2011
MATE
INTERNATIONAL
ROV
COMPETITION

Phoenix Hell-Divers Engineering

Explorer Class

Linn Benton Community College

Albany, Oregon USA

Technical Report

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Burl Hine—Chief Operating Officer
Ben Dean—System Engineer
Michael Tilse—System Engineer
Jody Eaton –Chief Financial Officer

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The Phoenix ROV

PHD Engineering Board of Directors (Instructors and Mentors):

Greg Mulder	Physical Science Consortium
Parker Swanson	Computer Science Consortium
Karelia Stetz-Water	English Consortium
Dan Lara	Science Engineering and Technology Consortium

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Abstract

Phoenix Hell-Divers Engineering has designed a compact ROV capable of performing the four tasks required by the MATE 2011 International competition. The Phoenix has been engineered to allow for ease of maneuverability. The Phoenix features state of the art innovations at a competitive cost. In response to the recent disaster involving the explosion and sinking of Transoceanic's Deepwater Horizon, the resulting oil-spill, and the multi-agency response, PHD Engineering has developed an array of modular attachments for ROV's which can be utilized to cut short any future events of a similar nature. We based the modules upon the needs we recognized while watching the capping efforts online and with the clean-up and restoration efforts being coordinated by NOAA. The design of our riser removal system is elegant in its simplicity and effectiveness. Our capping mechanism, which is designed to cap the flow of an underwater simulated oil-well is light-weight, effective and simple to remove. The biological sample retrieval system safely gathers creatures and transports them to the surface using a basket and scoop system. The pressure sensor reads depth, which allows the pilots to guide the water sampler to a specific location and take samples greater than 100 mL. The use of eight cameras allows the ROV pilots to watch the compass, pressure/depth sensor, all moving components, plus forward and aft views while piloting via an intuitive GUI and gamepad controller system. We are proud to compete with this ROV and also collect current data for research on underwater volcanoes during the summer.

Figure 1 PHD Engineering Team Photo

Linn-Benton Community College

Phoenix Hell-Divers Engineering 2011 ROV Team (See figure 1.)

Top to Bottom Left side: Burl Hine, Kristoffer Hess, Grant Blake, Nathan Murrow, Greg Mulder, Rachael Nolan, Symone Stinson, Coquille Rex.

Top to Bottom Center: Jody Eaton, Dillyn Winn.

Top to Bottom Right Side: Jeremy Louke, Parker Swanson, Jonah Brooks, Ivan Merlin, Keith Smee, Alex Frisk, Ben Dean, Ian Fridge, Eric Zounes,

Team members not pictured: Brady Fry, David Konyndyk, Jessica Eaton, Justin McCleod, Kati Davidson, Li Zhang, Nathan Fetters, Danielle Butler, Raven Dorr, Savannah Van Beek, Nick Cantrell, Michael Tilse, Lara Heitmeyer.

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Company Mission Statement:
To expand our knowledge by building an ROV for the MATE International competition, while having fun, sharing what we learn, gaining skills, recruiting compatriots, and making memories.

Involvement of People
We are a diverse community of fun-loving students whose goal is to expand our knowledge of applied science by building a fully functional ROV to compete in the 2011 MATE competition. We have fun in every aspect of our competitive experience. We are able to enthusiastically share our knowledge with many different audiences, furthering not only our own valuable marketing skills and experiences, but the interest of the next generation in this amazing field of study.

Process Approach
Improved quality is achieved more efficiently when activities and related resources are managed as a process. This leads to lower costs through effective use of resources, consistent improving, as well as focused and prioritized improvement opportunities.

System Approach to Manufacturing
Identifying, understanding and managing interrelated processes as a system contribute to our company's effectiveness and efficiency in achieving its primary objective; delivering a Remote Operated Vehicle capable of completing all mission tasks. This helps us better understand our capabilities as well as develop structured approaches that harmonize and integrate key processes.

Continual Improvement
Continual improvement of our company's overall performance is a permanent objective. We achieve continual improvement by measuring the variation of the inputs to our manufacturing processes and analyzing how these variations affect our products performance. PHD Engineering has been able to make continual improvements in our products, as well as allowed us to streamline our manufacturing and form stronger relationships with our suppliers, dramatically improving our efficiency.

1. Core Systems

1.1 Frame (Buoyancy)

The frame of PHD Engineering's ROV is composed of aluminum with a design that allows us to increase or decrease the length of the rectangular shape. One aspect that influenced the design of this ROV is its origin, which came from a recycled summer ROV project that PHD Engineering participated in through the Oregon Underwater Volcanic Exploration Team (OUVET) and was later donated for PHD Engineering's continued use.

The dimensions we chose for the length of the rectangular frame were influenced by the needs of the subsystems. As a company, we decided to allow the frame to evolve as each of the subsystems required space, sharing parts when possible to increase the use of that space. This gave us an advantage, allowing us to focus on the space availability which then allows all subsystems the ability to coexist within the frame. Our company focuses on meeting the needs of a situation first, then the aesthetics of the vehicle. To achieve neutral buoyancy, we used 2 sets of 4" dia. schedule 40 PVC, 1 meter in length. (See figure 2.)

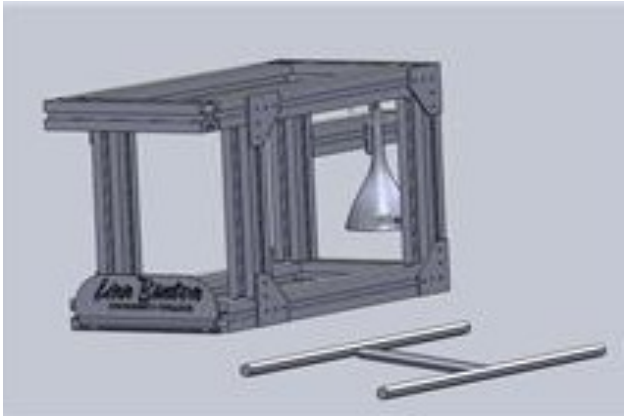


Figure 2. Phoenix Frame

1.2 Propulsion (thrusters)

Our propulsion system consists of four Seabotix BT-150 Thrusters that provide 18N of thrust each. Each thruster is controlled via a Critical Velocity 10 amp H-Bridge and 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.

1.3 Cameras

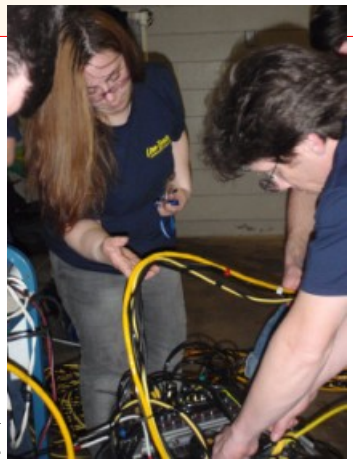
There are eight modified, low cost, PC303XS cameras aboard the ROV. These camera's are distributed by the online retailer Supercircuts recommended by Videoray from the MATE Rover website. They consume 100mA with an input voltage of 12 V DC (±10%) and their effective pixels are PAL:512x582 and NTSC:512x492 with a resolution of 380TV lines. These cameras were mounted onto a polycarbonate board inside a hollow aluminum tube with a cast epoxy backing and polycarbonate lens.

1.4 Tether

The ROV's tether is 30 meters in length, and was generously donated to our team by Sound Ocean Systems Inc. (SOSI.) It contains three twisted pairs of 24 gauge wire for data in addition to a twisted pair of 18 gauge wires for power. We bundled this tether with five RCA cables for video and two 140 psi nylon air lines for pneumatics. The entire assembly is neutrally buoyant in fresh water.

The tether is terminated at the ROV using Bulgin Buccaneer IP68 waterproof connectors. All connectors have been treated with silicone UltraBlack RTV compound for additional protection against leaks. The power line uses a 2 pin 900 series connector, rated for up to 100 amps. Data uses an 8 pin 400 series Buccaneer connector, rated to 5 amps. Four pins are unused and four are for data transmission. The data pairs on the ROV side are connected to an Arduino unit which commands the ROV.
On the pool side, the tether terminates with a 2 meter 18 AWG extension and spade connector which allows us to connect to the MATE power supply. The two twisted pairs for data are connected to a one meter CAT5 Ethernet extension with an RJ45 connector on the end. This allows it to be plugged into the laptop control station.

2. Control Systems


Preparing for Pool Test

2.1 Software Engineering

The software for the ROV is broken up into two main components include the surface-side Python code and the on-board Arduino code.
2.1a Communications Protocol

The Python code is primarily responsible for receiving controller input from the pilot, displaying necessary data to the screen, and relaying the pilot's commands to the Arduino on-board the ROV. These responsibilities were divided into two threads: one for communications and networking and the other for controls and the GUI. If one thread were to crash or slow down, the other would continue running as normal. From there, the two threads were further divided into individual modules, each one handling and encapsulating a specific task. This way new features can be added or removed at any time without having to greatly modify existing

code. The module handling pilot controls and the user interface was written using the Pygame library, which is a set of Python modules built on top of the SDL (Simple DirectMedia Layer) library. The networking module uses built-in Python networking functions to establish, maintain, and repair a connection to the TCP/IP server hosted by the ROV's on-board Arduino.

The primary function of the Arduino code is to receive and carry out any instructions sent to it over the Ethernet connection. This is accomplished by encoding instructions with an opcode and operand system, similar to assembly language, and decoding those instructions on the microcontroller. There are codes for motor, subsystem, and PID control. After receiving a command, the Arduino will implement it and then respond by returning the sensor data read from its analog input pins. This ensures that the communications remain in sync and we are able to know instantly whether the connection has been dropped, allowing us to reconnect automatically.

2.1b Microcontroller

We are using an Arduino Mega 2560 for the on-board logic of the ROV. The Mega 2560 has 14 PWM pins that can be used to run adjustable-speed motors, 40 digital I/O pins for on/off instructions, and 16 analog pins for gathering data from various sensors. It has 256 KB on-board flash memory and 8 KB SRAM, giving us more than enough room to store and run whatever code we write. This gave us a lot of breathing room during development, and ensured that we would be able to implement any new features the ROV may need. The Arduino brand was chosen due to our familiarity with the hardware, the large community of Arduino users, and the relatively large amount of online documentation available when compared to other microcontroller manufacturers.

2.1c Graphical User Interface

The Graphical User Interface (GUI) was designed to provide the pilot with any and all necessary information on the state of the ROV. We had initially planned to use the Tkinter library for the GUI, but we ran into many issues due to a conflict between Tkinter's event handling and the Pygame controller event handling code we were using for pilot controls. To resolve this issue, we decided to write the GUI in Pygame as well. In order to speed up and ease development, we chose to implement an additional library called Phil's Pygame Utilities (http://www.pygame.org/project-PGU+-+Phil's+pyGame+Utilities-108-3141.html,) which simplifies the creation of standard elements such as text boxes, radio buttons, and sliders. The primary goals of the GUI are to display all relevant sensor data, the state of each subsystem, and the current amount of thrust provided by each motor. It was also necessary to provide the pilot with a means of entering a specific depth at which he or she wants the ROV to hover. All of these goals were met with various graphical elements on a single Pygame window. (See figure 3.)

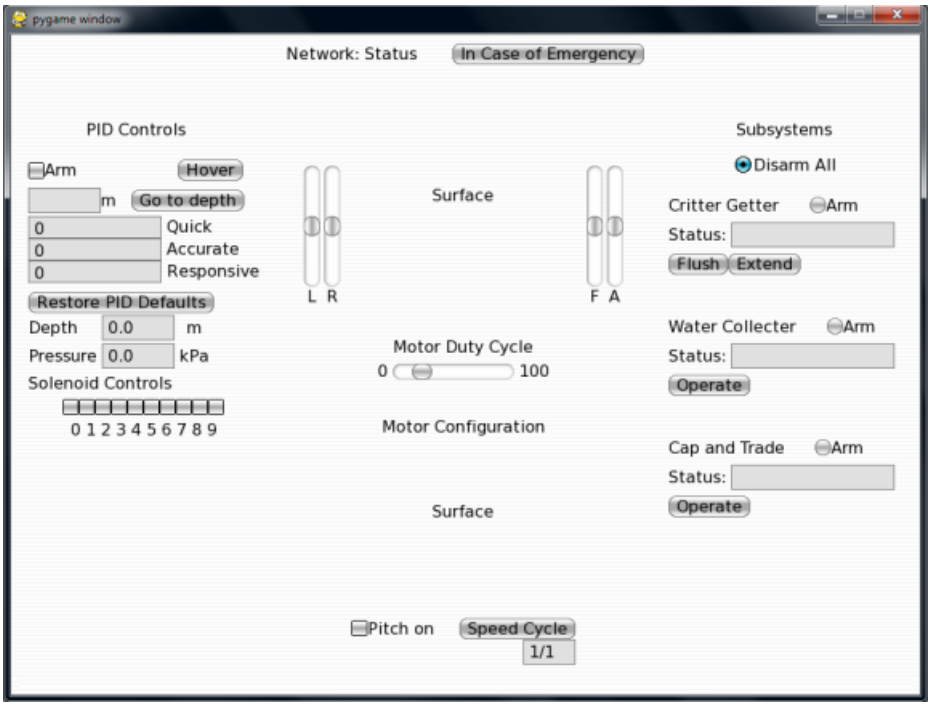


Figure 3. Graphical User Interface snap view

2.2 User Interface

The user interface was designed with a minimalist approach in order to give the pilot exactly what he or she might need in the most portable package possible. The goal is to allow the ROV to become operable wherever the tether and power could be set-up. For this purpose we chose to rely on laptops and peripherals, allowing the entire control station to be easily transportable and battery powered.

2.2a Control Station

The control station consists of one laptop, a television and digital video recorder and a USB game controller. The laptop runs the GUI and networking software and is the primary interface between the pilot and the ROV.

2.2b Human Interface Device

A standard Logitech controller is the primary control device for the ROV. This offers a fairly standard button layout and allows the development of a familiar and intuitive control scheme. The two analog sticks are used for vehicle motion with the left stick handling planar motion and the right stick handling vertical motion. The shoulder buttons are used for toggles and switches, allowing the pilot to adjust how the ROV handles. Finally, the face buttons are used to arm and activate each of the ROV's sub-systems.

2.2c Networking description

Because of the depth at which the ROV will need to operate and the impact of signal degradation over long serial lines, we decided not to rely on the microcontroller's built-in serial port. Instead, we elected to use an Ethernet connection to communicate with the on-board microcontroller. In order to do this, additional hardware was necessary to facilitate Ethernet functionality. We chose to retrofit the Arduino Mega 2560 board with an older model Arduino Ethernet Shield, which we already had on hand. Before we could do this, we needed to make several modifications.

The first modification was to bend the pins numbered 11, 12, and 13 on the Ethernet Shield. This allowed them to be connected to pins numbered 51, 50, and 52 on the Arduino Mega board. The second modification was to bridge the Ethernet Shield's reset pin to its ground pin using a 1.0 µF capacitor. This forces a reset on power-up.

In order to establish an Ethernet connection between the ROV's microcontroller and the surface-side Python program, we set up a TCP/IP server on the Arduino. The networking module of the surface-side Python code then acts as a client, connecting to the Arduino's server and exchanging information at set time intervals. The TCP/IP protocol was selected for ease of development and to ensure that any data sent would be received without corruption.

Network Interface Testing

2.2d Pneumatics

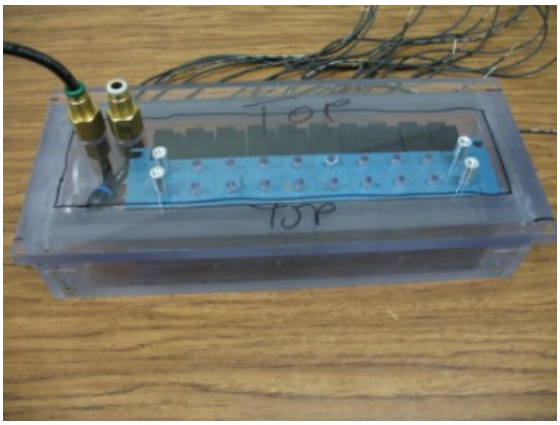


Figure 4. Pneumatic Box

A valve bank of 10 solenoid actuated air valves controls the pneumatically operated devices of the ROV. These valves are rated for approximately 827 kPa, but as per competition rules, the supply pressure will be 276 kPa absolute or 172 kPa effective. Each valve switches the pressure between two ports. When one port is pressurized, the other is open to the exhaust port, which in turn is open to surface atmospheric pressure via a return line up the tether.

Each pneumatic actuator has two ports and these are connected to the valves. In the non-energized state, air pressure holds the cylinder in the desired default position, either retracted or extended. Toggling the command input to the valve reverses the pressure and moves the cylinder to the non-default state. The formerly pressurized side is then exhausted to the atmosphere at the surface. (See figure 4.)

The MAC brand solenoid valves are 6 watt, 24 volt valves. Main power to the valves is provided by the 48 VDC to 24 VDC power converter housed within the fuse box. They are switched by 0V and 5V low and high logic signals from the Arduino microcontroller via TIP 120 power transistors on the ground side of each coil. The valves and power switching board are enclosed in a polycarbonate housing sealed with O-rings on the top and bottom covers. Cover valve port penetrations are via aluminum tubing extensions sealed with nylon washers and Ultra-Black RTV compound. Power and logic are provided through Buccaneer 400 series waterproof connectors. Currently, of the ten available valves, only six are used for the six pneumatic actuators deployed. Unused valves are capped. A pneumatic backup system has also been created for surface-side use.

3. Electrical System

3.1 Heat Dissipation

We 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 5 individual H-Bridges are the “brain,” “heart” and “muscle” of the ROV. See Appendix Figure 1.

3.2 DC to DC Conversion

The fuse box containing the “heart” of the ROV is a box custom made out of polycarbonate with both an open and an enclosed side. The open side of the box holds a 48v-24v and a 48v-12v 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. See Appendix Figure A.

3.3 Solenoid Box

The solenoid box, providing the “muscle,” is also a custom made box from polycarbonate. The box houses 10 two channel solenoids that are controlled via the Arduino Mega. The advantage of this box is the reduction in lines needed on the tether. Currently, only two pneumatic lines are needed to provide air to all 10 solenoids.

3.4 Pressure Housing

Figure 5. H-Bridge

The pressure housing is used to house the "brain" of the ROV. We 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. 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 Appendix Figure B and Figure 6.)

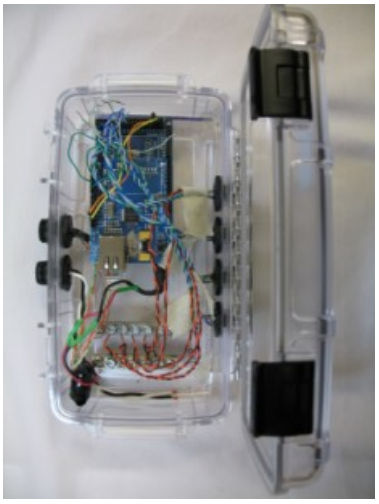


Figure 6. Pressure Box

3.5 H bridges and PWM

Five H-Bridges are set in individual plastic blocks. Each H-Bridge block is covered in epoxy while leaving the heat sink open to water. 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 Appendix Figure C and Figure 5.)

3.6 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, our company has experimented with various techniques and strategies for water-proofing.

Conductivity

Several popular solutions to the problem of conductivity and electrical shorts are oil immersion pressure housings and epoxy potting. For several years our company has been unsuccessful at implementing, or 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 our company 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 water-proofing. At competition last year, Kapi'olani Community College Team Limawai was kind enough to share with us their experiences with epoxy potting. Their technical report is available at the MATE website. (http://www.marinetech.org/rov_competition/2010/)

Corrosion

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

4. Payload Tools

4.1 Well-Head Cap

To successfully meet the cap sealing provisions of the contract, each member of the cap sealing committee was asked to design and build a "proof of concept" prototype to sell to the company for funding.

Most designs revolved around the following strategy:

1. Minimize flow-rate restrictions to assist in affixing the cap.
2. Attach the cap to the well-head.
3. Shut down the flow of fluid in the well-head.

Almost universally, the designs accomplished contract requirement #1 by using a valve in its open position until after the cap was locked in place. There were distinct differences in that some proposals sealed against the pipe in the process of attaching the cap, while others sealed against the pipe in the process of stopping the flow of fluid. (See Figure 7.)

Figure 7. Payload Tool Well-Head Cap and Clamp

Valve Selection

Two valve types were given serious consideration:

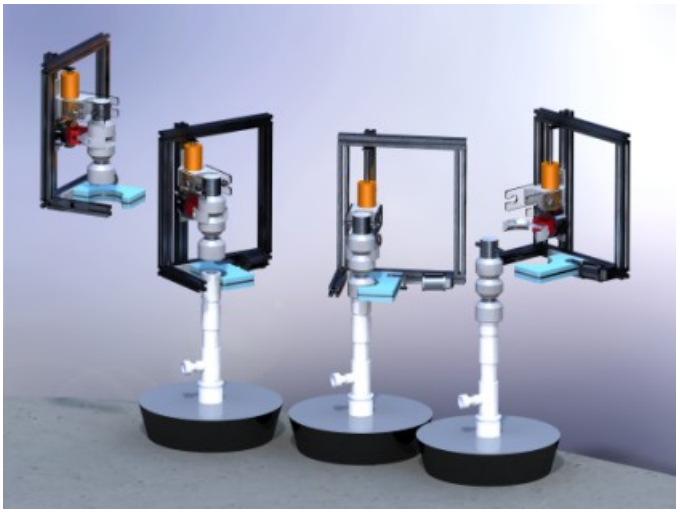
1. KBI KSC_2000S 2" Swing Check valve 150 psi [3]
2. A gate valve

For reduced cost and simplicity, a swing check valve was decided as the best choice. It would not require a brushless motor, such as a stepper motor, to run it, which eliminated the drive electronics point of failure, as the brass gate valves would have used up a disproportionate fraction of our budget.

Attachment Mechanism

Three mechanism types were given serious consideration:

1. *Safety spring-latch type*
2. *Compressed collet type*
3. *Quick-disconnect-fitting type, with ball bearing retention*



Payload Tool Well-Head Cap Sequence

Quick-disconnect-fitting type ball bearing retention.

The Ball Bearing retention mechanism was most strongly advocated by the Committee Chair. The holding force of this type of retaining mechanism is considerable. This is demonstrated by its use in high pressure connectors and padlocks. Further, it has significant ergonomic advantages in removal over all other design types considered.

Safety Spring-Latch type

The safety retention mechanism was attractive for its simplicity, but initial attempts to purchase metal latches were unsuccessful. Its holding strength was also suspect and restraining deflection seemed difficult. Most important of these was the ergonomic difficulty of removal by the SCUBA Divers, potentially creating a pinch hazard to fingers.

Compressed Collet type

The Compressed Collet type was partially completed during the weeks preceding the school's machine shop availability. Its ease of construction was attractive, and it would have been locked in place by a pipe compressing the "petals" around the riser pipe. This design was abandoned when the facilities to produce more desirable ball bearing mechanism became available. Its few flaws included its holding force, which relied on friction and could possibly not be trusted to hold against a great pressure. Also, unless designed for a wide range of sizes, it was more vulnerable to failure from manufacturing variances between the reproduction of mission prop components and the actual competition riser pipe. Finally, the ergonomics of releasing this mechanism were also a subject of concern.

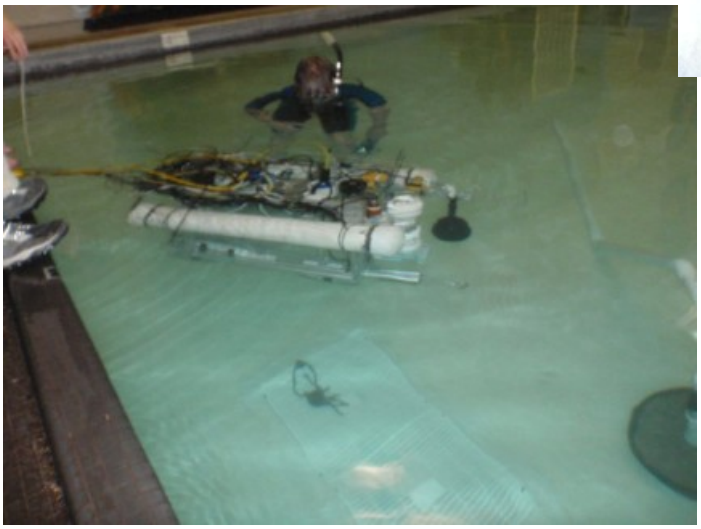
4.2 Biological Sample Collector

The Biological Sample Collector (Critter Git'er) is a simple scoop and basket mechanism. It faces outward from the back of The Phoenix. To use, the ROV is first maneuvered into a position so that the rear-mounted collector is on the sea floor facing the organism to be collected. The scoop blade is then raised and extended beyond the organism. Reaching full extension, the scoop blade drops behind the organism and guides it into the collection basket as it also retracts.

Constructed of ABS plastic, aluminum and stainless steel, the mechanism is operated by a Bimba stainless steel pneumatic cylinder. The scoop arm slides on Teflon blocks machined to fit smoothly in the ROV frame grooves. The collector basket is box shape with small square holes to allow free water flow. The basket is designed to collect and hold the organism samples for safe transport to the surface. (See Figure 8.)

Figure 8. Biological Sample Collector (Critter Git'er)

Critter Git'er gets a trial run during pool test



4.3 Water Sample Collector

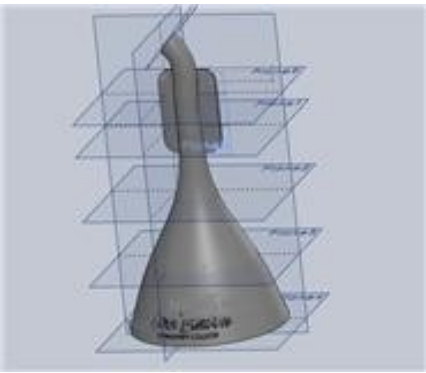


Figure 9. Pilot Positioning Cone

The Water Sample Collector's primary purpose is to sample 130 mL of liquid from a specified container at a specific depth. The collection container that we chose to use is a catheter syringe originally intended for blood samples. It can hold 150 mL of fluid at its capacity, is 20 cm long, and has a diameter of 7 cm. A circle with a radius of 7.1 cm was milled out of a piece of aluminum. Four 8mm bolt holes were drilled one on either side of the circle and two of them 2.5 cm away from one edge and 5 cm apart. The syringe was slid into the circular hole and stainless steel bolts were used to attach a Bimba pneumatic actuator with a plunger milled out of Delrin. 1/4" bolts were used to attach the apparatus to the frame using the bolt holes on the edge. Then, a 20 cm length of 5/32" airline was attached to the tip of the syringe. (See Figure 10.)

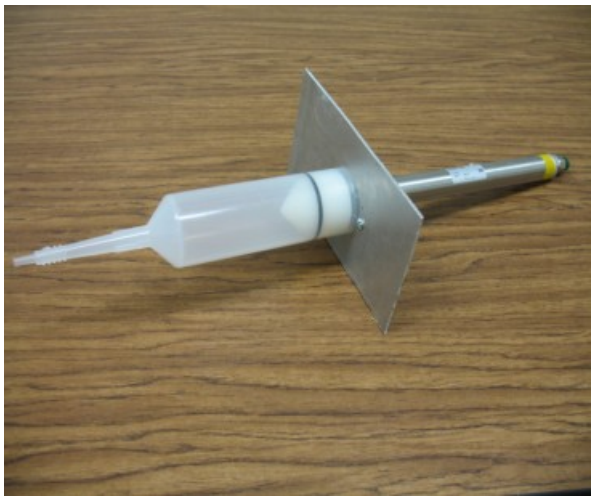


Figure 10. Payload tool Water Sample Collector

This tubing is attached to a Bimba BFTM-0911-D and then fed through a length of PVC piping. A weight was added to the tip of the collection tube to aid in allowing the tubing to sink directly to the bottom of the sample bag, thus providing a greater chance of obtaining an undiluted sample. A cone fitted to the end of the PVC pipe allows the pilot a 30cm diameter circular area to hover over the sample bucket's PVC tube. Once in place, the pilot will activate the downward thrusters, causing the angle of the cone to guide the tube into position. (See Figure 9) Once in position, the BFTM-0911-D is extended, dropping the tubing into the sample bag and the plunger is actuated to extract the sample. Collection time is approximately 25 seconds, at which time the BFTM-0911-D is retracted and this mission is complete.

Challenges We Overcame

#1. An essential member of PHD Engineering's Propulsion and Electronics Departments, Michael Tilse, made a discovery that saved our company's small $4800 budget, hundreds of dollars and hours of time. This discovery was an issue with the design of our DC to DC Converter made during the construction stage of the company's ROV. A result of not finding the issue and a fix in a timely manner would have resulted in delayed water testing of the ROV. The Electronics Department of PHD Engineering became aware of this issue when late testing resulted in a blown fuse for no apparent reason.
During Michael Tilse's investigation into the DC to DC converter he reviewed the original specifications of the design which was designed by another PHD Engineering employee. In his investigation, he used his electronics expertise to determine that part of the original design had been drawn in reverse. This allowed the company to fix this part of the equipment in a timely and cost effective manner. The alternative at this stage was to purchase and wait for equipment, delaying testing of essential equipment that used the DC to DC converter and taxing our companies limited budget.

#2. Up until Sunday, April 24th, the biggest obstacles that PHD Engineering had to overcome were our budget and finding a work-around that would allow us to power our cameras aboard the Phoenix; however, on that fateful day, two employees were on a mission to pressure test our pneumatics and fuse boxes. One fateful error in following procedure caused the whole thing to sink in the "no swim zone" by Detroit Hydro-Electric dam. An emergency staff meeting was held that night. With one of our most crucial members away due to a death in his or her family, the rest of the employees stepped up to the plate and filled in as many of the gaps as

they could. What had previously come together in 1300 man-hours was recreated in a matter of a couple weeks. Not only was it recreated, it was improved upon. Donations from family members and an outpouring of personal support facilitated the purchasing new parts. Still, it weighed on us that our test had littered the dam area, so a phone call was made to the Army Corp. of Engineers to receive permission for an exploratory mission, using last year's ROV to retrieve the lost ROV parts. This mission will test the limits of the NOVA, but it will also be an amazing opportunity to do the very first ROV inspection of an Oregon dam. Perhaps further enterprises may be in store in that area of expertise. The lessons that we learned were first and foremost, to always follow protocol during tests. Next, we learned that we can accomplish amazing things because we work together as a team. Finally, we learned that there is always an opportunity to expand our horizons in any situation we are faced with. We just have to look for it.

Troubleshooting Techniques

Here is just a few examples of troubleshooting techniques that our company implemented during the build process of our ROV.

1. Look at the mechanism, circuit or system and ask, "What is supposed to be happening?"
2. Draw a picture (where applicable) of what the system is meant to do, to help with the overall understanding of the process.
3. If there is programming involved, attempt to run the system without the program to check for possible errors in the code.
4. For electrical circuits use a multi-meter to check for conductivity.
5. For mechanical systems try to manually actuate the process to see where the fault is.
6. Isolate the part of the system that is not working from the parts that are proven to be in working order.
7. Attempt different methods of solving the problem to see which will work the best with minimal changes to the overall design.

Example: While attempting a pool test of our early ROV we found that our controller was unable to connect to the ROV. First we took a step back to discuss how the overall system was meant to work. Second, we decided to try the programming on a mini ROV to see if the fault was in the code. Third, when the code was proven right, we checked for the conductivity in the connections between the controller and the ROV. We found that one of the electrical pins in our water proof connecter was not connected. By taking a look at the mechanics of how the connector connected to the pressure box, we found that that action inadvertently pulled on the wires connecting to the pins causing one of the wires to break; this lead to the fault in the system.

Lesson Learned/Skills Gained

Of all the lessons we have learned over the course of this project, one lesson stood above the rest: **We can make it work!** From managing the tight budget to overcoming the minor mistakes and missteps in the design and construction, we found over and over again that success is made of teamwork and ingenuity, rather than funding and technology.

Going into this project with such a tight budget meant that we needed to make every penny count. This meant making the most of what we had as well as taking new and innovative approaches to the tasks at hand. When the required length of the tether rendered serial connections impractical, it became evident that we needed to take another approach to networking. Instead of taking the quick way out and buying a pre-made solution, we retrofitted an old Ethernet shield, converted a few wires in the tether to carry the signal, and rewrote all of our networking code. After a few setbacks and revisions, we managed to overcome this challenge without adding any additional expenses.

Each and every committee in our company ran into their own trials of this type, with each one learning to work together to overcome any and all challenges. From learning to prototype early and often, generating "proof of concept" prototypes for any potential solution, to making changes as we go and ensuring that we always have a back-up plan, we all learned that with enough teamwork and ingenuity, **we can always make it work.**

Future Improvements

"Future Improvements" is a collection of Phoenix Hell-Diver Engineering's most promising ambitions that, for whatever reason, didn't quite make the cut on this year's ROV. These improvements can be organized by category based on the three areas where ROVs face the most difficulty: propulsion, tether management, and navigation.

Propulsion

For Propulsion, one future improvement that the company is looking at is the addition of two more Seabotix BTD150 thrusters, coupled with a Pololu High Power motor driver 24v12. H-Bridges.

Tether Management

The reasons for wanting a fiber optic tether can be summed up as "maximum depth, and flexibility." Multi-mode fiber optic network cable has much longer maximum signal transmissions compared to Ethernet, and single mode fiber optic cable can go even further. By switching to fiber optic tether, our maximum bandwidth increases allowing us the option of doing video processing on-board the ROV and sending back video feeds as part of network communications. With reduction in camera video & power cables, this can make for significant improvements in tether flexibility. Fiber optics are notoriously fragile so this comes at a cost to the tether's minimum bend radius and ease of handling.

Navigation

An Inertial Measuring Unit (IMU) is a type of Inertial Navigation Systems (INS) which is greatly beneficial to the pilot's ability to navigate. These benefits have motivated our company to invest resources in to making this functionality a reality. Several IMU solutions have been explored:

1. DIYDrones "ArudlIMU V2 Flat"- This IMU features 3 axis accelerometers, 3 axis gyroscopes, GPS NMEA interface, 12C bus, and serial communication.
2. Wii Nunchuck & MotionPlus– These two video game accessories output accelerometer and gyroscope data respectively via 12C Bus. They can be combined to function as a 6 Degrees of Freedom IMU. Their primary benefits include availability, and low cost.
3. Sparkfun LSM303DLH Breakout boards– The LSM303DLH is a more middle of the road solution. It combines a 3-axis accelerometer and compass at a low cost, allowing for a tilt compensated compass today. In the future, if dead reckoning capability is desired, a 3-axis digital gyro such as the IMU3000 could be added. Because of our requirements, Sparkfun breakout boards were selected by our team for their simplicity and low cost.

Systems Engineers Michael Tilse and Bean Dean get help from Nathan Murrow and Jeremy Louke

Reflections on Experiences

On campuses nationwide, students come and go, taking the classes that they need, but never really making a connection with other students. When life deals blows and things get hard, as they tend to do, no one but their professor even notices their absence and no one but the collections department even contacts them. Not so, when a student becomes a member of the LBCC's ROV Team.

Being a part of PHD Engineering means having support, not only of our team mates, but of our local community. As a team, we have collaborated with one another on homework problems, tutored one another and been there for each other during difficult struggles. One thing we can count on is the ingenuity and persistence of not only our members, but also our advisors in finding solutions ranging from assisting a student in replacing her broken glasses with help from the Elks Lodge, to finding summer internships that further our interest in science and alleviate severe personal financial struggles. Local businesses have donated supplies and money to our project and our community responded in attendance and donations as well when we put on a physics demonstration as a fundraiser. We are proud to be presenting the Phoenix, our "impossible dream" made reality through hard work, cooperation and communication.

PHD Engineering and SPS Students Present Life & Death of Stars.

Members of the PHD Engineering Team during one of many pool tests

Nick Cantrell entertains during brain-storming session.

ROV Budget and Financial Statement

Item	Vendor	Qty	Cost	Depart.
Thrusters	SeaBotix	4	$2,800.00	PROP
Epoxy	Digi Key	1	53.65	GROV
Motor Driver	Sparkfun	10	85.01	CS
Arduino Mega 2560	Liquidware	1	55.65	CS
Connectors	Digi Key		387.09	ES
DC-DC Converter	TRC Electronics	1	157.95	ES
Nat. Semiconductor	HSWPART	10	94.00	CS
Epoxy	Allied Electronics	1	138.02	GROV
Epoxy	Mouser Electronics	2	39.95	GROV
Connectors	Digi Key		92.72	ES
Misc. Parts	Mainline Pump & IRR		19.59	WC&T
Drawer Slide	Home Depot	1	12.87	BSC
Acetone	" "	1	16.96	ES
SJ Union	" "	1	3.67	WC&T
150ft Garden Hose	" "	1	29.97	WC&T
Misc. Parts	Burcham's Metals Inc.		22.75	GROV
Pneumatic Acc	" "	1	27.00	H2OC
Misc. Parts	JoAnn Fabric & Craft		1.18	BSC
Extruded Aluminum	SpeedyMetals.com		20.67	FRAME
SCUBA Check/Fill	SCUBA		29.75	GROV
Misc. Parts	Robnett Hardware		6.80	FRAME
Earplugs	NAPA Auto Parts		6.00	GROV
O-Rings	MacDonald Ind. Sup.		2.70	GROV
Solid Rubber Tire	Harbor Freight	2	20.97	FRAME
Connectors	Digi Key		53.64	ES
Misc. Parts	Fastenal		30.40	FRAME
Misc. Parts	Greg Mulder		136.75	GROV
Platypus Bag	Peak Sports		8.95	H2OC
Electronics	Pololu Electronics		91.85	PROP
Promotional Items for MATE competition			400.00	GROV
Competition Travel Expenses			8,310.00	
Total Expenses			$13,156.51	
Revenue				
Donation	Thrusters from OUVET		$2,800.00	
Starting Fund	Linn-Benton Community College		3,000.00	
Donation	LBCC Student Life & Leadership		5,000.00	
Donation	Synergy Respiratory Care		500.00	
Fundraiser	Society of Physics Students		405.00	
Donation	MasterMachine Inc.		200.00	
Club Dues	ROV Student Participants		2,070.00	
Donation	Flight Voucher from Li Zhang		400.00	
Fundraiser	Courtyard BBQs		450.00	
			$14,825.00	
Balance as of 4-22-2011			$1,668.49	

Department Key:

CS	Control Systems	GROV	General ROV Fund
H2OC	H2O Sample Collector	ES	Electrical Systems
WC&T	Well Cap and Trade	FRAME	Frame
PROP	Propulsion	BSC	Biological Sample Collector

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L&R Saw and Machine
Burcham's Metal
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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
LBCC Facilities

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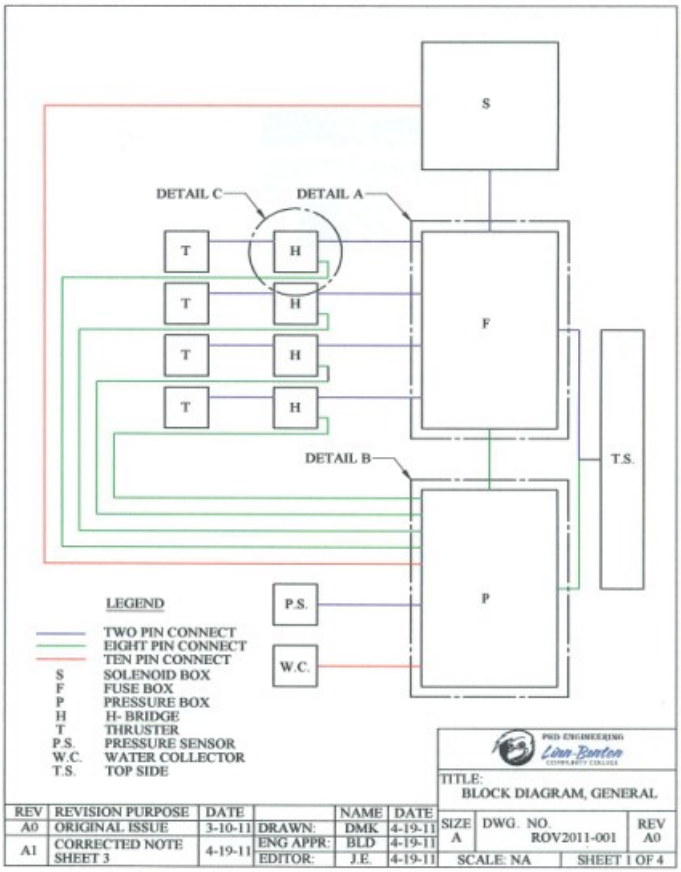
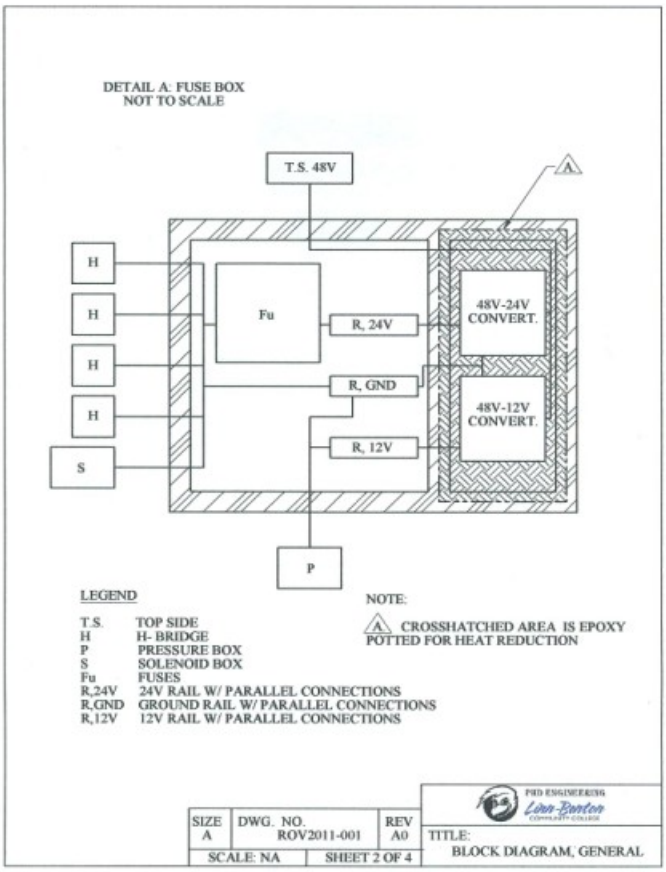
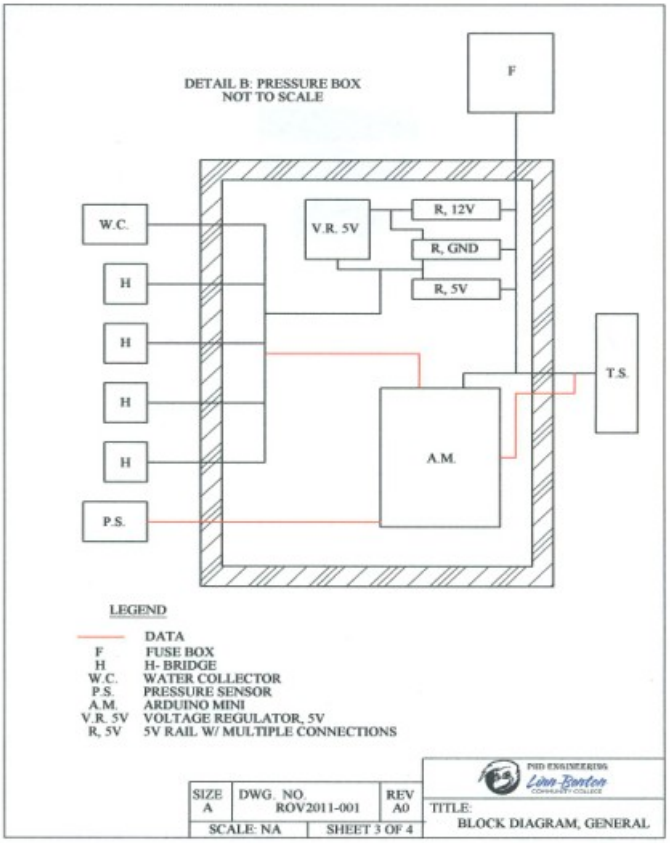
Appendix A: Electrical Block Diagram



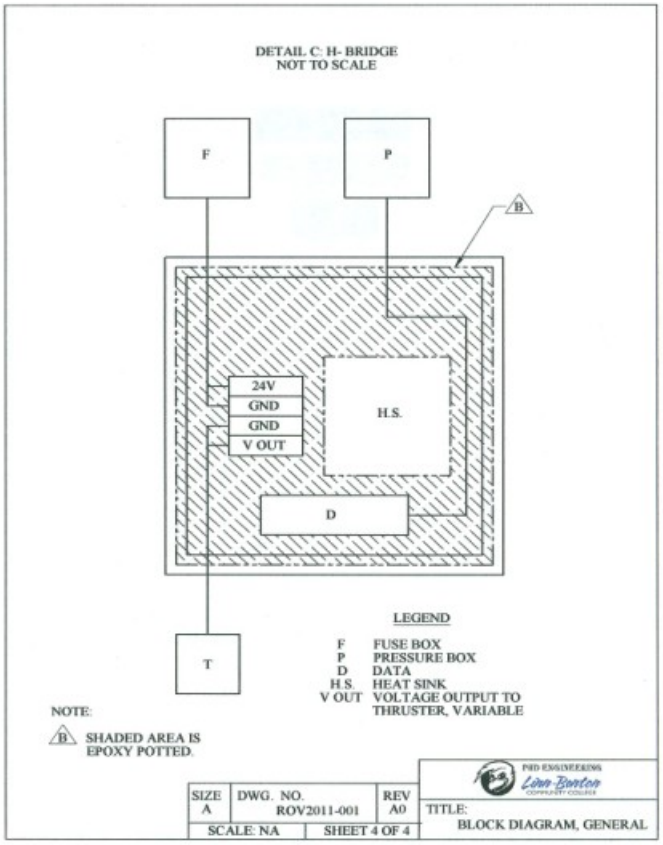
Appendix Figure 1



Appendix Figure A



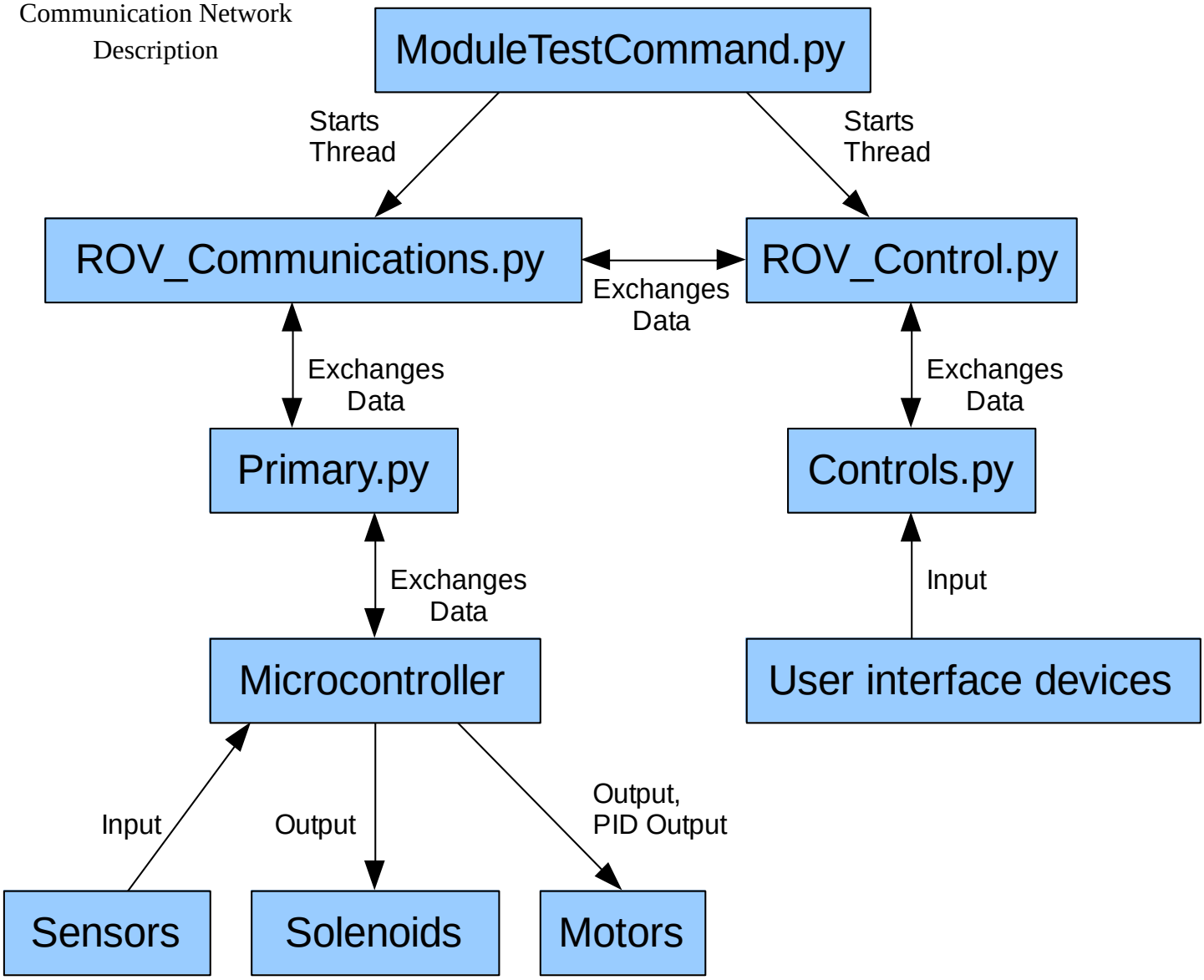
Appendix Figure B



Appendix Figure C

Appendix B: Communications Network Flowchart

Communication Network Description



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.