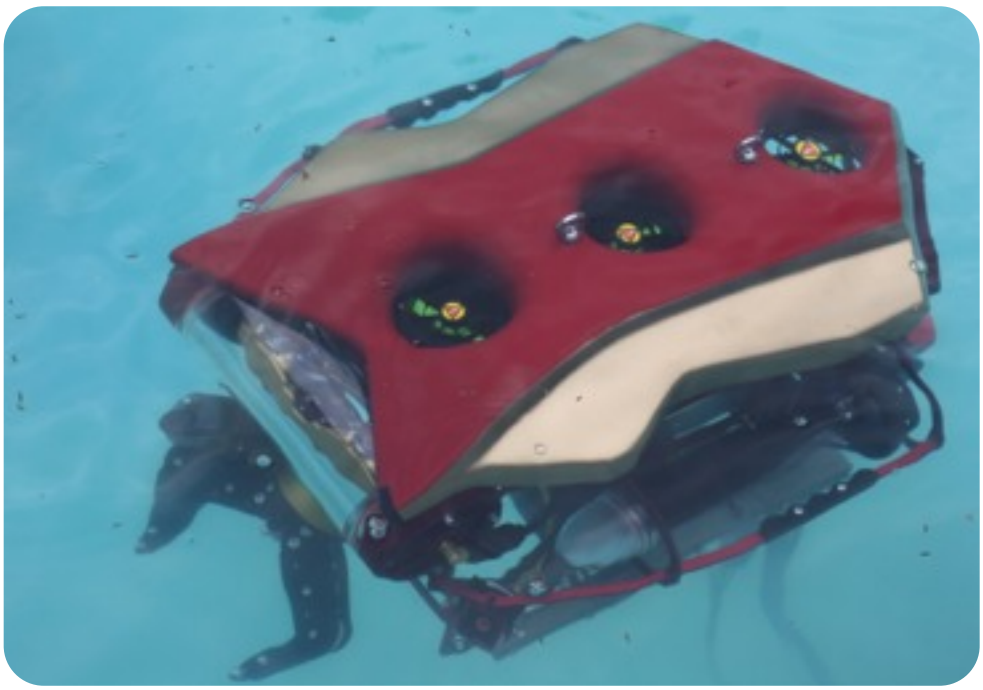
Sea tech 4-H Club
Mount Vernon, WA

S.I.G.M.A

Students for Innovative Global Marine Analysis



Project ΣVI

Mentors: Peter Janicki, Lee McNeil
CEO: Stanley Janicki
CFO: Sierra McNeil
Marketing Director: Matthew Atilano
R&D: Michael Janicki & Madison Walkup

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Abstract

Students for Innovative Global Marine Analysis (SIGMA) have produced a Remotely Operated Vehicle (ROV) designed as the next-generation solution for oceanic observation - Project ΣVI. Working specifically on the U.S. regional cabled ocean observatory in the Pacific Northwest, SIGMA hopes to enable a safe and effective means to predict oceanic behavior.

The five members of SIGMA designed and built ΣVI with the capability to complete the 2013 competition tasks published by the Marine Advanced Technology Education (MATE) Center. Before any fabrication, SIGMA first created a detailed Computer Aided Design (CAD) model of the ROV. ΣVI consists of a welded aluminum frame and a foam float bolted to the top of the ROV with weights at the bottom to give the machine neutral buoyancy. A removable mission sled is incorporated with task-specific tooling. Six thrusters allow ΣVI to navigate multiple degrees of freedom with ease, and are controlled by a hall-effect joystick and two potentiometers. A manipulator is positioned at the front of the machine, and is mounted to a plate that rotates down using pneumatic actuators. A rotating high definition (HD) camera, augmented by four auxiliary cameras mounted on the frame, gives optimal vision. Project ΣVI relies on a custom-made electronics system created by SIGMA.

SIGMA has created project ΣVI as a cutting-edge response to a challenge that has faced oceanographers for years - accurately predicting oceanic behavior. With the help of project ΣVI, SIGMA intends to bring the world a little closer to that goal.

1. S.I.G.M.A STAFF

Stanley Janicki

Company Role: CEO

Competition Role: Captain

With six years of experience building ROVs in Sea-Tech, Stanley is a task-oriented leader with schedule efficiency as his top priority. Proficient with CAD modeling, he accomplished the goal of creating a detailed, accurate and precise model of the entire ROV. He is currently in the twelfth grade as a college student.

Sierra McNeil

Company Role: CFO

Competition Role: Mission Commander

With six years of experience building ROVs in the Sea-Tech and the MATE competitions, Sierra McNeil has gained strong leadership skills, a good work ethic and a love of ROVs. She has had the honor of being the club leader's daughter, which has greatly increased knowledge and exposure to ROVs. At age 16, Sierra is currently a Junior in high-school as a home schooled student. She has plans to further her education at college, using the knowledge and skill she has gained from Sea-Tech.

Matthew Atilano

Company Role: Marketing Director

Competition Role: Transmissiometer Manager / Tether Tender

Matthew Atilano has participated in four regionally held competitions and two international MATE competitions. Leading the Sea-Tech 4H high-school level team to first place regionally for the last two years has been 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, building a more complex ROV, balancing time between the ROV project and completing his senior year of high-school while working with an entirely new team.

Michael Janicki

Company Role: Research and Development

Competition Role: Pilot

Michael is currently a 16 year old sophomore enrolled at Skagit Valley College. This is his second year of participating on the Explorer team. He is extremely interested in all things mechanical and electrical. Michael was very involved with the entire building process of the ROV, but specialized in the electronics - specifically designing a professional control box for the ROV. This is Michael's sixth year in Sea-Tech and his fourth ROV project.

Madison Walkup

Company Role: Research and Development

Competition Role: Mission Specialist

Madison Walkup has been working on ROV projects with Sea-Tech 4H for five years. She has been an active member, and is currently acting as the club reporter. This is her first year competing at the Explorer level. As a 17-year old freshman at Skagit Valley College, Madison hopes to use the skills she learned in Sea-Tech to help her finish her degree in Engineering.

Team Sigma ΣVI

2. Design Rational

2.1 Mission Oriented

Project ΣVI was created by SIGMA to perform multiple tasks involving installation and maintenance on a regional cabled ocean observatory. The versatile nature of the ROV gives it the ability to complete many tasks without extra special tooling, allowing it to comply with the needs of a variety of clients. The specific tasks put forth by the MATE Center required ΣVI to be equipped with a few unique tools, designed and built by SIGMA. The majority of these tasks can be completed with the machine's 24 Volt DC, parallel-motion manipulator. However, the frame was designed with a removable mission sled in the event that more specialized tools are required for future ventures. Custom mounted on the sled is a metric tape measurer, used to find the installation location of for the secondary node. SIGMA also designed a rotating tool used to level the node after installation. Five cameras allow for multiple perspective navigation, and six thrusters give ΣVI precise mobility, making the machine efficient and effective. In order to complete all of the missions put forth by MATE, SIGMA also produced an optical transmissiometer, built independently from the ROV. This device is used to measure turbidity over time, and was designed to be easily transported by ΣVI. These tools fully equip ΣVI for the tasks the MATE Center wishes to complete.

2.2 Design Process

CAD Modeling:

The production of ΣVI 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 NX6. Simulated assembly made it possible for SIGMA to detect design flaws and avoid wasteful trial-and-error. The model made the building process streamlined and simple, with the accuracy to allow SIGMA to cut the majority of the ROV's frame with a high-precision water jet. The process of cutting these parts was done at a sponsor's facility. The company did not cut the parts themselves due to safety concerns, but members embraced the opportunity to be involved in every step of the process. SIGMA took every measure to assure that project ΣVI would be a functional, effective response to the needs of our clients. The CAD model of the ROV assisted the company in making the fabrication process as accurate and simple as possible.

Figure 1 - CAD model of project ΣVI

2.3 Mechanical Structure

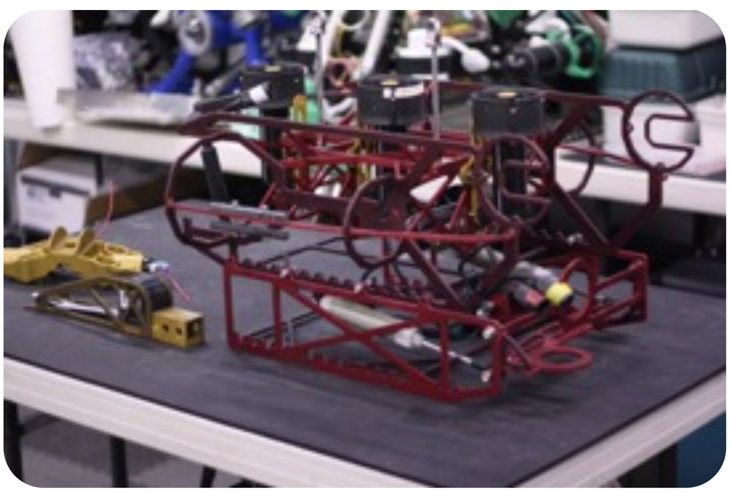


Figure 2 - Project ΣVI's aluminum frame

Frame

Project ΣVI is fitted with a sturdy 3/16" aluminum frame. Each section was cut on a water jet, then assembled by SIGMA 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 strong, giving the machine ease of transport. This is augmented by several convenient handles incorporated directly into the frame. Mounted on the bottom of the ROV is a removable mission sled, which was designed for diversity with future clients in mind. Bolted to the upper part of the frame is the float, which is removable in the event of a need for repairs. Multiple camera mounting points are incorporated throughout the frame should a mission require a different viewing field. All of the aluminum framework was anodized to preserve the metal, which increases the longevity of the machine by avoiding corrosion.

Mission Sled

The mission sled was also designed by SIGMA members on a CAD modeling program. It was cut from the same type of aluminum as the ROV frame, and conveniently bolts to the lower portion of the machine. Mounting holes for adding ballast as necessary are located along the bottom edge of the sled. The mission sled contains two specialized tools to complete the tasks put forth by our client, as well as the manipulator. Though the sled is also designed to have the capability to carry other tools should SIGMA refit project ΣVI to suit the needs of another client. The purpose of these tools will be discussed in detail in 2.4, *Payload Tooling*.

Righting Moment

A desire for a strong righting moment heavily influenced the design of project ΣVI. SIGMA achieved this through a balanced system of floatation and ballast. The float, machined from a block of high-density polyurethane foam coated with a thin layer of carbon fiber, is mounted at the top of the machine. The volume of the float was carefully calculated to give the ROV neutral buoyancy. To create the stiff righting moment desired, ballast is added to the lower portion of the ROV. This creates maximum stability even at high speeds. Because of the balanced nature of the ROV, project ΣVI is able to lift heavy objects and maneuver with ease.

Figure 3 - Polyurethane float in the process of being coated in carbon fiber

2.4 Payload Tooling

Manipulator

Project ΣVI is capable of completing the majority of the tasks put forth by MATE with the aid of its 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 manipulator is essential for the transportation of the various components of the cabled observatory, as well as the delicate removal of biofouling.

Figure 4 - Disassembled Manipulator

Optical Transmissiometer

SIGMA's response to MATE's need to measure the turbidity of a hydrothermal plume is a custom-built optical transmissiometer. Modeled with CAD, and water jetted from aluminum, the transmissiometer is compact and easily transported by Project ΣVI. It utilizes a photo resistor and an inexpensive pond light to detect opacity. The information gathered by the sensor is recorded at a deck side computer using data acquisition (DATAQ brand) software.

Additional Tooling

The installation and maintenance on the regional cabled ocean observatory does not require many specialized tools. However, Project ΣVI is equipped with a few mission-specific features. Mounted to the mission sled is a metric tape measurer. It is fitted within a custom-made aluminum bracket, and secured with a locking pin, making replacement and adjustment simple. Situated above the tape measurer is an auxiliary camera used to provide video feed of the measurement needed to find the designated location for installation of the secondary node. Mounted at the front of the machine is the rotating tool SIGMA designed to level the secondary node after installation. It is made from 1/2 inch PVC pipe fittings, designed to fit over the handle of the secondary node. It rotates via a gear motor mounted within a waterproof canister. With the aid of project ΣVI's main camera, the node-leveling tool accurately creates a stable, parallel mounting platform for the secondary node.

2.5 Propulsion

Figure 5 - VideoRay thruster

ΣVI 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 upper center of the ROV, and horizontal sway, as well as yaw is achieved through one Seabotix thruster mounted within the lower center portion of the frame. The company wanted to build their own thrusters but time constraints did not allow such a project. The VideoRay thrusters have over a 2-1 thrust to weight ratio, and give ΣVI smooth, 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 are produced specifically for ROV's. Each produces 2.2 Kg of thrust, and are equipped with a brushed motor housing, end caps, propellers and kort nozzles. All of the thrusters are interfaced into the frame using mounting bars for easy removal and maintenance.

2.6 Cameras

Figure 6 - CAD model of camera housing

One of Project ΣVI's most prominent and useful features is it's color, wide angle 720 line camera with auto-focus. The camera housing was carefully modeled in CAD, then machined by company staff from an aluminum billet. It is sealed within a 12.7 cm diameter acrylic tube, 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. To provide multiple viewing platforms, four auxiliary cameras are mounted on the frame of the ROV. 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 viewing field, and provide high-definition, color video. They are completely waterproofed, 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 ΣVI, a multiplexer is used to reduce monitor space and provide a fast way to asses the feed from each camera simultaneously. To achieve this, a 5-line multi-coaxial cable is incorporated into the tether. This connects to the quad video multiplexer in the deck-side control box, which combines four video signals into one monitor signal. The fifth signal is streamed into the company's auxiliary monitor.

Figure 7 - Project ΣVI's camera housing

2.7 Electrical Control System

Control

Project ΣVI embodies a simple design without compromising proper function or performance. Therefore, a hardware-only approach was selected to control the ROV. SIGMA and its associates have utilized software to control machines in the past, and though this approach has some advantages, they are outweighed by unnecessary problems due to the added complexity. The hardware-only approach circumvents these issues by being simpler and more

reliable than a software approach. The system utilizes three outsourced motor controllers which SIGMA custom-interfaced with the system. These controllers were purchased from Dimension Engineering and chosen because they operate at 48 Volts DC. The first controller drives the fore, aft and yaw of the machine whereas the second controls the vertical and side thrust, while the third is for the node leveler and camera. The controllers utilize 0-5 Volt analog control signals for the operation. The second controller is set so that 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 turn capability of the ROV. Potentiometers were used for vertical control. The joystick and both of the potentiometers are mounted to a small, plastic control box, which is connected to the main control case by a cable. The main power input is fused with a 30 amp fuse, as well as a large emergency off switch as a safety future in case quick shut off is necessary. Each individual output is protected by appropriately rated fuses.

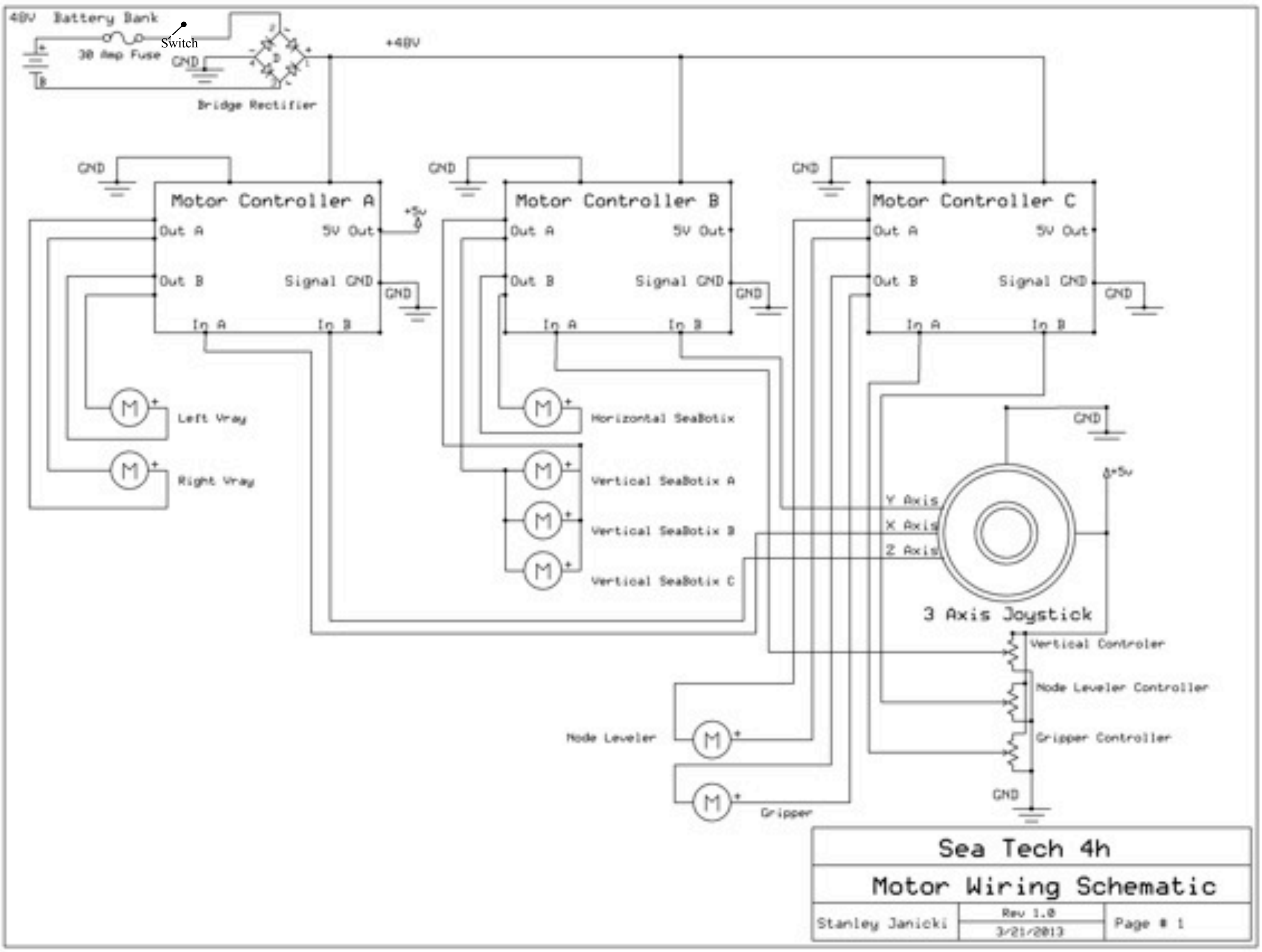
Control Case

The control system is mounted inside a single pelican brand case. A single flat panel, glare-resistant monitor is permanently mounted inside lid of the case protecting the monitor inside. The main body of the control case consists of a multi-level, three panel assembly that can be removed from the case simply by pulling out two screws. The main, and bottom panel houses the main electrical components; The middle plate which holds the three panels together, is securely fastened to the case, and is open providing easy access to the electrical components below it. The top face panel moves about two sturdy hinges on the back allowing for easy access. The top face panel of the case accommodates the emergency off switch, as well as a set of military-grade bulkhead connectors which connect the control system to the tether and the control case. The systems within the control box were built independently so if one component fails, the entire system will not go down; and if a component does fail, due to the thoughtful design it is an effortless fix.

Connectors

The tether is terminated on both ends with robust connectors. The surface end of the tether is split into two military-grade connectors. A 12 pin connector supplies power to project ΣVI. An 8 pin connector supplies power to the cameras and lights. On the ROV side, the tether is split into a 12 pin Sea-Con connector for power and an 8 pin Sea-Con connector. To ensure a watertight connection, the Sea-Con connectors were equipped with underwater cable terminations. This process was performed by SIGMA. On the four compact cameras SIGMA utilized 3 pin Cooper Interconnect connectors. These connectors were tested by Cooper to see if they would work for the SIGMA's needs.

2.8 Motor Schematic



2.9 Safety

Project ΣVI was built with a safety as a priority, keeping in mind SIGMA's safety philosophy: safe staff equals an effective process. Thruster guards prevent the exposed propellers from possible entanglement or unwanted contact, and safety labels identifying all moving parts to clearly mark the potential dangers. Handles incorporated into the frame allow for safe launch and retrieval methods and were designed to be appropriately distanced from the thrusters. Electrical safety concerns have been addressed by ensuring every subsystem within the control box was built independently so if one component fails, the entire system will not. In the event of an emergency the main power input is fused but also includes a large emergency shut-off switch which has the capability to cut all power to the machine. In addition to these features, SIGMA always follows a strict safety protocol when running the machine (see Appendix D).

3. Expenditure Summary

Category:	Company Expenditure:	Donated Amount:	Total Cost:
Frame & Buoyancy	$0.00	$3,450.00	$3,450.00
Propulsion	$3,052.40	$1,800.00	$4,852.40
Cameras & Sensors	$435.88	$0.00	$435.88
Tilting Camera Assembly	$310.09	$0.00	$310.09
Controls & Console	$1,137.07	$150.00	$1,287.07
Gripper & Mission Tools	$132.89	$250.00	$382.89
Fasteners	$80.57	$0.00	$80.57
Connectors	$231.44	$45.00	$276.44
Engineering Documentation	$75.33	$0.00	$75.33
Grand Total:	**$5,455.67**	**$5,695.00**	**$11,150.67**
		Fair Market Value:	**$11,150.67**

See Appendix C for detailed report.

4. Team Process

4.1 Troubleshooting

Any major project will inevitably require troubleshooting. At MATE’s 2013 Regional Competition during ΣVI’s qualifying run the main camera stopped working and SIGMA was unable to qualify for the International Competition. Luckily, the company was given a grace round, and was given a few hours to resolve the camera issue. SIGMA isolated the problem by testing each camera individually

Figure 8 - Stanley Janicki and Madison Walkup testing Project ΣVI for buoyancy

then reconnecting power. The company was then able to determine that there was a faulty underwater connector that was creating a short. After this SIGMA was able to complete their second run and qualified for the International Competition. This proved not only to be a technical opportunity to troubleshoot, but also a team-building situation as the company worked under high-stress conditions.

4.2 One Challenge/Troubleshooting

The process of producing an effective response to the needs of our client, MATE, required many hours of trial-and-error troubleshooting, despite careful planning. One particular challenge SIGMA came up against was the float was cut from the wrong density foam. The volume had been calculated to achieve neutral buoyancy, but with the higher-density foam ΣVI was significantly positively buoyant. As soon as they had identified the issue, SIGMA carefully considered the possibilities for correcting it. One option would be to reduce the size of the float, while the other was adding more ballast to compensate for the buoyancy. SIGMA rejected the idea of reducing the float, because it would be wasteful for excess material to go unused, would reduce the machines righting moment. After spending several hours experimenting with different weights attached to the bolt-holes at the bottom of the mission sled, SIGMA estimated the approximate weight that needed to be added to bring ΣVI down to neutral buoyancy. After this, SIGMA water jetted custom weights that corrected the buoyancy.

4.3 Interpersonal Challenge

SIGMA consisted of five members which had never worked together before, and had even competed against each other in years past. Two of the members are graduating Seniors, while the other three are Juniors, so assigning roles based on knowledge level rather than seniority was difficult. Discovering how each member processed information, handled stress and followed through with commitments was a huge part of the project. Learning how to work together with a completely new team proved to be both challenging and rewarding.

4.4 Teamwork

SIGMA made a superhuman effort to include the team in every step of the process of building project ΣVI. This includes writing the technical report and spec sheet as well as designing the presentation poster. The ROV was built completely by company staff, no parts were made by mentors or consultants. In order to minimize confusion and maximize effectivity, at the beginning of the project SIGMA developed an outline of the tasks that would be required and which company member would manage these tasks:

Madison: Evaluation Planing, Tech Report, Poster, Tether, Frame, Presentation outline

Sierra: Mission task CAD design, Press release, ROV Construction, Thrusters

Stanley: Fundamental systems integration CAD, CAM and machining of select parts, Cameras

Matthew: Website, Mission tooling, Gripper, Flotation, Special tools

Michael: Control system, Electronics, Control box, On board ROV wiring

The team also kept a detailed log book, and frequently sent out week-to-week schedule coordination as well as checking in with each company member to asses how their part of the project was going.

4.5 Lessons Learned

Technical

Time management is essential to the production of an effective ROV, and this became evident as soon as SIGMA began the process. SIGMA carefully compiled a list of the parts that needed to be water jetted and assigned a specific block of time that the water jetting would take. However they were faced with the challenge of having to accommodate a supplier who took more time than was expected to process their order. This set SIGMA back by several weeks, and recovery was difficult. In the future, SIGMA plans to prepare for such delays. For the remainder of the year we were careful to provide ample time in order to prevent another setback.

Interpersonal

Communication at the beginning of the project was not regular, and because of this teamwork was slightly strained. As time progressed the company developed a system for making sure that information was correctly relayed, and working together as a team became much more enjoyable and rewarding. This system consisted of regular email updates from team members and photo updates to our Facebook page.

4.6 Future Improvements

This year, SIGMA was generously sponsored, and budget concerns did not hamper the production of the ROV. However, SIGMA would like to serve other clients in the future, and recognizes the need for budget constraints put forth by different programs or organizations. This year particularly, SIGMA did not have to factor in transportation restraints either, as the transportation of the ROV is minimal. For future ventures a more compact machine would be easily transportable, and less costly to ship. In addition to this, SIGMA would like to expand their horizons to include deeper dives. This would require onboard electronics as well as a longer tether. Deeper diving would allow SIGMA to fill the needs of a wider field of clients.

4.7 Reflections

Building project ΣVI was a very rewarding experience to the SIGMA members. Building ROVs has affected each member's life in a significant way, and many of them plan on pursuing engineering as a profession. Project ΣVI was taken very seriously, and the end product is both professional and impressive. The professionalism of SIGMA members in addition to the machine has already caught the eye of the engineering world, and the ROV has been commissioned for a mission on a boat in the summer of 2013. Building on the experience gained from working on project ΣVI, SIGMA hopes to produce ROVs with greater results, and continue fostering a love of science and engineering in students.

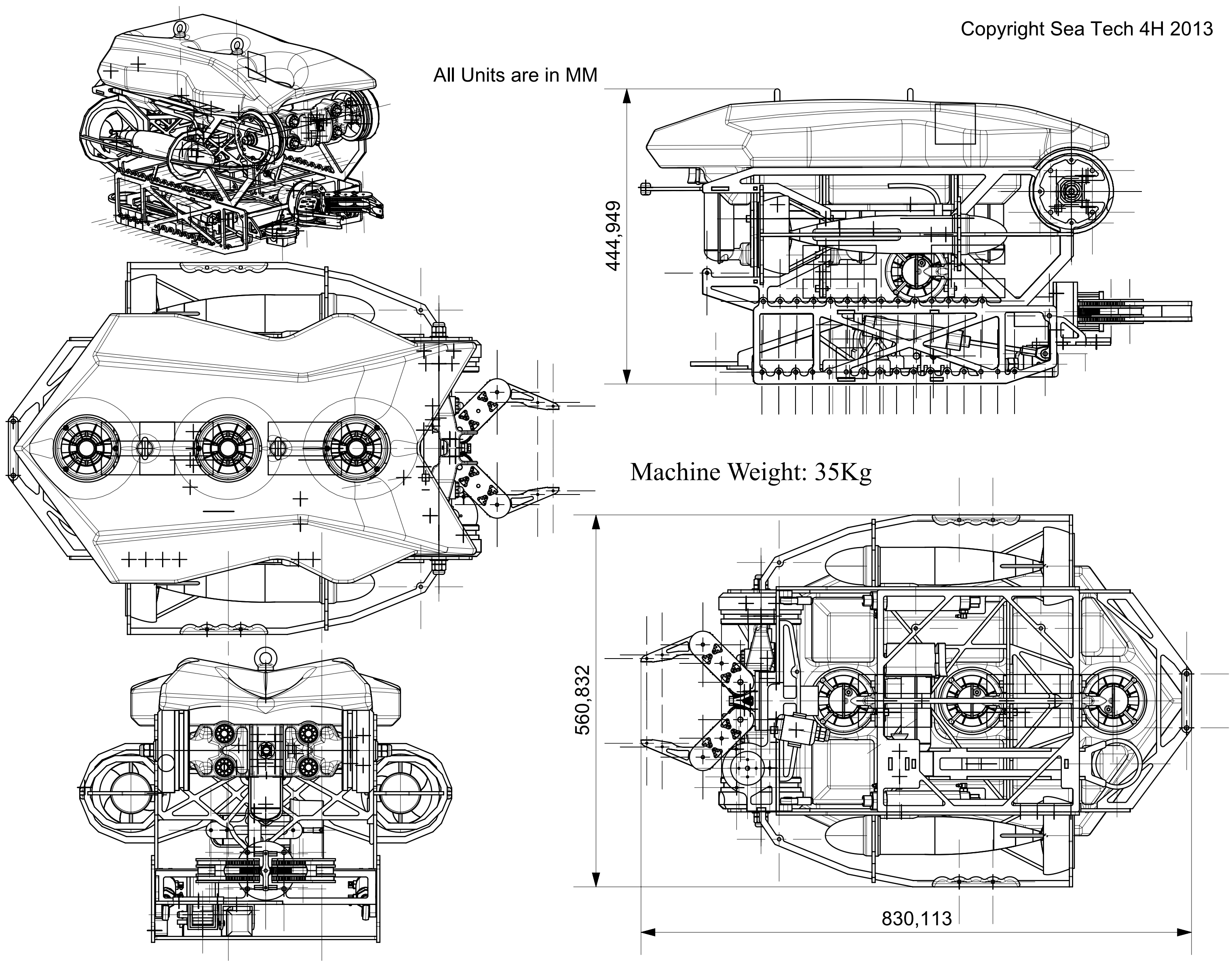
5. Acknowledgments

SIGMA would like to recognize the companies, organizations, and individuals who made this project possible. Without their support, project ΣVI would never have been completed:

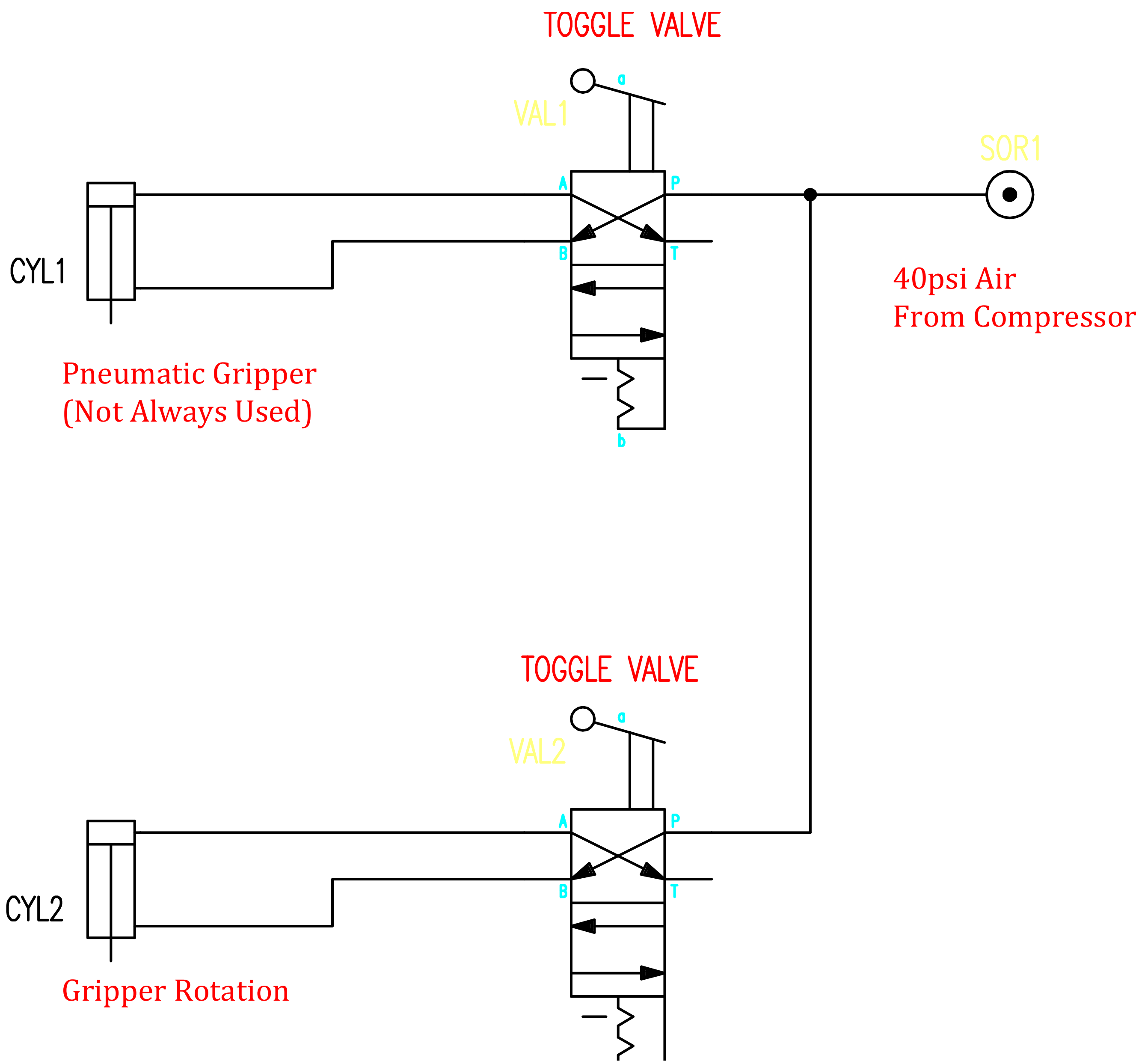
- Lee McNeil, our club mentor, for your constant expertise and guidance. You have taught us so much, and we would never be who we are today without you.
- Peter Janicki, our team mentor, for your expert advice and support.
- The MATE Center. Your competition has challenged us to create greater things. Thank you for your inspiration.
- Janicki Industries, for your sponsorship of our project through monetary contributions. Your donations of supplies and services were indispensable, most notable the water jetting and milling services, which allowed us to expand our scope of technology.
- The Skagit County 4-H Office, for your continued support of our endeavors.
- Subcon and Ocean Inovations, for the generous discounts of the waterproof connections.
- VideoRay, for the discount on our thrusters.
- Seabotix, for the discount on thrusters.

6. APPENDIX

6.1 Appendix A: CAD Model of Project ΣVI



6.2 Appendix B: Pneumatic Diagram



6.3 Appendix C: Detailed Budget Sheet

Category / Item #:	Qty:	Item Description:	Mfg. P/N:	Source:	Donated value:	Unit Cost:	Total:
Frame & Buoyancy							
1		Water jetted aluminum frame		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		Janicki Industries	$475.00	$0.00	$0.00
4		Use of milling machines		Janicki Industries	$650.00	$0.00	$0.00
5		Carbon fiber		Janicki Industries	$375.00	$0.00	$0.00
				Sub-total:	$3,450.00	Sub-total:	$0.00
Propulsion							
1	5	SeaBotix ROV thrusters (reused from last year)	BTD150	SeaBotix		$390.00	$1,950.00
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:	$3,052.40
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	4	380 line board camera	PC303XS	Super Circuits		$39.99	$159.96
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 compound		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
				Sub-total:	$0.00	Sub-total:	$435.88
Tether							
1	5	BNC to BNC coupler	#70000454	Allied Electronics		$3.95	$19.75
2	2	5 line BNC coaxial cable (reused from last year)	#CTL5B-50B	L-Com		$126.00	$252.00
8	1	Clear Lexan Box	#7092K12	McMaster Carr		$22.19	$22.19
9	5	BNC Solder Bulkhead	#512-1276	Allied Electronics		$3.23	$16.15
				Sub-total:	$0.00	Sub-total:	$310.09
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 (reused from last year)	#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	Dimensions Engineering 2x50HV motor controller				$249.99	$749.97
11	3	Potentiometer	Black	Allied Electronics		$2.99	$8.97
				Sub-total:	$150.00	Sub-total:	$1,137.07
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 Steal 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 SubCon connector		Ocean Innovations	$20.00	$21.11	$84.44
2	4	2 Contact 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
				Fair Market Donated Total:	$5,695.00	Company Cost	$5,455.67
		Total Cost (Both Donated and Company Cost):					$11,150.67

6.4 Appendix D:

Safety Protocol & Checklist

ROV Setup & General Safety:

- [ ] When connecting ROV to power, (a) team member(s) must check to ensure correct polarity.
- [ ] All controllers, monitors, and equipment must rests securely on command center table.
- [ ] Confirm 30 amp fuse is in place and working correctly.
- [ ] Power cord plugs must be fully inserted, and out of the way in order to eliminate tripping hazards.
- [ ] Keep all parts and hands away from propeller blades when ROV is powered on.
- [ ] When servicing electrical components, confirm that power is of and disconnected.
- [ ] When testing powered components, make sure before adding power, that there are no conductors that are touching, which could cause short circuiting.
- [ ] In the case of an emergency, 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 terminal to avoid short circuiting & sparking.

Safety Protocol