



The Narwhal

LBCC ROV

Explorer Class

Linn-Benton Community College

Albany, Oregon USA

Technical Report

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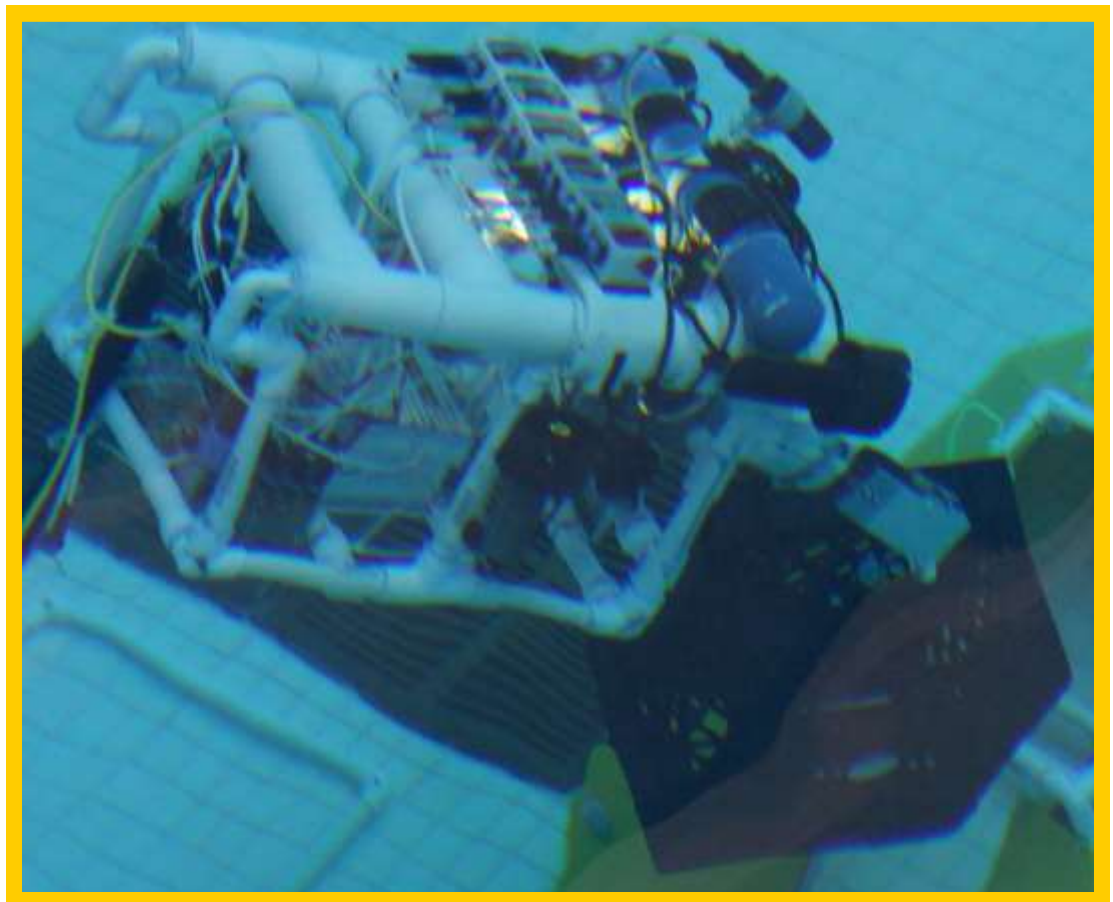




Table of Contents

I. Company Information	3
1. Abstract	3
2. Mission Statement	4
II. Design Rationale.....	5
1. Core Systems	5
1.1 Frame	5
A. Clip-On Connectors	5
1.2 Propulsion	6
1.3 Cameras	7
1.4 Tether	7
1.5 Manipulator	8
A. Gripper	8
B. Arm	8
1.6 Electrical Data Connectors	9
2. Control System	10
2.1 Software Engineering	10
A. Communications Protocol	10
B. Microcontrollers	10
2.2 User Interface	11
A. Control Station	11
B. Human Interface Device	11
C. Graphical User Interface	12
D. Pneumatics	12
3. Electrical System	13
3.1 Heat Distribution	13
3.2 DC to DC Conversion	13
3.3 Pressure Box	13
3.4 H Bridges and PWM	13
4. Transmissometer Payload	14
5. Waterproofing	14
III. Challenges We Overcame	15
IV. Future Improvements	15
V. Safety	16
VI. Expenditures	17
VII. Lessons Learned/Skills Gained	18
VIII. Troubleshooting Techniques	18
IX. Team Reflections on Experience	19
Acknowledgements	21
References	21
APPENDIX A: Other LBCC ROV Activities	20
APPENDIX B: Arduino Pinout	22
APPENDIX C: Power Block Schematic	23
APPENDIX D: Software Flowchart	24
APPENDIX E: Thruster Spec Sheet	25
APPENDIX F: Safety Checklist	26
APPENDIX G: Electronics Overview, Power Distribution, and Fuse and Safety On/Off Box	27



Company Information

Abstract

The LBCC Narwhal is a Remotely Operated Vehicle (ROV) developed by LBCC for the Marine Advanced Technology Education (MATE) Center to install, maintain, and retrieve ocean observation systems. Primary design goals for the Narwhal were to make it modular, simple, and cost effective. The team built an open frame chassis to allow easy access to vital systems housed inside the frame. The snap-on clip design permits components to be mounted, repositioned, and removed easily. Five Seabotics thrusters provide multi-directional propulsion for the Narwhal in three axes. All tasks are executed by a versatile manipulator with a wide range of vertical motion and the capability for full 360 degree rotation of the gripper. With support for up to 8 cameras, the Narwhal grants maximum field of vision to the pilot. It is controlled with a custom graphical user interface using a joystick on a laptop connected via Ethernet to the Narwhal. The simplicity of **the Narwhal's design fulfills the company's overall goal of reducing production cost, improving modularity, and accelerating product assembly.**



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Mission Statement

Company Mission Statement:

To encourage students to improve their scientific knowledge, technical skills, and teamwork by designing, constructing, and operating a Remotely Operated Vehicle in competitions and scientific research expeditions.

Community Involvement

LBCC ROV is a diverse team of students whose goal is to expand our knowledge of applied science and engineering by building a fully functional ROV for the MATE competition. We enthusiastically share our knowledge with many different audiences, furthering our communications skills as well as fostering the interest of the next generation. We do this through outreach to local schools and youth organizations by running ROV workshops and demonstrations for them.

System-based Manufacturing

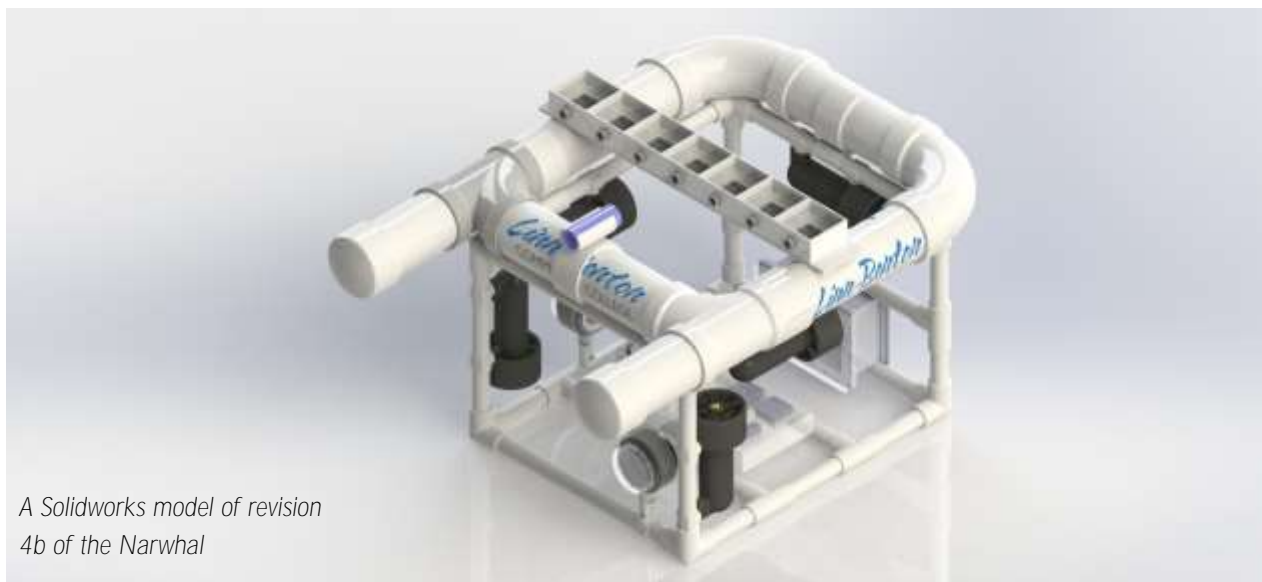
Dividing the production of the ROV into systems enables our subteams to achieve their objectives efficiently. Subteams design and construct a single subsystem, enabling their members to focus on unique skills. Communication for each subteam is routed through a single officer, who facilitates participation by members **of other subteams. This encourages a healthy balance between specialization and variety in students' skills** and experience.

Research Expeditions

LBCC ROV has participated in several research partnerships with other universities. Our students collaborate with faculty at those institutions, and take summer research trips to operate the ROV for the faculty at various locales. We also have a student working on the *R/V Atlantis* this summer performing tasks similar to the MATE competition missions.

Work Experience

Our members get jobs. Companies frequently search for employees with a history of team involvement, problem solving, and project completion. Our members are able to demonstrate these skills with confidence after working on the ROV. In addition we work to connect members with internships, scholarships, and grants to continue their education before joining the workforce.



*A Solidworks model of revision
4b of the Narwhal*



Design Rationale: Frame

1. Core Systems

1.1 Frame (Buoyancy)

After considering various materials for frame construction, we decided on PVC. PVC has many advantages: it is cheap, lightweight, easy to work with. Due to its hollow nature, it is naturally buoyant if sealed properly. We have successfully tested the schedule 40 PVC we used up to 15 meters of depth. The disadvantage of a PVC frame is that it cannot be disassembled once glued. However, because the material is inexpensive and easy to work with, a new frame can be assembled in as little as 45 minutes for \$65 (Fig 1.1.3). Prototypes can be tested before gluing by sealing the joints with petroleum jelly. This allows our team to iterate new prototypes quickly, enabling our design to remain flexible. We are currently on our 4th main revision of the PVC frame (Fig 1.1.4); minor changes have been made to each frame in-between major revisions.



Fig 1.1.1 2" PVC tubing on top for main buoyancy, 3/4" tubing for bottom structure. Smaller than previous year's frame.

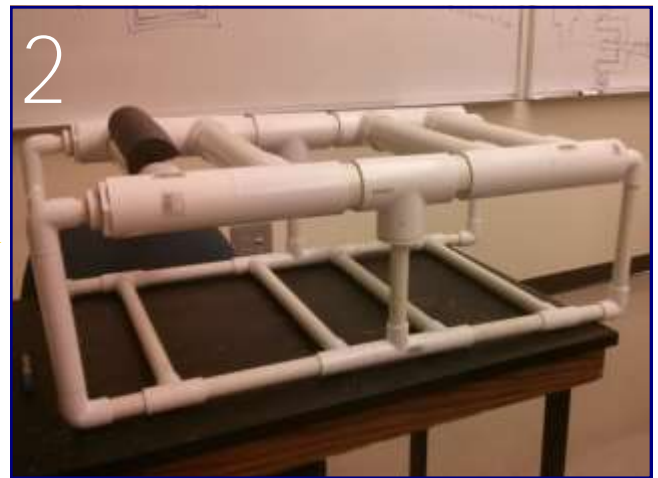


Fig 1.1.2 Increased buoyancy with top cross tubes. Mounting cross tubes added to bottom.



Fig 1.1.3 Reduced length and width of the ROV. Top buoyant section too long to connect to bottom, necessitating awkward joints at the top corners, causing increased cost and reduced structural integrity.



Fig 1.1.4 Open top facilitates access to internal systems. Top buoyancy tubes increased from 2" to 3" PVC pipes. Increased buoyancy by 5.7L of air, even after the removal of top cross tubes



Design Rationale: Propulsion



Fig 1.1.A Unpainted snap-on connector for camera

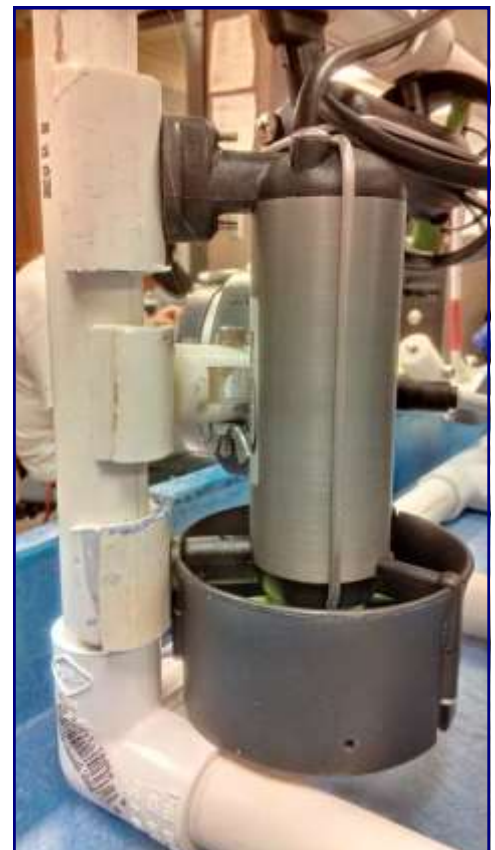
1.1.A Clip-On Connectors

In the past PHD Engineering used an aluminum frame, so this year we needed to develop new connectors. We wanted to build them inexpensively and quickly, and they needed to be easy to mount, reposition, and remove. Since water leaks into the frame unless it is completely sealed, we decided to settle with PVC.

We cut slots into short lengths of PVC, and bent them with a heat gun. With these modifications, the pieces snapped tightly onto the frame, and the components could be screwed in without affecting the integrity of the buoyant parts of the PVC frame. (Fig 1.1.A) We were able to attach the thrusters (Fig 1.2), cameras (Fig 1.3.1), arm, and h-bridge using these connectors, and a modification of this technique was used to mount the brain box and power brick.

After using the connectors for a few test runs, although they performed admirably, we noticed that the bolts sticking through the bottom of the connectors scratched the frame. We reconstructed them using two layers of PVC. The components were bolted to the top layer, the top layer was then glued to the bottom layer (which provided a buffer for bolts and screws), and the bottom layer snapped onto the frame. These PVC clips make components easy to replace or reorganize, but are strong enough that even the motors will not detach accidentally.

Fig 1.2 Motor and camera mounted with snap on connectors.



1.2 Propulsion (Thrusters)

The Narwhal's propulsion system consists of 6 SeaBotix BT-150 Thrusters (Fig 1.2) 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 a surface power brick routed down a tether and connected to an onboard fuse box. This is a custom made epoxy-potted container that converts and fuses the power before it is sent to the H-Bridges. 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 User Interface on a laptop with a Logitech G-UF1 3 controller.



Design Rationale: Cameras

1.3 Camera

There are 5 PC303XS cameras on the Narwhal, recycled from last year's build. Each camera draws 100mA of current with an input voltage of 12 V DC ($\pm 10\%$) and their effective resolutions are PAL: 512x582 and NTSC: 512x492 with a resolution of 380TV lines. (Fig1.3.1) We chose NTSC cameras because their simple design is reliable and easy to troubleshoot. **Additionally, their small size allows them to fit nicely into the 3" OD aluminum tubing used as housing material.** The tether uses CAT 5 cable to transmit video signal topside which requires the use of baluns on the camera side and DVR side of the cable, which have proven to be a bit fragile, but our design allows for them to be changed easily.

These cameras are mounted onto polycarbonate boards inside hollow aluminum tubes with cast epoxy backing and polycarbonate lenses. (Fig1.3.1) The mounts are a custom design created by LBCC ROV members, and have been tested at depths up to 80m. Addition they are simple to construct, inexpensive, and adaptable to a variety of small cameras.

1.4 Tether

Multiple tethers are available for communicating with Narwhal in various environments. The tether used for competition is 10m long (Fig1.4), neutrally buoyant in fresh water, and has a redesigned bundling technique to reduce the risk of injury to handlers. Power is supplied to the Narwhal by a pair of 10 gauge wires that carry 48VDC from the surface power supply.

The current 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 from the surface. There are four CAT5 cables for cameras and data. At the surface, the tether is attached to the MATE power supply through a switch box, a half meter 10 AWG extension, and a 75Amp Anderson Power-pole connection. The switch box provides additional safety fusing, bleed down resistors, and controls voltage to the Narwhal. It also adds a layer of safety with an additional fuse breaker, and on-off control. The data lines are connected to a one meter CAT5 Ethernet extension with an RJ45 connector at the end, allowing the Narwhal to be attached to the control station via Ethernet ports.



Fig 1.4 Tether inside red luggage used for tether storage.



Fig 1.3.1 (top) camera mounted behind polycarbonate

Fig 1.3.2 (bottom) Aluminum and epoxy camera housing





Design Rationale: Manipulator

1.5 Manipulator

We needed a versatile tool to manipulate objects for most of the required tasks. We designed a gripper capable of holding a variety of objects and attached it to a motorized arm with two degrees of freedom. The gripper is primarily used for opening and closing doors, twisting handles, removing biofouling, and carrying scientific modules.

(Fig 1.5.1)

1.5.A Gripper

Designing a simple gripper was a difficult task, as it needed to be able to firmly grasp a variety of objects of different shapes and sizes. These objects include U-bolts, a metal J-bolt, several kinds of PVC fittings, and ½-inch PVC tubing. Our current design uses a 2 L-shaped metal plates for either side of the gripper. A pneumatic piston opens and closes the gripper, and is operated manually by a switch on the surface. We have implemented a wrist with unlimited rotation, by boring a hole through a gear to let the pneumatic piston shaft rotate without getting the pneumatic lines tangled by rotation. (Fig 1.5.2)

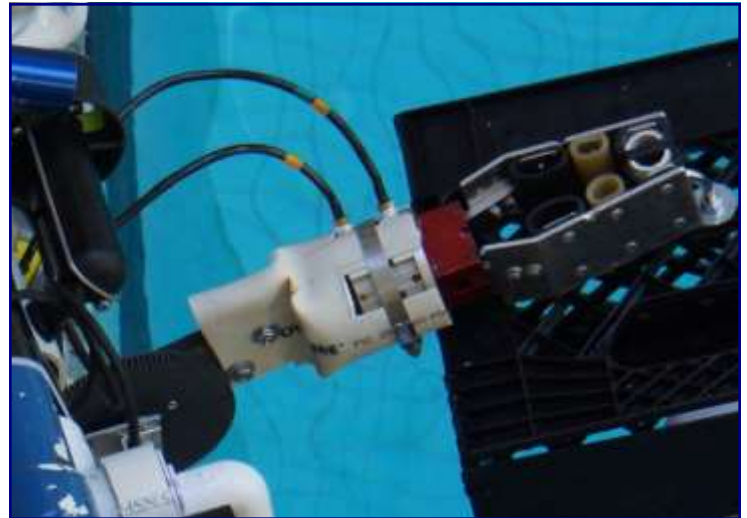


Fig 1.5.1 An older model of the manipulator, used at regionals.

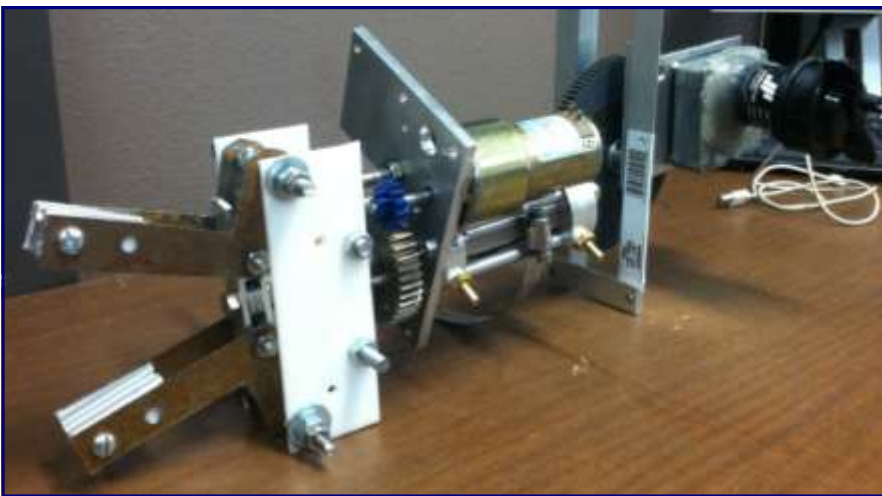


Fig 1.5.2 The current model of the manipulator, with 360 degree rotation.

the gripper's pneumatic shaft running through the wrist's gearing, allows it to rotate indefinitely. This removes the burden of tracking the wrist's rotation, which would otherwise be necessary to avoid tangled pneumatic lines. It also allows the gripper to level the secondary node by rotating the leveling screws. Developing a shoulder allowed us to turn our existing claw up and down, which should greatly expand our mission capabilities.

Design Process

Anticipating the need for a capable manipulator, a SolidWorks model of the manipulator was created.

- First iteration: many joints, cable-driven, complex.
- Second iteration: fewer joints, servo-driven, less complex.
- Final iteration: even fewer joints, bilge pump and servo, simple.

1.5.B Arm

The arm's purpose is to control the orientation and position of the gripper. Since the Narwhal itself can move in all three cardinal directions and rotate horizontally, the arm only needs to move in two directions to provide the gripper with six degrees of freedom. A Johnson model 2851 bilge pump motor and custom gearbox at the base of the arm is used to rotate the arm up and down. A waterproofed servo motor is used at the arm's wrist to rotate the gripper on an axis running parallel to the arm. The design of the wrist, with



Design Rationale: Data Connectors

1.6 LBCC Custom Data Connectors (CDCs)

Previously, the team used commercially available waterproof plugs for electrical connections between various components of the ROV. The commercially available connectors have proven inadequate for multiple reasons. First, the cost of commercial connectors has consumed large portions of past budgets. Furthermore, they suffer debilitating wear and corrosion after **repeated use**. In response to these shortcomings, our team's priority this year was developing our own custom plugs. Our creation, the CDC-1 (patent pending), represents a major innovation in underwater electrical design. We focused on making the plugs small, durable, and waterproof to 100m. The design needed to provide adequate interfacing between the overmolding and the plugs to ensure maximum protection from water creepage. At the same time our design is easier and faster to connect and disconnect than current commercial models.



Fig 1.6.1 (top) Connectors disconnected



Fig 1.6.2 (bottom) Connectors connected

The connector design uses off-the-shelf 4-contact stereo plugs, which are inexpensive and allow a compact profile since the 4 contact pads are aligned along the axis of the cable. A single axis for the 4 contact pads also avoids a tolerance stack across multiple center lines especially if there were individual seals for each contact. The ability to procure off-the-shelf electrical connectors was key. We use a cylindrical shape to provide uniform sealing. (Fig 1.6.3 and 1.6.4) The specific model of connector chosen has a cylindrical shaft along the entire length of sealing surface which provides a solid and consistent surface to support the seals. In addition, the 4-contact audio connector is designed to endure at least 5000 connect/disconnect cycles. If we were to mass produce these connectors, we project that we would be able to sell them profitably for \$40/pair, 50% less than comparable commercial models.

Fig 1.6.3 3D models of connectors

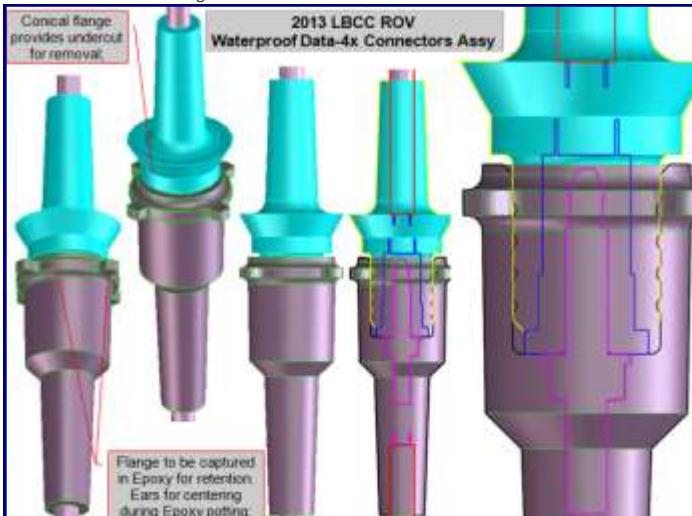
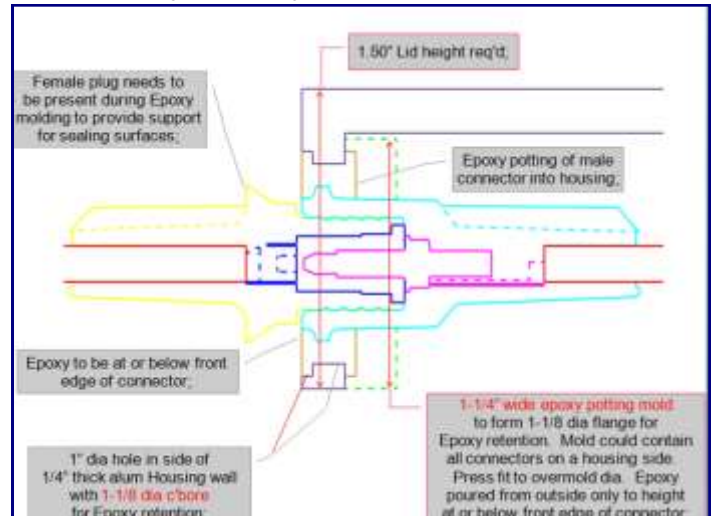


Fig 1.6.4 Design document for connectors





Design Rationale: Software

2. Control Systems

2.1 Software Engineering

There are two distinct code portions of the Narwhal, the ROV-side Arduino C with various libraries, and the user-side Python 2.7 which provides a networked interface between the pilot and the Narwhal, through a laptop and USB game controller. Not all engineers have extensive programming experience, so the Python and Arduino languages are excellent choices because they are quite readable to non-programmers. For instance, when we need to make changes to the control scheme it is trivial to show the driver a block of broken code and have him try to fix it.

While Python 3.0 is technically stable, using 2.7 enables our software to run on a wider variety of hardware and is less susceptible to the rapid changes in 3.0. Python's ability to rapidly prototype and its access to heavily documented libraries made it our choice for design modular, portable, and readable code.

An important principle to the software team is Open Source Software. One reason Arduino and PyGame were chosen was because of their open nature. Not being locked into proprietary platforms like VxWorks or Windows allows us to develop more freely and offer our source code back to the community.

2.1.A Communications Protocol

The use of the Arduino Ethernet Shield Revision 3 to provide client-server operations between the Narwhal and the surface was chosen due to the reliability of TCP/IP (Transmission Control Protocol/ Internet Protocol) over long distances. The Arduino has a variety of ways to implement serial communications. This involves two tough challenges: the engineering wiring scheme and writing the protocol. Ethernet has distinct advantages over custom wiring in both cost and signal integrity. TCP/IP has a well documented capacity for packet (signal) redundancy and implementation for specialized use.



Fig 2.1.B Arduino and Ethernet shield inside Pressure Housing

The Python library Twisted was considered for use due to its proven ability in the realm of enterprise-level communications but was deemed too much of a time investment. While it would be nice to have a more extensible networking framework, the requirements of the data transfer were low enough that a simple TCP stack sufficed. Being able to provide a less abstract data structure for communicating between Python and the Arduino was beneficial when debugging communications.

2.1.B Microcontroller (Figure 2.1.B)

We chose the Arduino Due as our primary control interface for the electrical components on the ROV. (Fig 2.1.B) It has 66 Input/Output (IO) ports which we use for both sensor input and motor control. Its



Design Rationale: Software

Atmel SAM3X8E ARM Cortex-M3 CPU is a huge step up from the ATmega2560 we used in the past, both in clock speed (16Mhz versus 84Mhz) and architecture (AVR versus ARM). This upgrade made it possible to implement balancing functions directly on the ROV that were previously performed on the laptop in Python, lowering latency by a huge degree. The only issue we faced in upgrading to the Due was that its 3.3V operating voltage forced us to modify all components that were previously powered directly off of the **ATmega2560's 5V operating voltage.**

While the array of microcontrollers is vast, we chose the Arduino platform because of its the community support and openness. The documentation on hardware and software libraries is unmatched among other **hobbyist microcontrollers, and the Arduino's openness allows for code reuse and sharing. This contrasts** with many closed source options like ARM SOCs (System On a Chip), VxWorks, and higher end platforms like laptops.

2.2 User Interface

Without an accurate description of both the internal and external influences, the pilot will not be able to get the performance necessary to complete the missions. Making an accessible and easily modifiable workflow using PyGame, PGU, and VPython gives our pilot the all information he needs.



Fig 2.2 The control station with controller, DVR screen, and laptop screen.

2.2.A Control Station

Our piloting system consists of a viewing screen for cameras, solenoid switches, and a laptop with USB game controller. (Fig 2.2) Providing visual feedback on the screen is useful for both debugging and testing. Alerting the pilot to networking errors, motor freezes, and allowing quick changing of the controls were the main design goals. (Fig 2.2.C) Our camera system displays up to 8 camera streams on a DVR monitor. A separate laptop screen shows the relevant control information of thrusters, arm controls, and implied direction of the combined thrust (see GUI section 2.2C).

2.2.B Human Interface Device

Our controller scheme leverages the ingrained video game skills developed by most of our company. It mimics a spaceship simulator, because the neutral buoyancy of the ROV is similar to how ships handle in games such as Freespace or Descent. The controller itself has a very common layout (two joystick, D-pad, 4 right buttons, and 4 shoulder buttons) similar to the ubiquitous Playstation and Xbox controllers. The laptop takes the USB input from the controller and converts it directly into an instruction set sent over ethernet to the Arduino, which converts the instruction set into power levels and directions for each motor.



Design Rationale: Software

2.2.C Graphical User Interface

To create a minimal but functional GUI for our pilot (Fig 2.2.C), we used a combination of PyGame, PGU (Phil's PyGame Utilities), and VPython libraries. PyGame is an open source library that gives an easy API (Application Programming Interface) access to USB HID (Human Interaction Device) protocol, as well as providing intuitive GUI creation. PGU provide easy interfacing with the USB controller of choice and integrating tightly with the backend communications. Visual Python allows for easy display of 3d objects such as vectors to convey the overall direction.

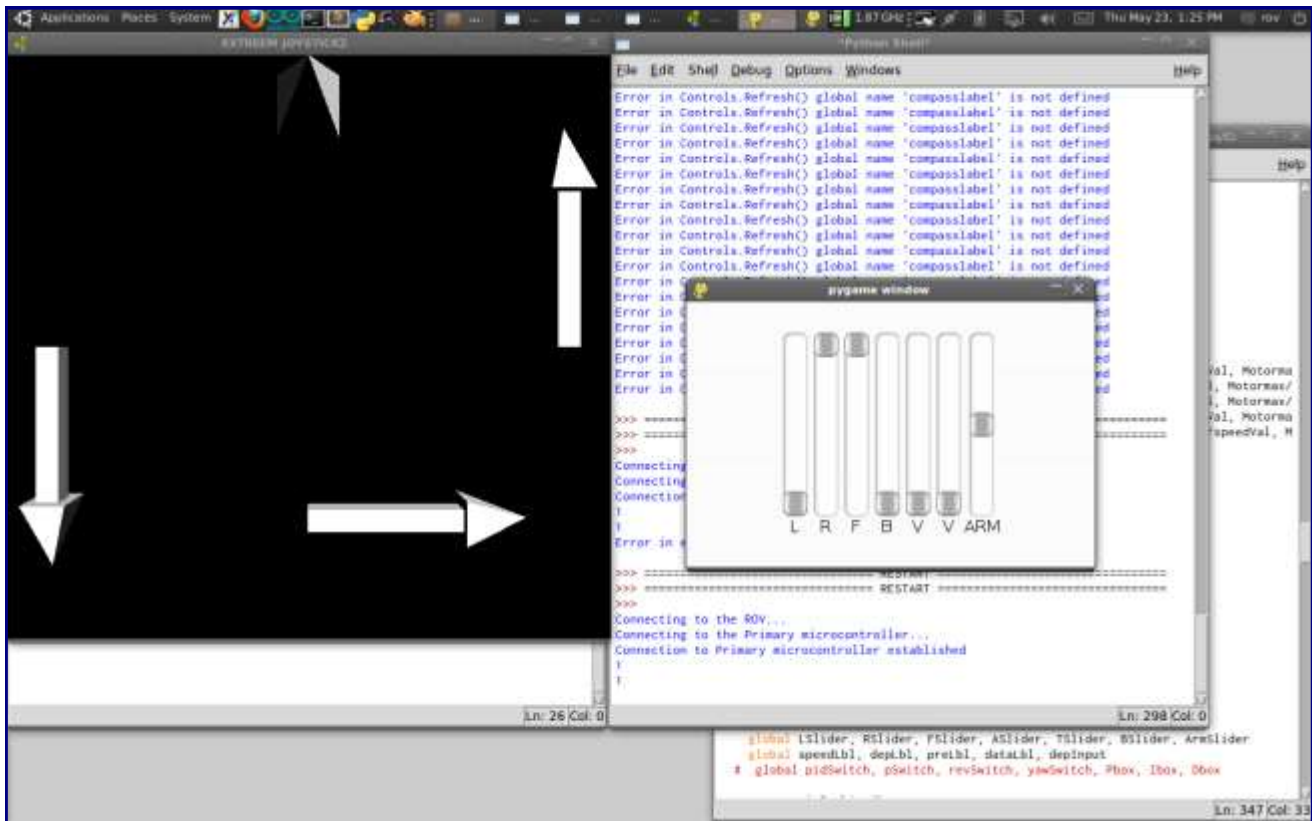


Fig 2.2.C The Pilot's Interface



Fig 2.2.D Solenoid switch for pneumatics

2.2.D Pneumatics

Although we aimed to keep the number of separate systems on the Narwhal to a minimum, our need for two fast-acting and powerful linear actuators led us to implement a pneumatics system. Air pressurized to 40 PSI is sent down the tether in either of two polyurethane 1/4" OD pneumatic lines rated to 148 PSI. A manually operated solenoid switch at the surface is used to change which line the air travels down, allowing us to operate both pneumatic pistons simultaneously. (Fig 2.2.D) These pistons are used to open and close the manipulator's grabber and the latch on the hook for the ADCP.



Design Rationale: Electrical

3. Electrical System

3.1 Heat Dissipation

We decided to split up the electronics system as much as possible, focusing on separating heat producing elements and hard-to-replace devices into different housings. We built a power brick, a brain box, and 7 individual H-Bridges, which respectively are the brain, heart, and muscles of the Narwhal.

3.2 DC-to-DC Conversion

The conversion box containing the heart of the Narwhal is custom-made of polycarbonate. (Fig 3.2) One side of the box holds 48V-24V and 48V-12V DC-to-DC converters. Both converters are encased in epoxy except for their heat sinks. This moved the two the biggest heat producing elements away from the fragile components while remaining waterproof. The other side of the box distributes power to other ROV systems. Self-resetting fuses in the conversion box help ensure diver safety.



Fig 3.2 The DC-to-DC power brick.



Fig 3.3 (top) Brain pressure housing

Fig 3.4 (bottom) H-bridge container

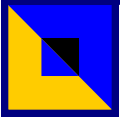
3.3 Pressure Housing

The pressure housing is used to protect the brain of the Narwhal from water, pressure, and corrosion. The housing contains an Arduino Due microcontroller and Arduino Ethernet shield V5 attachment. Team member Michael Tilse milled the two aluminum parts of the box near the end of last year. The aluminum top is secured to the aluminum bottom with a layer of plastic in-between, sealed by rubber collars on both sides, and secured by 24 bolts. The data communication lines from the surface interface devices and H-Bridges enter the box through the plastic. This robust design has been successfully tested down to 80m.



3.4 H bridges and PWM

7 H-Bridges are set in individual plastic blocks. Each block is potted in epoxy, but the heat sink is left exposed to water. These blocks move another source of heat away from other components. All H-bridges are interchangeable, facilitating easy replacement of malfunctioning parts.



Design Rationale: Payload

4. Transmissometer Payload

Prior to the competition each team is required to design and construct an optical beam transmissometer. This transmissometer is used to measure the varying opacity of a rotating plastic disk simulating an underwater ash plume.

The transmissometer is a simple device used to measure turbidity of the medium in which it is placed. The function of the device is built upon the concept of diffraction of light through a medium reducing the intensity of a collimated light source of known intensity. The transmissometer constructed consists of a 650nm wavelength laser diode operating at <math><5\text{mW}</math> aimed at a phototransistor a distance of 10cm from the laser diode. (Fig 4.1)

The both components are potted in optically clear epoxy contained in a Polyvinyl Chloride housing and wired to a tether constructed of Ethernet cable. The tether is routed through a surface float to an Arduino Due at the command console. The Arduino Due microprocessor interprets the change in voltage from the phototransistor and displays it in a readable graph format on our primary computer.

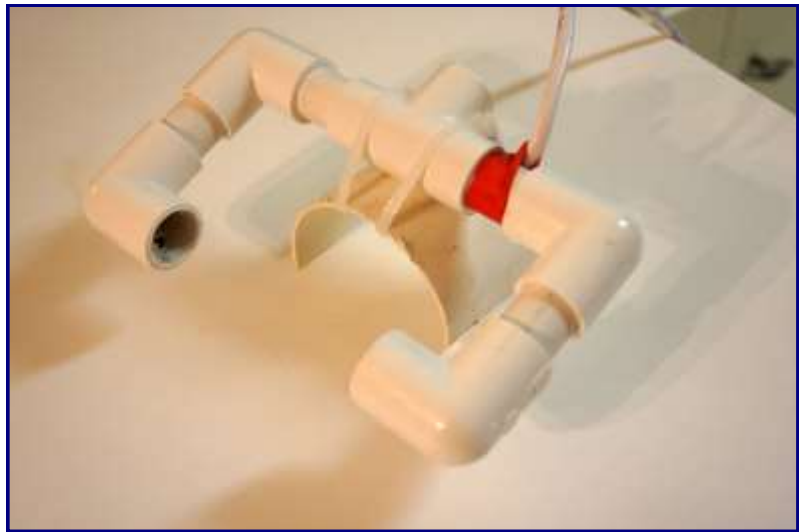


Fig 4.1 Laser Transmissometer. Laser on left, light sensor on right.

5. Water-proofing

The most difficult part about designing underwater ROVs compared to other types of remote vehicles is the fact that they must operate over long periods in a high-pressure and highly corrosive environments. This is most often solved by waterproofing. Over the past several years, LBCC ROV has experimented with various techniques and strategies for water-proofing.

Our company has insulated our electronics with epoxy potting, where they are cast in polymer. Because of the permanence of this method, we thoroughly dry test systems before entombing them. (Fig 3.2) In past **years we received excellent advice from Kapi'olani Community College Team Limawai, who kindly shared their experience with epoxy potting.** We specifically sought out clear non-shrinking epoxy, as shrinkage can shear off components. The clear epoxy allows us to see indicator lights on the electronics and determine if they are powered and operational.

To protect against corrosion, the Narwhal is primarily constructed from non-ferrous material. The few metal parts are made from stainless steel or aluminum. As an extra protective measure, we have a policy of rinsing the Narwhal with fresh water after every use.



Challenges We Overcame

III. Challenges We Overcame

Lack of appropriate tools was a challenge in completing the manipulator. Two versions of the shoulder and four versions of the claw were prototyped before we were satisfied with their function. Most tools used in previous years had been used on loan, and we were unable to obtain funds for replacements. The tools that we used to build the claw and shoulder were sparse: a flat file, a drill press, a hacksaw, a homemade bearing puller, and a Phillips screw driver. Our materials consisted of scrap aluminum, PVC, and rubber. The drive motor used to articulate arm motion is a repurposed 12V bilge pump motor. The whole company pulled together to help build the arm. Many members lent assistance to the arm team, who themselves were working long hours using sheer willpower to shape metal according to their demands.

As a result of our limited materials, the total bill for the construction of the arm was \$32.

A persistent non-technical challenge faced each year by LBCC ROV is a high rate of personnel turnover. Because we are a two year school, the most experienced students on the team are only in their second year of building ROVs. For example, this year only 5 members of the 20 person team had any previous ROV experience. It is difficult for the returning members to pass on their experience to new teammates when they themselves have only a year to draw from. As such, the entire team faces a daunting learning curve **every year. We spend a large amount of time sorting through the previous team's work, repeating the same mistakes, and needlessly duplicating efforts.** This time would be better spent prototyping, building, and testing, which would be possible if we had more year-to-year continuity. We are making an effort to break this cycle by offering ROV and microcontroller classes. These workshops teach students to design and build small ROVs. This allows many more students to develop the basic skills necessary for ROV construction. We have found that this makes new students more comfortable with the challenges inherent in a multi-system ROV.

IV. Future Improvements

For the past two years, we have been working to replace our NTSC security cameras with HD IP (internet protocol) cameras. This transition would significantly streamline the camera system while greatly improving image quality. Power over Ethernet capable IP cameras can be powered over the same cable that carries data. Multiple IP cameras can be connected to an onboard Ethernet switch and the data sent topside along one cable. An IP camera system will halve the number of camera cables on the ROV, which also means a reduction in the number of connectors necessary. Currently, all of the camera signals end up in a DVR which is housed inside a Pelican case and requires a separate monitor from the computer which controls the ROV. IP cameras will plug directly to the computer. This greatly simplifies our control station and increases the ease of setup. We are currently testing and building housing for several different camera models.

Other plans include the development of a many-jointed manipulator on the ROV controlled by repositioning a scale model of itself on the surface. We drew inspiration from the remote manipulators we saw at our tour of the Hanford Nuclear plant. The benefits of this project include enhanced comprehension of the **manipulator's position by the pilot and the ability to perform a wider array of fine movements with it.**



V. Company Safety Philosophy

Safety is a primary goal of our company. Though we are dedicated to exploring, testing, and rapidly prototyping new ideas, none of our objectives are worth sacrificing our health and well-being. In addition, LBCC ROV realizes that many of the tools and materials we are dealing with are dangerous or hazardous to our health, sometimes in ways that are not obvious to common sense. Because of this, we have implemented the following safety practices, which are prominently posted in multiple locations in the lab, taught to all new members of the team, and enforced by positive peer pressure. The safety practices are designed first to prevent severe bodily harm (such as from electricity or power tools), long term disability (deafness from loud machinery, blindness from lasers), and lastly to prevent harm to the ROV or our tools. Because of the amount of power equipment located in the ROV lab, no one was allowed to work alone while in the lab.

Company safety practices

- ◆ Safety glasses are required when working in the lab or near pressurized air
- ◆ Ear plugs are used when loud power equipment is in use
- ◆ Vehicle is always powered off before servicing it
- ◆ Everyone must be accompanied by at least one other person when working in the ROV lab
- ◆ Prior to using any powered tool in the lab, a company member must be checked off by a company official to ensure that they know all of the safety practices for that tool
- ◆ The last person to leave the lab must check to make sure all tools and electronics are unplugged
- ◆ Never leave pressurized air tanks standing on end
- ◆ All pressurized air tanks are stored horizontally in secured locations
- ◆ All pool tests are conducted under the supervision of a lifeguard and/or rescue diver
- ◆ Ensure everyone is at least one meter away before powering on the ROV or pressurizing the pneumatic system

Equipment Safety

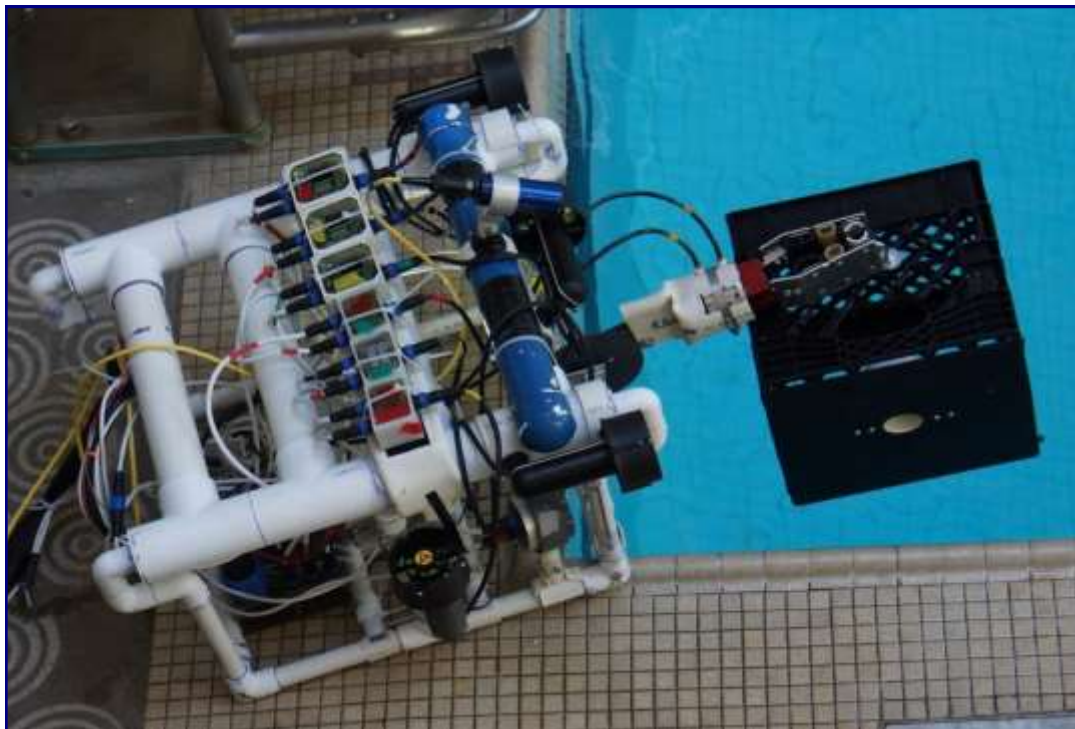
- ◆ Water sensor in brain box allows us to shut down the ROV if any leakage occurs
- ◆ Thrusters are mounted inboard to minimize risk of fouling by lines, wires and fingers
- ◆ All propellers are surrounded by shields to minimize risk of fouling by lines, wires and fingers
- ◆ Stainless steel safety cable in tether allows us to recover the ROV in the event of system failure
- ◆ Fuses in the onboard power brick prevent any component on the vehicle from overloading the electrical system
- ◆ Main fuse is located before all electronic components, including main power switch
- ◆ New connectors are designed so that power is the last contact made, after data and ground
- ◆ Lasers used in transmissometer are within safety regulations indicated in the competition handbook
- ◆ Max pressure in pneumatic system is 40 psi
- ◆ First Aid Kit is prominently located in lab and is taken with us on every away mission
- ◆ Ensure that everybody is at least one step away from the ROV before switching the power on



Budget

VI. LBCC ROV 2013 Expenditures

Category	2013 Expenditures	Scavenged Equipment Value	Support and Dona- tions
IP camera	\$140.00		
PVC for frame	\$65.00		\$80.00
Materials for CDC-1 custom connectors	\$190.00		
Other connectors materials	\$48.00		
Pneumatic pistons (2)	\$20.00		
Mission props for testing	\$50.00		
Arm expenses	\$32.00		
Meals for work-parties	\$550.00		
MATE Registration	\$100.00		
Lodging and food at MATE Competition	\$1,950.00		
Travel to MATE Competitions	\$400.00		
Bilge pump motor		\$25.00	
Propulsion System		\$5,132.56	
Electronic Components		\$51.45	
Linn Benton Community College			\$3,000.00
Fundraising			\$500.00
Total	\$3,545.00	\$5,209.01	\$3,580.00



Revision 3 of the Narwhal competing at regionals in Lincoln City, Oregon.



Troubleshooting

VII. Lessons Learned/Skills Gained

This year, the company decided to attempt a new electronic method of communication. We set up a Google Sites page to enable all members of the ROV team to post pictures, questions and suggestions on how to improve the overall design and function of the ROV. It included a Gantt Chart organizing our project workflow and deadlines. Unfortunately, not many team members made use of the service, and even fewer members used the page as their main source of progress updates on the ROV. We theorize this may have been the format of the page, which was designed for displaying information rather than discussing it.

We quickly realized that many team members were communicating with each other via email and Google **Chat, and that most information sharing happened outside of the company's Google Group page. We then** decided that instead of using the website as a primary means of communication, we would meet weekly in person, and use the email list attached to the Google Groups website for most group communication. After this change was made, progress in all aspects of the ROV experienced an exponential increase and overall knowledge of the ROV improved for all active members of the team. We attribute this to high attendance at the lively weekly meeting, and frequent use of the email list.

From this experience, we learned that while new forms of communication may be attractive, they may not have the adoption rate needed for good team communication. Relying on tried and true methods like weekly meetings and SMPT made sure that all team members were reached. This is not the say all new tech is useless tech though, Google Chat and Google Docs were heavily utilized in communication and preparation. We developed skills in using whatever means necessary to communicate our ideas and needs to other members, whether that was email, Google chat, or face-to-face conversation.

VIII. Troubleshooting Techniques

LBCC ROV uses one simple troubleshooting technique. When we encounter a problem, the most experienced member present on the related subteam works on ascertaining the source of the difficulty. In the meantime, the rest of the team brainstorms possible solutions to the type of problem presented, thinking both short and long term.

An excellent example of this occurred at regionals. Upon arrival we discovered that the U-bolt on the SIA **was a 2" bolt, not a 4" bolt like the one we had mistakenly installed on our test props back in in our lab. We had specifically designed our gripper to work with the 4" U-bolt. The gripper's 9cm (3.5") high plates would** clasp together, insert themselves into the U-bolt, and press outwards, forcing the U-bolt securely into a groove carved in them.

Since this technique could not work with a 2" U-bolt (the gripper couldn't fit inside it), a timely solution was essential. Members of our team immediately began constructing modifications to allow the gripper to perform this new task. We quickly discussed possibilities, evaluated multiple changes, and tested three of them in the space of half an hour. We iterated quickly and were able to modify our current design by **hot gluing PVC pieces inside the rubber grippers, giving enough lateral strength for the gripper to hold the 2" U-bolt** between its claws enabling us to pass regionals.

This, however, was only the beginning of the troubleshooting process. Once we returned home, we began a full scale reevaluation of our manipulator goals, and after the arm subteam prototyped several new designed, we ended up with the powerful gripper seen in Fig 1.5.2



Reflections

IX. Team Reflections on the ROV Experience

“This year, I took on the role of a CEO for the team in addition to my role as the camera systems engineer. The challenges associated with personnel management, planning and systems integration are numerous, but the experience has taught me much about how to operate effectively in a leadership position. Building an ROV as a college student can be especially challenging. It can be difficult to balance the requirements of school and a job and still put as much effort into the ROV as you would like. Team cohesiveness and communication have been essential in our ability to build the Narwhal despite the challenges faced by each individual member.”

— Kyle Neumann, CEO & Camera Systems Engineer



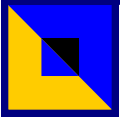
“Before this year I had never considered that I might one day build a robot. And even several months into the project, I still felt that was an unlikely outcome. Seeing the work and dedication displayed by the team in the past few weeks has taught me about the importance of team cohesion, and the value of having a tangible goal. Before the frame of our ROV came together, work was sporadic and uncoordinated, but after we cobbled together enough working parts to achieve a moving pool test, morale improved greatly. People started spending long hours, nights, and weekends, communicating constantly and striving to improve our systems. When teaching next year, I hope to harness this team energy by founding an ROV club at the charter school where I will be.

— Nick Ruedig, Peon

“Something different about working on the ROV team, as opposed to working on other science oriented teams, was that everyone pulled their own weight. The willingness of everyone to work and learn was a refreshing change of pace for me. Funny, how working with capable individuals changes a team experience like ROV for the better.”

— Jonas Cervantes, CFO





Acknowledgments

Organizations

Marine Advanced Technology Education (MATE)
Oregon Underwater Volcanic Exploration Team (OUVET)

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Burcham's Metal for their generous discount on material

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SeaBotix for their generous discount on motors
CCTV.com for their generous discounts on cameras
Snap-On for their generous donation of tools
Rotary Motions Hobbies for their generous discount on motors
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Individuals

Dan Lara
Cressey Merrill
Greg Mulder
Karelia Stetz-Waters
Parker Swanson
Special thanks to Michael Tilse.

Linn-Benton Community College Departments and Student Organizations

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

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

Technical Report Team

Griffin Alberti	Li Zhang
Marcus Lopez	Jonas Cervantes
Emily Smucker	Daniel Takamori
Kyle Neumann	Nick Ruedig

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Appendix A: Other LBCC ROV Activities

During the school year and summer the LBCC ROV team leads a variety of research and outreach activities.



For three summers in a row, the team has collected rock samples from the bottom of a volcanic lake in Central Oregon to help geologists better understand the formation of the caldera.



The LBCC ROV team has held dozens of mini-ROV workshops across the state helping introduce ROV ideas and related technologies to middle and high school students and teachers. This summer the team will be putting on an underwater AUV workshop for the American Association of Physics Teachers summer conference in Portland highlighting the MATE competition and utilizing Arduino Microcontrollers.



This summer LBCC ROV student Jonas Cervantes will spend three weeks aboard the R/V Atlantis (above) helping the science team collect Ocean Bottom Seismometers (shown below) from Trawl Resistant Mounts off the Oregon and California coasts.

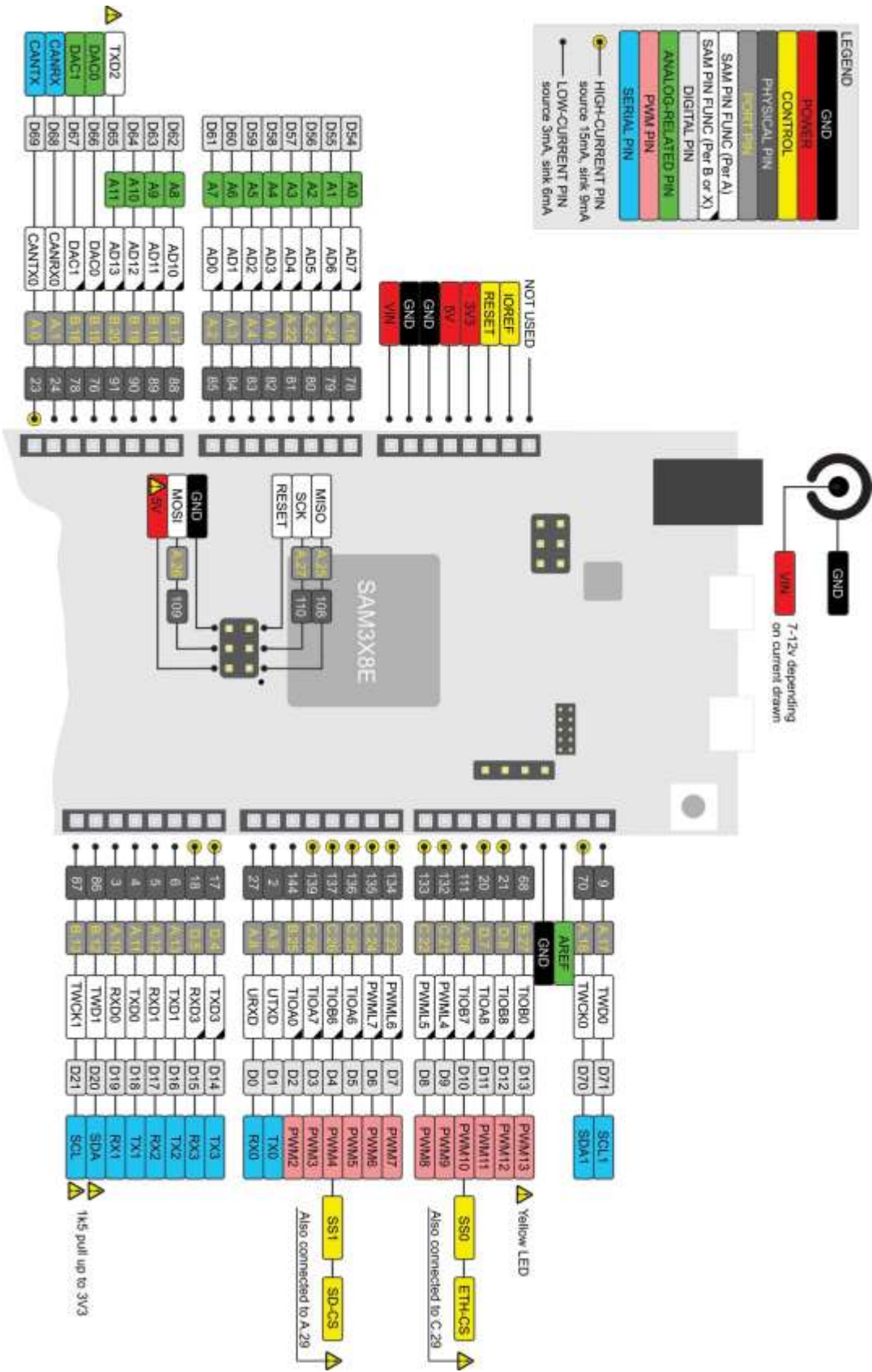


Li Zhang and Ben Dean prepare the LBCC ROV "EDO" for launch. Jesse Lowther proudly displays the team's first rock sample collected from a depth of 50 meters.



Appendix B

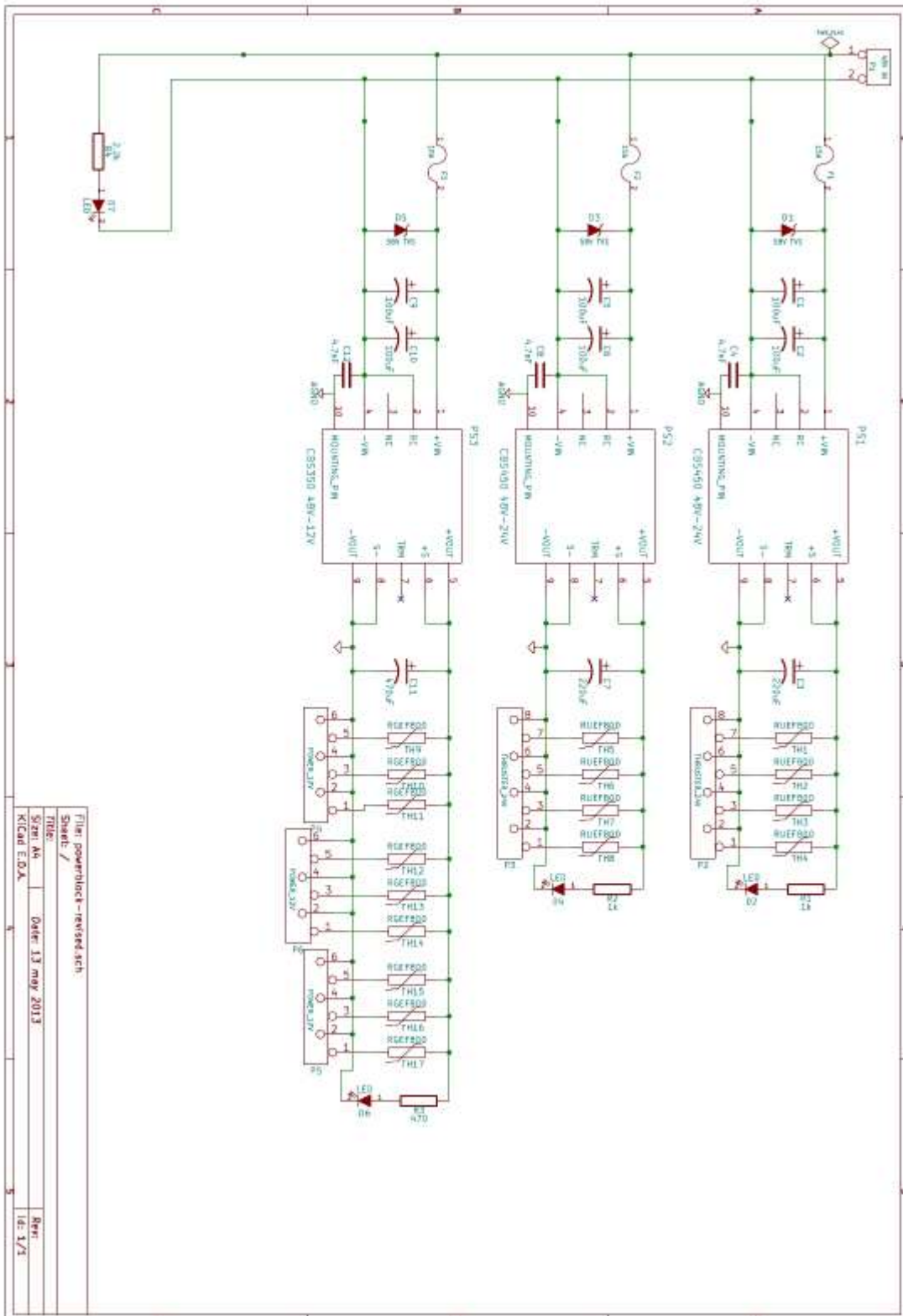
Arduino Pinout





Appendix C

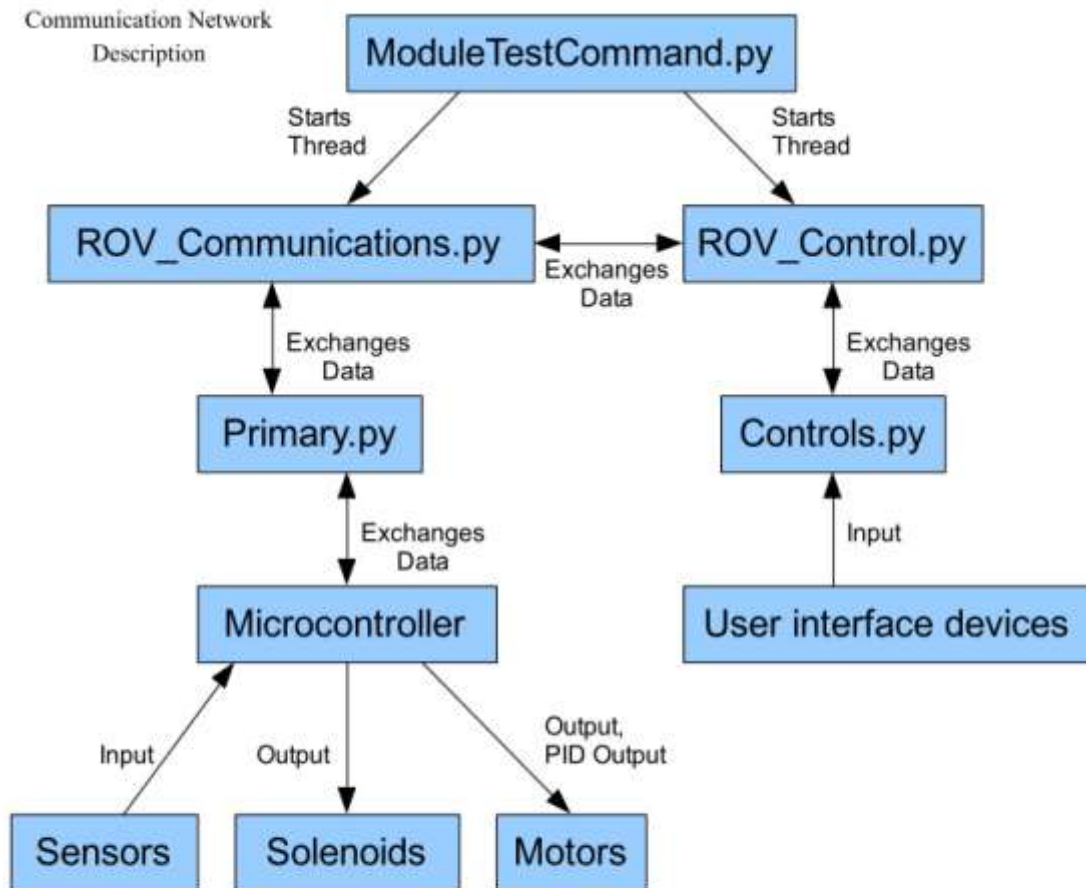
Power Block Schematic





Appendix D

Software 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.



Appendix F

Safety Checklist before starting/submerging the ROV

Safety officer is responsible for checklist completion before each mission.

- All team members are in appropriate attire, consisting of:
 - Safety glasses,
 - Team uniform,
 - Close-toed shoes.
- First aid kit is present.
- Check all connections to make sure all electrical sockets are capped or connected.
- Ensure that every component of the ROV is securely attached to the frame.
- Verify that batteries are correctly connected.
- Designate “axe-man,” ready to throw the fuse**-box switch in an emergency.
- Ensure that everybody is at least one step away from the ROV before switching the power on.

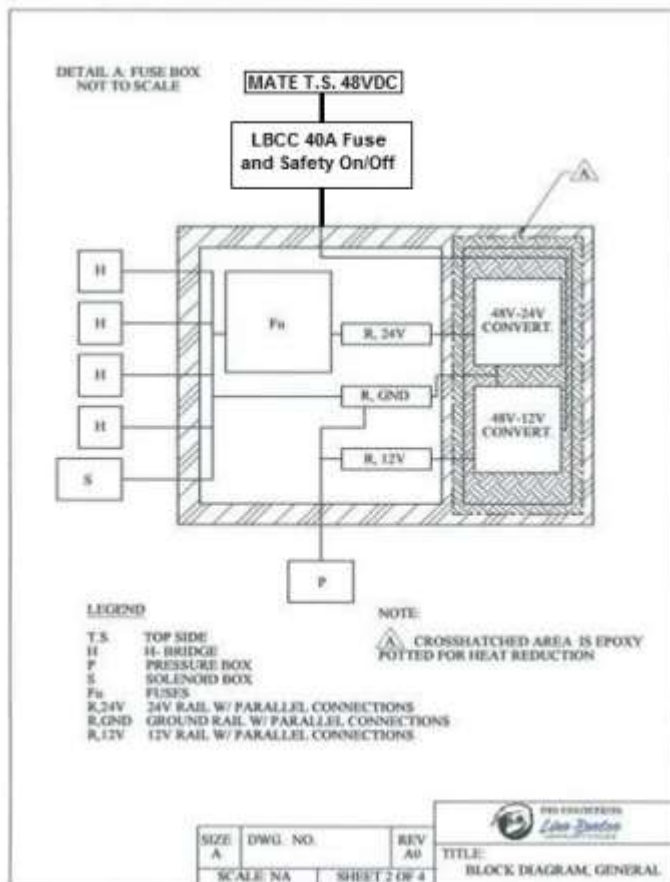
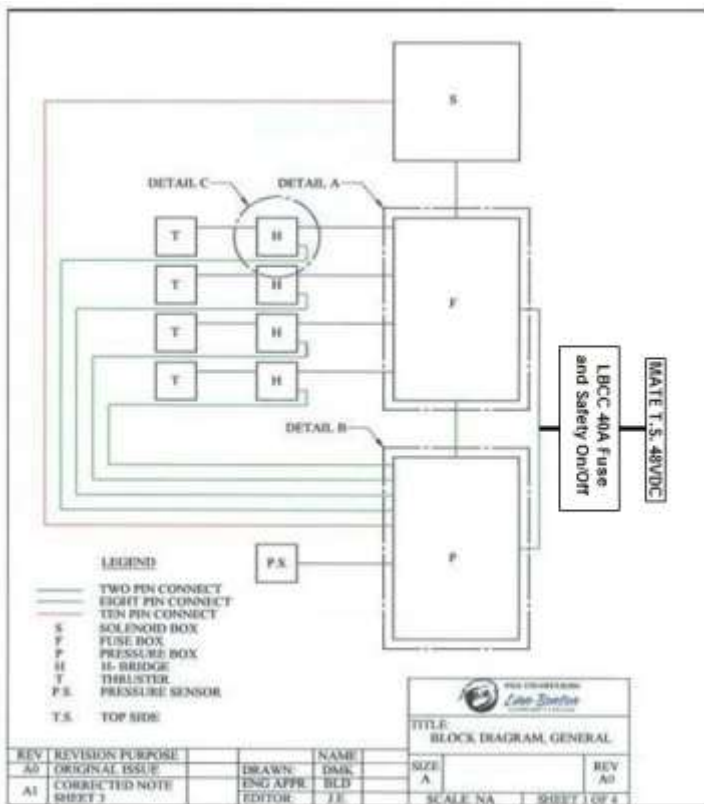
Safety Officer

Mission Date



Appendix G

Electronics Overview (left) and Power Distribution System (right)



LBCC 40A Fuse and Safety On/Off
 (to be plugged into MATE T.S. 48VDC Power Supply)