2016 MATE International ROV Competition

Technical Report for *Sea Wolf* ROV

Palos Verdes Institute of Technology

Palos Verdes High School, Palos Verdes Estates, California, USA

"SeaKing Depth in Underwater Engineering"

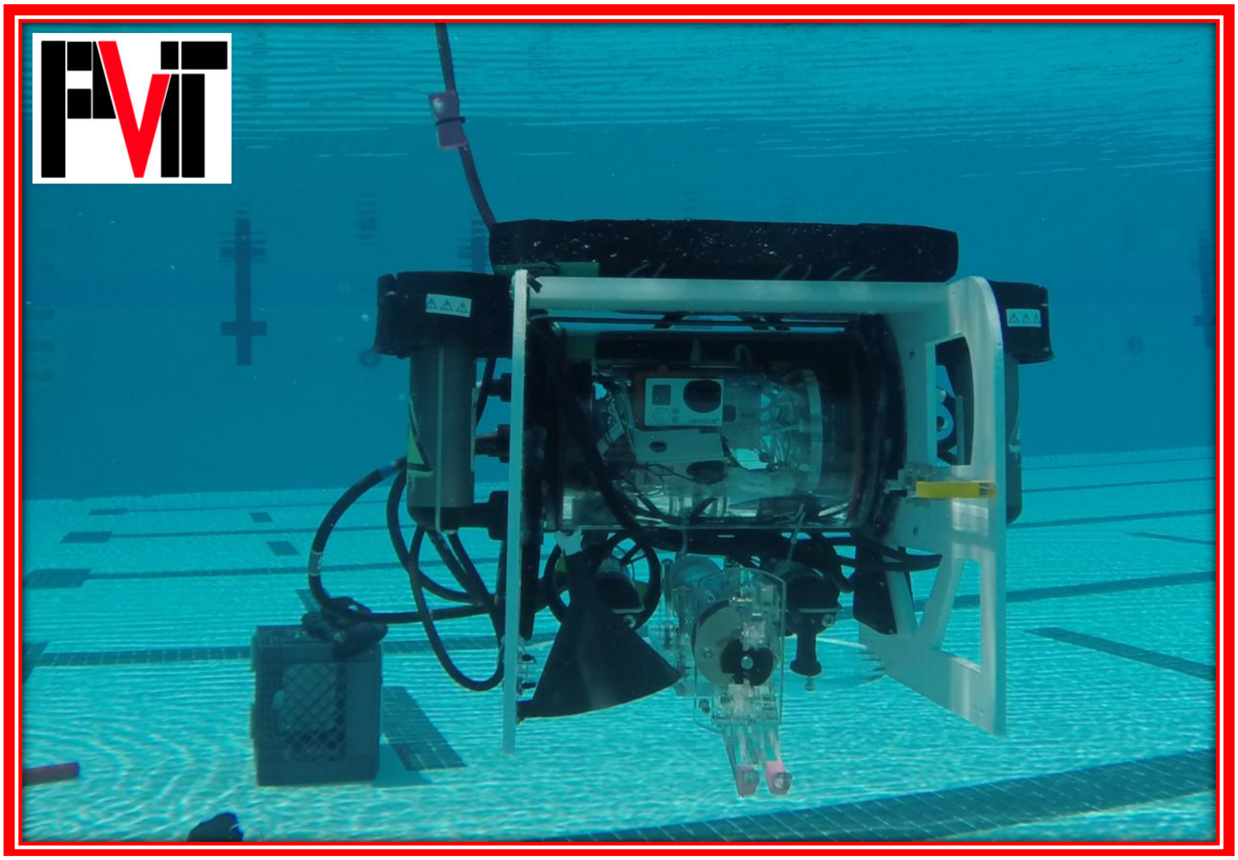

Fig. 1: The *Sea Wolf*   Photo: Casey Jo

2016 PVIT Ranger Team

JOSHUA MAGID: Chief Executive Officer, 3rd year, Class of 2017

KRAIG KREINER: President, 4th year, Class of 2016

LUCAS ALLEN: Chief Safety Officer, 4th year, Class of 2016

BRIAN SMALLING: Pilot, System Designer, 2nd year, Class of 2018

JOHN ROBERTSHAW: Electrical Engineer, 4th year, Class of 2016

CASEY JO: Chief Financial Officer, 2nd year, Class of 2016

MAX EBLING: Project Engineer, 2nd year, Class of 2016

JORDAN EWALD: Mechanical Engineer, 1st year, Class of 2018

JEFFERY HAAG: Mechanical Engineer, 1st year, Class of 2018

GARRET SMITH: Mechanical Engineer, 1st year, Class of 2018

NICOLAS KALEM: Mechanical Engineer, 1st year, Class of 2019

DAVIS DILLENBERG: Electrical Engineer, 1st year, Class of 2019

ERIK VAUGHN: Electrical Engineer, 1st year, Class of 2019

JOSEPH ARRIOLA: Mission Specialist Assistant, 1st year, Class of 2018

LORRAINE LOH-NORRIS: Instructor

KURT KREINER, NANCY KREINER & JULIE SMALLING: Mentors

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Abstract

Palos Verdes Institute of Technology's (PVIT) newest Remotely Operated Vehicle (ROV), *Sea Wolf*, is the product of nine years of engineering experience. *Sea Wolf* is designed to meet the harsh demands of outer space and deep-sea environments. *Sea Wolf* features customized tools to study environments on Europa, and collect and analyze samples and the effects of oil spilled in the Gulf of Mexico.

Sea Wolf is an original concept; designed and developed with mission success in mind. PVIT ROV is organized into five mini-teams for easy planning, transfer of knowledge, and building of the *Sea Wolf*. Each team is responsible for their respective payload tools and props. Before the fabrication of each item, we create drafts on CAD programs like Autodesk and Corel Draw. PVIT fabricates customized parts utilizing laser cutters, 3D printers, drill presses and Computer Numeric Control (CNC) machines.

The *Sea Wolf* is the product of nine months of diligent work, resulting in a small, lightweight, maneuverable, and effective ROV. *Sea Wolf's* frame is made of durable polypropylene, and it is driven by four SeaBotix motors. A single claw is able to complete most tasks, while other tools like a hook and a temperature sensor are able to complete remaining tasks.

The following pages detail the preparation and engineering that went into producing the *Sea Wolf*. PVIT believes that *Sea Wolf* is able and ready to respond to Marine Advanced Technology Education's (MATE) request for proposal and the best ROV for the job.

Fig. 2: Team Photo   Photo: Lorraine Loh-Norris

Mission Theme

Once an emerging technology, ROVs have gained a significant place in the technology landscape because they complete highly detailed tasks in places humans cannot safely work. MATE's Request for Proposal (RFP) seeks an ROV capable of meeting technical mission demands in two distinct and challenging environments, outer space and deep sea. Water exploration—essential to our survival—is the common theme to both mission environments. ROV technology plays a pivotal role in exploring and preserving this resource and *Sea Wolf* is the ROV for the job.

The first application of the ROV is exploration of Jupiter's moon, Europa, to search for proof of life. Europa has a warm core and liquid water covered by ice. With abundant salt water, a rocky sea floor, and the energy and chemistry provided by tidal heating, Europa may have the ingredients needed to support simple organisms. The ROV must endure a one-way trip 588 to 601 million kilometers from Earth to a moon where its warmest point is minus 162° C. The ROV must penetrate Europa's ice sheet and perform a long-term investigation of the moon's ocean and seafloor.

The second application of the ROV is exploration of the Earth's oceans to evaluate and address the long-term effects of the Deepwater Horizon oil well leak that occurred in the Gulf of Mexico in 2010. The ROV must provide the data necessary to evaluate the health of the corals and identify residual oil mats. The ROV must also cap an oil well to prepare the wellhead for use as an artificial reef.

Sea Wolf is fully equipped and ready to execute the five missions in both environments. *Sea Wolf's* technical design highlights include:

- A small and lightweight frame meets constraints of rocket transport to Europa.
- Wide-angle cameras enhance accuracy of measurements and provide greater line of sight.
- A versatile, custom-designed claw precisely manipulates objects.
- A custom-designed connector guidance tool supplements claw functionality.

Sea Wolf is well qualified to meet the diverse requirements and environmental demands of MATE's RFP.

Fig. 3: Europa Photo: Google Images

Project Management

The *Sea Wolf* project team was split into five mini-teams, each focusing on one sub-mission. This approach effectively distributed the knowledge and experience from the seven returning team members to the seven new members. This teamwork approach was carried through to the Tech Report and the Sales Presentation. Every team member gained hands-on experience working on the ROV related to their assigned mission. Each team was responsible for their respective props and payload tools.

Weekly meetings began with the teams coming together to coordinate overlapping issues, including sharing payload tools. Whenever a mini-team had a problem they would brainstorm and consult with other mini-teams for advice and ideas. This project management approach provided a comprehensive, uniform, and efficient approach to building the ROV.

Mini-Teams (Table 1):

Project Leader and overall coordinator: Kraig Kreiner

Task	1: Mission to Europa	2: Mission-Critical Equipment Recovery	3: Forensic Fingerprinting	4: Deepwater Coral Study	5: Rigs to Reefs
Leader	J. Magid	J. Robertshaw	M. Ebling	C. Jo	B. Pennington
Team	B. Smalling D. Dillenberg	J. Ewald E. Vaughn	L. Allen	N. Kalem	J. Haag G. Smith J. Arriola

Project Schedule (Table 2):

	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June
Set Budget	Completed October 28									
Establish Mini Mission Teams	Completed November 22									
Work on Props		Completed January 31								
Develop Speeches							Work In Progress			
Get in Pool	Completed April 8									
Team Photo						Taken April 12 →				
Tech report Final Draft	Completed April 16									
Designing the ROV	Completed June 25									
Complete the ROV	Completed May 9									

Mission Strategy (Table 3):

The following single-page document is used to clarify, summarize, and focus the planning and execution of *Sea Wolf* creation and operation.

Key: Collect/Return to surface   Desk analysis   Underwater operations

Task 1: Mission to Europa

Task	Points
Insert the temperature sensor into the venting fluid.	10 pts
Measure the temperature of the venting fluid.	20 pts
Take picture of the ice crust.	
Determine thickness of ice crust.	10 pts
Take a picture of the ocean depth.	
Determining the depth of the ocean under the ice.	10 pts
Retrieve ESP cable connector from the elevator.	5 pts
Lay ESP cable through two waypoints.	10 pts ea. (20 tot)
Open door to the port on power and communications hub.	5 pts
Insert the cable connector into the port.	20 pts
Total:	100 pts

Task 2: Inner Space: Mission-Critical Equipment Recovery

Tasks	Points
Find (photograph) the four mission-critical CubeSats.	
Identify the serial numbers of the four CubeSats.	5 pts ea. (20 total)
Recover four CubeSats and place in collection basket.	5 pts ea. (20 total)
Total:	40 pts

Task 3: Inner Space: Forensic Fingerprinting

Tasks	Points
Collect one sample each from two oil mats on the ocean floor.	5 pts ea. (10)
Returning the samples to the surface.	5 pts ea. (10)
Analyze gas chromatograph of each sample to determine oil's origin.	10 pts ea.(20)
Total:	40 pts

Task 4: Inner Space: Deepwater Coral Study

Tasks	Points
Photograph two coral colonies (PVC).	5 pts ea. (10 total)
Compare photos to previous photos to determine their condition.	5 pts ea. (10 tot)
Return two coral samples to the surface (Pipe Cleaners).	5 pts each (10 tot)
Total:	30 pts

Task 5: Rigs to Reefs

Tasks	Points
Install flange to the top of the wellhead.	10 pts
Secure the flange to the wellhead with one bolt.	10 pts
Install wellhead cap over the flange.	10 pts
Secure the cap to the flange with two bolts.	10x2= 20 pts
Total:	50 pts

Project Costing (Table 4):

Revenue source is the Peninsula Education Foundation of the Palos Verdes Peninsula.
PVHS Booster Club provides funding for travel to the international competition, estimate $2,400

Total Value Reused Components	**$ 3,930**
Total 2016 Cost (Misc., ROV Components and Props)	**$ 1,420**
Total ROV Value	**$ 4,252**

Reused Components and Residual Material

**Note all costs are rounded to the nearest dollar*

Components	Description	Quantity	Cost Each	Sub-Total
Camera	GoPro Hero 3 Plus Black Edition	2	$ 400	$ 800
Motors	SeaBotix BTD 150	4	$ 450	$ 1,800
Arduino	Arduinos	2	$ 20	$ 40
Controller	PS2 controllers	2	$ 10	$ 20

Connectors	SEACON connectors	6	$ 167	$ 1,000
Pololus	Pololus	5	$ 16	$ 80
Polypropylene	Frame Material, sheets	2	$ 40	$ 80
Acrylic	Frame Supports, sheets	Various	Various	$ 20
Cement, bag	Residual material	1	$ 90	$ 90
PVC Pipes, Fittings, etc.	Previous Competition Residual PVC	Various	Not Available	Not Available
Total Value Reused				**$ 3,930**

2016 Miscellaneous Purchased Items

Misc. Items	Description	Quantity	Cost Each	Sub-Total
Poster Board	Large Tri Fold	2	$ 80	$ 160
MATE Registration	Competition Requirement	1	$100	$ 100
Toolbox	Tools /Materials, i.e. solder wire	1	$ 150	$ 150
Misc. Expenditures	Additional materials, i.e. wire, glue, switches, electronic components	Various	Various	$ 330
Total 2016 Misc. Costs				**$ 740**

2016 Parts Purchased for ROV Build

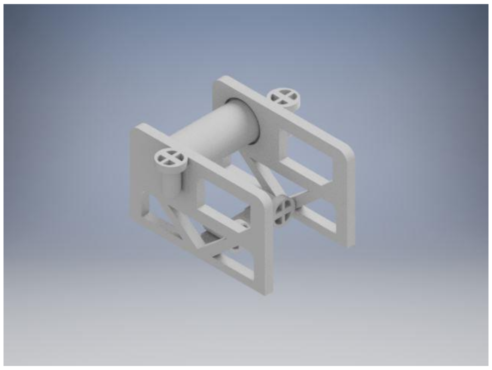
Parts/Material	Description	Quantity	Cost Each	Sub-Total
Power Pole Connector	Competition Requirement	2	$ 16	$ 32
Linear Actuator	Component for Claw	1	$ 87	$ 87
Ammeter	Tool	1	$ 30	$ 30
Velcro	1.22 Meters	1	$ 10	$ 10
Temperature Sensor	Competition Requirement (Previously Awarded by MATE)	1	$ 0	$ 0
Acrylic	12x24x.118	1	$ 10	$ 10
Acrylic	12x24x.220	1	$ 13	$ 13
Shrink Tube	Marine Grade, box	1	$ 100	$ 100
Screws/Nuts/Etc.	For Securing parts	Various	Various	$ 50
Polypropylene	Frame for the ROV, sheet	2	$ 40	$ 80
Total 2016 ROV Costs				**$ 412**

In addition to the costs above, PVIT purchased all of the PVC parts as listed in the MATE Prop Manual, these new parts along with the residual PVC materials we had in house, were sufficient to build all the required props for competition. The cost of new prop materials is **$268.**

Design Rationale

Sea Wolf is designed for optimal performance in underwater conditions and to survive space launch and long space flight conditions. With a small frame for easy maneuvering and high quality payload tools, *Sea Wolf* is ready for any underwater task. The ROV's Brain is composed of an Arduino Mega along with 5 Pololu motor controllers. Four SeaBotix BTD-150 motors provide power to drive the ROV. Polyethylene provides optimum buoyancy and stability for easy maneuverability. All tools are located on the ROV for maximum effectiveness, but within a 48 cm diameter to retain the small size of the ROV and to minimize the cost of transport to Europa. The control system was developed with a PlayStation 2 controller for ease of operation. The temperature probe is strategically located to provide easy access to a vent and minimize the vent force on *Sea Wolf* itself.

Fig. 4: ROV CAD Model Image: Nico Kalem



Frame

Sea Wolf is designed to be compact and lightweight for its journey to space. The frame is constructed from polypropylene because it is strong, easy to cut, and neutrally buoyant. To meet the size constraints imposed by the spacecraft's 48 centimeter cube cargo hold, the frame is 35cm X 46cm X 27cm. The acrylic tube that houses the Brain was modified to fit into the new frame. The Brain and horizontal motor mount are integrated into the frame crosspieces to reduce size and weight. Openings in the sides of the frame minimize weight and drag, and provide easy access to attach and maintain the Brain.

Fig. 5: Frame & Thrusters Photo: Brian Smalling

Propulsion

Four SeaBotix BTD-150 thrusters propel *Sea Wolf*. Each thruster has a mass of about 700 grams. The two vertical thrusters operate together as a single unit. The two horizontal thrusters operate independently, so that the ROV is able to spin 360 degrees. All thrusters operate in both forward and reverse directions. This setup does not allow for ROV strafe. However, pilot training with full use of the variable speed horizontal thrusters in combinations of forward and reverse directions allows complete maneuverability despite the lack of a strafe motor. All thrusters are placed out of the way of tools and cameras so as to not interfere with mission tasks.

Thruster safety is a primary design concern because the thrusters are the most potentially dangerous part of the ROV. All four thrusters come standard with shrouds in accordance with MATE Specification 3.2.5. Also, thrusters are clearly labeled with warning signs to warn divers of potential danger. Commercial SeaBotix thruster design and manufacture was utilized to ensure *Sea Wolf's* safety and functionality. The investment in these durable, high-quality thrusters can be amortized over their expected four-year lifespan.

Tether

The tether was constructed using an Ethernet cable and two 14-gauge speaker wires. The speaker wires supply 12-volt power and ground to the *Sea Wolf*. The Ethernet cable provides wires for serial communications, video signal, video ground, and the temperature probe. The tether is approximately 15.3 meters long and has a stress relief device that attaches it to the *Sea Wolf* to prevent damage to its connectors if it is pulled.

Fig. 6: Tether
Photo: Brian Smalling

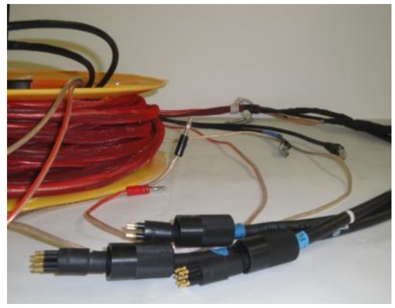


Fig. 7: Tether Connectors
Photo: Brian Smalling

Temperature Sensor

Sea Wolf is equipped with a temperature sensor to provide liquid temperature data from Europa. The sensor is a resistive sensor, meaning that it uses a resistor to calculate temperature. The sensor is a probe that has two wires running up to the surface as part of the tether and directly to a multi-meter. Using a spreadsheet, this signal of ohms is converted to a temperature reading.

Dragon Claw

Sea Wolf features a custom designed and fabricated claw. The claw has two fingers that are located across from each other. The upper finger has a unique notch on top to hold cable or line. The lower finger is actually a double finger so that when the claw closes, the fingers interlock to create a firm grasp of props. This setup and the shape of the fingers was designed to maximize the ability to grab the PVC, which is especially important to succeed with tasks on Europa and in the Gulf of Mexico. The original concept featured three fingers equally spaced on a circular base plate to be used for a wider variety tasks. The fingers were repositioned and the width of the base plate was cut down to decrease the mass of the claw and to make mounting the claw easier. A linear actuator increases gripping force between fingers and provides the reliability needed to ensure mission success on a distant moon and in a deep-sea environment

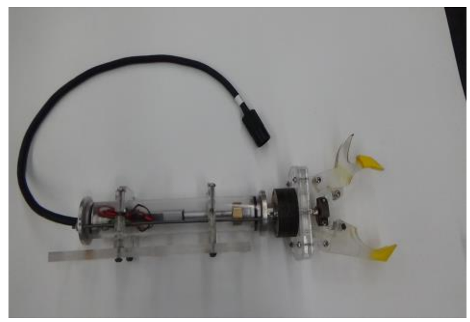


Fig. 8: *Dragon* Claw   Photo: Jordan Ewald

Because the claw can only grasp horizontal objects, *Sea Wolf* features a hook. It is used to pull vertical objects such as the door to the communications hub.

Cameras

Sea Wolf's unique two-camera system allows pilot and operators to see from multiple angles. The cameras are needed to drive and operate the ROV, making the system a critical component. The cameras must endure the harsh environment while reliably sending video to the pilot. The GoPro Hero 3+ Black Edition camera was selected for several reasons. First, the vertical wide-angle view aids the pilot in accomplishing underwater tasks. Second, it has the capability to take a video in 1080 at 60 or more fps. Third, its small size and durability meet RFP requirements. Finally, the price point

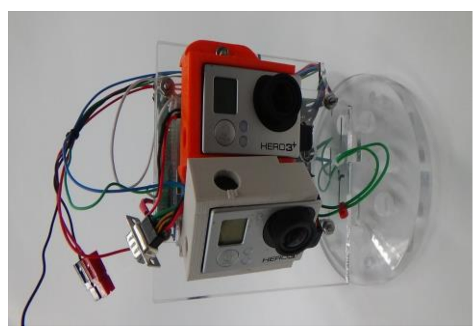


Fig. 9: Cameras   Photo: Casey Jo

is cost effective. The video signal is sent from each camera via a composite video-out cable to an EasyCap (a composite-to-USB signal converter), which is displayed on the laptop using a video view application. This is the most cost effective and efficient way to get the camera feed to display onto the video screen. *Sea Wolf* uses a breakout board connected to the GoPro port to power the cameras from the surface power supply, with the original camera batteries removed. One camera faces forward and one faces downward to allow for more accurate piloting. In addition, the downward-facing camera aids in the accuracy and speed of missions such as Deepwater Coral Study and laying ESP connectors through waypoints in the Europa mission. Individual mounts were custom designed and 3D-printed for both cameras to hold them in place and to provide easy access when one of the Brain end caps is removed.

Analyzing Digital Images

Sea Wolf uses an open-source Java Applet software to determine the size of objects in the water. The software requires inputting a known measurement for comparison for calibration. In the case of this mission, we use the one meter length of PVC on Europa's ice crust. *Sea Wolf* measures objects by piloting to the object, and taking a screenshot of what the ROV sees, which includes the 1 meter length of PVC pipe. This photo is sent to a connected computer that is running the software to analyze the image.

"Brain"

Each of the 5 Pololu 24v23 motor controllers has a distinct location on the module where they can be easily plugged into the on-board Arduino Mega 2560. The fifth Pololu is a spare allowing for additional motorized payload tools to be easily incorporated into the *Sea Wolf*. The motor controller holding device is custom made out of acrylic cut out on the laser-cutter. The design allows us to fit the onboard electronics into a compact, watertight space while remaining sufficiently cooled and to allow for more room in the tube for two cameras. To prevent fogging in cold-water conditions, self-indicating desiccant maintains a dry atmosphere in the water-tight tube. All circuitry is soldered and wired in-house. The new, small-sized Brain was a significant design and fabrication effort in building the *Sea Wolf*. The end caps of the Brain are aluminum and subject to corrosion. Anodizing and zinc coating have minimized put not prevented corrosion. A sacrificial anode made of zinc has been mounted to complete the corrosion protection system.

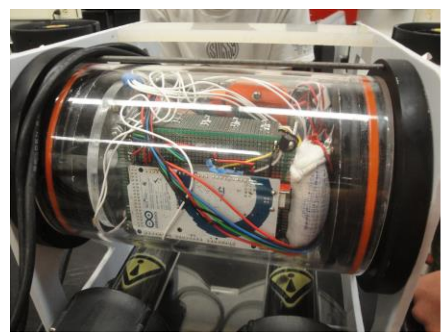


Fig: 10: Brain Photo: Kraig Kreiner

Fig. 11: Sacrificial Anode in End cap
Photo: Kraig Kreiner

Command, Control, & Communications (C3) Diagrams

Diagram 1: Pictorial Block Diagram

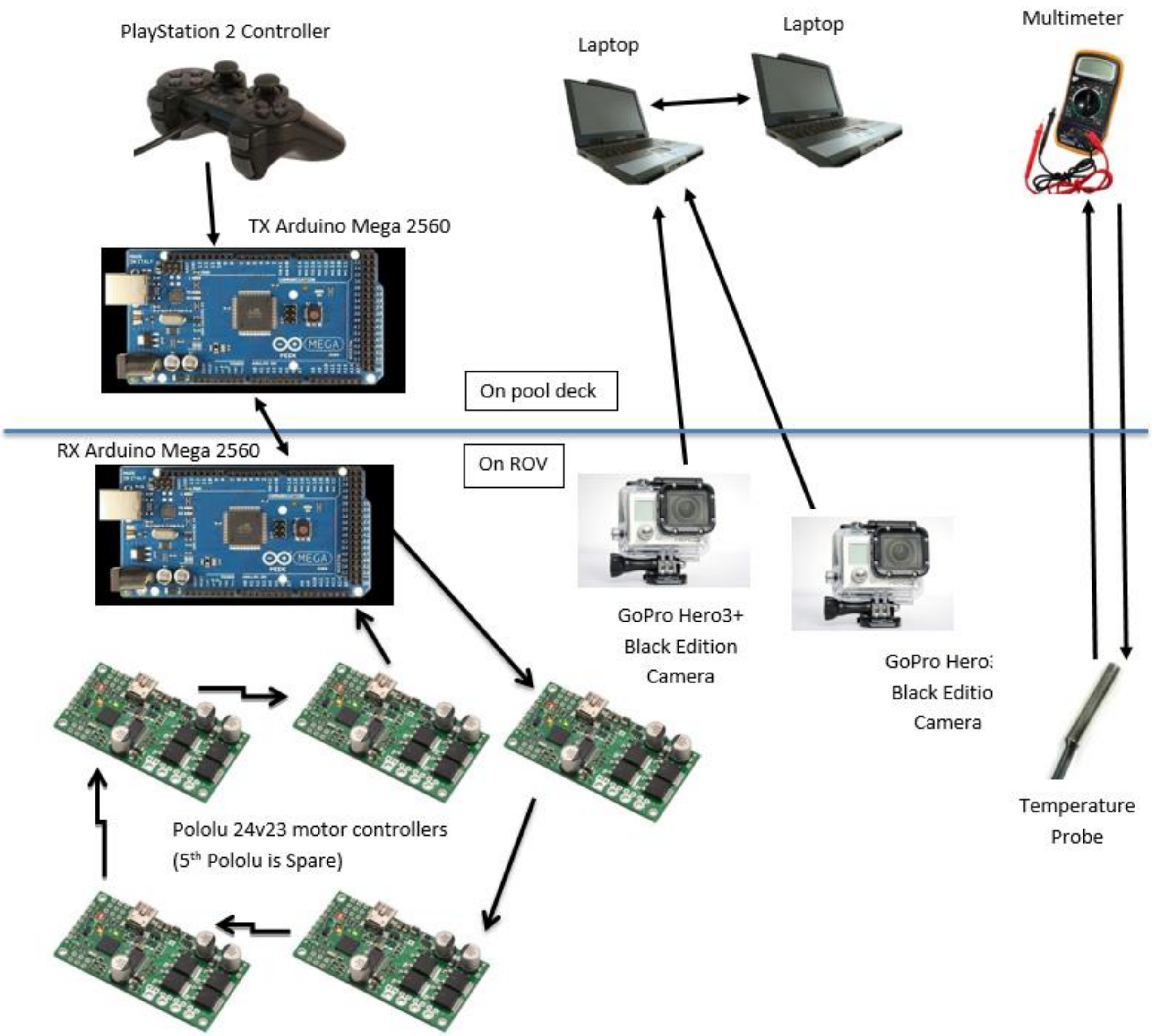
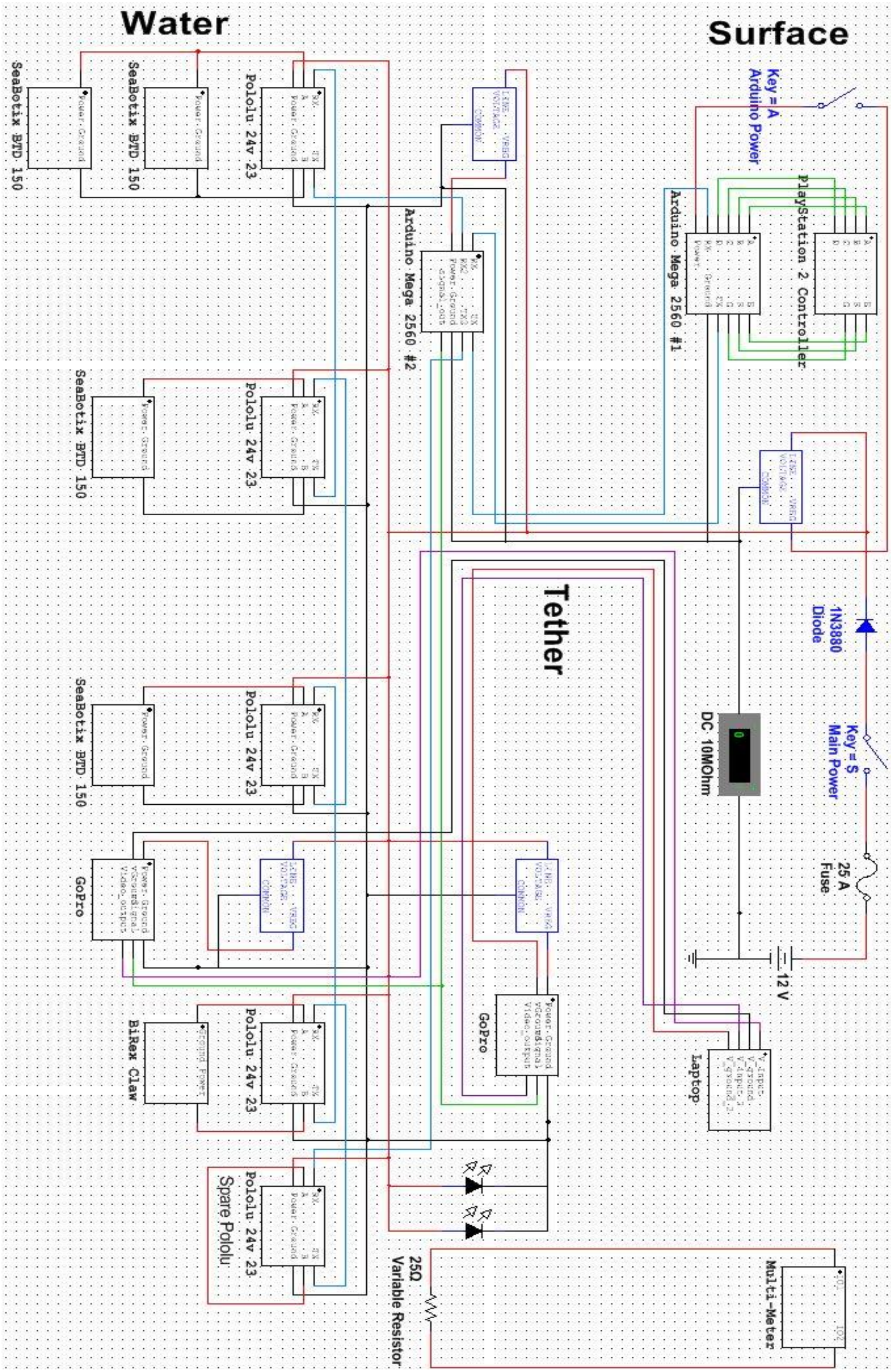


Illustration of electronic command and control system (arrows depict electronic signals): Pilot delivers commands with the PS2 controller to the TX Arduino in the on-deck control box. Electronic signals are translated and transmitted to the RX Arduino underwater. RX Arduino sends commands to individual Pololus, one Pololu for each motor. Images from on-board cameras are transmitted to on-deck laptop. Laptops communicate via Wi-Fi.

Fuse Calculation:

Overcurrent Protection = ROV Full Load Current * 150%.
Fuse Rating = [(4 * SeaBotix Thruster Rating) + (Linear Actuator Rating)] * 150%.
Fuse Rating = [(4 * 4 amps) + (0.22 amps)] * 1.5 = 24.33 amps

Diagram 2: System Integration Diagram (SID)



Arduino Software Flowcharts

Diagram 3:

On-Deck Arduino

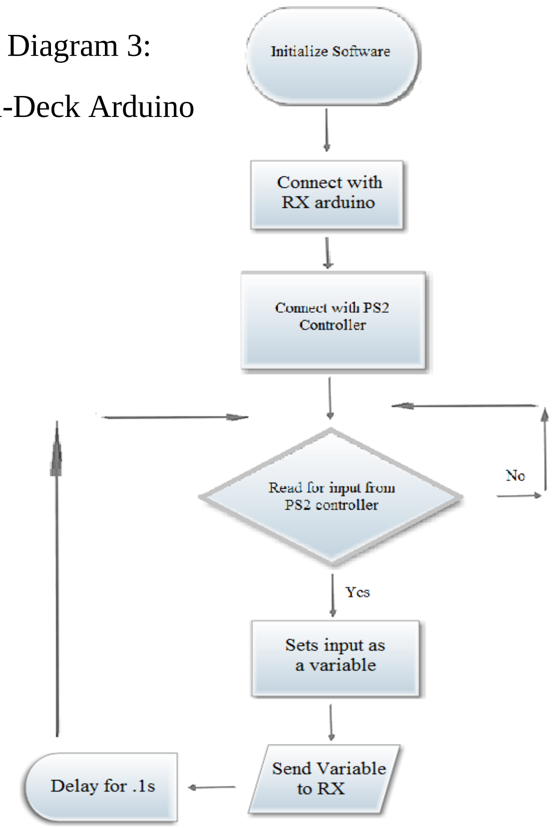
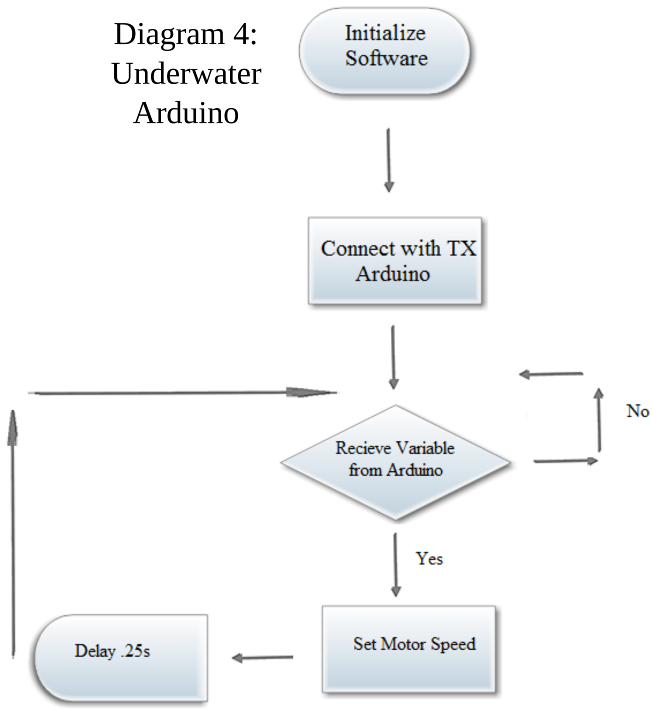


Diagram 4:
Underwater
Arduino



Command and Control System

The *Sea Wolf* is controlled from the surface with a Play Station 2 (PS2) controller, and as such, requires the PS2x open source library to interpret the data and send it to the Arduino Mega 2560 in the on-deck control box. The Arduino Mega 2560 on the surface sends the information down the tether to the second "on-board" Arduino Mega 2560. Communication between the two Arduinos is handled with the Easy Transfer Library program. The on-board Arduino then takes the input and communicates with the five 24v23 Pololus to control the motors. Our programmer customizes the programs for our number of motors and motor configuration.

The on-board Arduino and Pololus are mounted on a custom designed acrylic holder, designed and fabricated by PVIT. This was a challenging piece and critical in maintaining the small size of the brain and thus the overall size of the *Sea Wolf*.

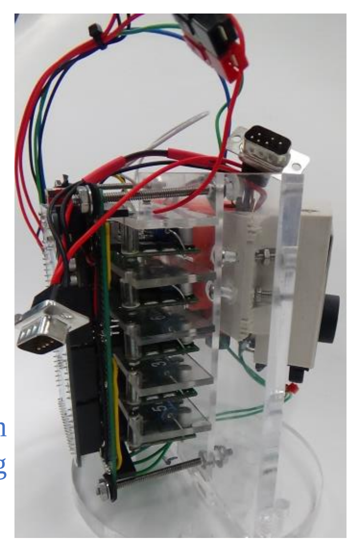


Fig. 12: Control System
Photo: Max Ebling

Custom Design and Fabrication

Laser Cutter

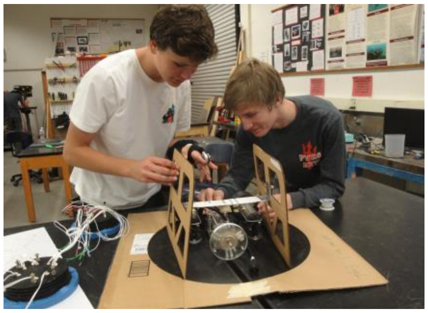


Fig. 13: Prototype Photo: Max Ebling

PVIT fabricated many of the crucial parts on the *Sea Wolf* on our VERSALaser laser cutter. Our VERSALaser can cut through most of the materials needed for ROV construction and makes useful parts from sheets of varied materials. It has the capability to cut through acrylic, polypropylene, PVC, wood, and cardboard. We always use cardboard to make a prototype so we can evaluate our designs and don't waste expensive materials. We use Inventor and Corel Corporation's Corel Draw X7 to create our designs, which are then electronically transmitted to the laser cutter for fabrication. The laser cutter cut many custom parts on the *Sea Wolf* including its polypropylene frame, crosspieces, and acrylic mounting components for the SeaBotix thrusters, and the *Dragon Claw*. As a safety feature, a closed fume exhaust system is used to vent the exhaust produced by laser cutting. The laser cutter is extremely precise and efficient and this in-house tooling capability allows us to experiment with unique designs and materials in an incredibly cost efficient manner.

3D Printer

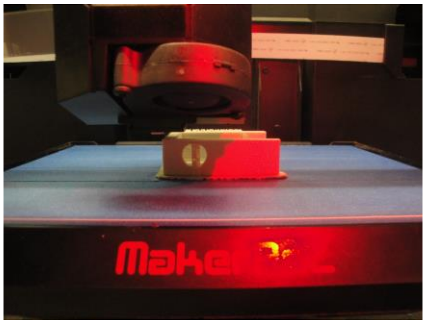


Fig.14: 3D Printer Photo: Nico Kalem

The ROV team can prototype original designs and fabricate them on a MakerBot 3D printer. The printer was used to create the GoPro camera mounts. We used Autodesk to create 3D models that were imported to the printer for fabrication. We limited our use of the 3D printer to parts that are not under stress due to their limited strength.

Modeling Programs

Before making any of the *Sea Wolf's* parts, we model components on CAD programs. For any 3D printed piece, we use Autodesk to create 3D models of the part we are fabricating. For laser cutting, we create 2D sketches in Corel Draw. Each piece is meticulously thought out and planned in advance.

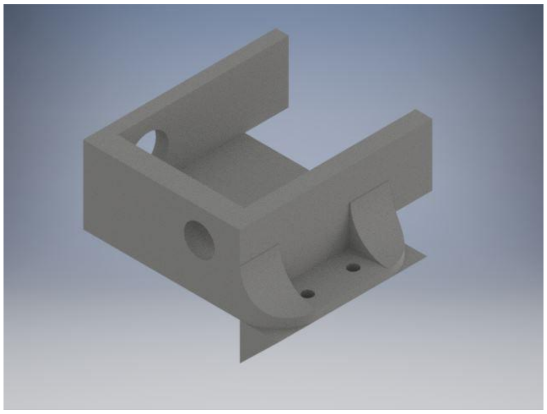


Fig. 15: Camera Mount Model
Image: Brian Smalling

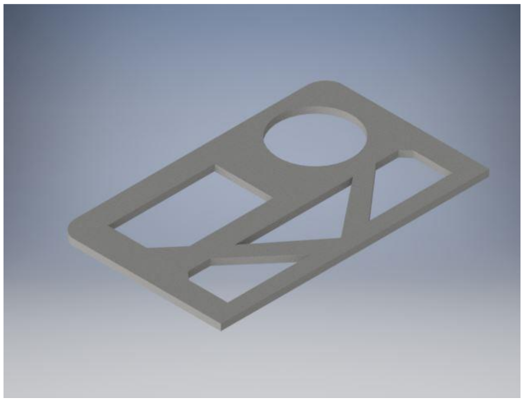


Fig. 16: ROV Frame Model
Image: Nico Kalem

Safety

Company Safety Philosophy: Safety is our first priority. All employees are trained to handle and operate the *Sea Wolf* ROV safely. PVIT has designed a safety program to incorporate safety procedures for manufacturing, testing and operations.

PVIT follows basic Environmental health and safety (EHS) guidelines including workshop safety precautions in our manufacturing facility, such as keeping the workspace free of both equipment and materials not in use, and clear debris and tripping hazards. When in and around water we eliminate, to the extent possible, conditions causing slippery working and walking surfaces. Additional EHS information can be found on the web at Oceaneering Americas Region HSE Employee Handbook. And of course, when working on the *Sea Wolf*, Personal Protection Equipment (PPE), such as safety glasses and close-toed shoes are required at all times.

Job Safety Analysis: Key elements of our Safety Program are our Job Safety Analysis (JSA), Safety Instruction and Observation Program, and Safety Checklists. The JSA, is a categorized summary of task hazards and protocols to minimize risk of personnel injury. This is an important document, used to educate new company team members and reviewed by all team members each year. It is updated during annual reviews. With 50% new team members this year, the JSA is critical in instilling the safety mentality required of PVIT members. The JSA is included as an appendix to this report.

Safety Instruction and Observation Program: The Safety Instruction and Observation Program is the enforcement tool used to ensure the JSA is being followed. Our observation procedures use Safety Task Analysis Cards (STAC) which outline tasks and their safety hazards, consistent with the JSA. Workers use these cards on-the-job to note any particular safety practices or hazards that should be reviewed. The cards are later reviewed and adjustments are made to procedures if needed.

ROV Safeguards: In addition to using PPE, *Sea Wolf's* design includes preventative safety measures such as motor guards, a 25A fuse in the positive power supply line within 30 cm of the attachment point, and warning labels. As a final fail-safe, the *Sea Wolf* is engineered to be slightly positive in buoyancy to ensure a safe return to the surface in the event of a major hardware or software failure. During manufacturing we smoothed all edges of the *Sea Wolf* frame and eliminated any sharp points on the vehicle to eliminate hazards to personnel.

Operational and safety checklists: PVIT strictly follows safety checklists during production and operation of the *Sea Wolf* ROV. Below are PVIT's checklists.

Checklists:

Safety Checklist

_____Ensure all personnel have hair tied up, jewelry or earphones removed, as they can become entangled in the equipment.

_____Ensure everyone is wearing closed toed shoes.

_____Ensure safety glasses are worn in the lab and on deck.

_____Ensure there are no hazardous objects in the vicinity before working with the *Sea Wolf*.

_____Ensure all electronics are located far from the water.

_____Instill proper communication between all team members.

_____Ensure all wires are covered.

_____Ensure the power connections and PS2 controller are plugged in correctly before powering on the control box.

Pre-Run Checklist

1. Check electrical power connections.
2. Dry-run to check that the *Sea Wolf* cameras are working properly.
3. Check to ensure waterproof seals are secure.
4. Check thrusters to make sure they function and are clear of obstructions.
5. Check *Dragon Claw* for proper functionality.

Tether Protocol

1. Unroll the tether.
2. Safely plug the tether into the control box and *Sea Wolf*.
3. Secure the tether so the control box will not be pulled when working with the tether.
4. Prohibit foot traffic on tether, and manage tether tripping hazard
5. Safely unplug the tether form the control box and *Sea Wolf*.
6. Roll up the tether.

On Deck Checklist

1. Follow Tether Protocol.
2. Check all connections.
3. Power up the *Sea Wolf*.
4. Test thrusters and *Dragon Claw* again.
5. Safely place the *Sea Wolf* in water.
6. Release trapped air pockets.
7. Deck crew give “Ready” signal.
8. Pilot calls “3, 2, 1, Launch.”

Post-Run Checklist

1. Disconnect the tether from *Sea Wolf*.
2. Follow Tether Protocol.
3. Disconnect all connections.
4. Dry *Sea Wolf* and safely set on cart.

Troubleshooting

Electronics Troubleshooting

Operational troubleshooting on the *Sea Wolf* has improved over previous PVIT ROV models. The troubleshooting begins in one of three areas: the craft, the tether, or the surface control box. Using a multimeter, we test the continuity of the electrical system in each of the three areas to determine where any problem lies. Based on continuity, we start testing circuits to see if they are complete. If any circuits are open, we replace the broken component and retest for a complete circuit. Once all systems successfully function, we test the vehicle. If no further complications arise, the *Sea Wolf* is ready to launch, otherwise, we repeat the troubleshooting process

Challenges

Claw Design and Placement

We encountered a number of technical challenges and with each success and failure, we improved our ROV. The design and function of our claw was technically challenging due to the number and diversity of the mission tasks. We developed several design ideas which were evaluated for functional capabilities specific to our missions. We initially designed a four finger claw, however, during our testing phase, it had trouble grasping the round PVC; the claw could not secure the smaller pipes and could not open wide enough for the larger PVC objects. We reengineered our design and used a three finger system attached to a linear actuator. The primary claw design improved the claws ability to extend the fingers at a greater angle and close tighter. This system is best suited for successful missions, such as being able to pick up the simulated coral and transport it without damaging it.

Because of the variety of tasks, we considered whether or not we wanted a second claw, one downward facing and one forward facing. We spent many hours designing a second claw, but after multiple discussions and referring to the missions, we decided that a hook could take place of the second claw. A hook would be able to do the same job at a lower cost and much more simply. For the Oil Rig mission in the Gulf of Mexico, our team had difficulty finding the most efficient way to pick up the wellhead caps and place them on the wellhead. This task was key in determining that the best location for the claw was to have a forward facing claw located at the bottom of the ROV. Due to the placement of the caps on the seafloor and the wellhead being elevated, we decided that this claw position is the most effective one possible. This claw position also allows easy placement of the bolts into their respective slots on the wellhead.

Weight Reduction

Achieving a minimal weight for the ROV and tether proved to be a significant challenge. The original design focused on maintaining the optimum small size with the assumption that the weight would subsequently fall in line. This was not the case. A better approach would have been to weight the ROV components as they were developed and anticipated total weight. That would allow changes before final construction. Subsequently there was a re-design after the MATE regional competition with the sole intent of reducing weight.

Weight Loss Trade-off Matrix (Table 5):

Feature	Options	Decision	Trade-off	Compensation
Thrusters	4 vs. 6 or 7	4	No strafe ability	Pilot expertise
Tether Length	15 m vs. 23 m	15 m	Less freedom of movement	Pilot expertise
Tether component	1 vs. 2 Ethernet cables	1 Ethernet cable	HD video unavailable	HD video not functional anyway
Aluminum Brain Endcaps	Size & Thickness	Trim flange face, countersink center	Manufacturing time & expense	None. Lost practice time
Frame cross members	Size & Thickness	Eliminate one and trim a second	Manufacturing time & expense	None. Lost practice time

Mini-Team Creation

The biggest non-technical challenge that we faced as a team was how to get everything done as scheduled while educating new team members. We have fourteen team members, seven of them are new this year. We also had five tasks to assess and many props to build. To solve this problem, we devised a system of "mini-teams" for each separate task. We put an experienced member in each group to lead the teams and to mentor the new students. This method worked extremely well, as all props got built quickly and all necessary payload tools were designed and constructed early in the season.

Lessons Learned

A skill that I acquired while working on the ROV this year is learning how to operate the laser cutter. When I joined the ROV team this year the laser cutter was an exotic but interesting machine that I couldn't operate. However, through working with parts such as the claw, I learned how to use the Corel software to design and draw components. I learned that an important aspect of operating the laser cutter is positioning parts on the acrylic so as to not waste material. This skill of knowing how to use the laser cutter will help in the future on other projects. **–Joseph Arriola – Mission Specialist Assistant**

Throughout our preparation time for our MATE competition, we learned many things having to do with our interactions with each other. An example would be how freshman should always work with seniors. As a freshman working with the older members of the team, I have learned much more than I would have otherwise. Seniors are a great source of information, being that they have a lot of experience and knowledge to pass down. **–Nico Kalem – Mechanical Engineer**

Future Improvements

Future modifications planned include an improved flotation system for the ROV, like foam flotation coated with fiber glass to maximize buoyancy. Since foam deteriorates over time, fiberglass would be more durable. In addition, a fiberglass coating would make our ROV more aesthetically pleasing and would allow us to paint our company colors and logo on the ROV. More importantly, we believe, fiberglass will improve the hydrodynamics and mobility of the ROV in tight spaces.

Another improvement will be to design and build an articulating claw with rotating wrist action. We have used a fixed wrist claw successfully, however, having a more versatile instrument will enable us to accomplish multiple tasks with fewer tools onboard and enable our company to respond to more demanding customer requests. This will require additional programming, but we are up for the challenge.

We continue to be challenged in working with underwater high definition video. High definition video will increase our underwater measurement accuracies and better serve customer needs on search and survey tasks. We continue to pursue this and hope to make it operational one day.

Reflections

This was my fourth year on the ROV team. I had the great honor of attending internationals multiple times for this competition, which was one of the best experiences of my short life. As always one of my goals was to build an effective ROV but this year more so than others, because I'm a senior. I also had the duty and the privilege to pass down things I have learned to a future generation. I had the ultimate privilege to not only have a great student mentor like Dennis Smalling but also to be a mentor to a young teammate Jeffery Haag. As the President of this team, and former CEO, I am extremely proud to have led this group of engineers on the path toward success. As a departing senior, I believe I have passed down all of my knowledge gained to the younger members over the time that I have worked here. –**Kraig Kreiner - President**

As a freshman and this being my first year on the team, I was somewhat overwhelmed in the beginning due to a lack of knowledge, but I was interested. More experienced members on the team have taught me the skills and knowledge I needed to become a strong and productive part of the team, especially in the electrical engineering realm of the project. Being a part of the team has taught me many skills that I will use throughout my entire engineering life, such as using a laser cutter, operating different programs, but I have also learned things about working together and as a team. One accomplishment that had a big effect was the size of our vehicle. Making the ROV small enough to not only fit in basic parameters but also the challenging objectives of the missions was a big focus this year in the production of our robot. Each day we had goals to work towards and the only way to complete those goals was to work as a well-oiled machine. I look forward to building on and extending my knowledge to use in next year's competition and in the field. –**Erik Vaughn – Electrical Engineer**

Appendix

2016 ROV Budget, established Nov. 1, 2015 (Table 6)

Item	Description	Additional Notes	Price
Hardware	ABS Flush SPGXh		$15
Hardware	ABS Reducer		$13
Hardware	PVC Bushing (2"X1-1/2")		$2
Hardware	PVC Bushing (2"X3/4")		$2
Hardware	PVC Bushing (1/8"X48')		$4
Hardware	Velcro	1.22 Meters	$10
Hardware	Ceramic Coating X2	Spray on Ceramic Coating	$60
Hardware	Heat Sensor	Heat Sensor	$15
Hardware	Acrylic	12x24x.118	$10
Hardware	Acrylic	12x24x.220	$13
Electronic	SEACON Connector x5	2 pin, 3 pin, 8 pin	$450
Hardware	PVC	Lots of PVC	$250
Hardware	Shrink Tube	Various	$100
hardware	Poster Board		$80
hardware	Screws/Nuts/etc.		$50
Hardware	Polypropylene		$40
Electronic	Arduino		$120
Electronic	Pressure Sensor		$15
	MATE Registration		$100
Teacher	Hotel/Plane Ticket	International, Teacher costs	$1000
International	Shipping	Shipping Containers - International	$1500
	Toolbox	Various	$150
Total			**$3,999**

PVIT 2016 Job Safety Analysis (JSA) (Table 7)

HOUSEKEEPING

TASK	**Hazard**	**PROTOCOL**
Machining	Contact with body Dangerous debris	.follow safety checklist, use personal protection equipment(PPE)
Mission Runs	Leaking and breaching of electrical systems	Perform pre-run checklist,
General Shop work	Stepping on sharp items and tools	Putting all items back where they belong Wear close toed shoes
Electrical Power Tool (soldering iron)	Unsafe contact with skin or clothing flying debris	Properly hold tools Keep all people not involved at a safe distance

HAND SAFETY

TASK	Hazard	PROTOCOL
Laser Cutter	Contact with fingers	Keep lid closed, watch for sharp edges.
Drilling	Contact with fingers	Wear work gloves, Keep hand clear of drill bit.
Soldering	The use and contact of hot objects	Keep clear of hot surfaces, notify others of hot surfaces, stow hot iron in designated areas.
Drill Press	Hitting fingers	Use designated clamps. Keep hands clear.

LIFTING & BACK SAFETY

TASK	Hazard	PROTOCOL
Moving the ROV	Heavy lifting Dropping heavy objects on self	Lift with the knees.
Launch/Recovery of ROV	Heavy lifting, awkward position.	Kneel on deck, use caution, and don't fall in the water.
ROV supply boxes	Heavy lifting Crushing fingers	Lift with the knees, use handholds, keep the load close
Moving Pelican Cases	Heavy lifting	Use wheels when possible, ONLY lift in pairs
Local transport of ROV	Heavy weight on body	Use rolling cart.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

TASK	Hazard	PROTOCOL
Power tools	Puncturing of skin debris	Eye protection, gloves, close toed shoes.
Metal Machining (Lathe)	Debris in eyes	Face protection, gloves, close toed shoes, goggles.
ROV operation	Injuring of body parts	Eye protection, close toed shoes.

TOOL SAFETY

TASK	Hazard	PROTOCOL
Drill Press	Damage to skin Crushing of fingers	Safety Glasses, Gloves, Close Toed Shoes
Dremel	Breaking of skin	Safety Glasses, Gloves, Close Toed Shoes
Soldering Iron	Serious burning of skin	Safety Glasses, Close Toed Shoes, Hot tip holder/cleaner
PVC cutter	Cutting of fingers	Safety Glasses, Close Toed Shoes

ELECTRICAL SAFETY

TASK	Hazard	PROTOCOL
ROV Operation	Electrical shock	Follow all checklists, keep extension cord dry.
Troubleshooting ROV Control System	shock	Power Off.
ROV Electrical Design & Fabrication	Electrical systems failure	Use fuse, diodes, comply with MATE regulations. No power supply in water.

Employee Observation Program:

Utilize Safety Task Analysis Cards (STAC).

List of Figures and Tables

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