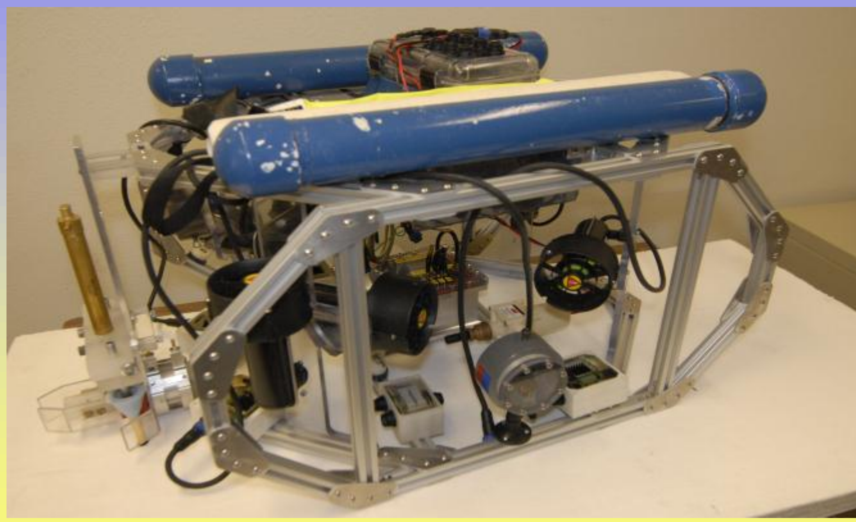
2012 MATE International Competition

Technical Report

Pacific Hell Divers Engineering

Linn-Benton Community College

Albany, OR USA



The ORCA 2012

PHD Leadership:

Sarah Luebke (CEO)

Sammy Mouy (CEO)

Jessica Eaton (CEO)

Jody Eaton (CFO)

Ben Dean (COO)

Steven Solders (CSE)

Members:

Griffin Alberti, Danielle Butler, Kerry Codoley, Alex Frisk, Ryan Harp, Matt Holmes, Brandon Huff, Kyle Humphry, Andrew Larson, Jason Marks, Phillip Marks, Jonathan Naylor, Kyle Neumann, Scott Neuman, Rachael Nolan, Blythe Nourie, Daniel Reichert, Coquille Rex, Chad Sarni, Francis Shala, Nathan Slocombe, Samuel Stephenson, Steven Solders, Symone Stinson, Keith Steel, Daniel Takmori, Marc Thompson, Dilyn Winn, Li Zhang.

Mentors:

Greg Mulder	Physical Science Consortium
Karelia Stetz-Waters	English Consortium
Dan Lara	Science Engineering and Technology Consortium
Michael Tilse	Machine Tool Consortium

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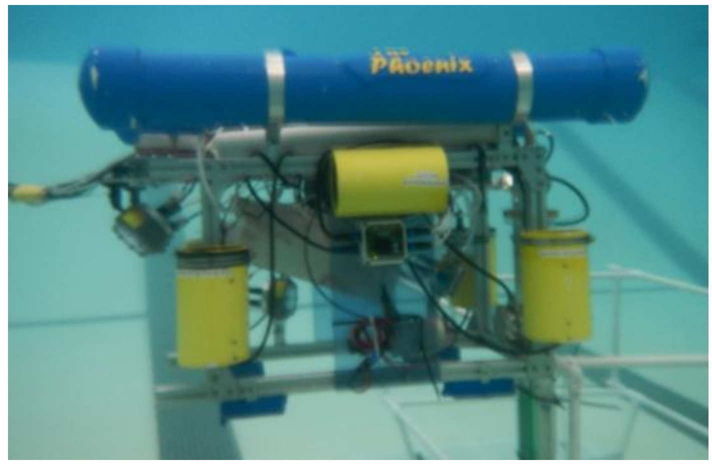
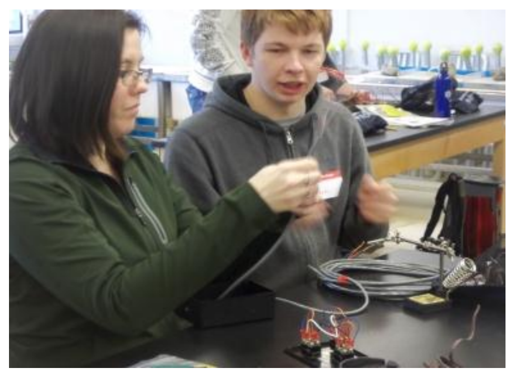
Linn Benton Community College



2011 ROV the "Phoenix" was extremely useful for early testing.



Andy Larson helps teach the Teacher during an MTS ROV Day.

Contact Information:
Pacific Hell-Divers Engineering
c/o Greg Mulder
Linn-Benton Community College
6500 Pacific Blvd. SW
Albany, Oregon 97321
Phone: 541-917-4744
Fax 541 917-4755
http://rov.linnbenton.edu

1.1 Abstract

The Oregon Remote Controlled Adventure (ORCA) is a Remotely Operated Vehicle (ROV) commissioned by Pacific Hell-Divers (PHD) Engineering in concordance with the Marine Advanced Technology Education (MATE) Center for the purpose of performing varied tasks relating to assessment and damage mitigation of World War II shipwrecks. The primary design points of the ORCA are modularity, maneuverability and ease of use. To this end, it is built on an open frame chassis with four thrusters for horizontal vector movement, and four for vertical thrust. Each task is accomplished using a dedicated module that is easily detachable for speedy on-site modifications and repairs should the need arise. Supporting up to nine high-resolution cameras, the ORCA grants maximum field of view to the pilot. The ORCA is controlled through a Graphical User Interface (GUI) custom designed by PhD Engineering. Though the vehicle possesses a variety of modular sensors and subsystems, it has been designed with the goal of minimizing operator training time.

1.2 Company Mission Statement

To expand our knowledge while building a ROV for the MATE competition, while having fun, sharing what we learn, recruiting compatriots, and making memories.

Getting the New Lab ready for the 2012 Build.

ROV Team recruiting High School students during College Night at LBCC

Middle School Students during a recent MTS mini ROV build day with LBCC's ROV Team

2.1 Frame

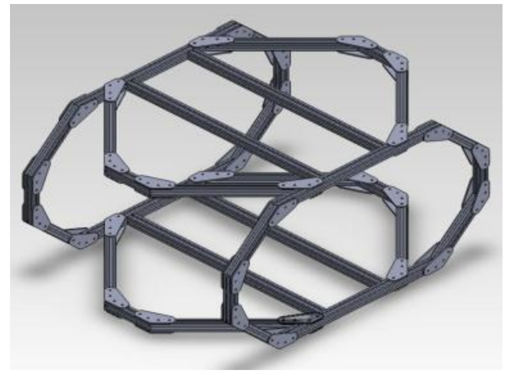


Figure 2.1.0: SolidWorks design of ORCA Frame

The company's given task was to build and design a frame (*Shown in Figure 2.1.0*)to support the ORCA. The configuration should optimize workability and functionality, while aiding in completion of it's missions. The frame must be able to house all of the various components used to complete those missions.

Many of the mission specific tools are mounted on the outside of the frame; while most of the core systems are mounted internally. PhD Engineering chose to use (2cm x 2cm) extruded aluminum for the ORCA's frame (*Shown in Figure 2.1.1*) as this style of aluminum makes attaching modules fast and easy. The many 45° angles allow for easy mounting of the vectored thrusters.

Figure 2.1.1: Example of extruded Aluminum used on the ORCA

2.2 Thrusters

The thrusters provide the ORCA with the essential aspects of motion including the ability to make pinpoint maneuvers and the power to get from task to task in a timely fashion.

The ORCA's propulsion system consists of 8 SeaBotix BT-150 Thrusters (*See Figure 2.2.1*) that provide 18N of thrust each. Each thruster is controlled via a Critical Velocity H-Bridge which is encased in epoxy, with the heat sink exposed; this
allows for better waterproofing, greater heat control within the system, and interchangeability between the systems. Power is provided from the fuse box, a custom made onboard box that converts and fuses the power before it is sent to the H-Bridges. The control of the H-Bridges is done by the Arduino Mega 2560 in the onboard Pressure Housing. Steering for the propulsion is attained by the surface side interfacing of the Arduino Mega and the Python GUI (Graphical User Interface) on a laptop with a Logitech G-UF13 controller.

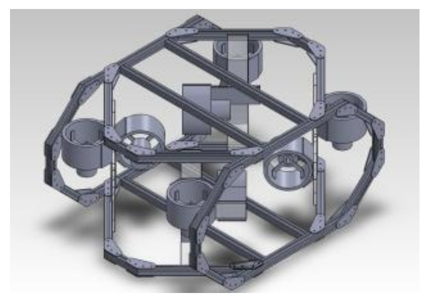


Figure 2.2.1: Possible Thruster placement in Drawn in solid works

2.3 Programming

Control Systems

The control systems on the ORCA start with 2 main components which were chosen based on their financial viability and a great cost per performance ratio. An Arduino Mega 2560 with Ethernet shield drives the ORCA, with an Intel Core 2 Duo laptop with Python GUI control system, is how the user controls and monitors the ORCA. These two systems allow for both easy prototyping, code portability, and a low entry barrier for learning the technical details on the system as a whole.

Software

There are two distinct code portions of the ORCA, the robot side Arduino C with various libraries, and the user side Python which gives access to a networked interface between the pilot (through a laptop) and the ORCA. (See appendix 5.1, pg.17).

Arduino

While the array of available microcontrollers for this sort of application is quite vast, there are a few distinct advantages to using an Arduino. The community support for open source libraries for both components and algorithms is virtually unmatched among other hobbyist microcontrollers. Another distinct advantage stems from the openness of the Arduino platform. While a commercial product, the Arduino remains an open hardware platform which has other

2.4 Electronics

Heat Dissipation

PhD Engineering decided to split up the electronics system as much as possible, focusing on moving heat producing elements and devices that would be harder to replace should a box fail into separate housings. This led us to developing three main boxes that along with 8 individual H-Bridges are the brain, heart, and muscle of the ORCA. (*See Figure 2.4.1*)

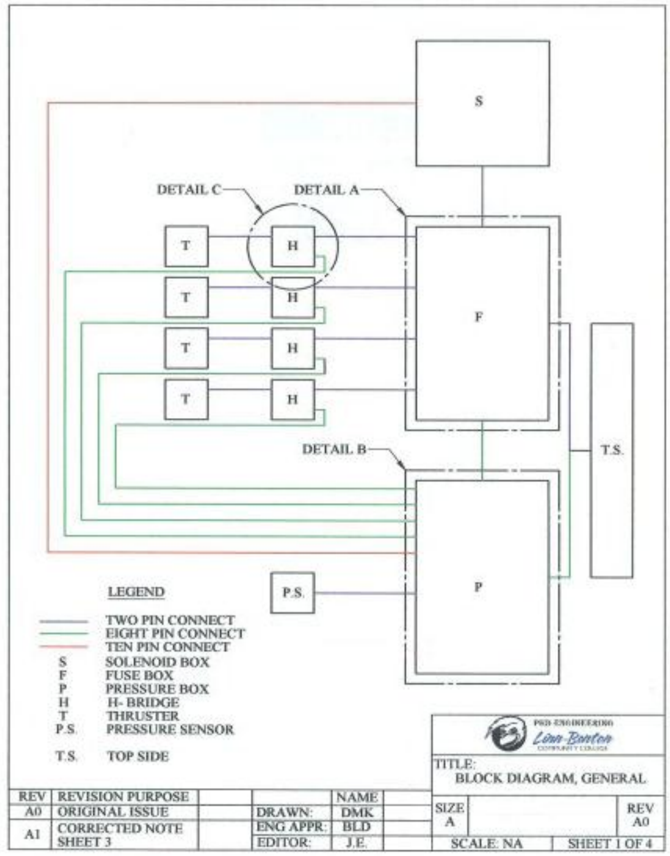


Figure 2.4.1: Overview of electronics

DC to DC Conversion

The conversion box (*See Figure 2.4.2*) containing the heart of the ORCA is a box custom made out of polycarbonate with both an open and an enclosed side. The open side of the box holds a 48*V*-24*V* and a 48*V*-12*V* DC to DC converter. Both converters are encased up to their heat sinks in epoxy. In this way we were able to move two of the biggest heat producing elements out of the box and still keep them water-proofed. The enclosed portion of the box is for distributing power before it is sent to the other boxes, sensors and H-Bridges. Self resetting fuses in the conversion box on the ROV as well as a 40Amp fuse and a general cutoff switch on land, help insure diver safety

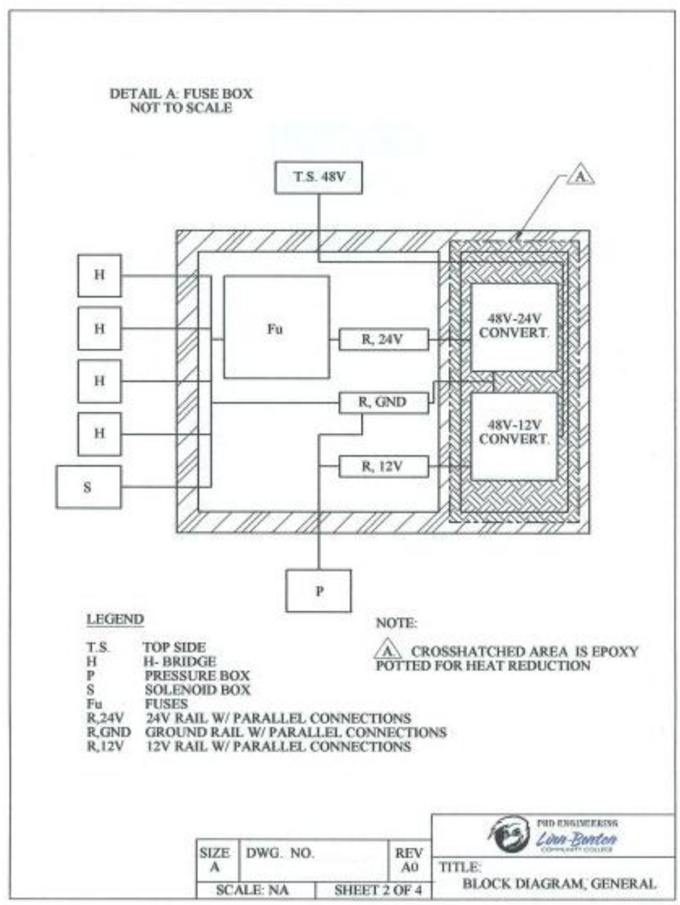


Figure 2.4.2: Fuse box

Pneumatics Box

The pneumatics box, providing muscle for the ORCA's subsystems, is a custom milled box from a solid 6061 aluminum block (*see Figure 2.4.3*). The 18cm x 13cm x 10cm box is powered by 24*V* and houses nine SMC dual acting solenoids controlled via the Arduino's switch TIP-120 transistors. A 0.95cm clear polycarbonate lid seals against water and allows for visual inspections between missions. The advantage of this box is that only two pneumatic lines are needed down the tether to supply air. Our pneumatic system powered by a certified SCUBA tank and regulator. All team members are instructed on how to safely use, transport and store the SCUBA tanks and pneumatic equipment.

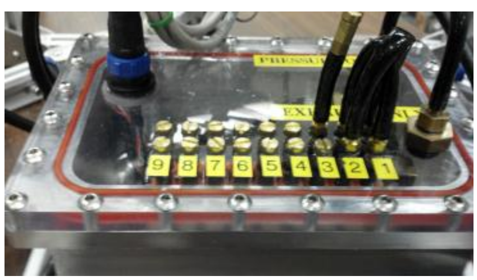


Figure 2.4.3a: Pneumatics box

Figure 2.4.3b: Pneumatics box

Based on an Atmel AVR CPU, the Mega 2560 gives access to 14 PWM (Pulse Width Modulation) channels, an additional 40 digital IO pins, and 16 analog pins. This multitude of input/output negates the use of multiplexing through external circuits which is a benefit for reducing the complexity of the overall clarity and compactness of the system. Another distinct advantage of the Arduino platform comes from the line of the so-called shields. These are essentially prototyping breadboards that plug directly on top of the Arduino which expand functionality. While fitting the physical dimensions of the official models the shields are also highly documented and supported online.

Communications

The use of the Arduino Ethernet shield to provide client-server operations between the ORCA and the surface was chosen due to the reliability of TCP/IP over long distances and ease of implementation. While the Arduino has a variety of ways to implement your own serial communications, this is a tough task both in the sense of engineering your own wiring scheme and writing the protocol. Ethernet has distinct advantages over custom wiring for both cost and signal integrity. Also TCP/IP has a very well documented capacity for packet (signal) redundancy and implementation for specialized use.

GUI

The microcontroller code has to be written in the embedded language related to the CPU, but a programmer is far less limited by the programming language that the interface is written in. Python 2.7 was the language of choice for creating both the communications protocol and the GUI (*Figure 2.3.1*) used to control the ORCA. Python's ability to rapidly prototype and its access to heavily documented libraries make an obvious choice to design modular, portable, and readable code. PyGame is an open source library that gives an easy API access to USB HID (Human Interaction Device) (*Figure 2.3.2*) protocol, as well as providing intuitive GUI creation.

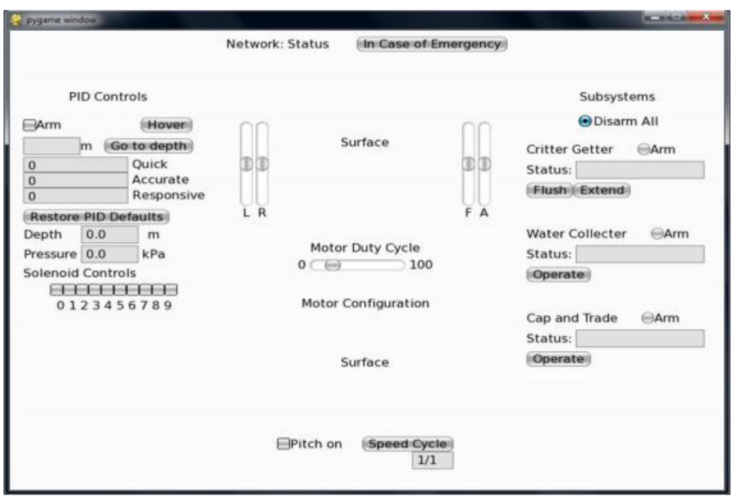


Figure 2.3.1: Screenshot of Graphical User Interface (GUI)

Figure 2.3.2: USB HID (Human Interaction Device)

Open Source Software

Because the Arduino and Python libraries are open source, along with the Arduino hardware itself, it is an important part of the programming section's goals to both release our own code to the public and use open source software elsewhere when viable. The community support of hobbyist programming and robot building is an exciting field that is developing rapidly. This gives us the opportunity to support the art by allowing others to use our own code and ideas to implement better and more exotic designs. As such, PhD Engineering's code is available at: http://rov.linnbenton.edu.

Pressure Housing

The pressure housing is used to house the "brain" of the ORCA. PhD Engineering built the pressure housing using an OtterBox 3500 water-poof box that is rated to a depth of 30 meters. The box contains an Arduino Mega 2560 microcontroller and Arduino Ethernet shield V5 attachment (*See Figure 2.4.4*). All data communications lines from the surface interface devices, or H-Bridges for propulsion are connected to the pressure housing via Bulgin water-proof bulkhead connectors. In addition, the Arduino Mega provides the attached sensors and H-Bridges the 5V needed for their logic processing. (*See Figure 2.4.5)*

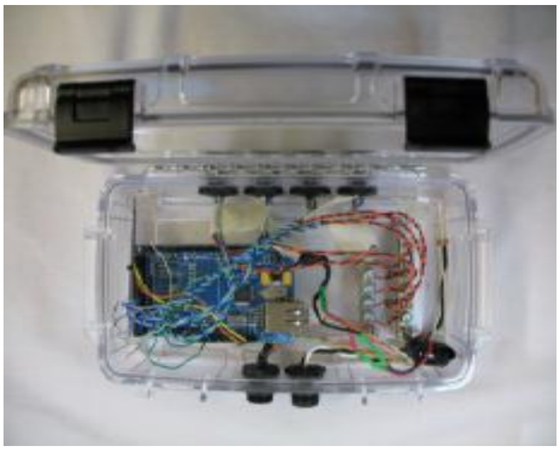


Figure 2.4.4: Otter box housing brain of the ORCA

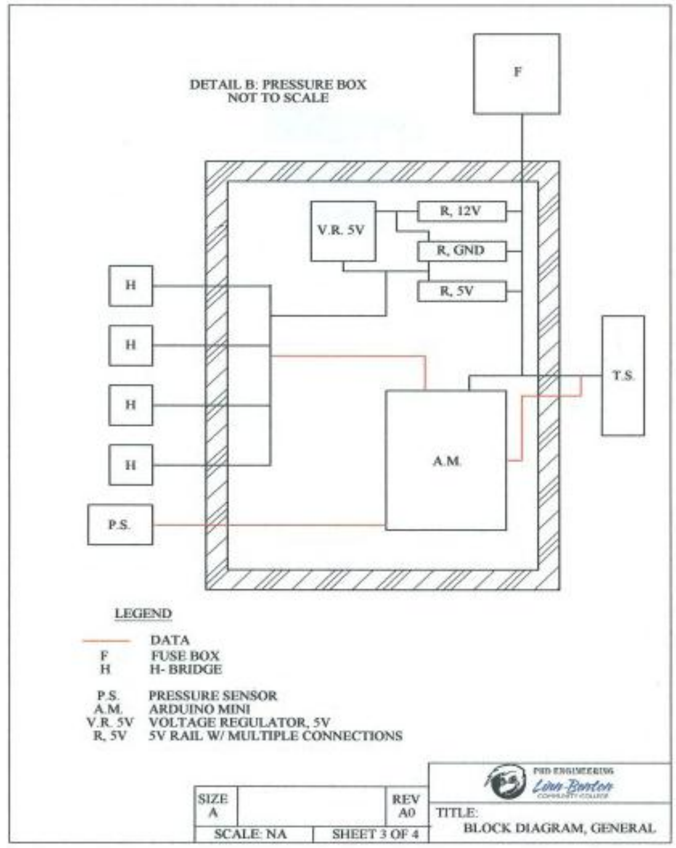


Figure 2.4.5: Schematic of pressure box

H bridges

Eight H-Bridges are set in individual plastic blocks. Each H-Bridge block is covered in epoxy while leaving the heat sink open to water (*as shown in Figure 2.4.6*). This feature allows for each H-Bridge unit to be interchanged with any other unit should one fail and moves a significant source of heat out of the main box. (*See Figure 2.4.7*)

Figure 2.4.6: 1 of the 8 H-bridges of the ORCA

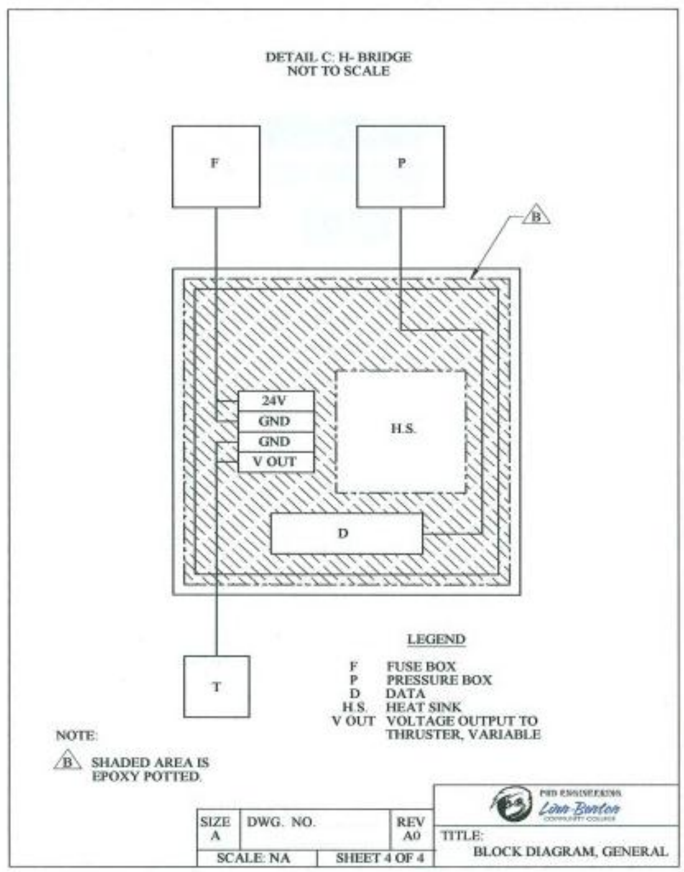


Figure 2.4.7: Diagram of an H-bridge

Water-proofing

If there is one way in which ROV's distinguish themselves from other robots, it's their ability to function in a highly corrosive and conductive salt-water environment, and to do so at great depths. The difficulty in designing around this operating environment falls under the all-inclusive category of water-proofing. Over the past several years, PhD Engineering has experimented with various techniques and strategies for water-proofing.

Several popular solutions to the problem of conductivity and electrical shorts are oil immersion pressure housings and epoxy potting. For several years PhD Engineering has been dissatisfied with the results of these solutions.

With oil immersion, a failure of gaskets or seals can result in contamination of the environment or loss of protection against electrical shorts. Within the scope of low temperature applications PhD Engineering has had some success resolving this issue by substituting paraffin wax for mineral oil.

Because of the difficulty in fabrication and the price of bulkhead penetrating connectors, pressure housings prove to be a point of failure; a leak here can have catastrophic consequences. Experience in their construction has helped resolve some of these issues, and the use of silicone UltraBlack RTV Compound, or Marine Epoxy on underwater connectors seems to prevent leaks.

This year our company elected to deal with the problem of insulating electronics by emulating the success of other companies with epoxy potting, where the electronics are cast in a polymer casing. Because of its permanent nature, our company does thorough dry testing of systems before they are committed to this form of waterproofing. At the competition in 2010, Kapi'olani Community College Team Limawai was kind enough to share with us their experiences with epoxy potting.

To deal with corrosion, the ORCA is mostly engineered around and constructed from non-ferrous materials or stainless alloys of steel. To extend the lifespan of components, PhD Engineering has a policy of washing the ORCA with fresh water after use.

2.5 Cameras

There are a total of 6 security cameras on the ORCA. These cameras were donated by CCTV for a previous ROV, and were made available for this year's build. They are model number PC303XS. Each camera draws 100mA of current with an input voltage of 12 V DC (±10%) and their effective pixels are PAL: 512x582 and NTSC: 512x492 with a resolution of 380TV lines. These cameras are mounted onto a polycarbonate board inside a hollow aluminum tube with a cast epoxy backing and polycarbonate lens.
(*See Figure 2.5.1*)

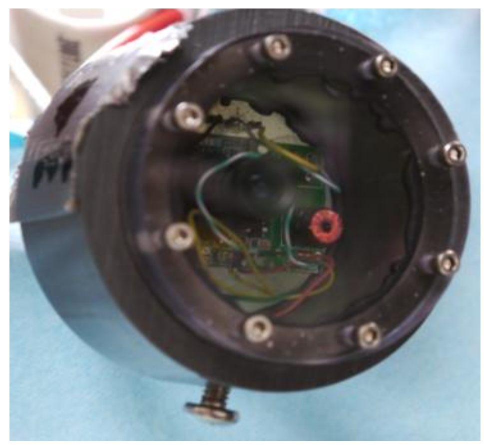


Figure 2.5.1: Showing the housing for the cameras

2.6 Tether

PhD Engineering has multiple tethers for the ORCA for flexible usage in a variety of environments. The tether that is used for competition is 0 meters long, neutrally buoyant in fresh water, and has a redesigned the bundling technique to reduce the risk of injury to handlers. Power is supplied to ORCA by a pair of 10 gauge wires that carries 48*VDC* from the surface power supply. It is then connected to the power distribution block. In addition there are two air lines; one for pressure, and one for exhaust. Both are controlled onboard the ORCA. For cameras and data there are four CAT5 cables. Topside, the tether is attached to the MATE power supply through a switch box (providing additional fusing, bleed down resistors, and controls the voltage to the ORCA), a half meter 10 AWG extension, and a 75Amp Anderson Power-pole connection. The data lines are connected to a one meter CAT5 Ethernet extension with an RJ45 connector at the end, allowing the ORCA to be attached to the control station via Ethernet ports.

3.1 Measurement and Orientation

In this mission the company must determine the length of the mock shipwreck to an accuracy of ±0.05 meters, while also finding the orientation of the ship wreck with an accuracy of ±10 degrees.

Design

A single IP Camera is mounted to the bottom of the ORCA. Once positioned over a shipwreck (*Figure 3.1.1*), this camera will take a picture of the whole wreck (*as shown in Figure 3.1.2*). Next the number of pixels in that picture will be counted from port to starboard and from bow to stern. The breadth of the shipwreck is known thus, with this information we can calculate the length of the shipwreck with a simple mathematical equation. The orientation of the ship is being determined by a compass chip inside a water proof case. This will display as a compass bearing on the HUD.

High-Intensity Lights (Simulated Sonar)

In addition to a ping/echo sonar system a side-scan sonar system will be simulated with a high intensity light. The light will give off a beam that simulates the sound waves of a sonar system and when this light reflects off the reflective tape in the PVC end cap targets simulating an echo. Shining the light on all the targets while maintaining visibility of these targets will demonstrate a successful simulation of a sonar scan. The High-Intensity Light is an LED which allows for the most luminance with the least amount of power.

- DM368 Highlights
  - High-Performance Digital Media System-on-Chip (DMSoC)
  - 432-MHz ARM926EJ-S Clock Rate
  - Two Video Image Co-processors (HDVICP, MJCP) Engines
  - Supports a Range of Encode, Decode and Video Quality Operations
  - Video Processing Subsystem
    - HW Face Detect Engine
    - Resize Engine from 1/16x to 8x
    - 16-Bit Parallel AFE (Analog Front-End) Interface Up to 120 MHz
    - 4:2:2 (8-/16-bit) Interface
    - 8-/16-bit YCC and Up to 24-Bit RGB888 Digital Output
    - 3 DACs for HD Analog Video Output
    - Hardware On-Screen Display (OSD)
  - Capable of 1080p 30fps H.264 video processing
  - Peripherals include EMAC, USB 2.0 OTG, DDR2/NAND, 5 SPIs, 2 UARTs, 2 MMC/SD/SDIO, Key Scan
  - 8 Different Boot Modes and Configurable Power-Saving Modes
  - Pin-to-pin and software compatible with DM365
  - Extended temperature (-40°C - 85°C)
  - 3.3-V and 1.8-V I/O, 1.35-V Core
  - 338-Pin Ball Grid Array at 65nm Process Technology

Figure 3.1.2: IP Camera

The above board is paired with a 5mp 1080p HD sensor. The lens has an 88 degree field of view above water with minimum distortion.

3.2 Lift Bag

As part of the contracted mission, the ORCA must clear a worksite of debris before attempting to determine whether fuel oil is on board the shipwreck. A “lift bag” system was designed to do the following:

1. Transport and attach a lift bag to a fallen mast (10 points)
2. Inflate the lift bag so the mast is lifted off the bottom. (10 points)
3. Move the fallen mast so that it does NOT drag on the bottom and place it in a designated area (10 points)

3.2 Lift Bag System Components

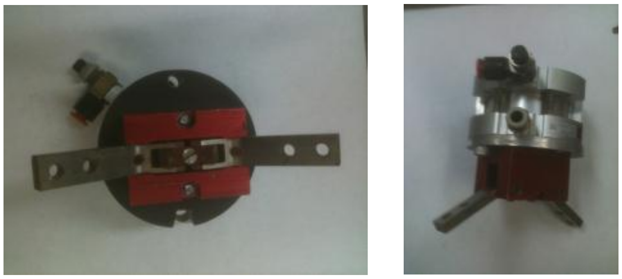


Figure 3.2.1: Pneumatic cylinder without fabricated claw

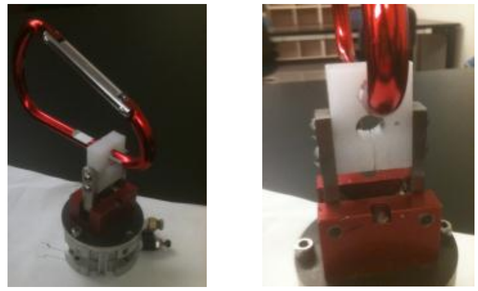


Figure 3.2.2: Pneumatic cylinder with fabricated claw

Figure 3.2.2a: Carabineer

Figure 3.2.3: Lift bag with

Figure 3.2.3a: Lift bag in casing

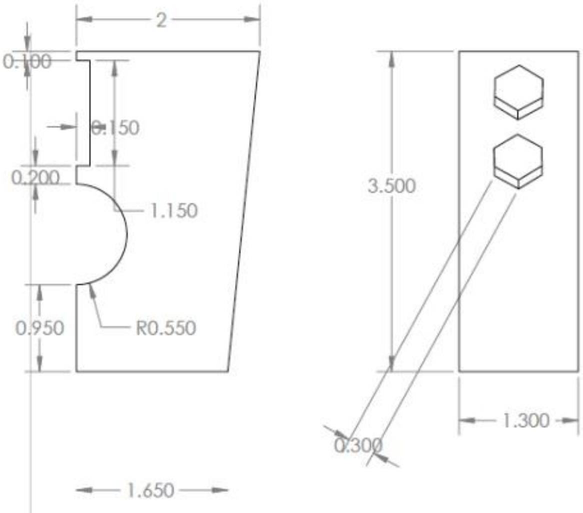


Figure 3.2.4: Solidworks of Claw

Composition Materials

- 1 Schedule 40 PVC pipe: 5.5cm diameter, 51 cm long, 2 cm cut along length
- 1 cm diameter Rope: 519 cm long
- Pneumatics hose: x meters long
- Pneumatic cylinder
- Rated 200 lbs. (890N) modified-D Carabineer
- Plastic fabricated claw

Current Design

The base design is a pneumatic cylinder that has a plastic fabricated claw securely holding a carabineer and rope. Once the ORCA clips the carabineer onto the mast, then the pneumatics hose inflates the lift bag and the mast is carried to designated area. The claw is then opened releasing the carabineer and rope. This allows the extra length of rope from the pvc encasing to be release and the lift bag to simply floats to the surface. (*See Figures 3.2.1 through 3.2.4)*

3.3 Coral

To maintain environmental awareness of the ecosystem surrounding the shipwrecks, a system has been designed to transplant coral from the side of a shipwreck to new locations.

Design

Our design is made of a mesh box with a trapdoor bottom and mechanical rake (*see Figure 3.3.1*). The primary method of collection is to use the outer lip of the box to dislodge the coral by positioning under the coral and thrusting upward. The rake will collect the coral if it falls outside the box. The mechanical rake's drive-train is powered by a servo pushing the rake out and up then back into the box, scooping up the coral. The trapdoor is spring loaded to open after the pneumatic latch releases it over the target area.

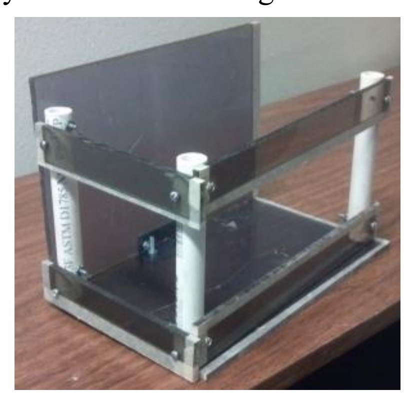


Figure 3.3.1 Coral Collector

Composition Materials

- Box frame: polycarbonate
- Arm: polycarbonate
- Rake: polycarbonate
- Pneumatic hose (length varies)
- Pneumatic Latch
- Stepper motor model: Hitec Deluxe HS-485HB

3.4 Fuel Tank

The fuel transfer system is designed to safely remove all of the oil from the shipwreck while simultaneously filling the tank with a saline solution. From one side of the fuel tank saline solution will be pumped in; from the other side the oil will be extracted as it separates and rises to the top.

Design

Located on the bottom of the ORCA there is a scissor-claw to attach the ORCA to the fuel tank (*see figure 3.4.1*). We line up with the center of the fuel tank and flip a pneumatic switch (*see Figure 3.4.2*). This switch opens our scissor-claw and pulls the fuel tank up snug with the frame. Then, with the fuel tank firmly in grasp, the Pilot lowers in the "fangs" (*see figure 3.4.3*). When the system is in place on the fuel tank, the Pilot turns on the pump and begins pumping saline solution into the tank. The solution is pumped in and the oil is forced out to be stored on the ORCA. When there is no more oil in the tank, the Pilot returns the "fangs" to their original position, and releases the scissor-claw.

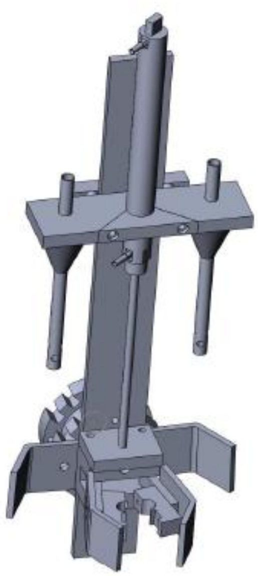


Figure 3.4.1: Fuel Tank Claw System

Figure 3.4.1a Fuel Tank Claw system

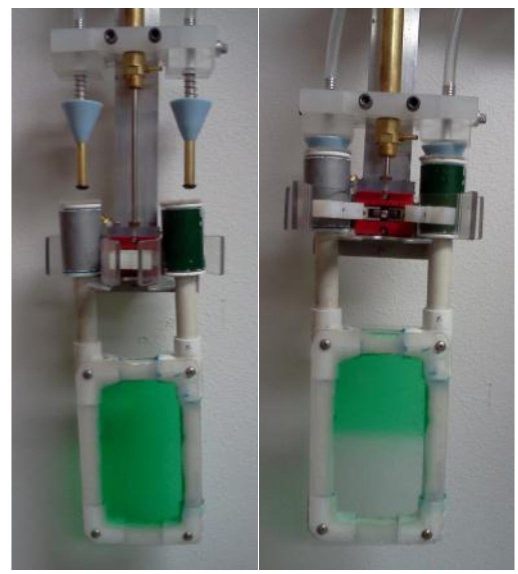


Figure 3.4.2: Fuel Transfer system

Composition of Materials

- The pump that we chose for this mission is a 12 volt pump
- For fluid storage, we used two 2-liter platypus bags. One is filled up with saline solution and the other will be used to store the oil as it is pumped out of the tank. ½ inch tubing connects the bags to the pump and fangs.
- The scissor-claw is powered by pneumatics, it can be fixed in the open or closed position.
- The fangs consist of two 16 cm long tubes of aluminum.
- Two soft rubber cones were molded to create the seal between the fuel tank and our fangs.
- We used a polycarbonate top plate to harness our fangs, pneumatic cylinder, and slide.
- A 20mm Kuhnke pneumatic pump lifts and lowers the fangs.
- The aluminum slide connects our claw and top plate to the ROV.

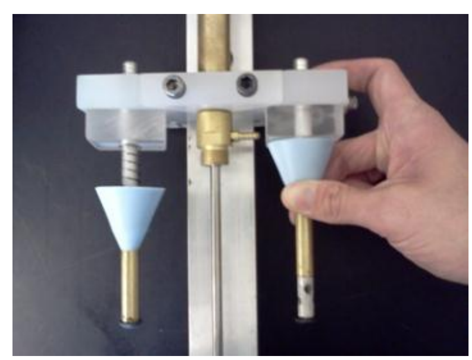


Figure 3.4.3: Fuel Tank "Fangs"

During the building of this system, many prototypes were tested before this final product was developed and realized. The team involved with the system "went back to the drawing board" many times to improve on their successes and failures, and in doing so developed what PhD Engineering feels is an environmentally safe way to remove contained petroleum based liquids.

3.5 Metal or Not

To determine if the debris samples in the test grid are made of a metal or non-metal substance a metal detecting system was designed.

Design

As the ORCA passes by each sample, the device (*Shown in Figure 3.5.1*) will come in contact with the sample. If the debris is metal a magnet in the device will complete an electrical connection which will display as a light on the HUD.

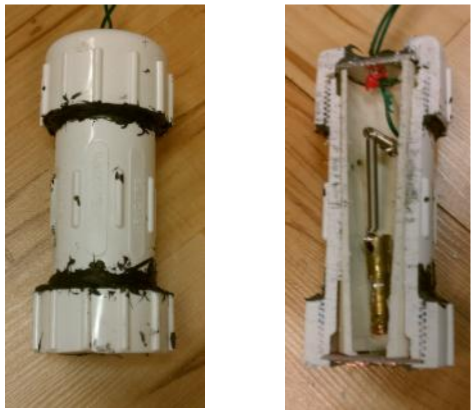


Figure 3.5.1: Metal Detector

3.6 Magnetic Patch

Following the extraction of the oil from the fuel tank, place a Velcro patch on each of the protruding inlets on the tank.

Design

The provided cap rests inside a metal tube with the loop on the cap resting against the side of the tube which is hooked by the wire (*see Figure 3.6.1*). Then the metal tube is mounted to ORCA's frame. To patch the tank, the ORCA will be maneuvered so that one of the tubes is above an opening. The ORCA will then push down until the Velcro attaches. Next the ORCA will lift up from the tank, leaving the patch securely attached to the tank (*see Figure 3.6.2*). This is then repeated for the second cap.

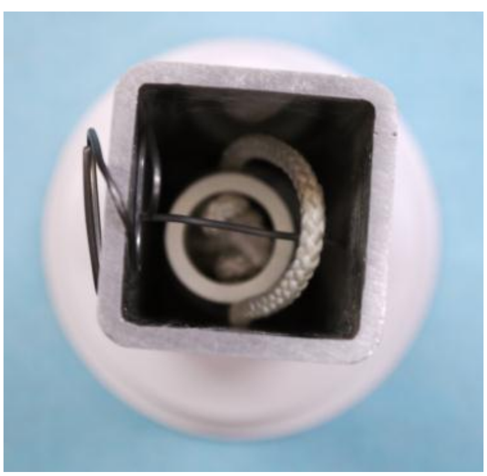


Figure 3.6.1: Top view of the capping tool

Figure 3.6.2: Capping tool relative to Cap

Composition of Materials

- Square aluminum tubing: 3.8cm x 3.8cm x 15.3cm
- Stainless steel wire: 18gage x 15.5cm

3.7 Simulated Sensors

To meet the need in simulating the use of an ultrasonic thickness gauge and neutron backscatter device to determine the contents of the fuel tank, this task involves three steps once the hull is clear of other debris.

1. Contact the ultrasonic thickness gauge to a 61cm x 46cm black plastic target.
2. Move to a nearby calibration tank to calibrate the neutron backscatter device.

Finally, return to the hull of the ship to use the calibrated neutron backscatter device.
All points of contact must be maintained for a minimum of five continuous seconds. The sensor should be visible via the onboard cameras, where the pilot will be able to judge if the sensor is making contact.

Design

Both the ultrasonic thickness gauge and neutron backscatter are combined into the same device, a 2cm x 2cm square piece of metal attached to the frame of the ORCA (*See Figure 3.7.1*). This simulated sensor will be bolted to the frame of the ORCA.

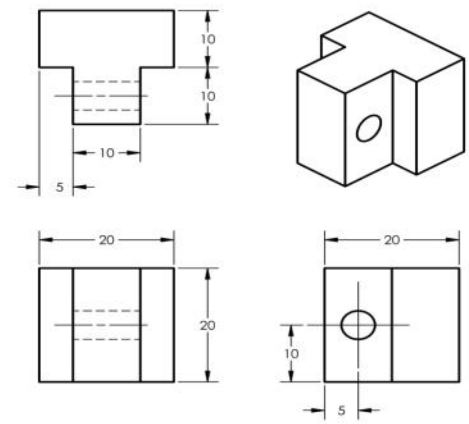


Figure 3.7.1: Simulated Sensors

4.1 Challenges

Budget

Because of budget limitations, one of the greatest challenges faced by PhD Engineering has been obtaining materials. However, because of this constraint, members have worked closely with local suppliers to procure resources at reduced cost. This networking has allowed the creation of close relationships with a wide variety of companies. In addition, this restriction has resulted in a strong focus on using recycled materials and eliminating waste and inefficiency in the development and testing process.

Resource Management

Because of the sudden influx of new members, and the loss of experienced members, it has been difficult for PhD Engineering to utilize the skills of our newest members in the most effective way possible. Another issue was the very limited opportunity for the testing of various prototypes and techniques used to accomplish the missions. Disorganization plagued the first phases of development on the ORCA. As a result, many of our limited opportunities for testing went to waste. This resulted in a stronger focus on organization and planning for key checkpoints in the development process from that point forward.

Troubleshooting

PhD Engineering uses a variety of troubleshooting techniques; but the first step in any troubleshooting situation is to fully understand what the problem is. Once the problem is identified, the members with the most experience in that system are brought in to assess the root cause. After discovering the cause, there are several approaches that can be utilized. When applicable, our members attempt to isolate the problem, disabling other systems to see if the issue is caused by interference. If the issue is mechanical, they may manually actuate the system to attempt to correct the issue. If it is discovered that an issue will require a radical redesign of the subsystem, the company attempts to assess the priority of these changes.

4.2 Safety

During testing the company makes use of 'call outs' to communicate what they are doing. This is something as simple as letting a company member know you are walking behind them to letting the company know you are turning on the power. This is an effective way to ensure the company is aware of what is happening at all times.
The Pilot has a system kill switch near him at all times. If there is an on-board safety hazard the pilot can quickly shut the entire ROV down. All corners and sharp edges on the ROV are filed and smooth, preventing cuts and scrapes. Guard bars are attached to the ROV frame to limit access to the motors. Safety rules in the lab are strictly enforced. No member is allowed to work in the lab alone; there must always be at least 2 others in the lab. Safety glasses and close-toed shoes are worn at all time in designated work area. No member is to use machinery without proper training. Food and drink are allowed only outside the work area.

4.3 Future Improvement

The company has many plans for upgrades and improvements. The most significant upgrade will be changing to brushless motors with electronic speed controls. This will give the ROV greater propulsion and efficiency. An upgrade of the motors will require a redesign of the pressure housing, electronics and connectors. The pneumatic arm is an integral component of the ROV. Improving the arm will provide the company greater utilization of the ROV. One of the upgrades will be to develop a larger range of motion for the arm. Portability of the ROV is very important to the company. This is an ongoing improvement. As the company is gaining experience it is able to design better and more compact ROVs. Future ROVs will be lightweight and highly portable.

4.4 Teamwork

During one of our first meetings after the MATE mission, goals were presented, company members broke the mission up into smaller components and choose which components to work on.
Subgroups included:

- Measurement: Researched many methods to measure the length of the ship wreck and chose the most appro priate means to complete this task.
- Orientation: Created a method to calculate the orientation of the ship wreck.
- Metal/Non-Metal: Designed and perfected a metal detection system.
- Sonar: Found the best option to simulate a sonar scan of the ship wreck.
- Mast/Lift Bag: Developed a system to attach and deploy a lift bag to the mast, and used it to move the mast.
- Coral: Created a device to remove and transport coral to the debris field area.
- Fuel Tank: Engineered a component to remove fuel from the ship wreck.
- Patch: Built a system to patch the fuel tank.

Each subgroup established a budget and timeline for their mission project. The timelines include a weekly breakdown, from start to finish, of how the sub-group is going to complete its project. As part of the timeline, the subgroups submit a budget estimate.

4.5 Testing

In almost all subsystems that we created, we went through a process of designing, building, testing, and then modifying our subsystems for optimum performance. The fuel removal system is the most intricate of our subsystems. We fortunately scheduled many pool tests with time dedicated specifically to the fuel removal system to test its operation. In the process we modified the geometry of the grippers, changed the applied voltage to the motor, and improved our tank penetration system several times all to maximize the performance and environmental safety of our system. Several scheduled pool nights also focused on perfecting the lift bag filling and lifting procedure allowing the pilots to get proficient at moving the mast to the designated area. Testing and good programming along with a pressure sensor that we created allowed us to include a 'hover mode' for the ROV which allows us to tell the ROV to find and stay at a pilot designated depth. Some systems and components, such as brushless motors and stereographic cameras, were successfully tested in the air as proof-of-concepts but, due to estimated long production timelines, have been put into our "future improvements" list.

4.6 Lessons Learned

Because a major issue faced during the testing phase was a lack of communication and management, it became obvious that PhD Engineering had to place a higher priority on organization than in the past due to the large number of members working on the ORCA. As a result, we made several deliberate changes to the planning phase of our limited testing opportunities. This included implementing a schedule, ensuring that the proper members would be in attendance for troubleshooting, and creating a better environment for the pilots in training. This helped everyone focus on completing the missions while ensuring that communication was clear, concise, and expedient. By creating an environment where the pilots in training had every resource they needed, and avoiding unnecessary distractions, it allowed more testing to be accomplished. The improvements in communication lines allowed the members to develop a better understanding of the various issues faced by their prototypes during testing.

4.7 2012 PhD Engineering Expenditures

Category	Cost	Donated	Company Expenditure
Propulsion	$5132.56	$3232.00	$1900.56
Frame	$1440.75	$700.00	$740.75
Props	$17.14		$17.14
Culinary	$360.66		$360.66
Energy Management	$33.94		$33.94
Orientation	$160.30	$100.00	$60.30
Electronics	$51.45		$51.45
Mate Registration	$50		$50.00
Fuel	$42.47		$42.47
Camera	$61.22		$61.22
Measurement	$240.48		$240.48
Grand Total	**$7590.97**	**$4032.00**	**$3558.97**

5.1 Acknowledgements

Organizations

Marine Advanced Technology Education (MATE)

Oregon Underwater Volcanic Exploration Team (OUVET)

Companies

Burcham's Metal
L&R Saw and Machine
Osborne Aquatic Center
Pacific Integrated Handling
SeaBotix
White's Electronics
CCTV.com

Individuals

Dan Lara
Cressey Merrill
Greg Mulder
Karelia Stetz-Waters
Parker Swanson

Linn-Benton Community College Departments and Student Organizations

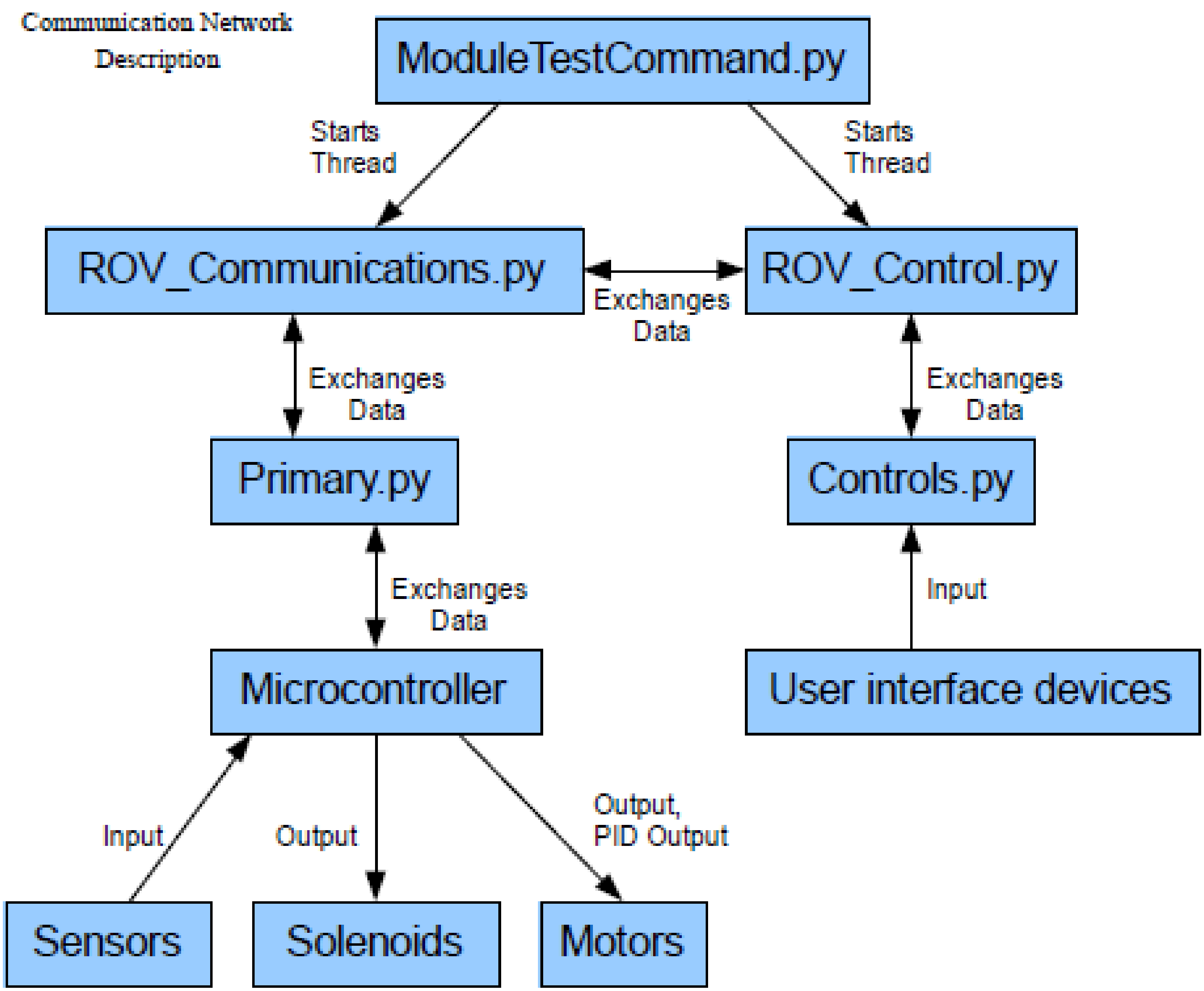
Physical Sciences
Computer Sciences
Welding
Speech
Media and Computer Sciences
LBCC Security Department
Student Activity and Program Committee
Engineering
Drafting and Engineering Graphics
English
Student Life and Leadership
Society of Physics Students
Health and Human Performance

A special thank you goes to our families and friends, for their support and encouragement

Technical Report Team

Kerry Codoley
Jody Eaton
Alex Frisk
Ryan Harp
Brandon Huff
Scott Neuman
Rachel Nolan
Blythe Nourie
Francis Shala
Samuel Stephenson
Daniel Takamori
Marc Thompson

5.1 Communication Flowchart



Python Modules:

ModuleTestCommand.py – Starts threads for communications and controls.
ROV_Communications.py – Handles threading protocol for communications.
ROV_Control.py – Handles threading protocol for controls.
Primary.py – Communicates with the controls thread and the microcontroller.
Controls.py – Communicates with the communications thread and the user input devices.