Sierra McNeil

Acknowledgments

SIGMA Inc. would like to thank the following supporters for their unfailing commitment, trustworthy advice, thoughtful corrections, and financial endorsement:

First, SIGMA would like to especially thank the MATE Center for putting on the MATE International Competition that not only challenges SIGMA to become better engineers, but also inspires them to further their careers in technological fields.

SIGMA would also like to thank it's regional coordinators, Rick Rupan, Fritz Starh, and Wes Thompson, for organizing and running the Pacific Northwest Regional ROV Challenge.

Thank you to Sea-Tech and 4H, for allowing SIGMA to have a program that it can operate under safely and educationally.

Lee McNeil, for his generous donation of time to the project, and also the use of his house and shop for meetings and use of equipment.

Shannon McNeil, for opening her home, and especially her kitchen, for SIGMAs late night meetings.

Janicki Industries, for their donation of facilities; including time, machining, materials, and expertise.

SeaBotix, for the discount prices they offered and provided us with in regard to their thrusters.

Peter Janicki, for his donation of time as SIGMA's leader, and also of monetary funds for materials and parts.

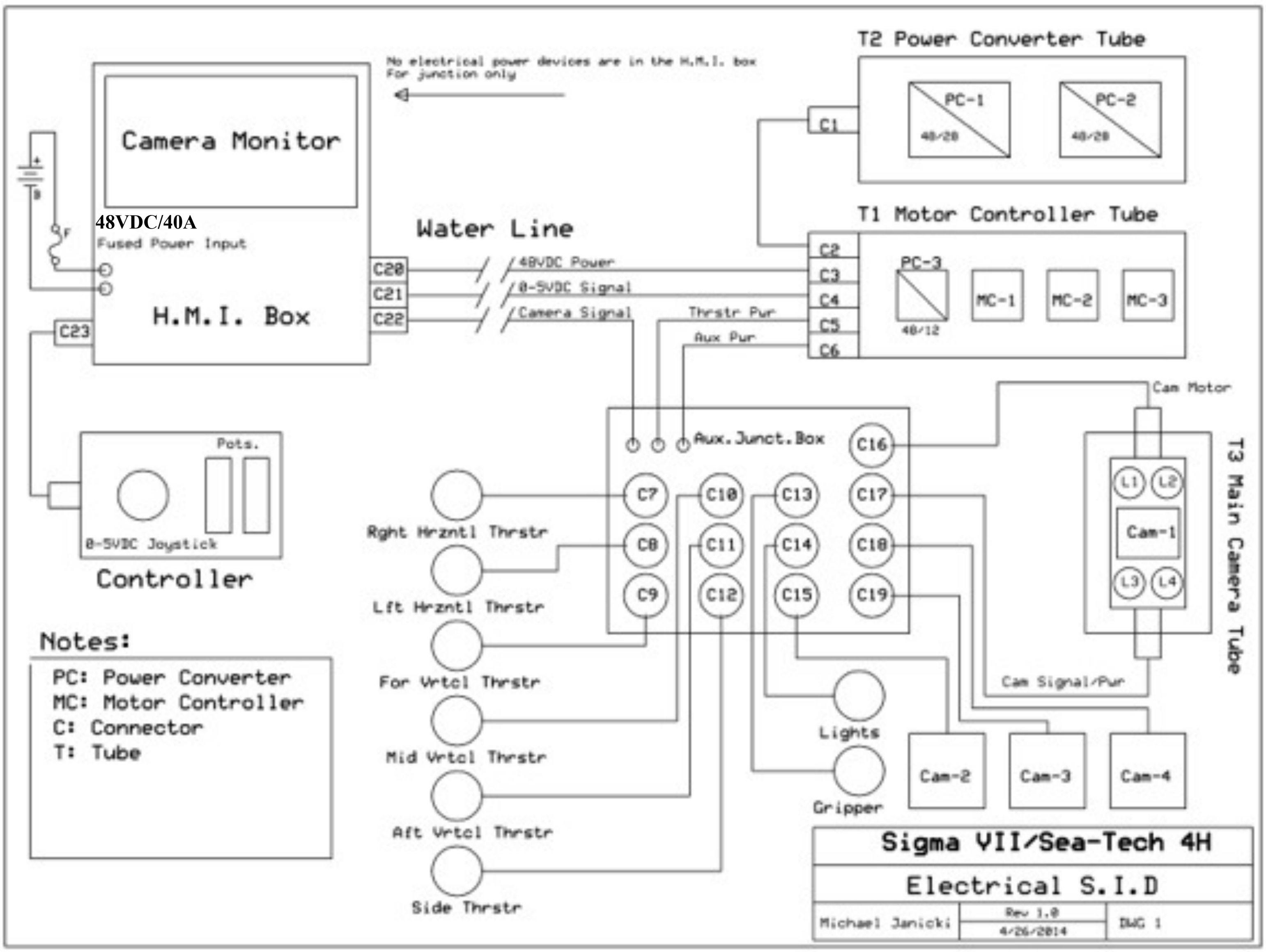
Jonah Leason, for technical advice, and also for his generous donation of time in reviewing SIGMA's technical documents.

VideoRay, for giving SIGMA considerable discounts on their thrusters.

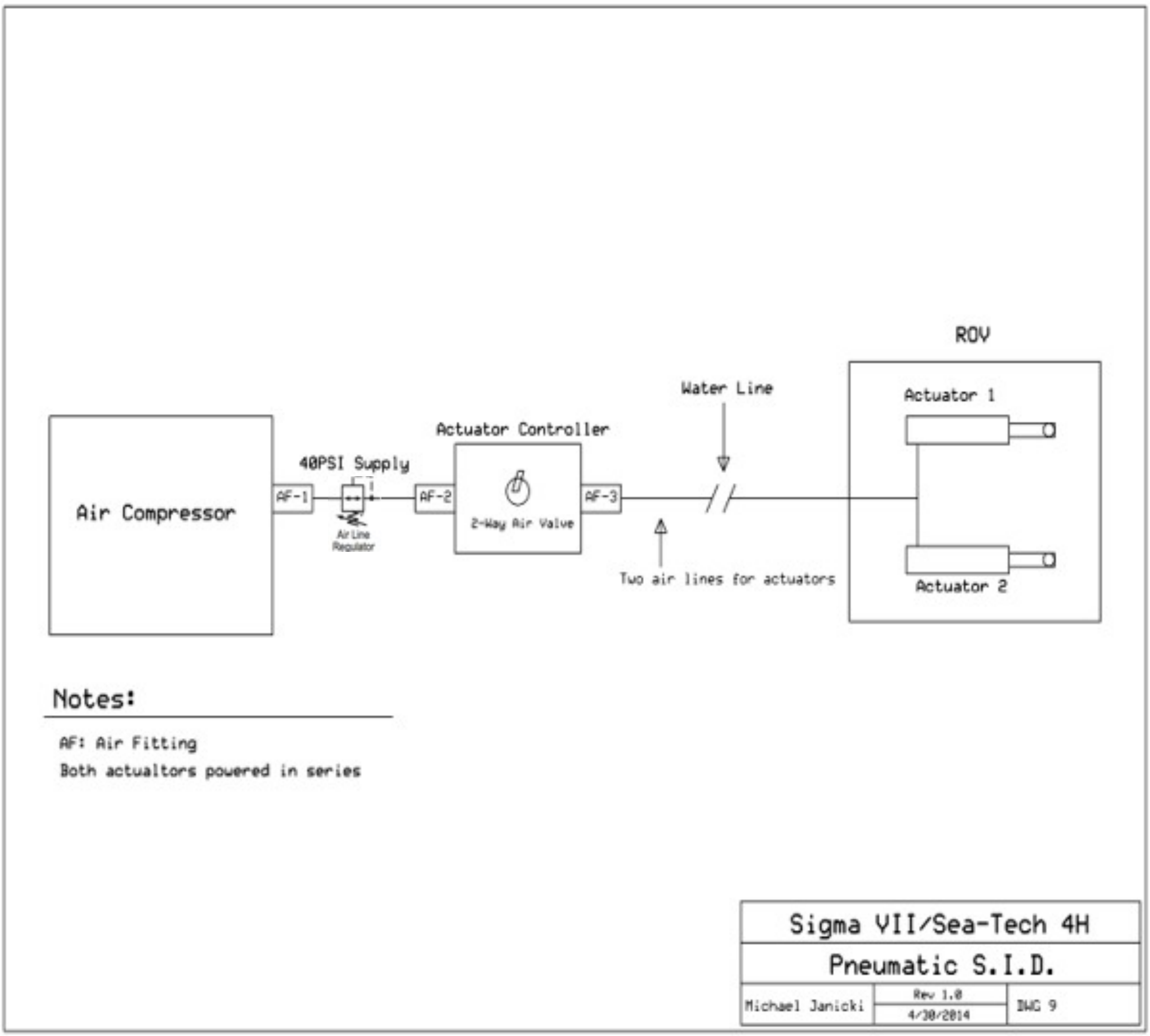
Igus, Inc., for donating a coaxial cable to the team free of cost under their Y.E.S. program.

Appendices

Appendix I: Electrical S.I.D.



Appendix II: Pneumatic S.I.D.



Appendix III: Launch Checklist & Protocol

ROV Setup Safety Checklist

- ❑ When connecting ROV to power, (a) team member(s) must check to ensure correct polarity.
- ❑ All controllers, monitors, and equipment must rest **securely** on command center table.
- ❑ Confirm **30 amp** fuse is in place and not blown.
- ❑ Power cord plugs are fully inserted, and out of the way in order to eliminate tripping hazards. Use strain reliefs when possible.

ROV Safety Protocol

- The pilot must communicate to the team that he intends to power on the ROV before doing so.
- Keep all parts and **hands away from propeller blades** when ROV is powered on.
- When servicing electrical components, confirm that power is off **and** disconnected.
- When testing components utilizing power, make sure that before adding power, there are no conductors incorrectly touching which can cause short circuiting.
- In the case of an **emergency**, or to power of machine, **press red emergency shutoff button** located on the control console to cut power to ROV.
- Keep any metal devices, cords and connectors away from battery terminals to avoid short circuiting & sparking.

Safety Protocol

Appendix IV: Tether Protocol

Tether Protocol

When In Use:

1. At no time will stepping on the tether be tolerated, and should be avoided to eliminate damage.
2. Pulling or yanking on tether is unacceptable.
3. When providing tether to ROV, do so in an orderly fashion as to eliminate entanglements.
4. Keep necessary length of tether out, and contain rest in tether box; this is for the purpose of avoiding tripping hazards and tether damage.
5. All connectors must be securely attached throughout the mission.

When Not in Use:

1. Neatly coil tether around wooden spool.
2. Protect video BNC connectors and tether connectors.

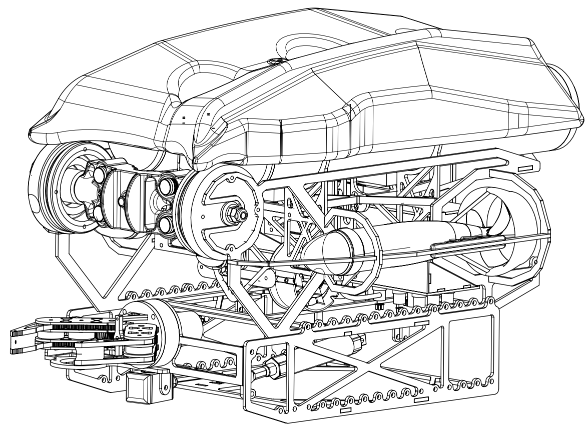
Appendix V: Detailed Expenditure Report

Category / Item #:	Qty:	Item Description:	Mfg. P/N:	Source:	Donated value:	Unit Cost:	Total:
Frame & Buoy-ancy							
1		Water jetted aluminum frame 2013		Janicki Industries	$1,500.00	$0.00	$0.00
2		15/cubic ft. Polyurethane foam		Janicki Industries	$450.00	$0.00	$0.00
3		Welding Services 2013 Employee time		Janicki Industries	$475.00	$0.00	$0.00
4		Use of milling machines 2013		Janicki Industries	$650.00	$0.00	$0.00
5		Water jetted aluminum frame 2014		Janicki Industries	$750.00		$0.00
6		Welding Services 2014 employee time		Janicki Industries	$300.00		$0.00
7		Use of milling machines 2014		Janicki Industries	$500.00		$0.00
8		Anodizing 2013		Precision Plating	$200.00		$0.00
9		Anodizing 2014		Precision Plating	$100.00		$0.00
				Sub-total:	$4,925.00	Sub-total:	$0.00
Propulsion							
1	4	SeaBotix ROV thrusters	BTD150	SeaBotix		$390.00	$1,560.00
2	2	VideoRay (Estimated $2000.00 each)		VideoRay	$1,800.00	$550.00	$1,100.00
3	8	Mounting Screws	LB319	SeaBotix		$0.30	$2.40
				Sub-total:	$1,800.00	Sub-total:	$2,662.40
Cameras & Sensors							
1	1	Gear-motor: 32mm; 24VDC; 67rpm	IG32-24VDC	Super Droid		$20.49	$20.49
2	1	Wide angle board camera 460 lines	PC823XS	Super Circuits		$79.99	$79.99
3	3	380 line board camera	PC303XS	Super Circuits		$39.99	$119.97
4	2	10-32 SS Rivet	#98005A150	McMaster Carr		$14.42	$28.84
5	2	10-32 SS Thumb Screw	#99607A167	McMaster Carr		$10.97	$21.94
6	2	#10 SS Serrated Washer	#91812A427	McMaster Carr		$7.89	$15.78
7	5	3/8" NPT Cord Grip	#2638	Dell City Electric		$0.96	$4.80
8	1	Urethane Potting com-pound		AeroMarine		$38.00	$38.00
9	4	Ultra-white LED; 48000 MCD; single bayonet lamp; (Sunbrite #SSP-1156B 15912)	370-0063	Allied Electronics		$12.53	$50.12
10	4	single bayonet lamp socket		Super Circuits		$3.99	$15.96
11	3	MCBH-3-M		Mecco		$44.78	$134.34
12	3	MCIL-3-F		Mecco		$27.99	$83.97
				Sub-total:	$0.00	Sub-total:	$614.20
Tether							
1	5	BNC to BNC coupler	#70000454	Allied Electronics		$3.95	$19.75
2	150	5 line coaxial cable	CF.KOAX1.05	igus, inc	$1825.50	$0.00	$0.00
3	5	BNC Solder Bulkhead	#512-1276	Allied Electronics		$3.23	$16.15
				Sub-total:	$1,825.50	Sub-total:	$35.90

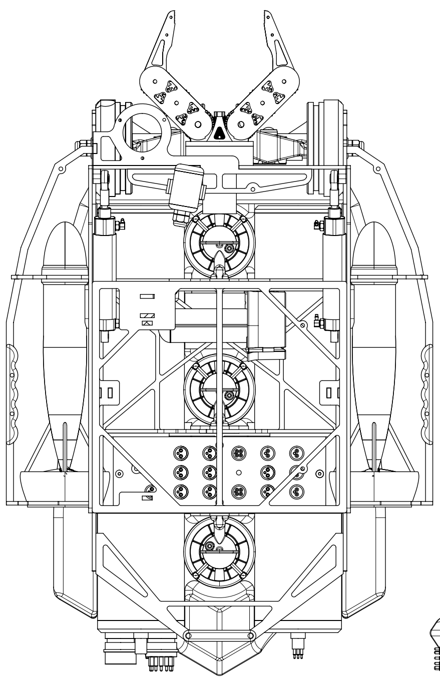
Controls and Console							
1	5	BNC bulkhead fittings		Skagit Whatcom Electronics		$4.99	$24.95
2	5	1' Foot BNC jumper cables		Showmecables.com		$2.75	$13.75
3	5	Right angle BNC adapters		Showmecables.com		$2.87	$14.35
4	1	19" insignia monitor	#19E430A10	Ebay		$152.00	$152.00
5	1	Quad Color Processor	#VM-Q401A	CCTV camera pros		$129.99	$129.99
6	1	.08" non glare acrylic 17"x22"	Clear	Tap Plastics		$15.32	$15.32
7	1	1/8" ABS sheet 18"x24"	Black	Tap Plastics		$15.32	$15.32
8	1	Miscellaneous SS fasteners				$12.45	$12.45
9	1	Water jetted pieces of aluminum		Janicki Industries	$150.00	$0.00	$0.00
10	3	Sabertooth 2X25 (motor controllers)		Dimensions Engineering		$124.99	$374.97
11	5	50k sliding taper potentiometer		Futurlec		$1.30	$6.50
12	1	BH-12-MP		Mecco		$107.40	$107.40
13	1	BH-12-FS		Mecco		$106.30	$106.30
14	1	IL-12-M		Mecco		$75.50	$75.50
15	1	MCBH-8-M		Mecco		$77.32	$77.32
16	1	MCBH-8-F		Mecco		$84.23	$84.23
17	1	MCBH-6-M		Mecco		68.78	$68.78
18	1	MCBH-6-F		Mecco		$72.98	$72.98
19	4	MCBH-2-M		Mecco		$36.41	$145.64
20	1	IL-6-FS		Mecco		$8.24	$8.24
21	1	IL-6-MP		Mecco		$7.42	$7.42
22	1	MCIL-6-FS		Mecco		$49.32	$49.32
23	1	MCIL-6-MP		Mecco		$47.07	$47.07
24	1	DVR with Software		Best Buy		79.99	79.99
				Sub-total:	$150.00	Sub-total:	$1,689.79
Gripper & Mission Tools							
1	1	Water Jetted Parts		Janicki Industries	$250.00	$0.00	$0.00
2	2	Delrin Gears		Jameco		$25.00	$50.00
3	1	Stainless Steel rod		Jameco		$50.00	$50.00
4	4	sealing screws with O-rings		Jameco		$1.88	$7.52
5	4	5/16" Plastic Washers		Ace Hardware		$1.00	$4.00
6	8	3/16" Plastic Washers		Ace Hardware		$0.80	$6.40
7	4	Bolt Spacers		Ace Hardware		$1.50	$6.00
8	1	Canister Plug		Sea-Tech		$0.00	$0.00
9	1	O-ring		Sea-Tech		$0.00	$0.00
10	2	Rubber finger tip screws				$1.25	$2.50
11	1	Strain relief connector				$0.95	$0.95
12	1	100Kohm slider Potentiometer		Mouser Electronics		$5.52	$5.52
				Sub-total:	$250.00	Sub-total:	$132.89

Fasteners							
1	50	5/16"-18 x 1"18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.33	$16.63
2	30	M3x12mmL Panhead Slotted 18-8S/S Seal screw		Fastenal		$0.59	$17.82
3	10	1/4"-20 x 1-1/4" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.13	$1.27
4	10	1/4"-20 x 18-8 Stainless steel Socket Cap Screw		Fastenal		$0.15	$1.53
5	10	1/4"-20 x 3/4" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.15	$1.53
6	10	1/4"-20 x 5/8" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.15	$1.45
7	20	1/4"-20 x 1/2" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.12	$2.44
8	15	#10-32 x 1/2" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.15	$2.26
9	15	#10-32 x 5/8" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.10	$1.50
10	10	#10-32 x 3/4" 18-8 Stainless Steel Socket Cap Screw		Fastenal		$0.10	$0.98
11	1	#5/16"-18 x 3' 18-8 Stainless Steel Continuous Threaded Rod		Fastenal		$5.82	$5.82
12	100	#10 18-8 Stainless Steel Small OD Flat washer		Fastenal		$0.02	$2.07
13	100	1/4" 18-8 Stainless Steel Small OD Flat Washer		Fastenal		$0.03	$2.67
14	100	5/16" 18-8 Stainless Steel Small OD Flat Washer		Fastenal		$0.05	$4.64
15	50	1/4"-20 NE 18-8 Stainless Steel Nylon Insert Lock Nut		Fastenal		$0.10	$5.00
16	50	5/16-18 NE 18-8 Stainless Steel Nylon Insert Lock Nut		Fastenal		$0.14	$6.95
17	50	#10-32 NM 18-8 Stainless Steel Nylon Insert Lock Nut		Fastenal		$0.12	$6.00
				Sub-total:	$0.00	Sub-total:	$80.57
Connectors:							
1	4	2 contact male SubCon connector		Ocean Innovations	$20.00	$21.11	$84.44
2	4	2 contact female - male SubCon connector		Ocean Innovations	$25.00	$36.75	$147.00
				Sub-total:	$45.00	Sub-total:	$231.44
Engineering Documentation							
1		Poster printing cost				$0.00	$67.87
2		Foam-core Board				$0.00	$4.99
3		Report Printing				$0.00	$2.47
				Sub-total:	$0.00	Sub-total:	$75.33
Travel Expenses							
1	4	Plane Tickets				$800.00	$3,200.00
2	6	Accommodations				$150.00	$900.00
3		Commodities				$0.00	$300.00
				Sub-total:	$0.00	Sub-total:	$4400.00
		$4,722.25					
		2013 Company Cost (orange cells):	$3,795.23	Fair Market Donated Total:	$8,995.50	Company Cost:	$9,922.52
				Total Cost (Both Donated and Company Cost):			$18,918.02

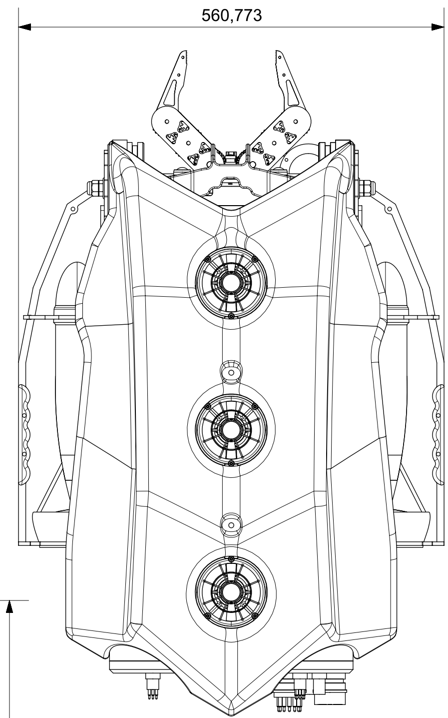
Appendix VI: Mechanical Sketch of ROV



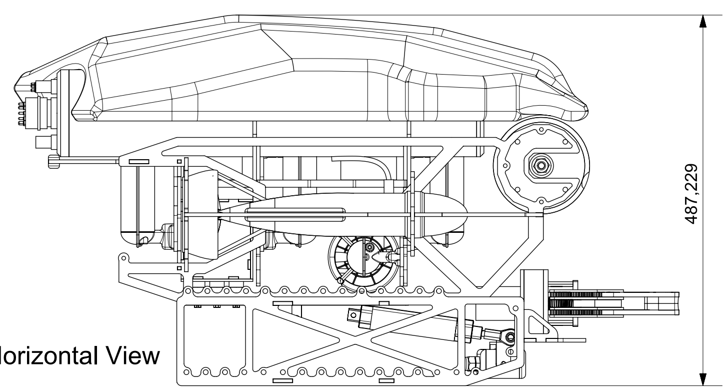
Isometric View



Bottom View



Top View



Right Horizontal View

Weight: 43kg
Note: All measurements are in millimeters

Appendix VII: Control Housing End Cap Drawing