PROJECT PHENIX

PHENIX TECHNOLOGIES

2012 MATE Competition Technical Report

GEARS — Garrett Engineering And Robotics Society, Inc. — www.GEARSinc.org

Non-profit organization:
Garrett Engineering And Robotics Society (GEARS)
McHenry, Maryland 21541

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Abstract

Project Phenix is a ten-person company that provides custom robotic-engineering solutions to a wide range of clients. Its members have a long record of completing elaborate and challenging tasks on the world stage. It has never disappointed a client, and holds many industry awards.

Although Project Phenix is new to underwater robotics, it has many years of land-based robotic experience in such areas as Hockey Puck remediation, Whiffle Ball recovery, Baton transportation, and extreme Cargo Crate lifting. It has used this experience to design a robust and reliable ROV for the SS Gardner mission. Support for this mission was provided by GEARS Inc. and Phenix Technologies.

The Phenix ROV's simple PVC structure provides enough strength to exceed the performance requirements of the mission. We used Autodesk Inventor and our in-house 3D Printer to build additional lightweight mounting hardware and custom housings. We designed a custom circuit board for communications, and created original Graphical User Interface software to provide the required level of control and flexibility.

Our vectored thrust system was designed specifically to provide agility for the sonar scanning and sensor calibration tasks. We use a solenoid-controlled, pressure-activated Sampler to recover the oil sample, and a simple tape measure to determine ship length.

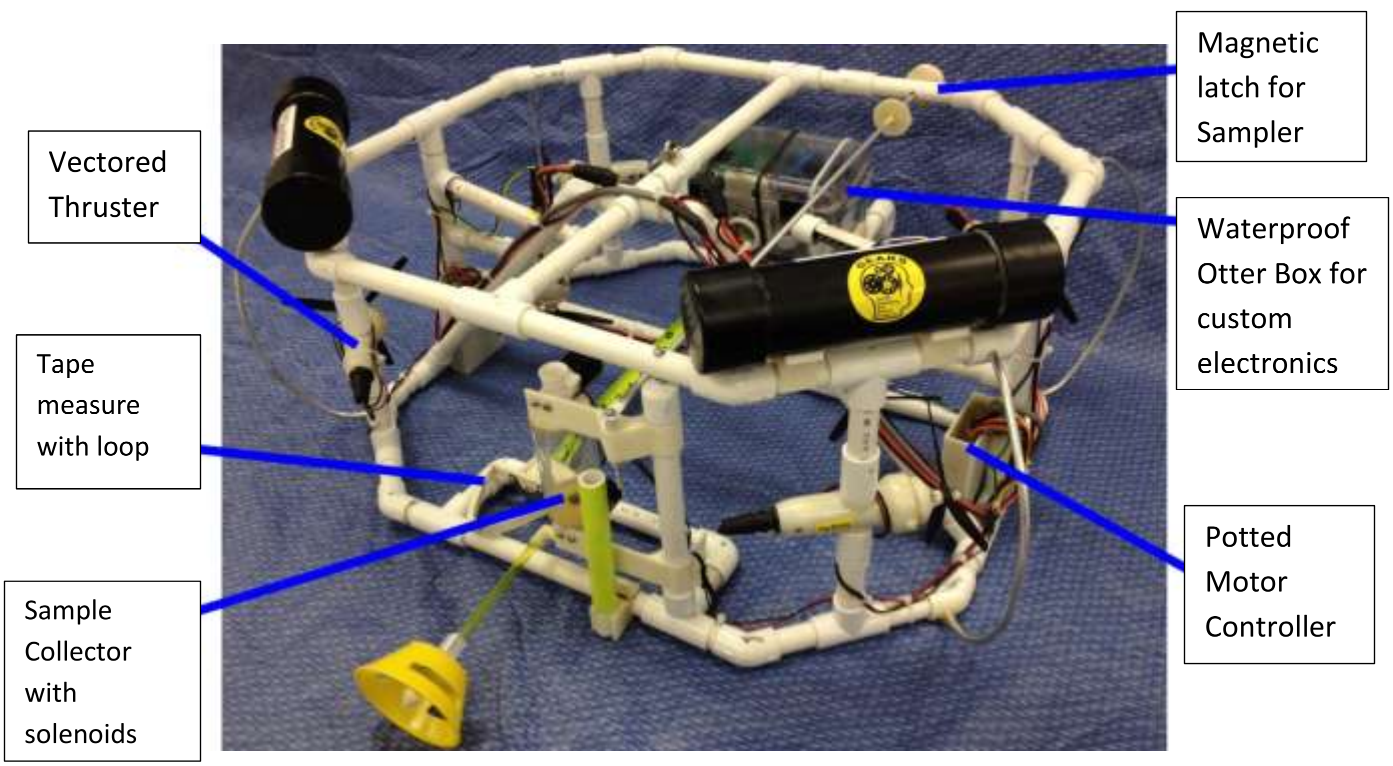

Figure 1- Project Phenix ROV

ROV Spec Sheet

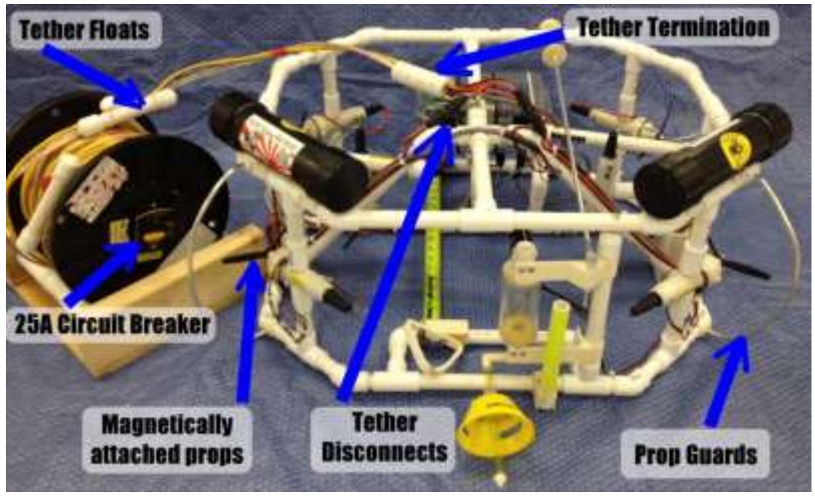

Figure 2 – Project Phenix ROV

Dimensions:

68.6cm (L) x 78.4cm (W) x 31.8cm (H)

Weight:

7.94 kg

Power system:

12V DC @ 9A max (full power)

Primary Materials:

PVC, 3D-Printed ABS Plastic components.

Cost: $1,581.00

Safety Features:

- 25 Amp Marine Circuit-breaker on tether drum – can quickly power down ROV if LEAK detector warning is displayed
- Magnetically attached props – provides a slip-clutch safety feature
- Leak detector display & alarm – to prevent electrical shock, and protect ROV electronics from water damage.
- Prop guards – to prevent thruster entanglement

Special Features:

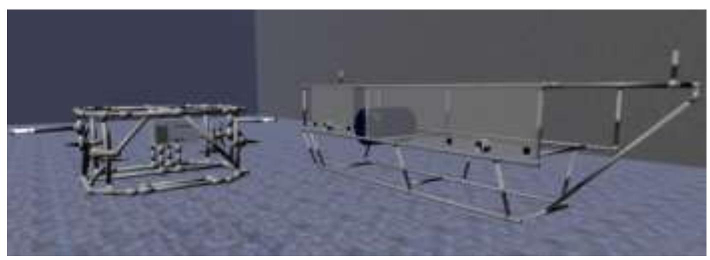

Figure 3 – 3D Simulator based on CAD model

- 3D Simulator created for pilot training
- Detachable dual-cord tether (power & Ethernet) with termination
- Ethernet based communications
- Custom interface circuit for network communications
- Custom motor controller
- Ethernet hub used to share network with cameras & Netburner
- Dual-Screen Operator-Interface programmed in LabVIEW
- Custom designed High intensity LED lighting
- Custom 3-D printed components for camera mounts and custom tools
- Pressure actuated sampling system
- Components and whole ROV were Tank and Pool tested

ROV Budget/Expense Sheet – See Appendix A

ROV Electrical Schematic

Figure 4 shows the how the ROV is powered via a single power cable which passes through a 25A Circuit-Breaker at the surface. Control is achieved via a cat5e data cable connected to a surface Laptop PC and Auxiliary Ddisplay. The Laptop runs a custom LabVIEW program to view the two IP cameras and exchange data with the devices on the ROV.

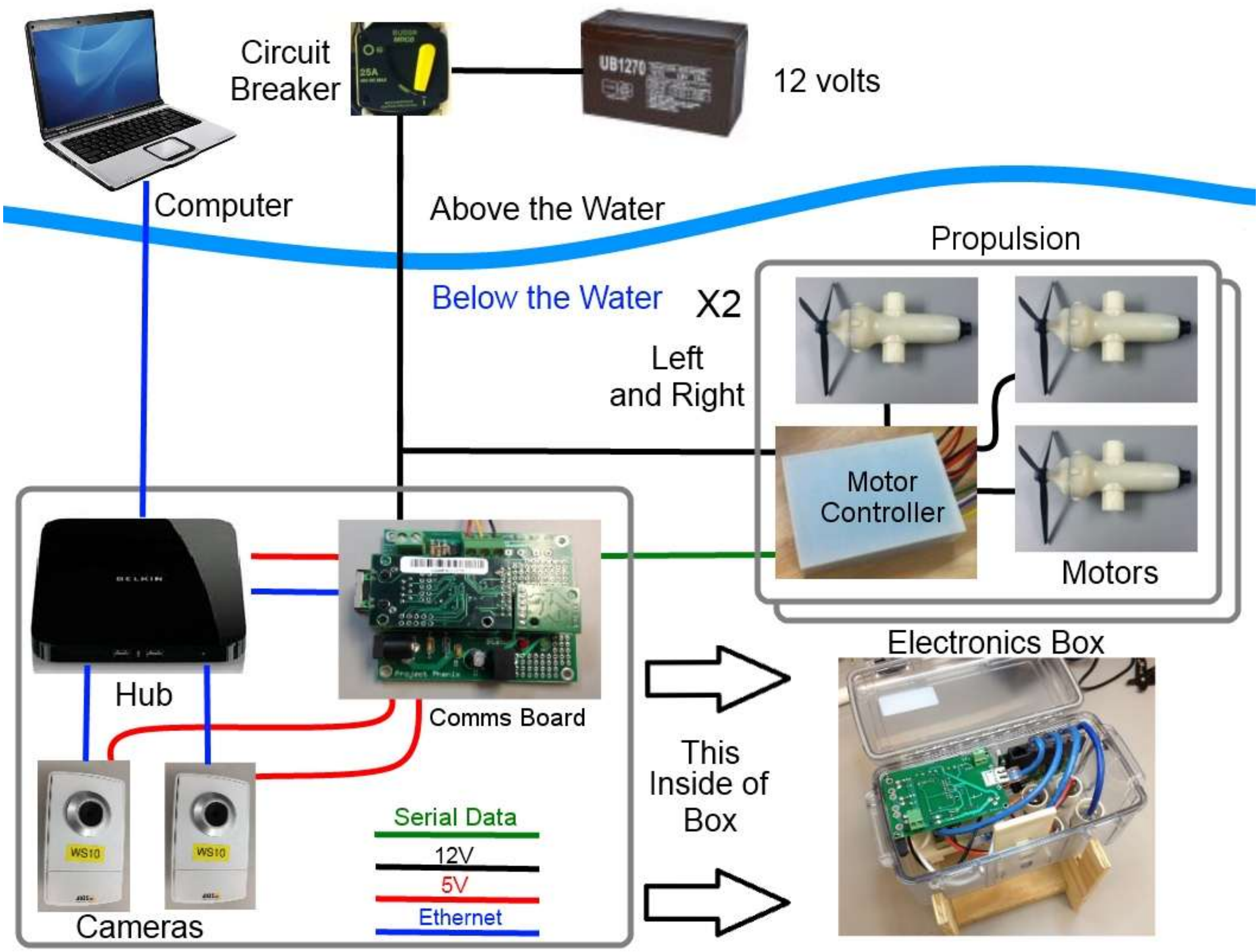

Figure 4 - Phenix ROV Electrical Schematic

Figure 5 shows the electrical schematic for the Phenix ROV's power system and control box. The Cable Spool contains a 25 Amp Marine Circuit-Breaker which is wired in series with the positive supply line. Two different power inputs may be plugged into the spool: Either a pair of Banana plugs, or a set of battery lugs.

At the ROV end of the tether, an electro/mechanical termination is used to attach the tether to the ROV, and to split out the 12V power into three sepparate cables. These feed the Control box and two motor controllers.

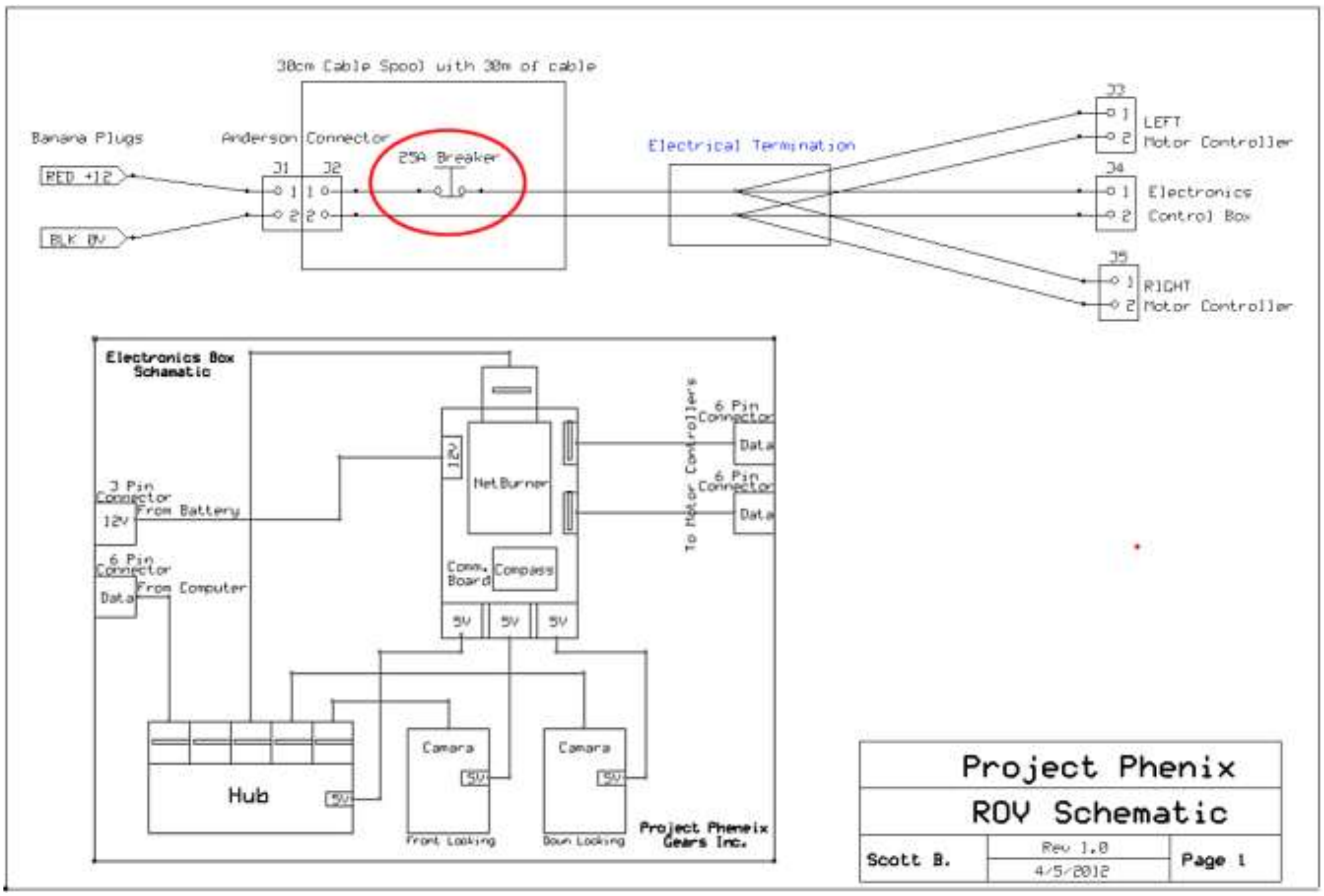

Figure 5 – ROV Power and Control Box schematic.

ROV Design Rationale:

Overall Structure and Thrusters Placement

Mobility was a key factor in the design of the Phenix ROV. Since fine positioning is required for the sonar-scanning task, we wanted to be able to move equally well in all directions. So we have used a vectored-thrust system. By setting four thrusters at 45 degrees (one on each corner on the robot), we are able to have three independent degrees of freedom (axial, lateral, yaw). The addition of two vertical thrusters provides two more degrees of freedom (vertical, roll).

The frame we built is designed specifically for the placement of the vectored thrusters. The shape is a rectangle but with the corners at 45 degrees instead of the typical 90 degrees. The horizontal thrusters are located at the middle of the 45 degree angled pipe pieces. The ROV is then able to maneuver up and down by using two additional thrusters suspended inside of the middle of the ROV. With the thrusters being in the middle of the ROV it allows the ROV to stay balanced while ascending and descending. We wanted to be able to move sideways in one swift motion; with this design it easily allows us to do so.

To prevent the torque from the thrusters twisting the ROV, we have used a combination of pusher and puller propellers so the direction of motor rotation can be reversed from the left side to the right side.

A diagonal cross brace system is used to stabilize the central tether attachment and lift point.

Control System/Electronics

One of our goals with the electronics is to be able to use them on future (deep water) vehicles. So, we decided to use Ethernet for our main communications. The main reason we use Ethernet is so we can use IP cameras, instead of standard video cameras which need dedicated video lines. IP cameras enable us to add more cameras in the future without changing the tether.

Within the ROV itself, we also have a compass (to measure the ship's heading) and two digital motor controllers that vary the voltage being applied to the 6 motors. The compass is a purchased item, and Project Kraken provided the motor controllers. Unfortunately, the compass and the motor controllers "talk" using serial data. To overcome this obstacle, we used a Netburner module (also purchased) to convert from Ethernet to serial data. To use the Netburner, we had to design and build our own custom circuit board; this board is called the Communications (Comms) board. The Comms board also contains a leak detector circuit, three 5V regulators for the cameras, and an Ethernet hub. *(See Figure 5)*

Our mentor provided the schematic for the Comms board, but a company member created the printed circuit board (PCB) layout and assembled the boards. This required learning to use express PCB, a free software program provided by the PCB manufacturer. Next year, the team will completely design their own communications board from scratch.

All the ROV Ethernet devices connect to an on-board 4-port hub, which sends the network data to the surface on a single cat5 cable.

Water and electronics do not mix, so we used a watertight “Otter Box” to keep our electronics dry. We used Switchcraft connectors to pass the wires into the control box. We drilled holes in the box for connectors, and then epoxied them in place. After connecting the wires to the inside of the bulkhead connectors, we backfill them with epoxy to ensure no water can get in. We also drilled holes in the control box for the two cameras view-ports, and then covered these holes with clear acrylic disks epoxied in place.

For safety purposes, we have a leak detector to warn the pilot if any water enters the box. This enables them to power down and do a rapid recovery to save the valuable electronics, and prevent any possibility of injury to pool personnel.

Software and Control

We decided to make our ROV a “smart” robot, meaning that our ROV has a computer at the surface that communicates with the ROV via Ethernet. The tether is just a very long Ethernet cord, plus a power cord to the robot. All of the downside ROV software was provided by either Project Kraken, or a third party vendor, so our company focused on the topside Operator Interface (OI) software. *(See Figure 6)*

We have two people controlling the robot, a pilot for flying the robot, and a copilot for using manipulators and recording the mission data. We used LabVIEW to program the OI to produce two custom displays. The company has considerable experience using LabVIEW on other land based robotics projects, but for this project, the lead programmer trained a junior member on how to use LabVIEW.

The OI performs the following functions:

- Displays the two video streams coming from the robot.
- Displays tether voltage and leak alarm coming from the ROV.
- Displays the vehicle attitude (compass heading, pitch and roll).
- Reads joystick data and calculates the data to be sent to ROV.

These are described in detail in the following sections.

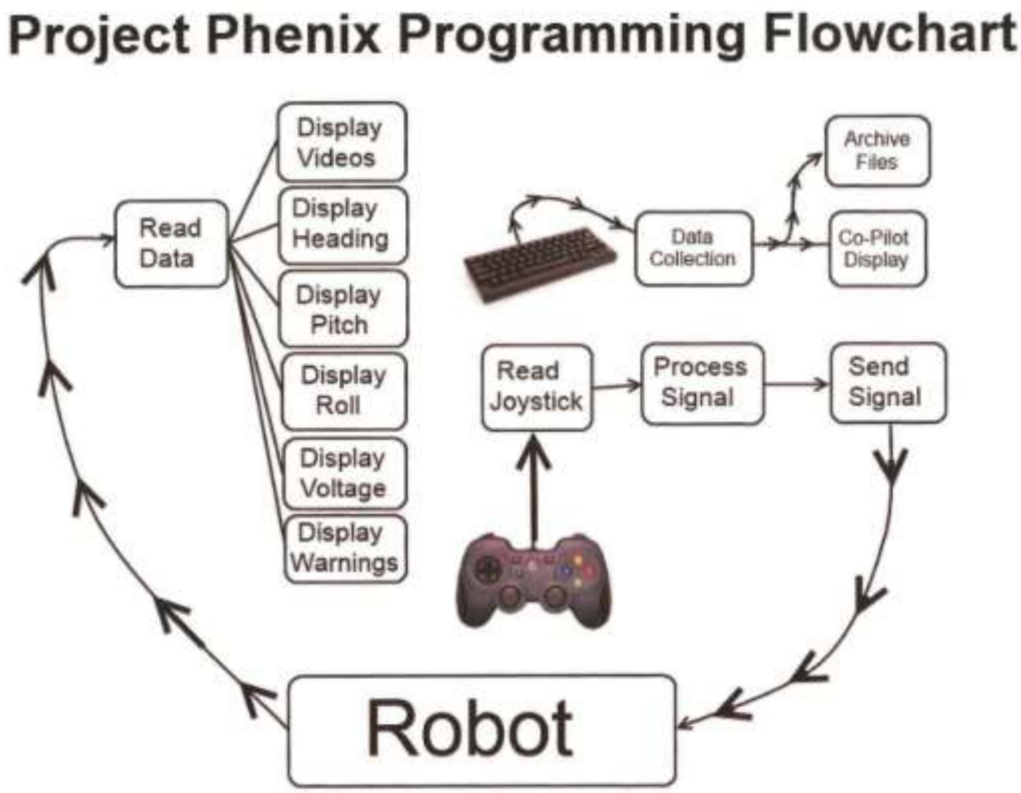

Figure 6 – Programming Flowchart

Video Processing:

Our robot has two network (IP) cameras, one pointing forward for flying and seeing the attachments on the front of the robot, and one pointing down for seeing the debris field, and reading the tape measure (for measuring the boat). On the pilot display, there is a full-sized video screen, and a preview screen. The pilot can switch between these two, depending on what he needs to see. On the copilot screen, there are two equal-sized screens, so the copilot can see forward, and down at the same time. The copilot can also take a capture of either screen, so he can take notes.

Leak Alarm/Tether Voltage:

Every 25 milliseconds, the software checks on the status of the leak alarm, and if there is a leak, half of the pilot screen becomes a red light with the word "leak" in it. It also displays the tether voltage at the ROV.

Pitch/Roll/Compass Heading:

On the copilot screen, there are gauges to tell us the robot's pitch (tilting front/back), roll (tilting left/right), and compass heading. On the copilot screen, all of these can be seen easily, the copilot can also lock the desired compass heading. On the pilot screen, the compass heading can be seen, but only when wanted, because it is semitransparent.

Controlling the Robot:

Our robot uses a vectored thrust system for movement, so the program must do the math to convert joystick axis values into thruster voltages. The four joystick axes are: axial, lateral, yaw, and vertical, these are converted into six thruster values: front left/right, back left/right, and vertical back/front. After scaling the joystick vales to the +/- range, basic addition/subtraction is used to combine the axis values to create thruster values. These are then split between commands sent to the two motor controllers.

Tether: Power and Control

Our tether has the following features…

- 25 Amp Marine Circuit Breaker/Switch for SAFETY
- 1 Power and 1 Data Cable Married Together
- Mechanical Termination at the ROV for strength and as a water block.
- Can be Disconnected from the ROV and Topside Computer
- 30 m long

These features are described in detail below.

The tether is wound on a 30 cm spool, which contains a 25 Amp Marine Circuit Breaker wired in-line with the positive power line. A 25 Amp rated Anderson Power-Pole connector block is used to plug the power supply cable into the spool. The system is shipped with two different interface cables. One with Banana plugs, and one with battery lug rings.

The tether uses 10AWG speaker cable for power and a cat5 cable for data.

A cable termination is located at the ROV end of the tether. We use this to mechanically connect the cable to the robot, split the tether into multiple cables to go to different parts of the ROV, and as a water-block to prevent water from flowing up the tether.

Since we use connectors on the power and data terminations, we can disconnect from our robot by unhooking a mechanical latch and unplugging the cables. This makes it easier to ship the robot, perform diagnostics and use spare parts in the event of a failure.

We have a 30 m long cable so after we are done with the competition we can go to one of the many lakes in our area and do some exploration.

We also needed to make the tether neutral. The team constructed hollow floatation tubes using ½” PVC pipe and end-caps, and attached them to the tether every 106 cm.

Floatation and Housings

Project Phenix decided to use an onboard electronic control system, so we wanted to place most electrical components and cameras in a single watertight control box linked to the tether.

One of the most important challenges of building our ROV was waterproofing the control systems. Project Phenix sought out the simplest and most efficient waterproof container which research showed to be the Pelican Waterproof Case. However, when our company began drilling hole for our electronics adapters, the plastic case chipped and cracked creating a potential leak. Later, it was also discovered that these cases were only rated for pressures up to 1.5 m deep. Fortunately we had not placed any electronics in yet, but we needed a new waterproofing system. Further research showed that Otter Box sells waterproof cases rated for pressures up to 30 m whose plastic was much softer for easier drilling operations. The new Otter Boxes cut easily and cleanly, allowing for good watertight seals on our adapters.

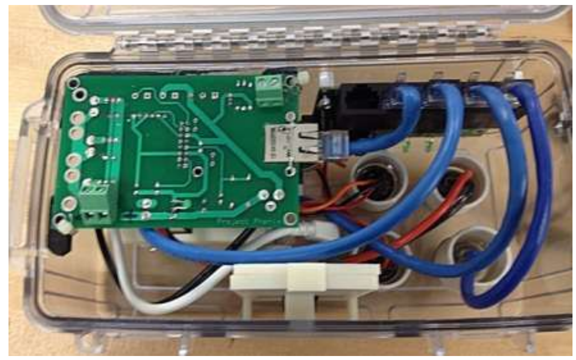

Figure 7 – Control Box Electronics

The team opted to use small connectors to form the link from the control systems inside the box to the tether and devices outside of the box. The connectors are epoxied into the control box to form a watertight seal. *(See Figure 7)* These connectors allow easy connection and disconnection from the control box, which enables swift setup and component replacement.

To mount the control box to the ROV frame, we designed and 3D printed custom mounting pieces that are glued to the control box, and snap on and off the PVC frame.

We expected achieving neutral buoyancy to be a challenge; however, the control box added a lot of flotation and made this task much easier. We needed less flotation overall because the box has such a great amount of lift.

Thrusters

We designed thrusters that were inspired by Project Kraken, our partner company. A 12V 1000 RPM gear-motor is placed in a 3D-printed plastic case which has an outer shell filled with a potting epoxy. Magnets are used to transfer the torque from the motor to the propeller across a thin aluminum end-plate. The thruster has a cable and connector attached to the motor, which exits the housing through a potted end, to create a watertight seal. A cable travels from the thruster to one of our two team-built motor-controllers. The motor controllers are contained in 3D printed ABS boxes filled with 3M epoxy. Each motor controller can run 3 thrusters, 1 auxiliary motor, and 4 simple on/off devices. The controllers have data and power cables connected to them. These cables plug into the control box.

Challenges

Overcoming mounting issues

Attaching items to the PVC frame was challenging. It was difficult to mount items with flat surfaces to the round pipe. Gluing was not always an option because several positions needed to be tested to determine the best placement. To solve this challenge, we designed a range of universal connectors, using Autodesk Inventor, and then fabricated them with our in-house 3D printer. *See Figure 8.*

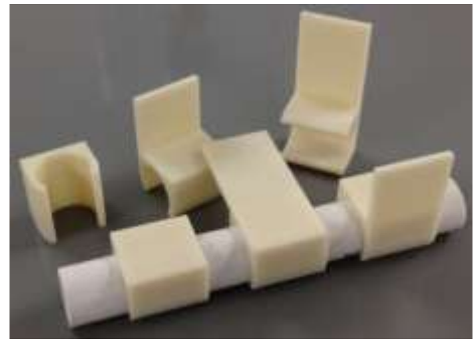

Figure 8 – Custom 3-D Printing

The first piece was a simple PVC clip that we can snap on ½ inch PVC pipe. This clip has a square top that can be glued anything with a flat edge to it. The mounted piece can then be relocated by rotating or sliding. One of these clips is glued to the bottom of the electronics box.

The second clip used the first clip as a base, and had a leg coming off the top. One of these clips is glued to side of the electronics box. A third variation also used the first clip as a base but it has a 10 cm leg coming off the side of the clip. We used this clip on the bottom of our sampler.

Cameras that won't fit in the case

Another technical challenge was mounting the two cameras in the electronics box.

Figure 9 – Custom 3D Printed Camera Housing

The camera was too tall for the electronics box in its normal housing. So, to fix this, we designed a 2-piece replacement mount. *(See Figure 9)*. The mount was designed on Autodesk Inventor and printed on our 3D printer. The housing comprises of two plates which sandwich the camera for more compact mounting. The front plate has three legs coming off the front so we can glue it to the inside of the Otter Box. The back plate has four snap latches (one on each sides) so we can cut off any two of the latches and use the other two to attach the back plate to the front plate sandwiching the camera in between.

Working as a team

Another challenge was producing this technical report, since it required input from all company members. To solve this challenge, the CEO (Levi) broke down the report requirements into topics, and assigned each topic to the most logical contributor. Some topics (eg: reflections) were assigned to all members. As each member produced their portion, they were assembled into the final report. This was then checked against the scoring document to ensure that all bases were covered. The final report was then passed to the two mentors for proofing.

Troubleshooting Techniques

Our company uses the following troubleshooting technique:

(1) Identify the problem,
(2) Hypothesize the cause,
(3) Test the hypothesis,
(4) Propose a solution,
(5) Implement solution,
(6) Verify that the problem is resolved.

One significant issue occurred that we had to troubleshoot just days before the competition. Our thruster power started becoming erratic, and we weren't able to fly at full power. The thrusters kept cycling on and off.

We performed various checks at the pool to try to identify the problem. The video feed from the robot was fine, so we knew there was not a general communications failure since both the cameras and thruster control use the same Ethernet cable. However, the thrusters would work fine if only one or two were run at low power, so we knew that the serial data to the controllers was working.

All thrusters seemed to exhibit the same problem, and since we have two independent motor controllers, we felt that these were not the problem (two identical failures seemed unlikely).

The key piece of information that helped us Identify the problem was the tether voltage in the ROV. We monitor this in real time, and display it on the pilot's screen. Whenever we would attempt to fly hard, the voltage at the ROV would drop to 7 or 8 volts. Yet, when we measured the battery voltage at the surface it was a solid 12V. So the problem had to be in the tether's power cable.

We hypothesized that a high resistance in the tether was the cause. When we returned to the shop, we measured the resistance of the tether power cable and saw that the negative side was 0.1 Ohms, whereas the positive side was 1.5 Ohms. By measuring all along the cable, we determined that this higher resistance was distributed evenly along the cable. With a motor load of 4 Amps, this 1.5 Ohms would result in a voltage drop of 6V which is what we had seen in the pool.

We determined that the ultra-fine stranded wire we had used, had corroded over time, and was slowly increasing in resistance. Only the positive side was affected because the negative side was tin plated, which corrodes less. Our only solution was to replace the power tether. We ordered a new cable with course strands. We rebuilt the tether and verified the proper resistance and motor operation at full power.

Payload Description

Lift bag Delivery: Delivering the lift bag and attaching it to the mast is a difficult and troublesome mission. When the bag is attached to the ROV it affects the weight and natural buoyancy. Since this is affected so greatly the mission needs to be accomplished extremely quickly. In order to attach quickly we need a good and consistent connecting mechanism. We decided to use strong magnets connected to aluminum and connected them to a C-clamp that connects to the lift bag. The magnets allow the bag to quickly snap onto the mast's U-bolt and we have a sturdy hold every time.

Oil Sample: Another major payload for this mission is the oil sample taken from the SS Gardner. We designed a custom sampler specifically to recover the oil and return it to the surface.

We started out using a plunger and screw mechanism. After designing it in Autodesk Inventor, we decided that this design was just too complicated to build. So we took another approach.

Our company decided to use the properties of liquids and forces. We discovered that a chamber filled with air placed underwater would have greater pressure on the bottom than the top. If both ends of the chamber were opened at the same time, the pressure of air leaving the chamber would pull liquid from the bottom opening to the top. We created a sample container with a 10 cm long piece of clear 5 cm diameter acrylic plastic. We drilled 2 small holes in a thin piece of ABS plastic and cut out a 5 cm circle around each of them. We threaded these holes and screwed in some pipefittings that would allow us to attach a solenoid valve on each end of the container. The thin caps were epoxied onto each end. We sealed the threads with plumbers tape and screwed on the solenoids. This made the container. Then we simply attached a long, rigid sampling tube to an elbow and screwed the elbow onto one solenoid. We attached the sampler to the ROV and it holds 150 milliliters, 1.5 X what is required to get the maximum score.

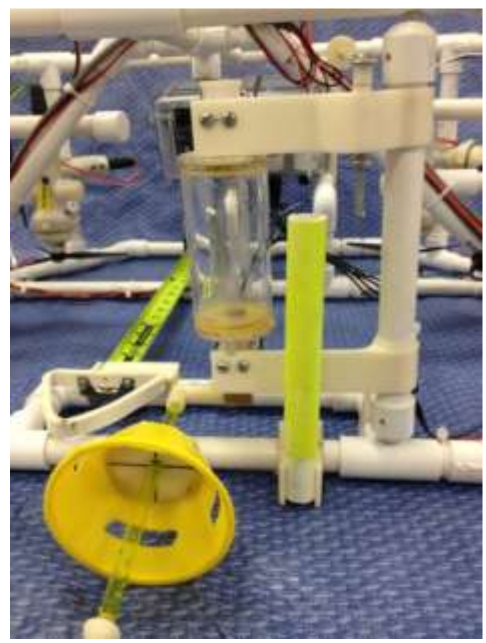

Figure 10 – Oil Sampler Chamber

The function of the solenoids is to keep the air in until we want to take a sample and then to keep the oil in until the mission is over. We tested a prototype of the design in a tank and it worked well. Then we attached the sampler to our prototype ROV and tested it again in a deeper pool. It worked even better. We were able to take the required sample in about 20 seconds.

Note: This technique of testing the component independently in the tank, and then in the pool as part of the robot, was used for all of the attachments and systems.

Since the long sample tube is a flying hazard when it sticks out the front of the ROV, we devised a method to stow the sample tube inside the ROV until we were ready to use it. The sampler is mounted on a pivoting strut, and attached by a custom support clip. This clip includes a triangle with a hole in it coming off the top of the clip. The hole in the triangle is used to attach a push rod that extends out the rear of the ROV. The pushrod is activated by backing the robot into a wall and pushing the rod in. This rotates the sampler 90 degrees into its active position, where it is lathed in place with magnets. *This mechanism is shown Figure 10.*

Future Improvements

Pressure Gauge

One component that we didn't include in this year's robot design was a pressure gauge since it was not necessary for this year's challenge or for navigating in a swimming pool. But for future challenges or for navigating in local lakes and ponds a pressure gauge would be just as helpful as a compass. Unlike our compass that is built into the Netburner module that is a sealed control box, a pressure sensor needs to be exposed to the pressure of the water. The dilemma that we then run into is how to expose the sensor to the water pressure but still keep the sensor waterproof. We will design a sensor to be waterproof so we can feed the output to the Comms Board. This will give us a more accurate and faster depth/pressure reading.

60 Meter Tether

A 60 m tether would not be necessary for the MATE challenge but it would be completely necessary for exploring our local lakes which exceed 100 m depth. 60 m is what we are limited to with our current design because the Otter boxes will fail if we go deeper.

The biggest challenge that we could encounter with a 60 m tether is voltage drop on the power wire. To overcome this we could use a heavier gauge wire or design a module to boost the voltage back up to 12 volts. Designing a module to boost the power back up to 12 volts in the ROV would be the best solution due to the fact that heavier wire is expensive and weighs more. With our tether only consisting of a power wire and Ethernet cord building a longer tether using the current set up is as efficient as we can make it. Hopefully the 60 m tether will come into play this summer after competition.

Wireless Cable Drum

Everyone who has ever built an underwater robot has encountered the problem of building a rotating drum with rotating slip joints for power and data wires. To eliminate this problem we want to put a battery (for non-competition use) and a router inside the cable drum so we can eliminate the rotating joints and we can manage our tether more efficiently. For the competition, we will have to have a two-conductor slip joint due to the fact that we utilize the power provided. Building a wireless cable drum will also let us add on a motor to control the length of the tether. Future improvement beyond building and incorporating a wireless cable drum include using the pressure sensor to automatically manage the length of the tether.

Lessons Learned

Technical

Scott: For us to use some of the components we needed to make our own custom circuit boards. So I learned how to use express PCB. I worked on the communications board; which has the NetBurner, compass, and 5v regulators. I learned many very useful things doing this, including: what different components do and how they work and what strategy to use when laying out a Printed Circuit Board. After accidentally blowing up a circuit board, I leaned about the importance of polarity, and having someone check your work.

Alex: My lesson learned this season was soldering. I very much enjoyed this experience. I am now pretty good at soldering and I really enjoy doing it. Whenever there is the chance to solder I always try to do that task. When I first began to solder, I would apply to much solder on the wire but now I am able to apply just the right amount.

Levi: I helped make the lights for the ROV. I learned how the water deflects the light rays differently and makes the camera field of view smaller.

Aaron: I learned how to use Express Schematic to design the LED light circuit. I then used Express PCB to layout and build the circuit.

Kevin: I learned that the differential pressure between the top and bottom of the sampler chamber forces the air out of the top as it sucks the oil sample in through the bottom.

Interpersonal

Scott: I learned that you have to trust your teammates to do the jobs they are assigned to do, and you focus on your job. All in all, it was well worth the time and energy I put into it.

Zach: I learned that clear communication is essential. I also learned to prepare for mechanical failure because it will happen. When it does turn to your team for suggestions and support.

Aaron: I worked with Scott to layout and design the printed circuit boards on the robot. By working together, we were more efficient in finding possible flaws.

Reflections

Zack: As project Phenix's first year, I feel that we been very successful. I learned a lot about waterproofing and fluid technologies. I am looking forward to next year.

Alex: The experience on Project Phenix was completely different from anything I have done before. There are issues on the ROV that are not on land robots. For example, water proofing cameras and electronics. I really enjoyed putting together the frame and cutting most of the PVC pieces. But my favorite was when I flew our ROV for the first time in the pool.

Teamwork

This company has pulled together as a professional team in all aspects of the ROV design, fabrication, testing, improving, and performing. Member responsibilities were agreed on as a team and everyone followed through. The team members have drawn on their past FIRST World Championship robotic experiences to make this Project Phenix Company a success.

The following is a brief schedule the team used to monitor their weekly goals and progress:

Meeting Date	Goals
9-Dec	Overview of rules and thinking about team Positions**
12-Dec	Finialize team Positions and Student overview of rules
19-Dec	Brainstorming Frame**, Missions, and Electronics**
2-Jan	Sketching ideas, start building frame, test Pelcin Case for leaks
9-Jan	Finish frame prototype; begin work with programming, electronics, and missions
16-Jan	Test OtterBox for leaks; programming, electronics, and mission protyping
23-Jan	Work on camera mounts, test waterproof plugs for OtterBox, look for small router
30-Jan	Figure out placement of electronics in OtterBox
6-Feb	ROV prelim wiring done
13-Feb	Program GUI Prototype Finished
20-Feb	Test ROV in tank at GEARS
19-Feb	GEARS & 4-H Robotics Open House - Talk to the public about MATE, our ROV and missions
20-Feb	Assign & work on Spec Sheet & Tech Report duties**
27-Feb	Follow up on Spec Sheet & Tech Report questions, continue ROV mission work
5-Mar	Protype test in tank, work on Spec Sheet & Tech Report weekly
12-Mar	Complete programming Version 1
19-Mar	Test attachments in tank at GEARS
26-Mar	Complete tether and modify attachments
2-Apr	Test electronics in OtterBox
9-Apr	Seal electronics box and attach to ROV for final time
16-Apr	Test attachments in CARC Pool
23-Apr	Finish last modifications of mission attachments to be ready for pool next week & determine the two drive teams
30-Apr	Test ROV at CARC, practice missions, return to GEARS to critique our missions & tweek final version of programming
7-May	Test ROV last time in CARC and pack tools and equipment
12-May	Compete in the PA Regional MATE Competition in Philadelphia, PA
14-May	Evaluate mission, poster, tech report, presentation, set goals for improvements & get to work on them & parent meeting to plan trip
21-May	Continue ROV modifications, do final updates on spec sheet & tech report, practice flying ROV in CARC pool
28-May	Happy Memorial Day - ROV flying practice in CARC pool (7-9 pm only)
4-Jun	Last day for modifications (1-7 pm at GEARS), test flying at CARC
11-Jun	Dairy Queen Spirit Night fundraiser, ROV talks, final flying practice at CARC pool - pack up, robot leaves on June 14th - FL bound!
June 20-23	Compete in the International MATE Competition in Orlando, FL
8-Jul	Family picnic & ROV flights to explore the Mt. Storm Lake!
	Mondays, 4:30 - 8:30 are main meetings at our GEARS (Garrett Engineering and Robotics Society) Center, there were some weeks that we met on Thursdays, but those were off meetings with small subgroups.

Acknowledgements

We would like to acknowledge the efforts of several people/groups:

- The MATE Center and personnel for making this competition possible.
- Our Mentor Mr. Phil, for starting this team and guiding us through the process. Instead of settling for a simple ROV that would just perform the mission, he pushed us to create a more capable ROV that we can use to explore real lakes and ponds.
- Our Mentor Ms. Arlene for coordinating travel, ensuring that we all attended our meetings, and encouraging us to be the best that we can be.
- Our Mentor Mr. Josh for helping the Payload group with sticky mechanical problems.
- Garrett Engineering and Robotics Society, for being the primary support organization for the team, and providing resources in the way of tools, materials, and an excellent test tank.
- Phenix Technologies (for whom our company and robot is named) for providing financial support. We greatly appreciate that companies like Phenix see the value of providing advanced training to today's youth. Learning comes from schools; understanding comes from being immersed in a challenging activity like the MATE competition. The result is that everyone benefits.
- Garrett College for assisting us with a space to construct our ROV, and access to an excellent pool for practicing our missions.
- Project Kraken, our partner company, with whom we shared ideas, and component designs.

Figure 11. Project Phenix Discovering that hard work really is rewarding.

Appendix A: ROV Budget/Expense Sheet

Item/Subsystem	Description	Source	Cost	Donated?
Tether				
	Power Cable	Mouser.com	$ 64.00	Y
	Ethernet Cable	Mouser.com	$ 15.00	Y
	Circuit Breaker	West Marine	$ 35.00	
	Plugs, Connectors	Mouser.com	$ 25.00	
	Termination	Lowes	$ 10.00	
	Potting Compound	Mouser.com	$ 50.00	
	Floatation	Lowes	$ 20.00	
ROV Frame				
	PVC pipe/connectors	Lowes	$ 150.00	
	3D Printed brackets and accessories	Garrett College	$ 50.00	Y
	Epoxy Glue	Lowes	$ 20.00	
	PVC Adhesive	Lowes	$ 25.00	
	Otterbox (Electronics housing)	Otterbox	$ 35.00	
	Floatation	Lowes	$ 30.00	
	Bolts & Nuts for Ballast	Lowes	$ 20.00	
Electrical				
	Cameras M1011	Axis Communications	$ 250.00	
	Network Hub	Dlink	$ 35.00	
	Comms Board	Various	$ 111.00	
	Connectors	Switchcraft	$ 110.00	
	Cable	Mouser	$ 50.00	
Propulsion				
	Thrusters	Project Kraken	$ 336.00	
	DC Motor Controllers	Project Kraken	$ 140.00	
Tools				
	Clear Acrylic Tube	GEARS	$ 10.00	Y
	Solenoids	West Marine	$ 25.00	
	Assorted Aluminum	GEARS	$ 50.00	Y
		ROV Cost	**$ 1,581.00**	
Control Station				
	Laptop Computer - Samsung	Best Buy	$ 990.00	
	51 cm Flat Screen	Best Buy	$ 99.00	
	Logitech Game Controller	Best Buy	$ 25.00	
		Control Station Cost	**$ 1,114.00**	

Appendix B: Breakdown of work done by other entities.

Two related MATE companies: Project Phenix (High School) and Project Kraken (College) formed a corporate alliance to improve both companies' chances of winning the bid. This is *Coopetition.

The two companies worked in a loose partnership to each design and build parts that are also used by the other company in their ROV. In this way, both teams benefit by having access to advanced parts, not commercially available at a reasonable price. Both companies incorporate the shared components into their own unique and independent ROV designs. The table below shows what parts were uniquely developed, by whom, and how they were shared.

Development Key
Independent element designed by this team.
Element designed by this team and shared with partner.
Joint design fabricated by both teams.
Element provided by partner team.
Mentor designed component
Third party purchased item.

Project Phenix		Project Kraken
Topside Control Software		Topside Control Software
Topside Display Software		Topside Display Software
Cable Drum & Power Interface		Cable Drum & Power Interface
Tether		Tether
Tether termination		Tether termination
ROV Frame		ROV Frame
Waterproof Housing		Waterproof Housing
Control Box Layout		Control Box Layout
Communications Board	-->>>	Communications Board
Cameras		Cameras
Camera Housings	-->>>	Camera Housings
Mounting Brackets	-->>>	Mounting Brackets
Network Hub		Network Hub
Motor Controller Board		Motor Controller Board
Motor Controller Software	<<<--	Motor Controller Software
Magnetically coupled Thrusters	<<<--	Magnetically coupled Thrusters
Manipulators		Manipulators