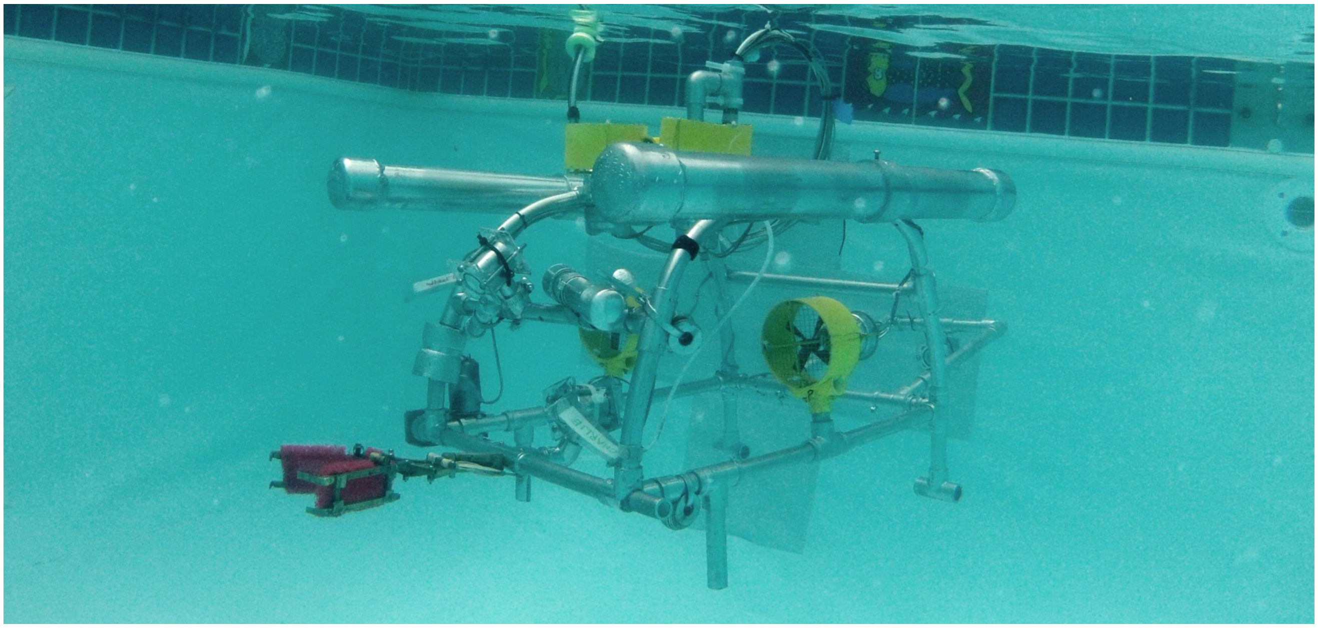
ATLANTIS INC.

COLUMBIA VIRTUAL ACADEMY

FREELAND, WASHINGTON USA



THE ATLANTIS INC. ROV: ROVBOTNICA

FROM LEFT TO RIGHT:

Austin Drake, CFO & Data Retrieval Specialist
Haley McConnaughey, Tether Operator & Safety Operator
Chris Wilson, Pilot & Engineer
Hannah McConnaughey, CEO & Dir of Marketing
Derrick Riley, Chief Electrical Engineer
Not pictured:
Mentors Ashley McConnaughey & Rob Setlow

www.atlantisrovteam.com | | www.facebook.com/atlantisrovteam | | www.youtube.com/user/atlantisrovteam

ABSTRACT

To create a solution, you must first understand the need for it. To ensure personalized service and client satisfaction, Atlantis Inc. prioritizes communication, research, and attention to detail.


Fig 1.1 Meeting with the UW OOI team

Atlantis Inc. has significant background in the ROV (remotely operated vehicle) industry, and is well-versed in the field of servicing underwater cabled network observatories. In 2012, we visited the Ocean Observatories Initiative team at the University of Washington [*see Fig 1.1*], speaking with scientists and engineers on site and touring the Applied Physics Lab to obtain firsthand knowledge of the equipment with which we would be working. We gained additional insight on the technical requirements through our meetings with a pilot of ROPOS, the ROV used by the Canadian Scientific Submersible Facility to service the Neptune cabled network observatory in British Columbia that has been in operation for six years.

Our ROV, Rovbotnica, is custom built to meet the rigorous requirements of maintaining the Regional Scale Node (RSN) at the Axial Seamount: connecting power, replacing parts, removing biofouling, and installing new instrument arrays. We test all of our hand-built systems extensively and refine our components based on repeated field trials.

Atlantis Inc. works from the ground up, beginning with a solid foundation of technical knowledge and resulting in a hand-crafted, customized ROV perfect for our customer's needs. We build our components personally, ensuring that our systems integrate well together and are of the highest caliber of workmanship.

TABLE OF CONTENTS

Appendices:

DESIGN RATIONALE

Rovbotnica has been custom-designed specifically to fulfill and exceed the needs of servicing the Regional Node System being installed by the UW team of the OOI. We prioritize in-house design and manufacturing for quality assurance, expedited repair time, and fewer operational constraints. As a result of this "build it from scratch" philosophy, we have increased cost efficiency, heightened performance, and enjoy seamless system integration. The vast majority of our components are brand new, carefully designed and handcrafted to ensure maximum client satisfaction and peerless performance while fulfilling the tasks necessary to maintain the scientific nodes. Our emphasis on design evolution, rigorous testing, minimized cost, and vehicle reliability have honed and refined Rovbotnica's tools and systems.

For example, the design of our payload manipulator, was honed after months of testing and practicing. Over several months, we refined our arm design, added teeth, and replaced grip material to ensure maximum retention of plugs, the ADCP, and optimize the capturing of essential node components. Even our propulsion system was specifically designed for the unique 360° maneuvering demands of node maintenance. Installing on-board motors for the first time resulted in additional weight, increased ballast, and custom-designed propellers. Rovbotnica has been rigorously tested in over 25 hours of field trials, and that practical, hands-on experience has allowed us to refine and perfect our design as we overcame significant, repeated challenges. Every system and component was designed and created as a custom solution, perfectly accomplishing all mission tasks with maximum efficiency.

FRAME AND BUOYANCY

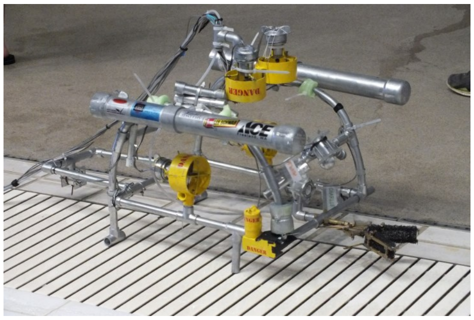


Fig 1.2 Rovbotnica's frame.

One of the most distinctive characteristics of Rovbotnica is its unconventional shape. Rovbotnica's half-moon shape reduces drag, weight, and by reducing PVC usage, overall cost of the ROV. [*see Appendix* 1] Streamlined shapes have a lower drag coefficient, which is why submarines and boat hulls are curved to allow for faster movement through water with less resistance[1]. Rovbotnica's curved frame also reduces the number of jutting corners which could damage or become entangled with the undersea nodes, its scientific instruments, or the surrounding environment.

The entire frame is made of two types of 1/2" PVC pipe; the base and ballast chambers consist of Schedule 40 PVC, the most commonly used type of PVC, and the arched supports *[see Fig 1.2]* are thinwall PVC. We utilize an innovative manufacturing process to create this unique shape, heating sand to 260° Celsius, then pouring it inside carefully measured and cut pieces of PVC.
First we drew life-size diagrams of our desired shape, then cut the PVC and inserted the T's needed for structural beams. These T's had to be inserted prior to the molding process to ensure alignment and fit. We inserted wooden stoppers the T's and PVC openings, keeping one end open to funnel in the sand. Once the PVC was filled with sand and began to soften, the final stopper was inserted, and we set the pipe on the diagrams, shaping it to fit the outline and holding it stationary during the cooling process.

The curved upper section of our frame and our handbuilt camera system are the only components of Rovbotnica that are carried over from a previous ROV model.

Another innovative feature of our frame consists of our four sturdy 'feet' on the bottom of Rovbotnica *[see Fig 1.2].* These feet provide stability and stress relief when Rovbotnica is not in the water: reducing torque, strain, pressure, and potential damage to our payload items. The back two feet have PVC 1/2" T's for stability, while the front two feet do not so that RSN power line entanglement is reduced. Additionally, by installing feet and therefore elevating the manipulator 12 cm, we can now hold even larger objects on-deck as well as sub-surface.

Rovbotnica weighs 5.9 kilograms in air, but is neutrally buoyant (equal density to the water) while subsurface, allowing for swift maneuvering. The majority of our ballast is consolidated in two air-filled cylindrical chambers, mounted slightly outside Rovbotnica's top frame junctions, to port and starboard. These chambers are made of 2" PVC, and contain 1000 square cm of air as ballast. However, after field trials, we determined that additional ballast was required to achieve neutral buoyancy. To fine-tune our neutral buoyancy at field trials, we created 2 additional air chambers from ½" PVC, which each contain 75 square cm of air. For our tether ballast, we repurposed a favorite childhood toy, the pool noodle, to lend floatation, using zip ties to bind 4 cm sections of pool noodle every 25 cm along our neatly bundled cables. This allows for swift ballast adjustment between saline and freshwater environments. We were able to test and perfect pool noodle section placement and number during our pool trials.

Our vehicle has a very stable equilibrium. Because we sequestered ballasting to the top of Rovbotnica, and placed all heavy components such as the manipulator, at the base, our center of gravity and center of buoyancy are aligned. This results in minimized pitching and rolling, allowing us to operate the ROV more efficiently. Our propulsion motors are placed symmetrically; however, due the position of the manipulator's rotational motor on the starboard side of the ROV, we added weights on the corresponding point of the port side to compensate for even weight distribution.

Unlike many ROVs, which have their tethers connected at the stern, our tether comes directly out of Rovbotnica on the vertical axis, inspired by the ROPOS ROV which services the Neptune underwater network observatory in British Columbia. As a result, Rovbotnica has 360° maneuverability without torque from a trailing tether, providing a distinct advantage while pivoting and positioning, such as when replacing the ADCP.

PROPULSION

This year, Atlantis Inc. created a completely new propulsion system for Rovbotnica. For several years, we'd utilized on-deck motors attached to metal drivelines to rotate our propellers, which enabled us to use far heavier and more powerful motors. However these drivelines frequently snapped at connecting joints, posing a serious reliability issue.

We spent months contacting experts, researching potential driveline materials, and testing alternatives, but were unable to find a suitable replacement material for our drivelines. We determined through risk-benefit analysis that the piano-wire drivelines lacked the reliability and high level of performance that were present in the rest of our systems. Although installing onboard motors was a major change mid-way through the season, we made the decision to ensure problem-free propulsion.

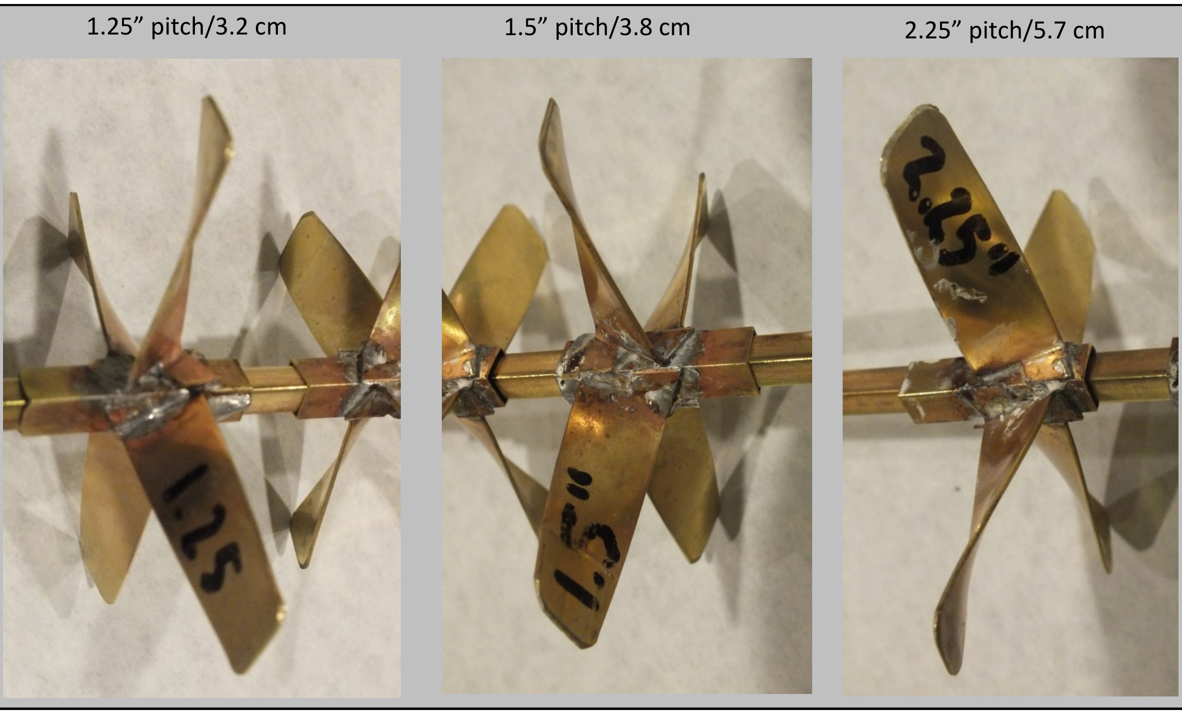
We now use four 1000 GPH (gallons per hour) bilge pump motor cartridges in our propulsion system, chosen for their waterproofing, high, steady rotational speed, and low cost. We placed one motor each on the port and starboard sides, for forward and backward motion, as well as turning on the yaw axis. We originally placed one motor on the top of Rovbotnica to allow us to ascend and descend, but field trials demonstrated that our vertical motion was extremely slow. Installing a second 1000 GPH bilge pump motor in parallel to facilitate our vertical movement addressed and resolved that issue.

To connect the motors to the control board, we used individual 10-meter lengths of 16-gauge double-wire cable so that each motor was an isolated component. In this way, should one motor's cable fail due to malfunction or mishap, the rest of the components are isolated and will continue to function, preventing full system failure. Each subsurface electrical connection along the tether was soldered and shrink-wrapped, then carefully waterproofed with silicone to protect the motors, their operator, the customer's investment, and the undersea environment.

One of Atlantis Inc.'s trademarks is custom-engineered propellers. We fabricate our own propellers for important reasons: the foremost of which is that we believe it is essential to be involved and informed in every aspect of our vehicle. Making our own propellers also allows us to customize the performance of our propulsion system to fit our client's mission objectives as well as ensure that every piece of our ROV is constructed with the highest degree of craftsmanship.

Servicing RSN technology requires require precision handling, and we needed to create a propeller model to optimize output for our onboard motors. By customizing each propeller instead of using a generic model allows us to emphasize performance qualities – such as precision – which might otherwise be compromised. Creating our own propellers also saves us money that would otherwise be spent on commercially designed propellers: another cost differential which we can pass on to our customers.

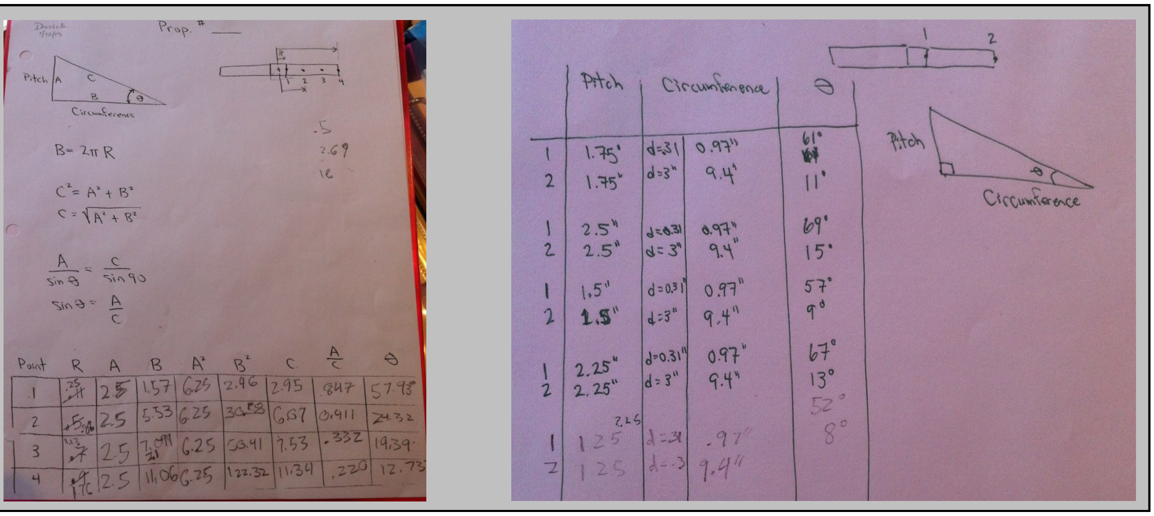
We chose to use 4 blades rather than 2 as multiple, lengthy blades with low pitch allow for more precision at low speeds. Our blade length, 3.8 cm, was a confirmed variable at the beginning of the testing process, as we preferred shroud constructed from 4-inch PVC. Our width, 1.3 cm, was dictated by our motor hub. To create our three propeller prototypes [*see fig 1.3*], we carefully calculated the blade angles needed for several different pitches [*see fig 1.4*]. Pitch is the distance a propeller travels during one revolution. We calculated pitch angles for a range of 2.5 cm to 6.4 cm [*see fig 1.4*], then hand-cut, -soldered, and angled our propellers [*see fig 1.3*]. To ensure accurate testing results, we isolated the pitch variable, keeping water depth, power supply, and the utilized motor constant. To measure thrust, we used our proprietary Thrust-O-Meter machine [*visible in fig 1.5*], which consists of a spring within a PVC tube with a scaled kg-of-thrust viewing slit. We calibrated the Thrust-O-Meter with one of the most reliable and commonly available units of weight: 0.11 kilogram sticks of butter.


1.25” pitch/3.2 cm

1.5” pitch/3.8 cm

2.25” pitch/5.7 cm

Fig 1.3 Propeller prototypes



Derick 4/12/13

Prop. # ___

.5
2.69
16

$B = 2\pi R$

$C^2 = A^2 + B^2$

$C = \sqrt{A^2 + B^2}$

$\frac{A}{\sin\theta} = \frac{C}{\sin 90}$

$\sin\theta = \frac{A}{C}$

Point	R	A	B	A^2	B^2	C	$\frac{A}{C}$	θ
1	.25	2.5	1.57	6.25	2.46	2.95	.847	57.93°
2	~~.5~~ .88	2.5	5.53	6.25	30.58	6.67	0.411	24.32
3	1.13 ~~.7~~	2.5	7.099	6.25	50.41	7.53	.332	19.39
4	~~.9~~ 1.76	2.5	11.06	6.25	122.32	11.34	.220	12.73

	Pitch	Circumference		θ
1	1.75"	d=.31	0.97"	61°
2	1.75"	d=3"	9.4"	11°
1	2.5"	d=0.31	0.97"	69°
2	2.5"	d=3"	9.4"	15°
1	1.5"	d=0.31"	0.97"	57°
2	1.5"	d=3"	9.4"	9°
1	2.25"	d=0.31"	0.97"	67°
2	2.25"	d=3"	9.4"	13°
1	1.25 2.25	d=.31	.97"	52°
2	1.25	d=.3	9.4"	8°

Fig 1.4 a & b: Calculating pitch and blade angles

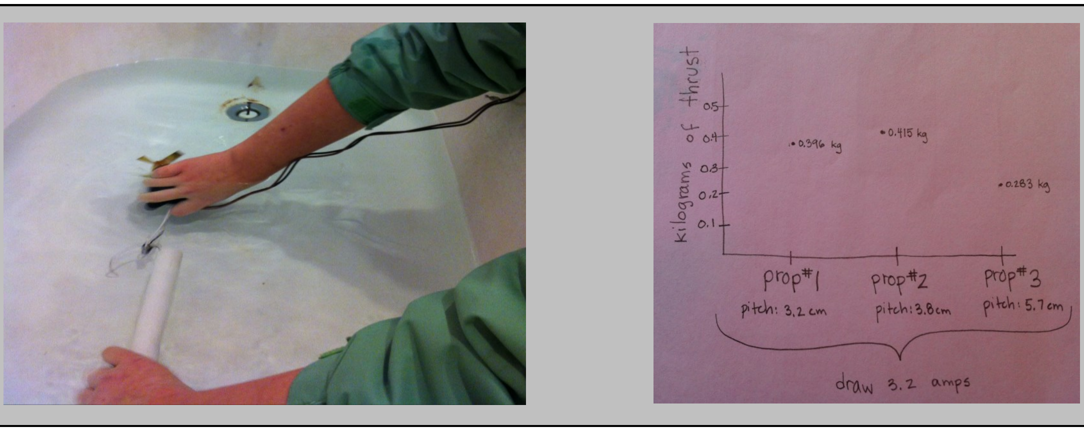


Fig 1.5 a & b: Testing the prototypes with the Thrust-O-Meter, graphing the results

We measured each propeller's thrust during several water-tank testing trials. Each propeller was individually attached to the Thrust-O-Meter and its thrust noted. Its amperage draw was monitored using a multimeter, then we divided each propeller's thrust by the amperage that it drew. The results [*see fig 1.5*] led us to select the most efficient model: a 4-bladed model with a 7.6 cm diameter, 1.2 cm blade width, and a pitch of 3.8 centimeters, which produced 1.86 kilograms of thrust per amp. After installing the new propellers and testing Rovbotnica in pool trials, both team members and spectators could perceive its newfound agility and maneuvering precision compared to previous years' propellers. This finding was further supported by further research, when we discovered that our propellers are similar to the design principle behind the propellers of tugboats. Tugboat propellers, with low pitch and multiple blades, are powerful and exacting, rather than the shorter, higher-pitched propellers of speedboats, which prioritize velocity over energy efficiency or precision.

CAMERAS

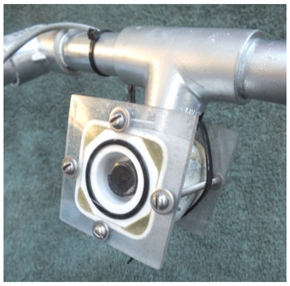


Fig 1.6 One of Rovbotnica's hand-built cameras

Our cameras were hand-built for a previous ROV model, designed to be dual-focused as well as frugal. Unlike most commercially available camera models, our lenses have adjustable focal length, allowing us to acquire tight focus or a deep field of focus. This hand-fabrication results in savings of hundreds of dollars over commercially available underwater cameras. Our clients receive not only a product that is not only superior, but also one that is extremely economical as well. These cameras are frugal, customized, and provide great advantage over single-focus commercial camera models, and for this reason we continued our use of them on this year's ROV.

We use a fish-eye lens in one of our hand-built cameras, and wide-angle lenses in the other three. Both lens types possess adjustable focus. We chose to build our own cameras from individual lenses to minimize the size and weight of our cameras, and therefore the overall weight of the ROV, without compromising video feed quality.

For each camera, we soldered each lens' three wires (video, power, and grounding) to a 15-meter video cable which would be bundled into our tether. For stability, we then used PVC glue to secure the lens within the ½" opening of a ¾" to ½" reducer bushing. This kept the lens from being damaged while we placed it in the housing and waterproofed the electrical connections. To create the housing, we used boiling water to soften 4 cm long pieces of 1 ½" PVC pipe, then molded them over a shaped form of 2"x 2" lumber to create a perfect 5 cm x 5 cm fit around the camera lens. To seal and waterproof the soldered and shrink-wrapped junctions where the lens connects to the tether video cable, we filled the housing with 1 cm layers of epoxy, working incrementally to minimize the formation of air bubbles. On the front of the camera, an O-ring provides a tight seal between the reducer bushing and a 5 cm square of Plexiglas. This square of Plexiglas is removable yet held watertight with 13-cm bolts in each corner connecting it to another rear Plexiglas square. [*see fig 1.6*]

Our cameras are mounted in the ROV frame using ½" PVC T's, which allow them to be placed anywhere on the ROV frame and repositioned with speed and efficiency. This affords us great flexibility and provides limitless camera angle options. Our deeply ingrained "build it from scratch" philosophy allows us to deliver a customized, frugal, and superior product to our customers.

CONTROL PANEL

Electrical schematic: Appendix 3

Atlantis Inc. uses an analog, hardware-only approach to simplify operation. As we transitioned to our new on-board motor system and began design on our customized manipulator this year, we knew that we had a limited timeframe. For this reason, we minimized unknown technical variables, forgoing software design or utilization this year. This software-free approach eliminated potential delays caused by learning to code, coding errors, and allowed us to create a simpler, more reliable control scheme.

Power is obtained from a 12-volt battery, first through the MATE-provided 25-amp fuse and then through Atlantis Inc.'s 25-amp fuse in our positive line. Both the positive and negative power lines are then wired to our positive and negative power junction terminals. Power then branches to five lines, one for our camera power, one for our rotational manipulator motor, and the other three each routed through a 10-amp fuse. Each fuse protects a PWM (pulse width modulator), which functions as a BDCM (bidirectional motor controller). One BDCM controls the starboard motor and one controls the port motor. Another BDCM controls both vertical motors wired in parallel. We assembled and soldered the bidirectional motor controllers personally for quality assurance. PWMs apply voltage to the motor in pulses: short pulses means the motor runs more slowly, whereas longer pulses increase rotational speed. Over the course of eight months, seven of these BDCMs failed due to electrical overload, faulty resistors, and untraceable problems. We refused to crumble in the face of adversity, identifying and installing three reliable BDCMs over time. This experience exemplifies the fragility of electronic components and the need for repeated testing to ensure robust equipment in Rovbotnica.

From the PWM, power to motors is controlled by our steering module, consisting of three 100K linear sliding potentiometers in a water-resistant housing. These linear potentiometers, which each slide along a 9 cm track instead of rotating on a vertical axis, allow increased ease of use and precision over the manual manipulation of rotating potentiometers while piloting. The regulated power then flows down the 16-guage dual-wire cables to the respective motors. A simple 3-way toggle switch, soldered to an 18 gauge power line, controls our on-board repurposed printer motor, which rotates the angle of the manipulator. These three settings allow the pilot or copilot to raise, lower, and lock the manipulator arms in place. The toggle switch was installed in a protective housing of 1 ½" PVC.

Rovbotnica's cameras receive power from the terminal via a DC to DC converter we installed to convert our battery's 12-volt power to the 9-volt current needed for our camera system. Our camera tether cables plug into our control system using repurposed microphone connectors, which are three-pronged to allow for the power, video, and grounding wires. The video feeds are routed from the connectors to our four-feed video transfer module (VTM), then to our LCD monitor. This VTM allows the pilot and copilot to alternate between the camera views displayed on the monitor.

Rovbotnica's control panel has been completely reassembled this year: only the power terminals and camera system come from a previous assembly. The control panel is newly mounted inside a water-resistant, repurposed hard-shell suitcase housing for safety and easy transport. Our suitcase housing, which cost $5 from a thrift store, presents a significant cost savings to a comparable $250 Pelican Case.

A Plexiglas cover further protects all electrical components from accidental splashes or drips during operation in a marine or ship environment. -stationary wiring has been housed in protective tubing and fitted with stress relief. Additionally, empty plastic water containers have been modified to provide a secondary level of protection around the BCDMs.

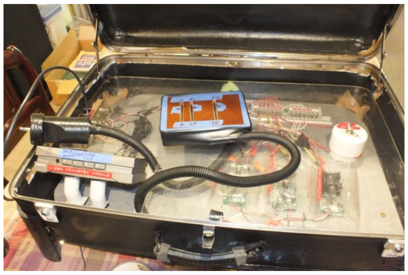


Fig 1.7 The Control Panel

As noted previously, we faced major and repeated challenges as we completely revamped our control system. Our decision to jettison our previous joystick arrangement was a tough call: we spent many weeks attempting to modify them to allow the installation of new linear potentiometers, to increase range of motion, and maintain ease of use. We also made several attempts to increase range of speed variation while still using our 100K (ohms) logarithmic pots, including replacing the motor controller's 100K and 10K resistors with a similar ratio of 10K and 1K resistors. We hoped this would reduce the ohm range to within the pots available range of motion. However, this Ohm range was so limited that we lost all variable speed. We experimented with manually steering using 100K linear rotating potentiometers, but it was too difficult to physically return the motors quickly to neutral. When we switched to linear sliding pots, we created a small, secure casing to mount them in, and discovered a whole new challenge. In addition to managing three potentiometers with two hands, the 'zero' of each differed. After rigorous field trials, we were able to mark at what position each potentiometers put the corresponding motor in neutral.

Due to our rigorous and significant testing, the control panel functioned flawlessly at Regionals.

PAYLOAD TOOLS

Manipulator

We chose to operate our brand-new manipulator with hydraulics to reduce the potential for underwater electrical shorts and increase reliability. In addition, the Atlantis Inc. staff has significant experience with hydraulics. Our hydraulics utilize water because it is readily available at the operation site, incurs no additional cost, and also presents no environmental pollution hazard.

With Rovbotnica's manipulator, we can transport, install, or remove a variety of scientific instruments and power cords. Our custom-designed claw features allow Rovbotnica to accomplish all the tasks of node servicing with a singular manipulator: connecting power, opening the BIA door, transporting the temperature sensor, SIA, and OBS, removing the pin to free the OBS (Ocean Bottom Seismometer), replacing the ADCP (Acoustic Doppler Current Profiler), and extracting biofouling specimens.


Fig 1.8 Rovbotnica's custom-built manipulator

Our single-piston hydraulics system, designed to open and close our manipulator, is based on the same principle used in a residential house's water-well pump system. The system floods via an unpressurized intake tube into a 40 psi compressor repurposed from a Recreational Vehicle water pump. The pressurized water from the compressor is pumped through a 5 cm connector piece of 250-psi-rated braided PVC tubing to our pressure accumulator. We personally constructed the pressure accumulator from 2-inch PVC pipe, rated at 400 psi, securing the 2-inch PVC cap with PVC glue rated at 1000 psi once hardened. To deploy and retract the piston, thereby closing and opening the arms of the manipulator, we use a hydraulic actuator, which we designed and built using a metal Y-shaped shut-off valve with two ball valves, a configuration often used in drip irrigation. The actuator, utilizing buttons instead of rotation switches, is effective, easy to use, and has split-second response time. The actuator's pressurized line along the thether to the piston is 1/4" tubing rated at 150 psi. The release line from the actuator is 10 feet of repurposed 3/4/" garden hose. [*see Appendix 4*]

We created our manipulator from entirely from brass. Brass can be soldered, and is a softer metal to which we could quickly and easily make modifications. Overall the manipulator is 37.5 cm long. The jaws are 12 cm long and 3.8 cm high. Maximum aperture is 8 cm at the tips of the manipulator arms. The piston is 15 cm long and has a diameter of 1.3 cm. [*see fig 1.8*]

To identify and address leaks, we conducted several pressure tests. We effectively stopped leaks in dryland joints with plumber's tape and epoxy. Our hydraulic piston's small leak presented a more formidable challenge. When silicone, ball-bearing grease, and other lubricants proved ineffective sealants, we decided to insert an O-ring. Because we lacked the machining capabilities ourselves, we contacted long-time sponsor Nichols Brother Boat Builders with our request. They readily agreed to machine a small channel to accommodate the O-ring within the piston. Our entire system has been tested and rated at 80 psi, double our maximum pressure supply, although numerous components are rated at 150 or 200 psi from tether to manipulator. *[See hydraulic safety discussion on pages 11 & 12.*]

Our first priority was swift seizing and releasing; our custom hydraulic piston and actuator achieved that goal. Next, we wanted to ensure firm grip while transporting or latching onto objects. We tested several materials as grip-pads on the 10 cm long by 3.8 cm tall manipulator arms, rejecting a number of materials due to poor performance. Ultimately, 2-cm-thick pads of high endurance woven-plastic material used for sanding wooden floors provided excellent grip. However, as we tested the manipulator over several weeks, it became clear that we would also need improved latching mechanisms.

After testing various configurations, we installed four overlapping 2 cm wide x 3 cm long teeth on the tips of the manipulator arms . On the bottom of the arms, we installed six 1 cm long horizontal prongs .5 cm in diameter. The addition of these teeth and prongs resulted in a 100% decrease in the dropped-item rate.

While the teeth and prongs greatly improved our grip on objects, transporting the bulky, cubic SIA still presented swing and sway problems during field trials. After a problem-solving session and a company discussion, we determined two 10 cm long (.75 cm in diameter) horizontal bars protruding from midpoints on either side of the manipulator arms would stabilize the SIA, thereby allowing us to install it more quickly and more securely. Indeed, installing the stabilization bars decreased average installation time by over a minute by preventing twisting or swimming motion of the SIA.

Other RSN maintenance tasks, such as removing the ADCP from its recessed holder within the floating mooring platform, required the manipulator to have a wide range of motion vertically. To raise and lower the manipulator, we installed a repurposed printer motor on the forward starboard corner of Rovbotnica. [*see fig 1.9*] The motor was waterproofed by first coating the entire motor up to the edges of the shaft with rubberized tool dip. Next, to minimize water encroachment to the shaft, we placed a small amount of grease on the shaft base, then surrounded the shaft with a bead of silicone enclosing the edges of the dip coating to maximize the seal. The printer motor's reducing gears allow the pilot to rotate the claw 345° at a slow, steady rate, its range of movement limited only by a structural crossbar and limited length of hydraulic line in the tether. Before discovering the cannibalized printer motor, many of the reducing gears we tested spun at a very swift rate, rendering the manipulator very difficult to control. However, when we tested the printer motor's reducing gears, it allowed us to make minute adjustments, better positioning the manipulator for accurate grabs.

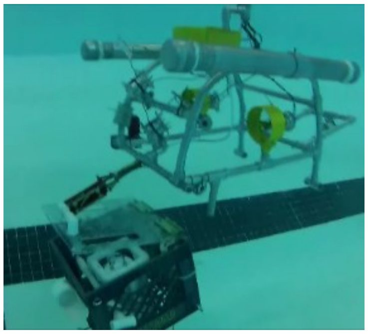


Fig 1.9 Rovbotnica's lowered manipulator. Printer motor visible in front starboard corner.

With our specialized grips, teeth, and rotational capabilities, our hydraulic-powered manipulator is powerful, exacting, and multipurpose.

Thermocouple

It was our greatest priority to ensure that the scientific data retrieved by our thermocouple was accurate and reliable. With the labor-intensive, time-consuming process of building all our systems and components personally, we carefully considered the ramifications of personally building, calibrating, and waterproofing the thermocouple.

Ultimately, the deciding factor was the fact that our manufacturing facility simply lacked the capabilities to heatshrink a seamless fluorinated ethylene propylene coating onto a fifty foot cable, thereby waterproofing it in a failproof manner. Other waterproofing methods, such as shrouding the thermocouple in flexible aquarium tubing, or coating the junctions in epoxy, affected ease of use and the reaction time of the measurement tip. Particularly since this was a payload tool, we refused to compromise on quality, accuracy, or reliability. Therefore, after custom-designing a thermocouple to meet our standards and specifications, we elected to have the it assembled and coated in FEP per our specifications in an off-site factory environment. We are confident in our ability to manufacture our own; however, we simply had too many manufacturing limitations to produce an acceptable waterproofing method for our handcrafted thermocouple that would meet our high standards of performance and data accuracy in our timeframe. Therefore, we designed a high caliber, customized probe, and commissioned its assembly from a leading scientific instrument manufacturer.

To accurately measure the ever-fluctuating temperature of the undersea vent, we use a Type K thermocouple. During Atlantis Inc's research visit to our local pediatrician, we were inspired by the temperature sensors used to measure oral temperature and those used to monitor the cold storage for temperature-sensitive pharmaceuticals.

Using these sensors as our design inspiration, we then determined that the Type K to be the most reliable and accurate of the four major types of thermocouple [2] (K, J, N, and E). It has a very quick response time and its accuracy deteriorates far more slowly than other types. Thermocouples consist of one positively charged wire and one negatively charged wire, and they quantify temperature by converting heat energy to millivolt signals. Those millivolt signals are translated from electrical energy to degrees with our voltmeter thermocouple reader. Our thermocouple is fifty feet long with a spotwelded measurement tip. It is fully insulated and waterproofed, sealed in Fluorinated Ethylene Propylene (Teflon) coating which was heatshrunk at the factory. It is sturdy and is very conducive of heat, resulting in a very fast reaction time while measuring vacillating temperature. To both protect our sensor and ensure that it maintains secure placement after being installed over the undersea vent, we manufactured a weighted, robust housing for the measurement tip. To protect our line, slack is coiled on a lightweight holder, and kept in the possession of our data retrieval technician.

We contacted several companies to see if they would be willing to manufacture our customized thermocouple, but unfortunately many were unable to do so. Leading scientific-instrument manufacturer Cole-Parmer was happy to build a thermocouple to our specifications.

For installation over undersea vents, our thermocouple is mounted in a housing of 10.6 centimeter rubber coupling, epoxied to a piece of 1-inch PVC which is 7 cm long. After testing the housing in field trials, we determined that the cylindrical housing was slippery and difficult to grip, especially after multiple submersions. To aid in the transport and precision placement of the sensor, we installed 5 cm stainless steel U-bolt as a handle on the housing. [*see fig 1.10*]

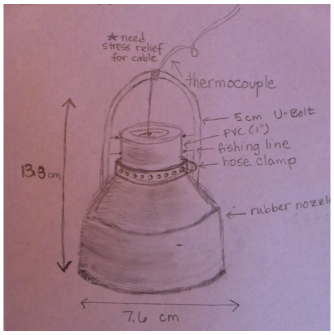


Fig 1.10 Intermediate design sketch of thermocouple housing

This way, we could easily grip the handle of the housing in the specially designed front teeth of the manipulator as we transported it to the undersea vent site. To counteract potential dislodgement due to the strong outflow from the vent mouth, we also installed small metal washer weights with zipties to the rubber housing. This additional weight anchors the sensor securely and prevent unnecessary loss of data.

The thermocouple is securely suspended in the housing using a tightly woven web of 100-lb monofilament line. The line from the measuring tip is wrapped around the U-bolt with electrical tape to provide stress relief.

OPERATIONS

Rovbotnica requires only a small staff of five for efficient and effective operation. One Pilot can easily control the propulsion with the potentiometer control module, designed as an intuitive, clearly labeled and streamlined user interface. The Copilot aids the Pilot by alternating the camera feed displayed on the monitor as needed via the video transfer module, as well as operating the hydraulic actuator to open and close the manipulator's jaws. The angle of the manipulator can be adjusted by either the Pilot or Copilot. One team member manages the tether, and we devote another member to monitoring the temperature sensor data. The Supervising Mission Specialist monitors mission performance & completion, time management, and ensures all safety procedures are in effect, also creating and enacting mission plans should problems arise.

SAFETY AND TROUBLESHOOTING

At Atlantis Inc., safety is perpetuated in many forms: in terms of personnel conduct, visual identification, shielding, fuses, kill switches, robust specifications, the elimination of sharp edges, and extensive troubleshooting. Our extensive testing procedures at our headquarters and in the field also ensure reliability, reduce risk, and allow us to identify and rectify hazards.

Fig 1.11
Control Panel kill switch

First and foremost, when handling, operating, or repairing Rovbotnica, wearing protective gear such as safety glasses and closed-toe shoes is mandatory. In the event of emergencies, all personnel are trained to kill power immediately. [*see fig 1.*11] All personnel are also cross-trained to allow for swift and effective identification of issues in any of Rovbotnica's systems. Prior to each mission attempt, we ensure all systems are working safely by evaluating our systems with our safety checklist *[see Appendix 2].*

Fig 1.12 Propeller shielding

For maximized visual identification of potential dangerous equipment, we colorcoded hazardous components high-visibility yellow, which provides stark contrast against both the metallic sheen of Rovbotnica's frame and the vivid red 'DANGER' warnings emblazoned on the components. [*see fig 1.12*] Our propeller shielding, our manipulator's rotational motor and gears, and our hydraulic pressure accumulator are all identified in this manner. Our propellers are safely shrouded in 2-inch PVC pipe, and all blades are carefully blunted. Brass crossbars prevent environmental debris, other components or systems, or the appendages of personnel from becoming endangered and potentially entangled. Mesh shielding encasing the reducing gears also prevents the manipulator's rotational motor from presenting an entanglement hazard.

Fig 1.1.3 Hydraulic pressure accumulator

To protect our electrical components and the personnel operating them, our hydraulic system and our electrical control panel both run through a single 25-amp fuse installed in the line from our power supply. Additionally, we installed a 10-amp fuse prior to each of our motor controllers, so that in the event that a single motor exceeds a safe power draw, the fuse will blow, allowing the rest of the motors to function normally. These fuses also protect our motors in the event of a power surge from our 12 volt battery. The particular 10 amp fuses installed in our control panel have a special feature: a built-in indicator LED light, which turns on after the fuse blows. This allows us to quickly and easily identify the source of the problem. All wires are neatly bundled or shrouded, and a Plexiglas cover protects our electrical components from accidental splashes or drips on deck.

Our hydraulic system has a maximum supply of 40 psi from our compressor. To ensure safe operation, every component of our hydraulic system underwent rigorous pressure tests and was certified by one of the leading boatbuilders in the Pacific Northwest, Nichols Brothers Boat Builders. Our pressure accumulation tank is test-rated at 200 psi, and each component has specs of 80 psi or above, as well as the entire system being test-rated and certified at 80 psi. The hydraulic system was also inspected and approved by MATE's 2013 Pacific Northwest Regional Challenge safety judge. [*see fig 1.13 on previous page*]

Our hydraulic system and control panel each have a clearly identified kill switch to immediately cut off power to Rovbotnica and system controls. Should electrical failure, an unsafe situation, or ROV entanglement arise, we are able to immediately cut power to all components.

In the event of an emergency, our first priority is to prevent any harm from befalling our personnel, and next to prevent water damage to our electrical components, which would cause additional hazards. Therefore, the first step in our emergency procedure is to shut off power and ensure all personnel are in a safe situation. Next, we contain our robot, the hydraulics, and the control panel to a dry area, then identify the source of the problem and isolate the malfunctioning system. If the problem is in the hydraulics, the entire system is quickly depressurized. If not, then the hydraulics remain pressurized so that we can quickly return to operational status in the water once the issue has been resolved.

In the event of an electrical problem, a lit fuse is often an indicator, but should all fuses remain intact, we keep a multimeter at our mission station at all times to test for unusual amperage levels at any point in the system. If the problem stems from serious damage in a key component, such as a hydraulic line failure, we move the entire ROV assembly to our repair station to rectify the situation. If the solution to the problem is simple, such as a loosened set screw, we make swift repairs or replacements using our mission-site toolbox, which is stocked with tools and materials needed for electrical and mechanical maintenance. We have significant and thorough experience in this area as we addressed and repaired problems during our extensive field trials.

For example, while at a pool trial testing the ADCP removal capabilities of Rovbotnica, an electrical problem resulted in our inability to control the starboard motor. We carefully and systematically measured amperage at all electrical junctions, using our multimeter. This allowed us to quickly identify the problem – the starboard pulse width modulator. Careful inspection revealed a solder bridge between two resistor pads. Reheating the solder and then wiping away the excess to eliminate the superfluous connection resulted in the starboard motor controller functioning perfectly and allowed us to regain control of the starboard motor. Our troubleshooting techniques allowed us to identify and solve problems innumerable times during our rigorous testing process, both of the individual systems and also of Rovbotnica as a vehicle.

CHALLENGES OVERCOME

The primary technical challenge this year was to develop and create entirely new systems, maintaining our level of excellence while working through the time-consuming iterative process of design, testing, redesign, retesting, and refinement.

This redesign process included addressing our lack of precision maneuvering. Our previous control scheme utilized cannibalized Atari joysticks and their rotating logarithmic potentiometers. While the joysticks were easy to handle while piloting, the logarithmic aspect of their potentiometers lacked control due to the very limited response range of rotation speed for motors and propellers. It prevented us from making needed minor maneuvering adjustments and also prevented Rovbotnica from operating at low speeds. We tested these logarithmic potentiometers with a multimeter while a pilot operated them, and found that the voltage passed on to the motors increased and decreased abruptly. Due to these dramatic power shifts to the motors, we were unable to increase or decrease speed in a gradual manner or make minute adjustments within the water column. As a consequence, we would be unable to quickly or efficiently install the SIA in the BIA.

This year, we replaced the joystick-mounted logarithmic potentiometers with three linear sliding potentiometers. Linear sliding potentiometers allowed us to increase backward or forward speed far more gradually, resulting in increased precision and less wasted time such as when we attempted to pull the pin to release the OBS from the elevator.

Another potentially crippling challenge came when we attempted to find a deep-water secondary testing facility to accurately simulate the mission conditions. By the end of April, we had not been able to test Rovbotnica in a deep-water facility, and were therefore unable to ensure that the entire vehicle, with all its systems, worked well under deep-water pressure while servicing the RSN's. As Atlantis Inc. is based in an island community with low population density, finding a pool which met our depth requirements was a challenge. Our home pool, at Island Athletic Club, which has sponsored us for several years, has a maximum depth of only 1.4 meters and prevented us from practicing many of the required functions for RSN maintenance. Finding a deep-water pool was imperative. Other pools in our community were outdoor, uncovered, and would not be filled until late May, far after the date at which we would present our RFP to MATE and demonstrate Rovbotnica's capabilities. However, after speaking with residents all over the island, we found a covered pool which measured 3.65 meters in depth at the North Whidbey Parks & Rec Aquatics Center, which agreed to schedule pool trials for deep-water testing. Since the only time available for the Center was mid-day, team members rearranged schedules and committed to three mid-day practices during the two weeks leading up to competition. Though the transport time was considerable, over an hour one-way, it was well worth it to ensure pilot practice and system testing under simulated conditions.

Developing a manufacturing and testing schedule greatly increased our ability and motivation to overcome challenges. By scheduling deadlines for system manufacturing and establishing dates for their testing and refinement, we boosted productivity and could delegate tasks. Company personnel could work on components of Rovbotnica individually, a method best exemplified by the manipulator manufacture process. Two to three members would work in a sponsor-provided shop, and other team members could work on electronics or painting Rovbotnica back at our headquarters. We maintained steady progress through attendance at regular meetings twice weekly, often totaling over ten hours a week. Due to this dedication and determination, we were able to meet both our main goals: a finalized propulsion scheme by January, and testing Rovbotnica as a whole by February.

The biggest personal, non-technical challenge for all team members was maintaining optimism and determination during the testing process and the seemingly relentless component failures throughout. Nevertheless, we supported one another and worked until we found a solution for every problem. It took grit, determination, and constant work and redesign for several months, working 10-15 hours a week throughout holidays, on birthdays, and regardless of what felt to be monumental adversity. For many weeks, systems failed at every pool trial, but through perseverance, skill, and hard work, each issue was resolved, and in late April, problem-free testing became much more frequent.

FUTURE IMPROVEMENT

Though our potentiometer piloting module is already simple and easy to use, in the future we would like to consolidate all three potentiometers into a more intuitive format. By controlling all three axes by means of a single joystick, the pilot could easily control the additional toggle for the printer motor in his or her other hand, promoting better synergy between ROV position and manipulator angle. Additionally, a single joystick would increase a pilot's response time, allowing him or her to adjust motor speed and direction using smaller movements. This would allow us to decrease total time needed to service the nodes, and as a result, decrease operating costs as well. With this ideal control arrangement in mind, Atlantis Inc. will conduct rigorous testing to ensure that linear rotational potentiometers in a joystick configuration are a viable substitute for linear sliding potentiometers during the summer of 2013. As always, our first priority is ensuring that our ROVs produce an impeccable performance, fulfilling and exceeding our customers' needs and expectations while emphasizing safety and economical manufacturing.

REFLECTIONS

Participating in the MATE competition for the last three years has completely changed the course of my life. As a team member of Atlantis Inc., I have mastered skills I was previously unexposed to, such as electrical engineering, hydraulic system design, and mechanical repair skills. As a team captain, I have learned the importance of organization, labor delegation, and maintaining a professional, positive environment even in the face of seemingly insurmountable challenges. Three years ago, I felt very strongly against embarking on a career involving science, an attitude unfortunately shared by many youth in America. However, due to MATE's requirement that teams function as companies, I have learned that my passions, marketing and communications, play a significant role in the fields of science and technology. Participating in the MATE ROV competition has opened many doors and given me many opportunities: meeting with the scientists and engineers at the UW Ocean Observatories Initiative, flying a plane, meeting with graphics & branding experts at the Alaska Fisheries Science Center, and becoming one of the youngest Signature Program presenters in the history of the prestigious Seattle Science Festival. My career opportunities and personal strengths have been molded and expanded by participating in the MATE ROV competition.

-Hannah McConnaughey, captain

This is my fourth year on a MATE ROV team. During this time I have learned many things, such as how to organize my time, figure out mechanical and electrical problems, stay cool when things get tense, use a metal lathe, soldering iron, milling machine, drill press, and multi-meter, speak in public places, and interact with the community at fundraisers. Because of my experiences, I have also been able to narrow my choices for a college major to Business, Mechanical Engineering, and Biology. One of the most rewarding experiences is to have finally won a MATE Regional competition and be able to represent the Northwest at the International Competition like my older brother did.

-Christopher Wilson, Pilot

Being a part of Atlantis Inc has really opened my perspective at possible areas of study. Over the course of 8 months of manufacturing our bot, I have found my interests to be in technical, mechanical and electric engineering. Through this project I have discovered the excitement of troubleshooting and solving complex technical issues and am planning on attending Edmonds Community College to engage in their Robotics Program in the fall. I believe this competition has helped me prepare for life after high school in that working together is more powerful than doing things by myself. Although working and building the bot has been a valuable experience, the social and professional interaction aspect has had a positive effect in that manners and attitude make large impressions. As well as being technical and logical like with the bot and electronics, I also have to be optimistic, yet realistic about my goals for the future. Along with a new outlook on my future, I have also been presented with many opportunities for my future education that, without being a part of Atlantis Inc. and the MATE competition, I would not have had.

-Derrick Riley , Electrical Engineer and Copilot

This last year has been one of the most influential years in my life. I've learned many new engineering methods and techniques, such as calculating the pitch for propeller construction. I was taught the art of PWM manufacturing, and have found new respect for the complexity of motor control. When we travelled to the University of Washington, we got to see the OOI setup, the concepts for the node system, and the application of the cabled observatory, from ecological management to monitoring seismic activity. Being part of Atlantis Inc. and the MATE competition has further developed my sense of teamwork, dedication, perseverance, and time management.

-Austin Drake, CFO and Thermocouple Specialist

I didn't realize how much the MATE ROV Competition had changed my life until we hosted a robotics outreach event at a local fair, during which I taught a little girl about robotics. She clearly shared the same love of robotics that made me help form my first robotics team when I was nine. I started the ROV team just for fun, but after four years, I am passionate about my work with ROVs and I am dedicated to the team. I have learned everything I know about engineering from this team, from using a drill press to calculating propeller pitch. I have developed problem-solving skills, teamwork, friendships, and understand how to work really hard. I am so grateful to MATE for giving me the opportunity to embark on this eye-opening journey.

-Haley McConnaughey, Tether Operator, Safety Officer, and Engineer

ACKNOWLEDGEMENTS

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MATE Center, the Marine Technology Society—Puget Sound Section, Nichols Brothers Boat Builders, Island Athletic Club, North Whidbey Aquatics Center, Ace Hardware, Les Schwab Tires, Cole-Parmer, the staff of the OOI we met at the UW (Eric McRae, Allison Fundis, Orest Kawka, Deborah Kelly, Dana Manaleng, Nancy Penrose, Giora Proskurowski) as well as those OOI members we didn't meet, Reuben Mills with ROPOS, South Whidbey Pediatrics, Bob McConnaughey & Karna McKinney & Rebecca White with the Alaska Fisheries Science Center of NOAA, Christopher Evans with Giddens Industries, Brewster Bede DDS, South Whidbey Pediatrics, Quantum Consulting Engineers, Whidbey Island Dive Center, Linds Jewelry, Front Row Creative, Sound Business Center, Eric Wilson, Coastal Bank, South Whidbey Lion's Club, the Seattle Science Festival, The Pacific Science Center, Sea-Life Productions, Eric Wilson, Shirley Groner, Ed Bennet, Luke Reid, Rick Rupan, Wes Thompson, Fritz Stahr, Jill Zande, Arne Bystrom Architecture, Peter Morton, Christopher Siani at the UW Applied Physics Lab, our parents, and our Mentors: Ashley McConnaughey and Rob Setlow

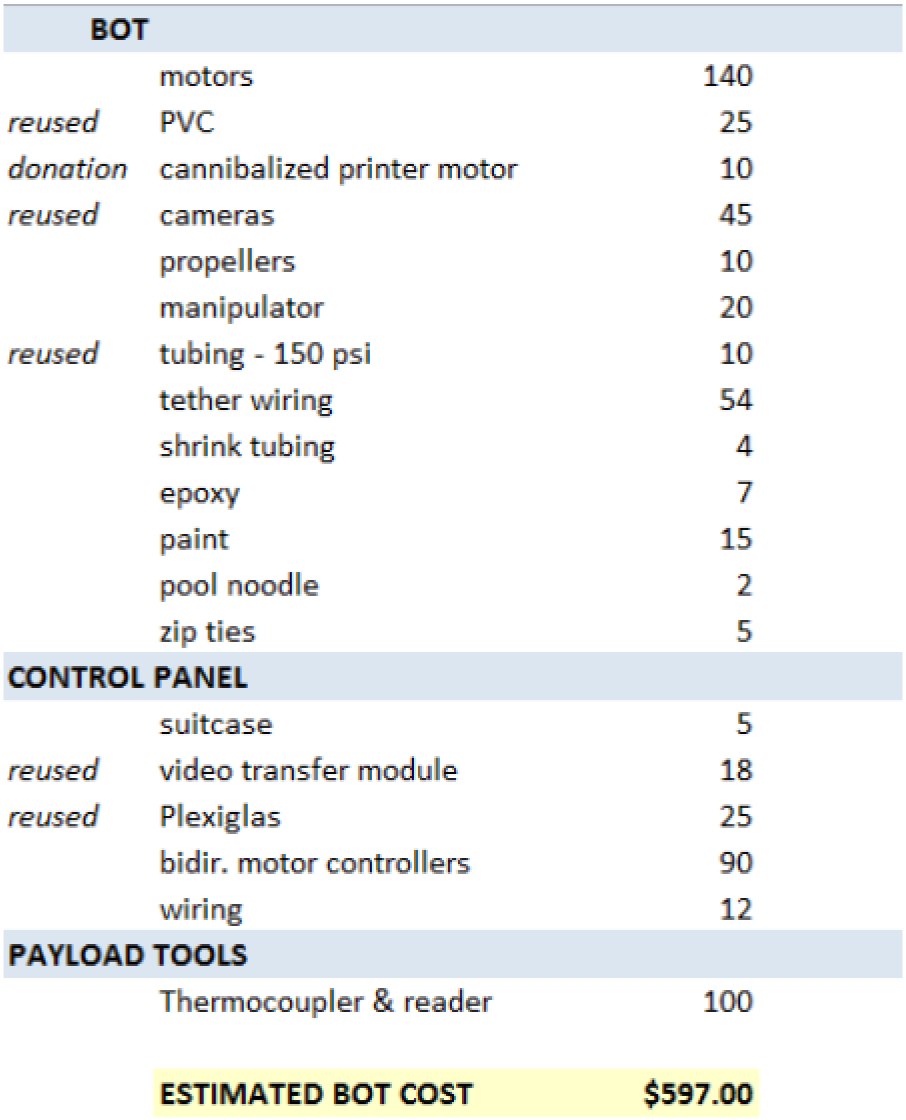
REFERENCES

[1] MATE Textbook *Underwater Robotics: Science, Design & Fabrication* pages 311-312

[2] http://www.facstaff.bucknell.edu/mastascu/elessonsHTML/Sensors/TempThermCpl.html

APPENDIX NO. 1

ATLANTIS INC. 2012-2013 EXPENSE SHEET



BOT		
	motors	140
reused	PVC	25
donation	cannibalized printer motor	10
reused	cameras	45
	propellers	10
	manipulator	20
reused	tubing - 150 psi	10
	tether wiring	54
	shrink tubing	4
	epoxy	7
	paint	15
	pool noodle	2
	zip ties	5
CONTROL PANEL		
	suitcase	5
reused	video transfer module	18
reused	Plexiglas	25
	bidir. motor controllers	90
	wiring	12
PAYLOAD TOOLS		
	Thermocoupler & reader	100
	ESTIMATED BOT COST	**$597.00**

APPENDIX NO. 2
SAFETY CHECKLIST

AT ALL TIMES:

☐ Safety glasses

☐ Closed-toe shoes

PRE-MISSION:

☐ All plugs dry and secure

☐ Stress relief foam correctly positioned for tether/control panel junction

☐ Tether neatly coiled

☐ Thermocouple cable neatly coiled

☐ Hydraulic lines neatly coiled

☐ Nuts on manipulator tight

☐ Propeller shrouds/mesh intact

☐ Rotational printer motor mesh shielding intact

☐ Potentiometers slide securely

☐ Ensure fuses are intact (4: ☐ ☐ ☐ ☐)

MISSION MOBILIZATION:

☐ All personnel alert & aware

☐ No water near unwaterproofed electrical components

☐All plugs dry and secure

☐ Tether and thermocouple cable do not present tripping hazard

☐ Plexiglas cover installed

☐ Doublecheck fuse integrity (5: ☐ ☐ ☐ ☐ ☐)

☐ Doublecheck Stress relief foam correctly positioned for tether/control panel junction

☐ Propellers spin correctly (3: ☐ ☐ ☐)

☐ Rotational motor raises and lowers manipulator correctly

☐ Hydraulics flooded

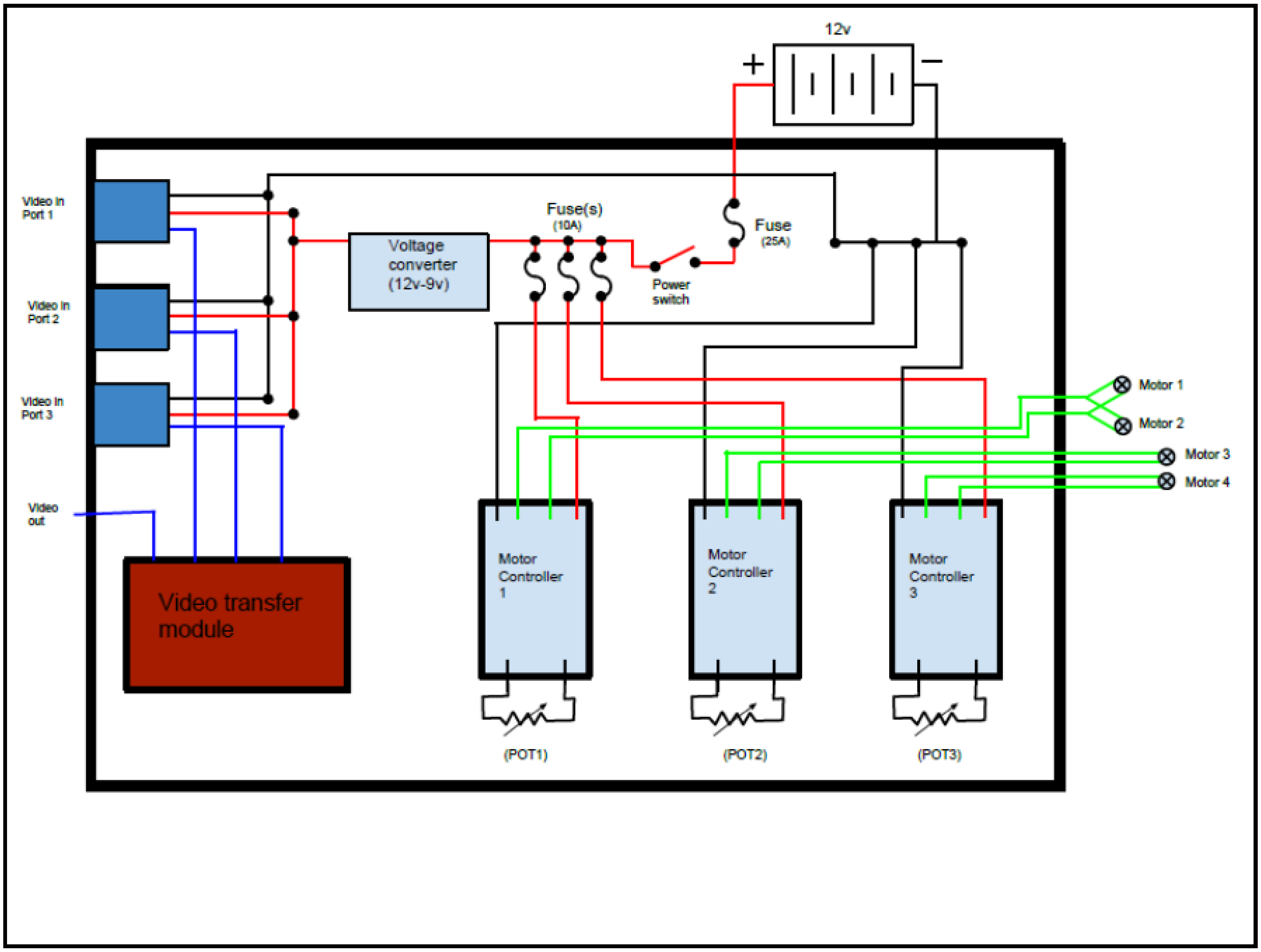
☐ No leaks in hydraulic tubing

☐ Hydraulic actuator opens and closes manipulator correctly

☐ No leak in piston

☐ Safety checklist completed

APPENDIX NO. 3
ELECTRICAL SCHEMATIC



APPENDIX NO. 4
HYDRAULIC SCHEMATIC