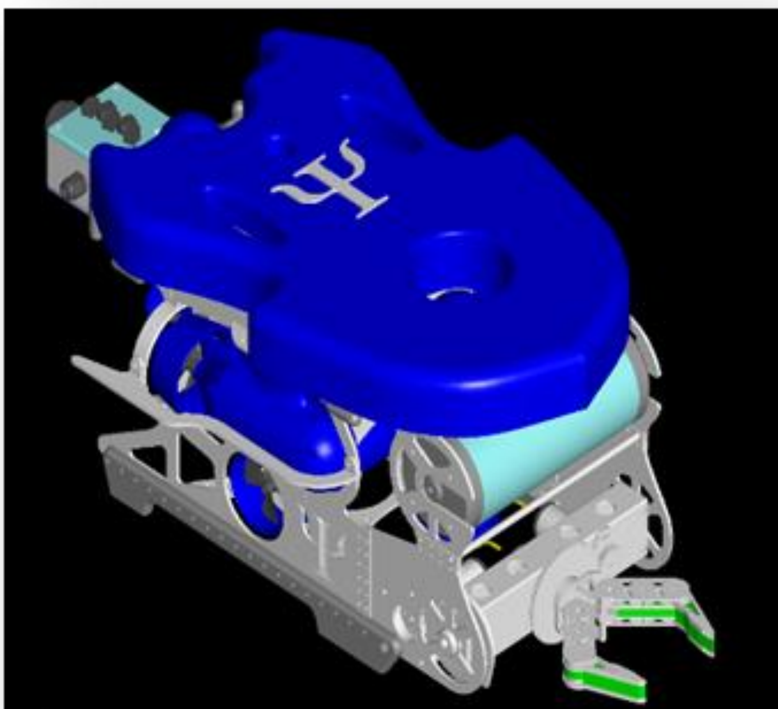
Psi Ψ

Psycrophile **S**ystems **I**nc.

From Sea-Tech 4-H Club Located in Mt. Vernon, WA, USA

2,350 miles from NASA Johnson Space Center

Proposal to NASA and Oceaneering Space Systems for a Dual purpose ROV



Tony Harvey
CEO

Gunnar Hoglund
CFO

Priya Kumar
Marketing Director

Spencer Cocheba
EHS Officer

Kasidy Walkup
Technical Writer

Lee McNeil
Mentor

Table of Contents

1. Abstract

Exploring the mysterious moons of Jupiter has been the subject of many scientists' proposals. Europa has been the center of attention, due to the expectation that beneath its icy surface, an undiscovered ocean awaits, with the possibility of extraterrestrial life. In the Gulf of Mexico, technology advances to "fingerprint" oil samples, recover equipment, create artificial reefs and collect biological material. On Europa an Environmental Sample Processer (ESP) needs to be connected, and temperature and depth need to be determined. In order to accomplish a dual mission to Europa and in the Gulf of Mexico we have designed and fabricated a prototype Remotely Operated Vehicle (ROV) Psycrophile Systems Incorporated (Psi), an advanced piece of technology capable of performing in both locations. Psi is equipped with an electronic multi-rotational claw capable of retrieving valuable samples. Five powerful thrusters allow the vehicle to propel through the water and stabilize it under a strong current. Light-emitting diode (LED) lights provide visibility in the dark ocean waters. A rotating high definition (HD) camera and four auxiliary cameras ensures observation of the unfamiliar terrain and situational awareness. Each tool toils toward the success of every mission as the team prepares for the extreme temperatures, blinding darkness, and ocean currents that wait.

2. Introduction

Psycrophile Systems Incorporated, Psi, is one of the three teams in Sea-Tech 4-H Club located in Mount Vernon, Washington. Sea-Tech was founded in 2000 by Mr. Lee McNeil as a homeschool club and became a 4-H club in 2001. In 2007, the club discovered Marine Advanced Technology Education (MATE) and began competing in the MATE ROV Competition. Sea-Tech has fabricated 50 ROVs and participated in MATE competitions with 33 teams.

The ROV Psi is built on accumulated knowledge gained through years of trial and error, making it the most technologically advanced ROV yet to be fabricated by the members of Sea-Tech. The dedicated and experienced members of Team Psi have designed this ROV not only to complete mission tasks stated in the MATE 2016 Explorer Competition Manual[1], but to function in the real world.

---

[1] http://www.marinetech.org/files/marine/files/ROV%20Competition/2016%20competition/Missions/Updated%20files/EXPLORER_MANUAL_FINAL_cover_3_1_2016.pdf

3. Team Biographies

Tony Hicks-Harvey

Company Role: CEO
Team Role: Propulsion systems
Poolside Role: Science Officer

This is Tony's fourth year participating in Sea-Tech 4-H and the MATE competition. At nineteen, his unique ability to take almost anything apart, fix it and put it back even better than before is both vital and admired. He is graduating this year with an associates in engineering and will transfer to Memorial University to pursue a career in marine engineering and naval architecture.

Gunnar Hoglund

Company Role: CFO
Team Role: Shore-side Controls and Tether
Poolside Role: Manipulator Operator

This is Gunnar's fourth year participating in Sea-Tech 4-H and the MATE competition. Determined to meet deadlines, his ability to take on any work required to finish a job is honorable. At eighteen he is currently attending Skagit Valley College and is completing his final year of Running Start for his general transfer degree. He plans to continue his education in computer science through a four year university.

Priya Kumar

Company Role: Marketing Director
Team Role: Sensors and Tooling
Poolside Role: Mission Commander

This is Priya's fourth year participating in Sea-Tech 4-H and the MATE competition. At fifteen and the youngest on the team, her resourcefulness and willingness to take on challenges is admired. She is currently undertaking advanced classes through homeschooling. Ambition drives her to do her best. She plans to attend the University of Washington for Running Start in the near future.

Spencer Cocheba

Company Role: Environment Health and Safety (EHS) Officer
Team Role: Ship-side Controls
Poolside Role: Pilot

This is Spencer’s fifth year in Sea-Tech 4-H and sixth year participating in the MATE competition. His passion for science, engineering and technology wildly contributes to our team’s success. Spencer is a seventeen year old hardworking homeschool student, who regularly attends Hill Creek Christian private school. He plans to pursue a degree in aerospace technology through a four year university.

Kasidy Walkup

Company Role: Technical Writer
Team Role: Shipside Controls and Buoyancy
Poolside Role: Tether Tender

This is Kasidy’s fourth year in Sea-Tech 4-H and the MATE competition. With a surreal amount of energy and passion for documentation, she happily completes any task she is given. At seventeen she is currently completing the required credits for her general transfer degree at Skagit Valley College. She plans to further her education by pursuing a corporate law degree at a reputable university.

Lee A. McNeil

Mentor

Our team mentor, Lee McNeil, founded Sea-Tech 4-H Club since it began in 2001. Participating in MATE for ten years. His loyalty and constant contributions, whether in funds or time, allows our club and team to be the best we can. On top of being a devoted husband and father to seven children, he is currently employed at Boeing as a Structural Test Engineer. He hopes to pursue a separate foundation for our club, to begin designing and manufacturing submarines.

4. Design Rationale

The ROV Psi was designed to be safe, robust, complete a variety of tasks and take full advantage of the available power. After many hours, team proposals and strategies the design of Psi was created on computer-aided design (CAD). Each member was assigned a portion of the ROV to design or improve using CAD. With five powerful thrusters, an electronically powered multi-rotational claw, fully gyratory main camera enhanced by four additional auxiliary cameras, and several mission specific tools, Psi was built to perform every mission specified in the MATE explorer manual with ease. The shape of the frame and float was designed primarily around our thrusters, claw and main camera. The weight and size of the ROV creates a strong riding moment which is beneficial when completing tasks. To ensure a safe environment, each instrument is secured inside the frame and safety measures are implemented and practiced throughout the team. A hardware based single control box minimizes the amount of gear necessary to run ROV Psi. Refer to figure 1.

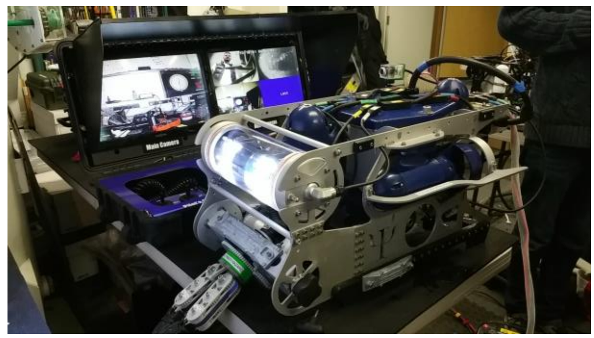


Figure 1 - Psi and Control Station

4.1 Frame and Buoyancy

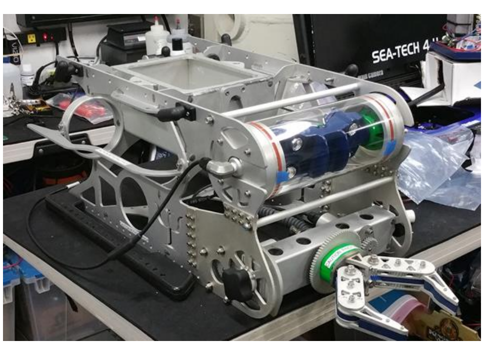


Figure 2 - ROV Frame

The Psi frame was designed to produce a fully integrated and compact design. Each tool was integrated on CAD to allow a better understanding of each position and space needed to complete the ROV. The frame is made of 2.3 cm (.9 in) thick water jetted aluminum welded together. Aluminum alloy 6061-T6 was used because it is lighter and cheaper than other materials, as well as easy to machine and anodize. The overall dimensions of the Psi ROV are 72.5 cm long (28.5 in) x 54.5 cm wide (21.5 in) x 43 cm high (17 in), not including the projection of the removable claw, and removable tether with junction box. The shape is designed to fit inside an 80 cm sphere. Refer to figure 2.

The float was designed on CAD around the vertical thrusters and toggle clamps that seal the ship-side control box. It was also designed to be aesthetically pleasing and to fit in the size requirements. The float is made of 192 kg/cu.m hydrostatic proof polyurethane foam coated in primer and paint. The float was machined by hand to match the CAD model. The dimensions are 73.5 cm long (29 in) x 48.3 cm wide (19 in) x 7.5 cm high (3 in).

4.2 Propulsion

Over the past 15 years Sea-Tech has used a variety of thrusters. Simply modified bilge pumps as jetted thrusters and heavily modified pumps driving propellers; trolling motors as purchased or modified; replacement units from Sea-Doo brand diver personnel vehicles; and purchased thrusters from SeaBotix and VideoRay. With this knowledge base gained from working with a variety of thrusters, we know what works and what doesn't, and the associated costs.

Figure 3 - Thruster Pieces

This knowledge, along with developing MATE requirements for safety and power consumption, and recent extensive thruster efficiency testing by our 2014 teams, have guided us to the following conclusions:

- Use the largest diameter propeller that can be practically located on the ROV.
- Turn the propeller with a low-speed-high-torque DC motor.
- Use Kort Nozzles which offer both safety protection and approximately a 20% increase in thrust.
- Use a large diameter-area-ratio (DAR) Kaplan styled propeller with close nozzle clearance requiring precision concentricity between nozzle and shaft.

Researching Kaplan propeller and Kort nozzle combinations, we arrived at a Kort 19a accelerating nozzle with a 4-blade Kaplan propeller having a disk/area ratio of 55%, designated Ka 4-55-19A. Using a polynomial coefficient table from a Bp-δ performance diagram found in "**Marine Propellers and Propulsion**," By John Carlton[2], we modified an Excel spread sheet developed many years ago, and computed an ideal design. Refer to figure 3.

---

[2]Carlton, John. Marine Propellers and Propulsion. Waltham: Butterworth-Heinermann Elsevier Ltd, 1994.

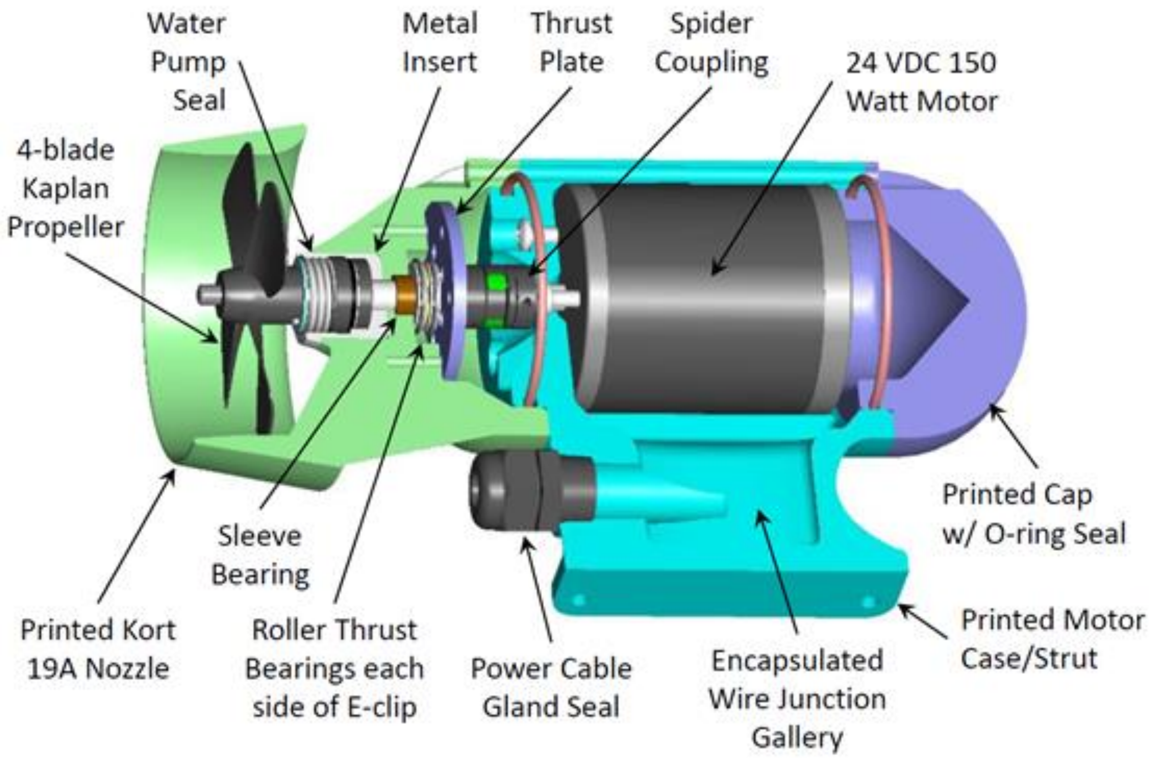


Figure 4 - Thruster CAD Model

This year our club experimented with 3D printing making all our thrusters' housings using Polylactic acid (PLA) plastic materials. We expected 3D printing to be cheaper and more efficient than machining metal. Through trial and error a new kind of thruster was 3D printed and tested. The design uses a 24 VDC 150 watt racing scooter motor to drive the 95 mm (3.7 in) diameter propeller nested inside of a 3D printed nozzle and housing. A water pump seal isolates the rotating shaft penetration. A metal thrust plate reacts axial shaft loads through roller thrust bearings. The shaft is coupled to the motor via a spider coupling. Refer to figure 4 cut-away CAD diagram above. Thrust testing the first prototype yielded a 7.26 kg (16 lbs) of thrust at 12 amps. Refer to figure 5.

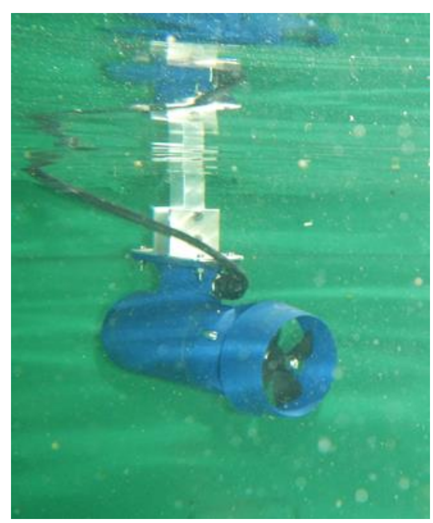


Figure 5 - Thruster Test

4.3 Shore-Side Control Station and Tether System

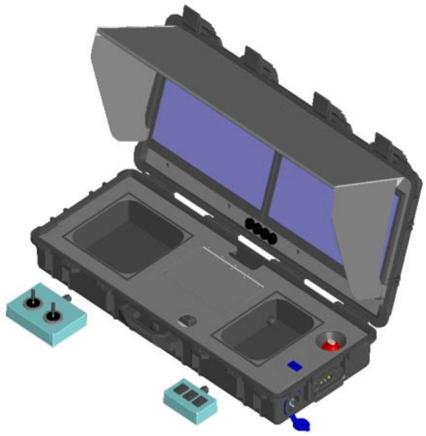


Figure 6 - Control Station CAD Model

The inspiration for the PSI shore-side control station came from the struggles of previous years. Each team constantly had to transport an overwhelming amount of gear poolside and assemble it. This caused many concerns both for part preservation and time consumption. The greater amount of equipment, the greater chance for error when assembling and tearing down between runs. Our solution to this was to create a system that integrates everything into a single package and cut down the amount of connections that require being plugged and unplugged. Refer to figure 6.

The control station needed to incorporate many components, which were separate in the past. We CAD modeled the entire system to fit in a single box. Everything was laid out on CAD inside a Pelican 1700 rifle case which houses two 19” monitors. The first monitor dedicated to the main camera, and the other to four auxiliary cameras that interface with the monitor via a multiplexer. The ROV is also directly controlled from the Pelican case which houses two control pendants, Pilot’s pendant manipulating the movement of the main camera and the thrusters, while the Engineer’s pendent operates the claw’s multiple actuations. Refer to figure 7.

In order to protect the control station during transportation the monitors are protected by a shade, intentionally built to fold over them during storage. This design hinders the closing of the case if the shade is not folded properly. The control pendants are stored nicely in cut outs below the monitors to prevent damage. When open, a gas spring lid stay prevents the lid from falling which could potentially damage the control station.

Power is routed through the station, AC power is routed through an internal protected power strip to power the video monitors and multiplexor. 48 VDC supply power is connected by an Anderson 100 Amp positive locking connector plug. The DC power can be monitored by a voltmeter incorporated into the design. An emergency shut off switch is installed directly in the control station and cuts power from the entire system and ROV if the need arises. The power and other signals are delivered to the ROV through a 75ft tether that is held together with a braided mesh sleeve connected to a removable tether box on the ROV. While on the surface the tether integrates with the controls through minimal connections to cut down on confusion and time. Refer to Appendix A for the electronics system interface diagram.

Figure 7 - Control Station

4.4 Ship-Side Control System

Due to the risks and time involved with using software based controls we have produced a purely hardware system. The control of the Psi ROV includes directional and variable speed control of five 24 VDC thrusters, and directional control only of four 12 VDC gear motors. The supplied power is 48 VDC at a 40 Amps maximum current limit. Sea-Tech 4-H teams have had an excellent prior history using Sabertooth brand pulse-width-modulated, (PWM), speed controllers, made by Dimension Engineering. They feature various modes of operation. All inputs modify a 0 – 5 VDC signal. The Psi ROV operates in the analog mode. Refer to figure 8.

The Pilot's station uses a pair of 2-axis potentiometer joysticks. In the analog mode for a Sabertooth 2x50 controller, 2.5 VDC is interpreted as zero speed, 0 VDC interpreted as full reverse, and 5 VDC as full forward. Because the thruster design uses 24 VDC traction motors, a resistor network was installed in the Pilot's pendant to reduce the potentiometer range to limit the PMW output to 24 VDC. Thus, the analog mode 2.5 VDC is still interpreted as zero speed, but 1.25 VDC interpreted as full reverse, and 3.75 VDC as full forward, for the 24 VDC motor. Each Sabertooth offers two channels of control. There are three controllers, with the third board operating the vertical thrusters in tandem mode, using one control input.

In this way four control inputs control five thrusters producing four of the six degrees of freedom: two vertical thrusters for ascent and descent (heave); one lateral thruster for side shift (sway); and two fore-aft thrusters for forward and reverse movement, (surge), as well as steering, (yaw). Pitch and roll are controlled by the righting moment of the ROV.

The mechanical systems control consist of four gear-motors operating the open and close function of the claw; the axial rotation of the claw assembly; the tilting rotation of the claw carriage; and the tilt function of the main camera and lighting platform. These functions are operated by four DPDT momentary rocker switches, (three on the Engineer's pendant and one on the Pilot's pendant). These switches initiate a 5 VDC signal to an array of four DPDT relays on the relay module board located on the ROV, powering the gear-motors in the commanded rotation. Because the gear-motors run on 12 volts, a 48 to 12 VDC transformer is located in the shipside control box. A second waterproof transformer is located on the tether termination box to power the video and lighting.

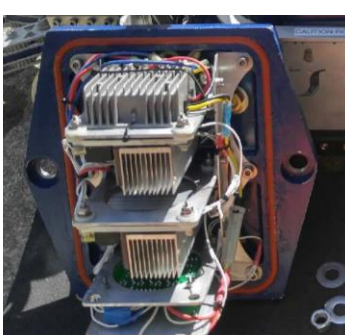


Figure 8 - Ship-Side Controls

To facilitate disconnection of the tether, sixteen Sub-conn wet mate-able connectors are used between the tether and all shipside components. The connector allocations are defined in Appendix B.

4.5 Video System

The main camera on Psi is a 700 line resolution, high definition (HD) charged couple device (CCD) with a 92 degree field of view (FOV). Encased in a 28 cm (11 in) long cast acrylic tube with a diameter of 12.7 cm (5 in) the platform is driven by a 53 rpm 12 volt 1:100 gear ratio motor paired with a video quality Mercury slip ring on the opposite side allowing a 360 degree axis rotation. Refer to Figure 9. Accompanying the main camera are four PC504XS Day/Night Durable Board auxiliary cameras with 90 degree FOV potted with clear silicone encapsulant and cast in clear acrylic boxes. These auxiliary cameras are mounted on metal corrosion proof 360 degree swivel camera tripod ball head screw mounts, allowing each camera to be uniquely and individually positioned. Refer to figure 10. All cameras plug into the tether box on the ROV using low profile series Sub-Conn Micro connectors.

Figure 9 - Main Camera

Figure 10 - Auxiliary Camera

4.6 Mechanical Systems

The ROV Psi is equipped with a Third Generation Sea-Tech claw. The team upgraded previous year's functional Legacy Claw design. Based on previous years' experience depending on an air compressor, this year's claw design eliminated pneumatics. The mechanical specialist designed and incorporated a gear driven tilt mechanism and axial rotation, a feat that had yet to be accomplished. The three way free movement allows our team to work with a wider range of targets thus increasing the chance of success.

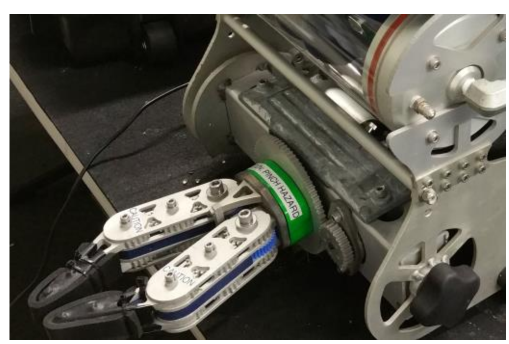


Figure 11 - Claw

Like the frame, the claw and motor housings are made of water jetted aluminum, making easy to machine and anodize. Teflon shims are placed between the layers of the claw to eliminate sticking. The claw tips are dipped in Plasti-Dip rubberized protective coating to enhance grip adhesion on hard objects. Shayang IG32 24 volts direct current (VDC) 74 rounds per minute (RPM) Gear Motors are utilized to tilt and rotate the claw. The gear motors plug into the control box on the ROV using low profile series Sub-Con Micro Connectors and are controlled at the surface using momentary rocker switches. Refer to figure 11. Refer to appendix D for the safety checklist.

4.7 Mission Tools

The ROV is equipped with mission tooling that assists in task completion. The cameras provide proper image processing to allow for CubeSat identification. The three way actuation claw allows the ROV to retrieve a variety of objects. Refer to figure 12.

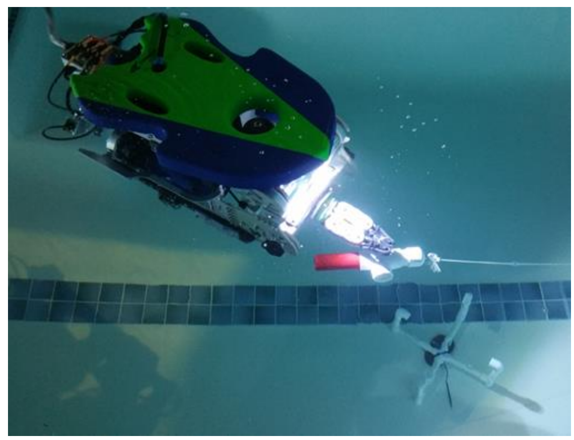


Figure 12 - Night Time Practice

Ice thickness dimensions are measured by sensing the water column depth with a pneumo-fathometer, or "pneumo" for short. The pneumo is powered at the shore station by a Gast 1/16 horsepower diaphragm compressor-vacuum pump, rated at 30 psi maximum pressure. The back pressure from the water column is sensed by a Dwyer digital pressure gage capable of reading in various units, including centimeters of water depth, avoiding the need to convert pressure to depth. Refer to Appendix C for the pneumatics system interface diagram.

The temperature of the venting fluid is sensed with a Type J thermocouple, rated at a range of 0 to 480 degrees C. It is attached to the bottom of the frame, with LED lights to help with depth perception and alignment. The 6" long x 3/16" diameter probes mounted in a gland seal, which is surrounded by an LED fountain lamp which provides a light pattern for the pilot to align the probe with the vent opening. The measured current is sent up a 120 ohm thermocouple wire and measured with a multi-meter located at the shore station.

5. Safety

The ROV Psi has been designed around the protective aspects highlighted throughout the MATE organization. The systems are mainly preventative in nature, such as fuses and emergency shut off procedures. The team operates with a safety Do-Confirm styled checklist, to further ensure the protection of team members and bystanders. All edges are rounded and buffed to guarantee that no injury is caused by ROV interaction. Any moving parts are labeled to warn personal of risk, and thruster nozzles are shrouded and surrounded with mesh to further prevent harm. Safety glasses are worn whenever eye safety is a concern. Hair is pulled back, and all loose items are removed.

6. Teamwork

Figure 13 - Team Psi

The accomplishments of Psi are owed to cohesive teamwork by our determined and dedicated members shown in figure 13. In competition at the international level, the team's comprehensive understanding of the vehicle and components is fundamental. Team members rely on each other to exchange information, ideas, and research to troubleshoot and evaluate problems. Individual contributions of varied skills were the key to the successful creation of Psi.

7. Project Management

A weekly updated to-do list for individual members and theteam were developed and implemented to manage the process of the fabrication. The understanding of individual assignments and others played a vital role to complete all of the tasks, avoiding overlapping work and leaving none. Each member was assigned a portion of the ROV, on which they worked. Expertise of individual's knowledge and skills were gathered to form this technical

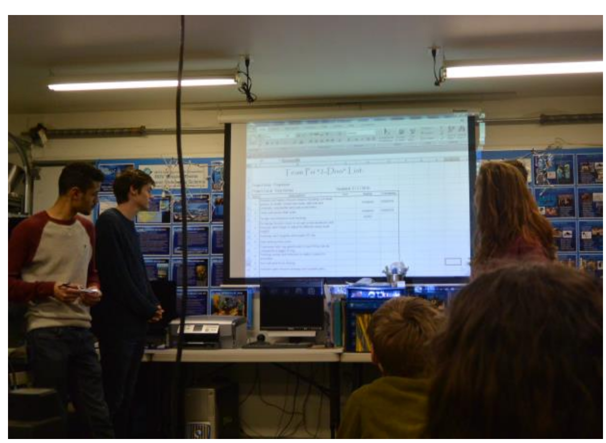


Figure 14 - Presenting the Plan for the Year

report. By being dedicated, encouraging and supporting of each other, the team stayed on the tasks and moved forward completing the ROV, Psi, overcoming the obstacles. Refer to figure 14.

7.1 Poolside Roles

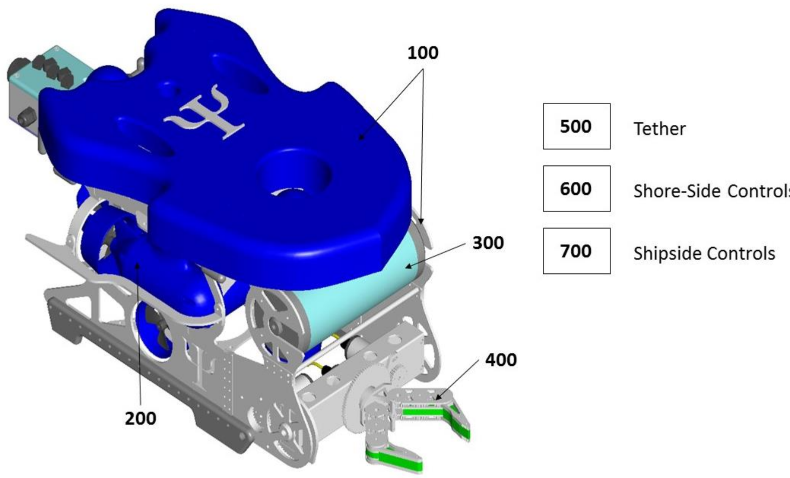
- ***Mission Commander:*** directs the dive team from task to task understanding the mission tasks, point strategies and the team's success rate in the practice sessions; makes strategy decisions to accumulate the most points relative to the remaining time on the clock; acts as contact person with the pool judges.
- ***ROV Pilot:*** Operates the ROV and controls the main camera position; takes direction from the mission commander and works in partnership with the manipulator operator to accomplish each task.
- ***Manipulator Operator:*** operates the multi-function claw to execute mission tasks in partnership with the pilot, taking direction from the commander; controls the four auxiliary camera images through the video multiplexer box to provide the best images for each mission task.
- ***Tether tender:*** manages tether deployment and position to ensure proper slack/tension and avoid snags; assists in ROV deployment; cannot communicate with team except as MATE rules specify.
- ***Science Officer:*** responsible for data acquisition, image capture and charting; takes direction from mission commander and partners with the dive team.

7.2 Company Roles

- **CEO:** manages project milestones; collects hours summary and maintains an even work load between team members.
- **CFO:** tracks budget/expenditures; is point of contact with sponsors; maintains budget sheet in real time.
- **Marketing Director:** oversee poster display; outlines the engineering evaluation presentations; accomplishes media outreach; maintains project photo album; creates ROV spec sheet; and maintains social media.
- **Technical Writer:** maintains project book; reviews technical and component specifications, photos and summaries in the project book.
- **Environment Health and Safety Officer:** responsible for team safety philosophy; develops safety protocols and operation check lists; and monitors personal protection equipment (PPE) usage by each team member.

8. Expenditure Summary

The costs of fabricating ROV Psi were carefully tracked in detail using a spread sheet. In an attempt to be cost effective, the framework of the ROC was fabricated from aluminum which is lightweight, durable, and inexpensive. Psi's thruster housings were 3D printed which also reduced costs when compared to previous methods of machining metal parts. Lastly, the ROV's buoyancy is composed of high density polyurethane foam.



ROV Build Expenses :

		Purchaced	Donated	Repurposed	Total
100	Frame and Boyancy	$310.35	$675.00	$0.00	$985.35
200	Propulsion	$954.46	$0.00	$0.00	$954.46
300	Video and Sensors	$1,091.29	$257.00	$1,200.00	$2,548.29
400	Mechanical Systems	$406.72	$405.23	$0.00	$811.95
500	Tether	$928.62	$9.38	$0.00	$938.00
600	Shore-Side Controls	$1,484.40	$0.00	$0.00	$1,484.40
700	Ship-Side Controls	$1,480.37	$650.00	$0.00	$2,130.37
	ROV Build Value:	**$6,656.21**	**$1,996.61**	**$1,200.00**	**$9,852.82**

Team Expense Estimation :

		Purchaced	Donated	Repurposed	Total
A	Travel To and From Huston	$1,000.00	$0.00	$0.00	$1,000.00
B	Accomodations	$3,420.00	$0.00	$0.00	$3,420.00
C	Meals	$1,800.00	$0.00	$0.00	$1,800.00
	Team Expense Estimation Total:	**$6,220.00**	**$0.00**	**$0.00**	**$6,220.00**

Total Value :

2016 Build Expenses	$9,852.82
2016 Travel Expenses	$6,220.00
2016 Total Expenses	$16,072.82
Donations	($1,996.61)
Repurposed	($1,200.00)
2016 NET Expenses	**$12,876.21**

9. Troubleshooting

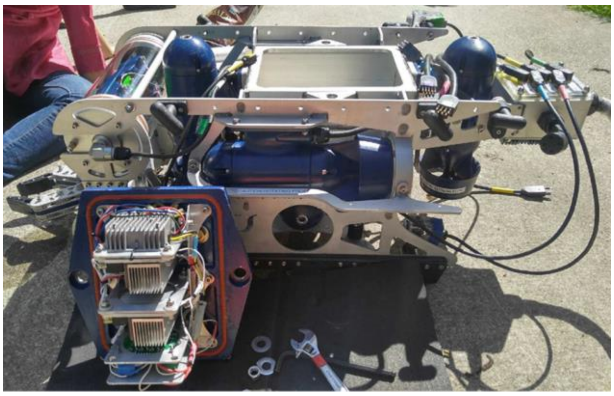


Figure 15 - The ROV Partially Taken Apart

Over the course of fabricating Psi, we have encountered and overcame countless problems that have required troubleshooting. When a challenge was discovered, we began by completing a careful assessment of all of the possible causes. Using methodical testing the cause was narrowed down. After the assessment, possible solutions were brainstormed and a solution which would be of greatest efficiency and likely to resolve the problem was decided on. The subject matter expert for the component or system in question would then fix the problem. As for testing the ROV, we conducted out-of-water tests to check components of the ROV during troubleshooting and before pool practice. In order to check the ROV as a whole, we used a small above ground pool, public pools and friends' pools. We would place the ROV in the pool and test it as a system referring back to troubleshooting techniques as required. Refer to figure 15.

10. Challenges

We have faced numerous challenges in the process of constructing Psi Utilizing our troubleshooting techniques, we overcame each challenge while gaining knowledge and skills.

Outsourcing

While relying on third party suppliers is a necessity, it comes with complications. Various fundamental parts, such as motors, took well beyond the estimated time to be delivered. The 3D printer, which was essential to manufacture our thruster housings took eight months longer to arrive than expected. This caused issues forcing us to outsource the thruster housing to someone who had a functional printer. Even when the parts arrived on time problems still arose, such as receiving the incorrect or defective parts.

Shore-Side Control Station

Despite the CAD model displaying a perfect fit in the control box, the shore-side control station did not position well in the box. This caused it to not close. Lowering the angle brackets holding the cover over the wiring created the space necessary to close the control box, resolving the issue.

Thruster Entanglement

The rope from the ESP entangled in the thrusters, causing two motors to burn out. As a solution, the team attached metal mesh with zip ties and duct tape initially. Subsequently, the metal mesh was replaced with plastic mesh for safety and practical purposes. Later, it was replaced with plastic screens printed on the thruster cone.

Leaking Thrusters and Encapsulated Motors

As with many first generation prototypes the PSI thrusters have their problems, a major one of which being sealing. Seeing as how electronics and water aren’t a good combination creating a watertight seal was very important. The thruster housing were 3D printed, while cheaper and more efficient than machining metal, 3D printing leaves an intolerance that can be problematic. This variation between parts can lead to issues because consistency is relied on when waterproofing the housings. A way to solve this was to fill the thruster housings with a potting compound. This ended up being a bad idea, the potting compound was able to leak into our electronic motors ruining or damaging them. Therefore was resolved by modifying the housing model to be able to insert a smooth metal surface for sealing.

Ship-Side Control

After several pool tests with poor video quality, dim lights, and unreliable thrusters we began to question the ground on ROV Psi After using a muli-meter to verify the problem, we grounded the frame in the ship-side control box. Thus restoring the video, lights and thrusters.

The 3D Printer

Dysfunction of 3D Printer caused the substantial trouble, contributing to the huge delay and innumerable problems and replacement of 3D printer with the financial stains. An attempt to effectuate the incompetent 3D printer to create the operational thruster was time consuming and utter failure. Arranging the production of 3D printed thruster by the third party was again time consuming to achieve desired results.

Deadline of Video Submission

In order to qualify without newly improved thrusters, as a temporally solution, the team reinstalled the previous model of problematic leaking thruster housings, had been already taken apart to attach new thruster, to the motors in order to meet the submission deadline for the qualification video to MATE. Consequently, it ended up taking long hours of troubleshooting with repetitive temporary repairs to complete filming. After the accomplishment of the filming and submission, the team disassemble the ROV, then began the constructive process of building the ROV according to the new design. Revew figure 16.

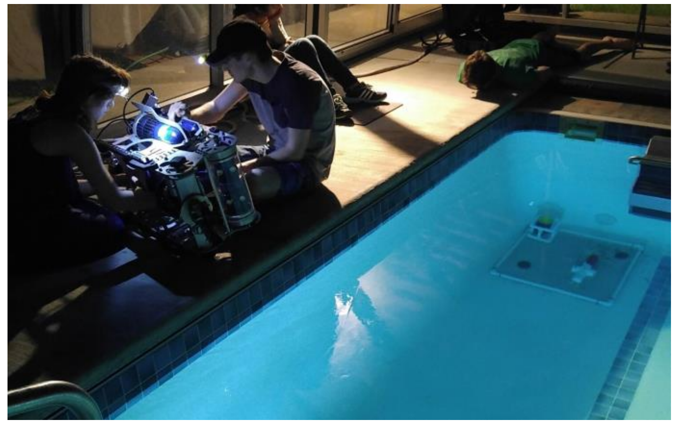


Figure 16 - Late Night Troubleshooting

11. Lessons Learned

Many situations during development of the ROV have resulted in frustration and stress, while this has been less than ideal, it produced countless learning opportunities. When designing the ROV it was positioned to be the most advance the team has ever made. It was a big project and that certainly showed in a few areas, especially in the control system. The control system was designed with a kind of electronic speed controller that no one on the team had any prior experience with. Lack of experience and shortage of time led to some hurried work that ultimately hurt us more than it helped. Time management and understanding are great examples of lessons learned from the production of the ROV.

12. Future Improvements

One of the few improvements our team has agreed to address is time management. Throughout the course of building our machine we were plagued by missing or faulty parts. Next year we are hoping to complete components of the ROV that require commercial parts earlier to save more time for things to go wrong. This will allow us the time needed to problem solve and practice.

As for our thrusters, realizing that the thrusters housing made of PLA easily alter under heat, our team considers constructing new thruster housings made of investment cast aluminum, a less heat sensitive material.

The greatest improvement we plan on constructing is problem solving the multiple imperfections throughout the design of the claw. These imperfections could potentially lead to major damage to the camera housing, an expensive and unwanted problem. The final improvement is funding, this year our club struggled with funding and finding committed sponsors, this put us behind immensely and caused many problems throughout the year. Our team is looking forward to completing these improvements and welcoming a successful new year.

13. Reflections

"Looking back, it's incredible what we've accomplished. Something nobody has ever done before. We've created a culmination of ingenuity, ground breaking technology, and flawless integration wrapped up in one elegant package. There were absolutely frustrating moments where the outcome of our project seemed bleak and nothing seemed to go as planned, but having tenacity and the honor of working with such a dedicated team has made all the frustration more than rewarding. We created one special machine." ~Tony Harvey

"While this year has been an emotional roller coaster, it was undoubtedly one of the best. For a while the team and I weren't sure if we were going to qualify for internationals, however the uncertainty only made us push harder. With countless hours and sleepless nights we were able to reach our goals of making an amazing machine and qualifying. The strenuous times definitely allowed us to grow professionally as a team and also as friends." ~Gunnar Hoglund

"This year definitely had a number of challenges and was exhausting at times, but solving problems has definitely created rewarding experiences. The more difficulties we overcame, made it that much more worthwhile to complete the ROV. I have gained invaluable knowledge from working with this dedicated and optimistic team who have made this a very exciting and enthralling year." ~ Priya Kumar

This year my primary job was to fix the shipside controls. The task was extremely tedious and took far too long. The electronics didn’t function very well before regionals, because we had an issue with the ground. When we fixed the ground every one of the ROV’s features worked better primarily the lights. In reflection I would check the ground if we had a problem that I could not immediately solve. Another thing that I would change is I would quadruple check the placement of every wire. We had one misplaced wire that drastically slowed our progress.” ~ Spencer Cocheba

“There have been a series of disappointments in the process of building Psi, but all in all I can honestly say I enjoyed it the most. Between losing parts and breaking different pieces of machinery, and the fact that funding was hard to find, it was pretty stressful. The saving grace to this project would definitely have to be the people on this team. Everyone is good natured and hardworking, making problem solving and fixing the multiple challenges we faced much easier than expected. Through it all, I am excited to see our machine perform and for the coming year.” ~Kasidy Walkup

“I appreciated the competence and work ethic of this team. This year was a big lesson in being organized. We spent a lot of time searching for lost supplies, which was frustrating and sometimes set us back, but overall I liked this year. All our members have busy lives, sometimes making it hard to devote time to our project, but we are all highly motivated and did not rely on others to get things done.” –Cami Hoglund (Past Team Member)

“This group of individuals has truly exceeded my expectations. Each member has dedicated numerous hours of work. I really appreciate the dedication everyone showed. I can say that, out of my 8 years of participation, this has been the most enjoyable despite the constant problems that occurred. Everyone approached a problem with a clear open mind that was ready to do what needed to be done to make it right. I love this team and appreciate all the experiences we have shared.” –Sierra McNeil (Past Team Member)

14. Acknowledgements

At this time our team would like to acknowledge the companies and families that have blessed us with generous donations throughout the machining of our ROV. Your contributions are immensely appreciated.

MATE for providing an opportunity for us to compete.

Skagit County 4-H provided a grant for our 3D printer.

Burlinton Rotory Club monetary donation.

Production Plating for anodizing parts.

HP provided an extra CAD workstation.

Mercotac supplied us with a video slip ring.

Vector Industries machined our aluminum control box lid.

Janicki Industries water jetted our frame and supplied floatation.

McArtney Underwater Technologies discounted our subconn connectors.

Colin Sheredy 3D printed our thruster assemblies.

Darias Bisson for the heli-ark aluminum welding.

James Harvey presented us with IT help.

Skagit Valley Family YMCA for letting us to practice.

Fidalgo Pool and Fitness Center for allowing us to practice.

Charles and Margaret Kotal for opening their home to film and practice.

Jonah and Ann Leason opened their home for several work days providing funds.

Steven and Felisa Hoglund made a charitable donation of $500

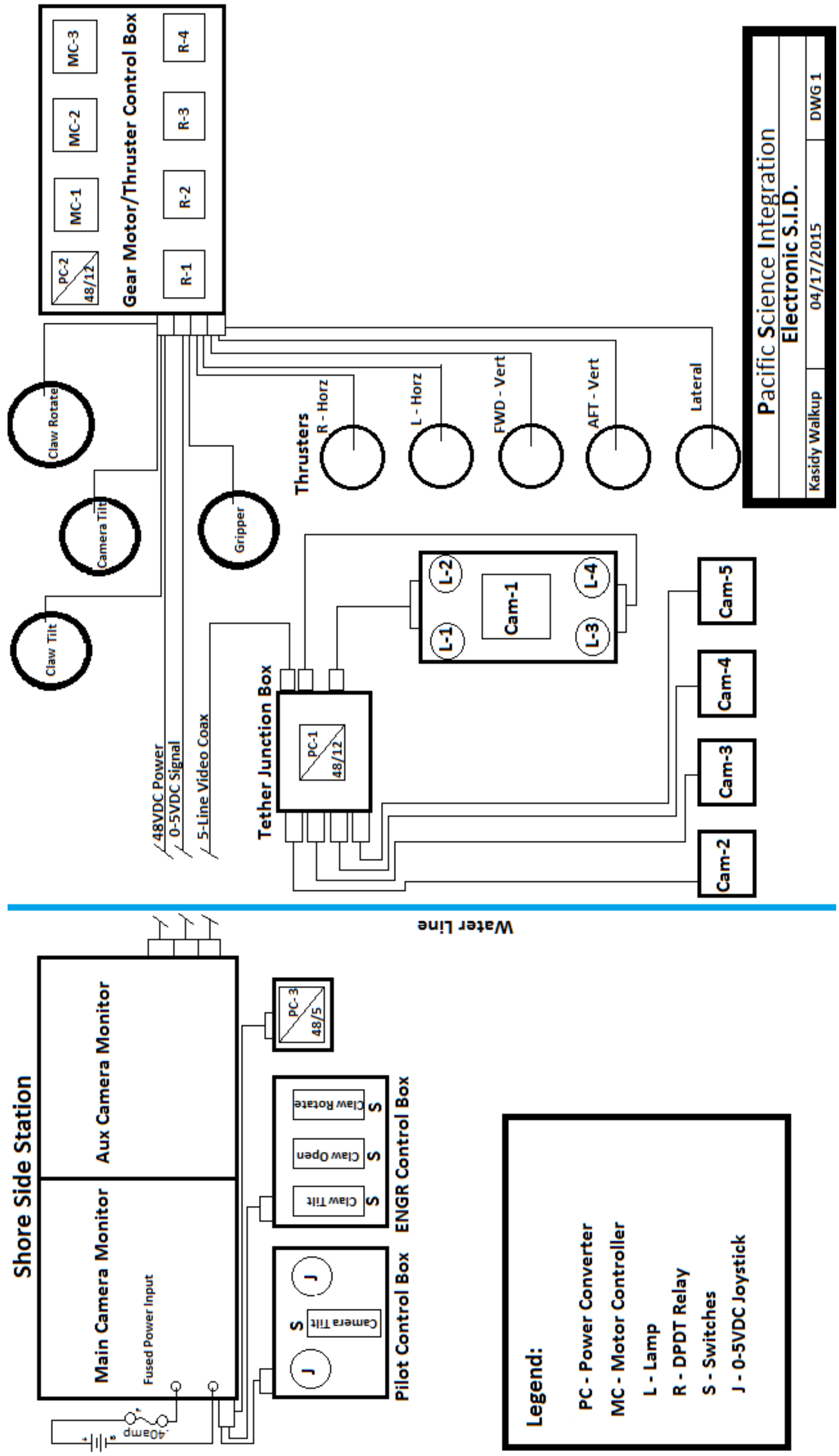
Sundeep and Yoko Kumar made a generous donation of $1,000 and loaned funds for a 3D printer.

Shannon McNeil opened her home and kitchen for all the Sea-Tech kids.

Lee McNeil assisted with multiple unmarked donations and priceless guidance.

Thank you for your support.

Appendix A: Electronic System Interface Diagram



Appendix B: Connector Allocations

(5) 3-cond (video signal/power) female bulkhead connector:
Sub-conn # MCLPBH3F

(5) 3-cond (video signal/power) male cord-set connector:
Sub-conn # MCLPIL3M

(4) 3-cond (gear motor) female bulkhead connector:
Sub-conn # MCLPBH3F

(4) 3-cond (gear motor) male cord-set connector:
Sub-conn # MCLPIL3M

(5) 2-cond (thruster power) female bulkhead connector:
Sub-conn # LPBH2F

(5) 2-cond (thruster power) male cord-set connector:
Sub-conn # LPIL2M

(1) 4-cond (48VDC power) female bulkhead fitting:
Sub-conn # ILB4F

(1) 4-cond (48VDC power) male cord-set fitting:
Sub-conn # ILB4M

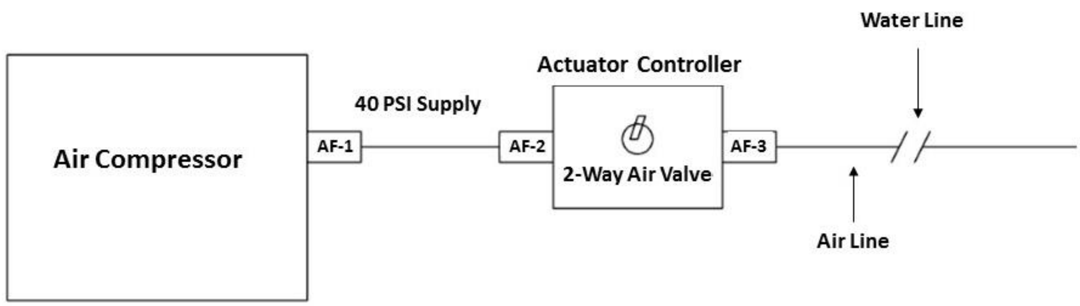
(1) 7-cond (thruster power) female bulkhead connector:
Sub-conn # LPBH2F

(1) 7-cond (thruster power) male cord-set connector:
Sub-conn # MCLPIL9M

(1) 9-cond (thruster power) female bulkhead connector:
Sub-conn # MCLPIL9M

(1) 9-cond (thruster power) male cord-set connector:
Sub-conn # MCLPIL9M

Appendix C: Pneumatic System Interface Diagram



Notes:

AF: Air Fitting
Both actuators powered in series

Pacific Science Integration		
Pneumatics S.I.D.		
Kasidy Walkup	04/17/2015	DWG 1

Appendix D: Safety Checklist

ROV Measurement Process

- [ ] Unplug Sub-Con Power connector
- [ ] Unpin and Remove Float Assembly
- [ ] Unplug Sub-Con 7 and 9 Pin Control
- [ ] Unplug All Five Video Connectors
- [ ] Unpin and Remove Tether Box
- [ ] Unplug Claw Connector
- [ ] Remove Snap Ring and Claw Assembly
- [ ] Wrap Tether Line around ROV

ROV Reassembly and Mission Preparation Process

- [ ] Unwrap Tether Line from ROV
- [ ] Re-Pin Tether Box on to ROV
- [ ] Slide Claw Assembly onto ROV
- [ ] Reinstall Snap Ring on Claw Assembly
- [ ] Reconnect Claw Sub-Con(s)
- [ ] Reconnect Camera Sub-Con(s)
- [ ] Reconnect 7 and 9 Pin Control Sub-Con(s)
- [ ] Re-Pin Float Assembly
- [ ] Reconnect Tether Sub-Con
- [ ] Connect Tether to Shore-Side Control Box
- [ ] Confirm Power to Extension Cord
- [ ] Plug in AC Power
- [ ] Turn on AC Power Strip (Confirm Power)
- [ ] Plug in DC Power
- [ ] Turn on DC Power (Confirm Power)
- [ ] Turn on Power to Monitors
- [ ] Confirm Power to Multiplexer
- [ ] Confirm All Actuators are Functional
- [ ] Confirm Thrusters are Functional
- [ ] Confirm All Video is Displayed
- [ ] Confirm All Mission Tooling is Functional