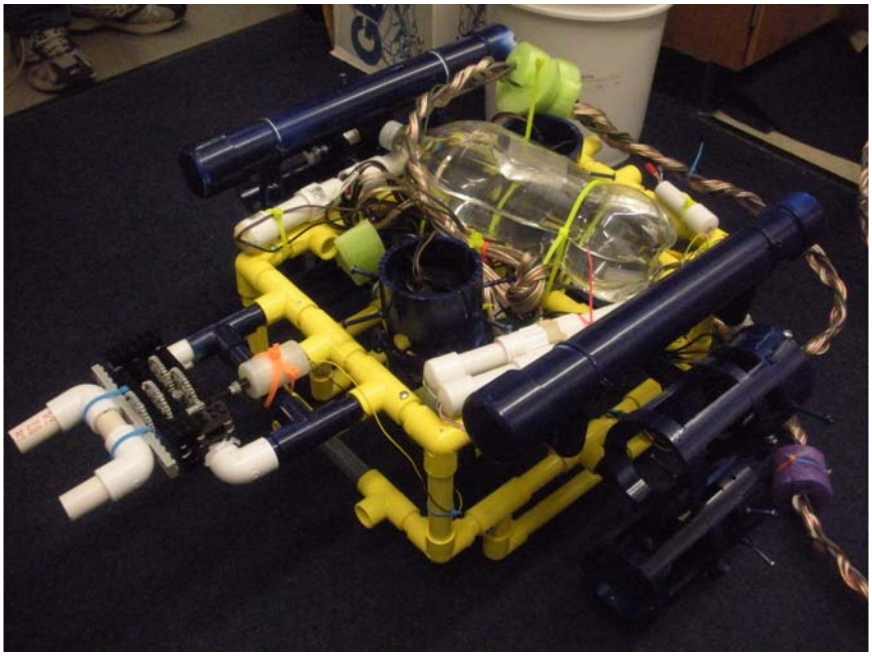
The Lincoln Group

The Narcoleptic Pelican



Gahanna Lincoln High School
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Team Members:

Name	Role	Grade	Future Plans
Sanchi Arora	Communications	11	Industrial Systems Engineering
Ainsley Baum	Pilot	12	Biomedical Engineering
Chris Chang	Research	11	Biomedical Engineering
Jeff Chen	Builder	11	Electronics Engineering
Houston Fortney	CEO, Electronics	12	Electrical Engineering
Nathan Hammonds	CFO, Tether Manager	11	Robotics Engineering
Zach Koors	Builder	11	Mechanical Engineering
Adam Motsinger	Builder, Pilot	12	Aeronautical Engineering
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Katie Sharkey	Communications	12	Mechanical Engineering
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Under the mentorship of: Fred Donelson

Abstract

The Lincoln Group has created a Remotely Operated Vehicle (ROV), affectionately duped The Narcoleptic Pelican (TNP), to compete in the 2011 Marine Advanced Technology Education (MATE) competition. The tasks that TNP will complete during this competition include: removing and repairing a riser pipe, closing a well valve, and collecting samples of saltwater and specimens.

TNP possesses numerous features to accomplish these jobs. Made from PVC, the ROV has the approximate dimensions of 100 cm by 165 cm by 44 cm and masses at 9.5 kg. Two cylinders of air and one adjustable aluminum bottle provide floatation for the ROV while foam floats provide the tether with buoyancy. TNP employs four lateral and two vertical thrusters for its movement. Furthermore, the team created a controller system made from Lego NXTs in conjunction with MOSFET H-bridge boards in order to give pilots analog control of the drive motors. The design of TNP is modular, meaning it contains a basic frame on which tool packages can be interchanged. Tool packages used to accomplish its mission include a gripper, a spinner, a barometer, and a suction sampler.

To create TNP, the Lincoln Group spent more than 800 hours designing, building, testing, and practicing. The process tested the team's ability to work together and fix problems, but in the end the team was able to successfully troubleshoot any problems, gain new skills, and ultimately produce a high quality product most suited for the challenge presented to us.

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Design Rationale: ROV Components

When the Lincoln Group created The Narcoleptic Pelican (henceforth TNP), it decided to plan its design around a set of principles that it believed would create the best possible ROV. These principles included: to condense the ROV's size, to create a modular design, to build with inexpensive parts, and to create a hydrodynamic, maneuverable robot. These principles, after months of building and testing, resulted in the final ROV seen in ***Picture 1***.

*(**Picture 1**: TNP, as of May 1, 2011)*

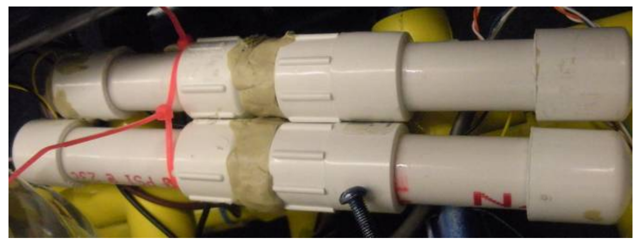
Frame

The frame of TNP consists of a rectangular prism made of half inch PVC with six ports (unused T-joints) on its front and back, as well as two pieces of 38 cm, one and a half inch capped off PVC and an adjustable water bottle to provide buoyancy to the ROV.

By using PVC, the Lincoln Group was able to build a cheap and effective ROV while keeping a few main goals in mind. First, its condensed nature makes it hydrodynamic, allowing water to flow through the ROV and reducing drag. Also, its lateral thrusters provide a good mixture of torque and speed when turning, increasing its maneuverability. Third, its air-filled PVC buoyancy allows it to travel deeper than previous designs that relied on "noodle" floatation. Most importantly, it provided a total of twelve ports on which to attach tool packages. With this large number of ports more options existed for where to place and how to design tool packages. In essence, the design fit into the team's idea of modularity.

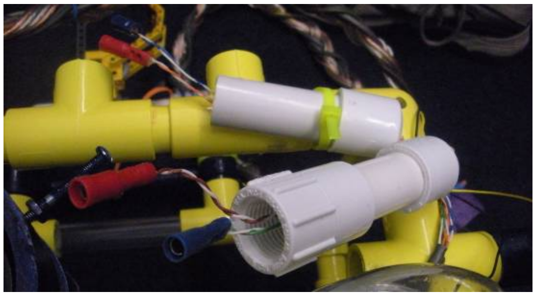
The aspect of modularity is one of the most important aspects of the ROV. This concept allows for ease of access to tool packages. Tool packages can be swapped and be placed anywhere on the robot. This is especially useful in the event of a tool package malfunction; a backup can be easily put onto the robot so that the mission can continue without a hitch.

Waterproof Electrical Connectors

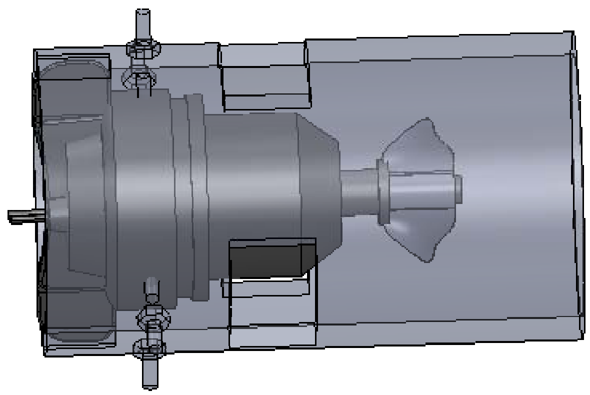


(***Picture 2**: Waterproof electrical connectors, sealed*)

To allow for complete modularity of the ROV's tool packages, waterproof connecters (see ***Picture 2*** and ***Picture 3***) were required to allow active tool packages to be interchangeable. We developed inexpensive waterproof connectors using PVC pipe and fittings. These connectors are constructed by placing a PVC cap on a five inch long (12.7 cm) piece of half inch PVC pipe. A hole is drilled into this cap to allow wires to be passed into the chamber. Then epoxy is poured into the capped end of the pipe and allowed to cure. On the other end of the pipe, either a male or female threaded coupling is attached with PVC cement. Finally, whatever standard electrical connectors are desired are soldered onto the wires. The two sides of the connectors are mated and waterproofed with plumber's putty. These connections have been tested underwater for over 30 hours at various depths and have not leaked.



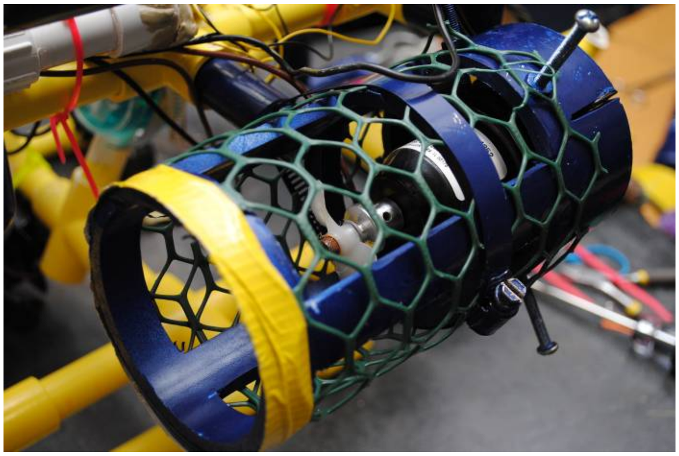
(***Picture 3***: *Waterproof electrical connectors, open)*



(***Picture 5***: *3D model of a motor in an old shroud design)*

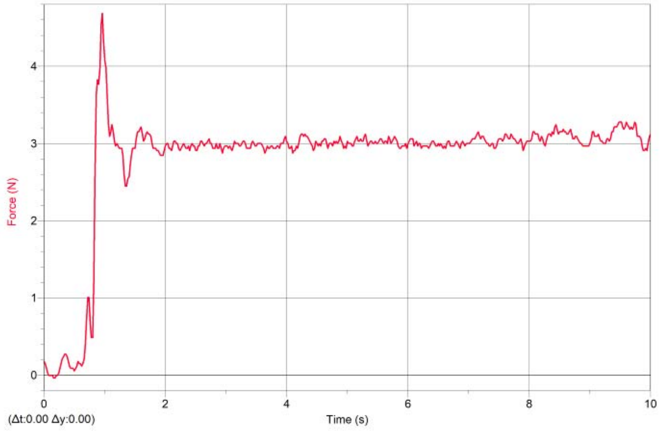
Propulsion

Six thrusters propel TNP in its respective directions. Four 1250 Johnson GPH bilge motors control the ROV’s lateral movement while two West Marine Bilge Pro 600 GPH bilge motors command the machine’s vertical motion. To create the motors, the team attached two bladed, two centimeter diameter propellers. Also, to increase the safety of the motors, the Lincoln Group added motor shrouds made from cut lengths of three inch (7.6 cm) PVC pipe around each of the motors, and surrounded them with plastic chicken wire. To allow more water to flow past the motors, large rectangular holes were cut into the shielding. The final design can be seen in ***Picture 4*** and a 3D model of a motor in a early design of the shroud can be found in ***Picture 5***.



(***Picture 4***: *Motor in shroud)*

A bollard test was run to test the thrust of the motors (a graph of one of the test can be found in ***Graph 1***). Without shrouds, the motors outputted 2.8 N of thrust forward and 1.5 N backward. With shrouds, the forward thrust remained relatively the same at 3 N and the backwards thrust reduced to 1.25 N. For all of the tests, the motors drew 2.15 amps.



(***Graph 1***: *Bollard test on a 600 gph motor, forward, in shroud)*

Cameras

TNP possesses two X10 Anaconda cameras *(*see ***Picture 6****)*. The team chose these cameras for multiple reasons. As far as cost, one can buy X10 Anaconda cameras commercially for 40 dollars each, relatively inexpensive as compared to other underwater cameras. The cameras were potted by hand in plastic vials with epoxy, and their built-in

60 foot cable made them easy to install. The cameras were potted in colored epoxy to make sure they are waterproof, and their RCA video jacks can easily link them to video cameras to record during missions. Another advantage of the cameras, their ability to image in color, allows objects to stand out better than black and white cameras, making missions easier to complete. To supplement the cameras' ability to view in color, TNP possesses two LED lights in order to see objects better, even in well-lit pools.

*(**Picture 6**: Potted camera)*

The Lincoln Group placed its cameras so as to maximize their effectiveness. The first camera faces towards the gripper and is used for tasks in which the gripper is needed. The second camera faces the opposite direction and has a long-range view of the area as well as a view of the spinner tool package and barometer. Having these two cameras allows TNP to be bidirectional, meaning the ROV can be operated effectively in both directions. This allows for a much higher degree of flexibility and the ability for more efficient tool packages.

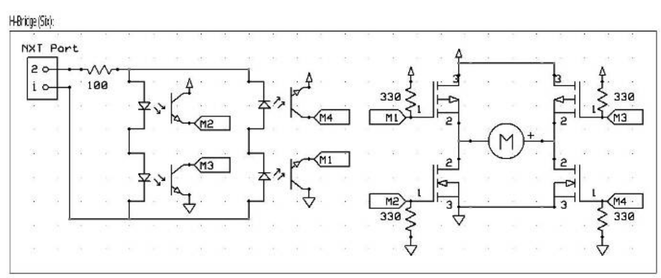
Tether

The members of the Lincoln Group had two goals for TNP's tether: to build it inexpensively and to build it out of thin, flexible material for ease of use. The tether consists of eight primary components: one 14 and three 16-gauge speaker wires, two camera wires, and two CAT 5 wires. In all, the tether only possesses a diameter of approximately 2 centimeters. Three of the speaker wires provide power to the ROV's drive motors. The CAT 5 wires allow for powering and interaction with various tool packages. An additional speaker wire provides power for any tool package that consumes a large amount of current. The wires were braided together to increase flexibility and neatness (see ***Picture 7***). Foam noodles are used to provide buoyancy. Though teammates considered other methods of floatation, the group decided that these methods would lessen the tether's flexibility or raise its cost, and they subsequently scrapped the ideas.

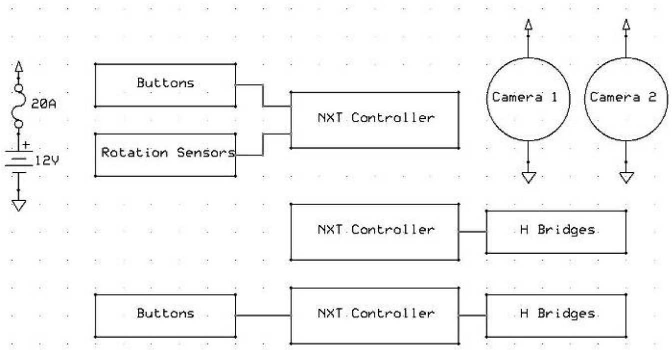
*(**Picture 7**: Braided tether)*

Controller electronics

The Lincoln Group's original plan was to use the same Playstation-PIC controller system that was used the previous year, but electronic difficulties led to the development of a different system. The team settled on using the Lego NXT, a programmable mobile device made by Lego for use in robotics. An NXT brick consists of 4 input ports and 3 output ports. The main reason for choosing this device was the ease of programming and design to match the tasks required. However, the NXT controller cannot control the drive or peripheral motors directly because it is not capable of providing enough current. To solve this problem, six bi-polar MOSFET H-bridges were constructed (electrical schematics in ***Diagram 1*** and ***Diagram 2***).



*(**Diagram 1**: MOSFET H-bridge electrical schematic)*

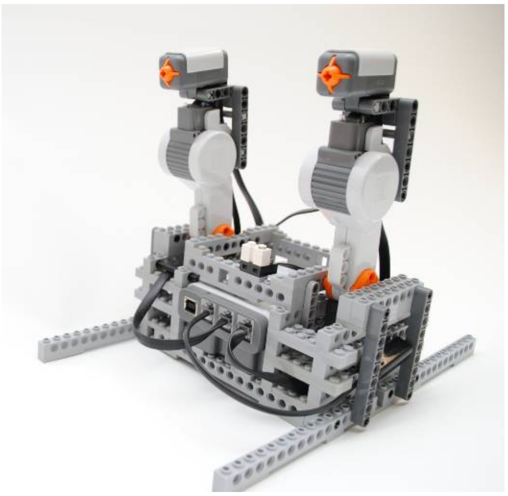


*(**Diagram 2**: Overall electrical schematic)*

Each H-bridge circuit consists of four MOSFETs: two n channel MOSFETs and two p channel MOSFETs. These MOSFETs are arranged so that on each side of the motor there is one p channel that can connect the motor to power and one n channel that can connect the motor to ground. When the n channel is activated on one side and the p channel is activated on the other side, the motor will spin in one direction. When the opposite MOSFETS are turned on, the motor will spin in the other direction. The H-bridges also employ four optoisolators. These components perform three functions. They isolate the controller's circuitry from potentially harmful voltage spikes that are produced by the motors. Additionally, because the controlling side of these isolators is a diode, the control side of the isolators acts as the controlling logic, turning on one pair of MOSFETs when the input is of one polarity, and turning on the other pair when the input is of opposite polarity. Finally, the optoisolators effectively amplify the input voltage to a voltage that is sufficient to turn the MOSFETs on and off. Each MOSFET board controls either a motor channel (left, right, or vertical) or a tool package. By using a MOSFET H-bridge, it is possible to have analog bi-directional control of the motors and tool packages.

Controller design and software

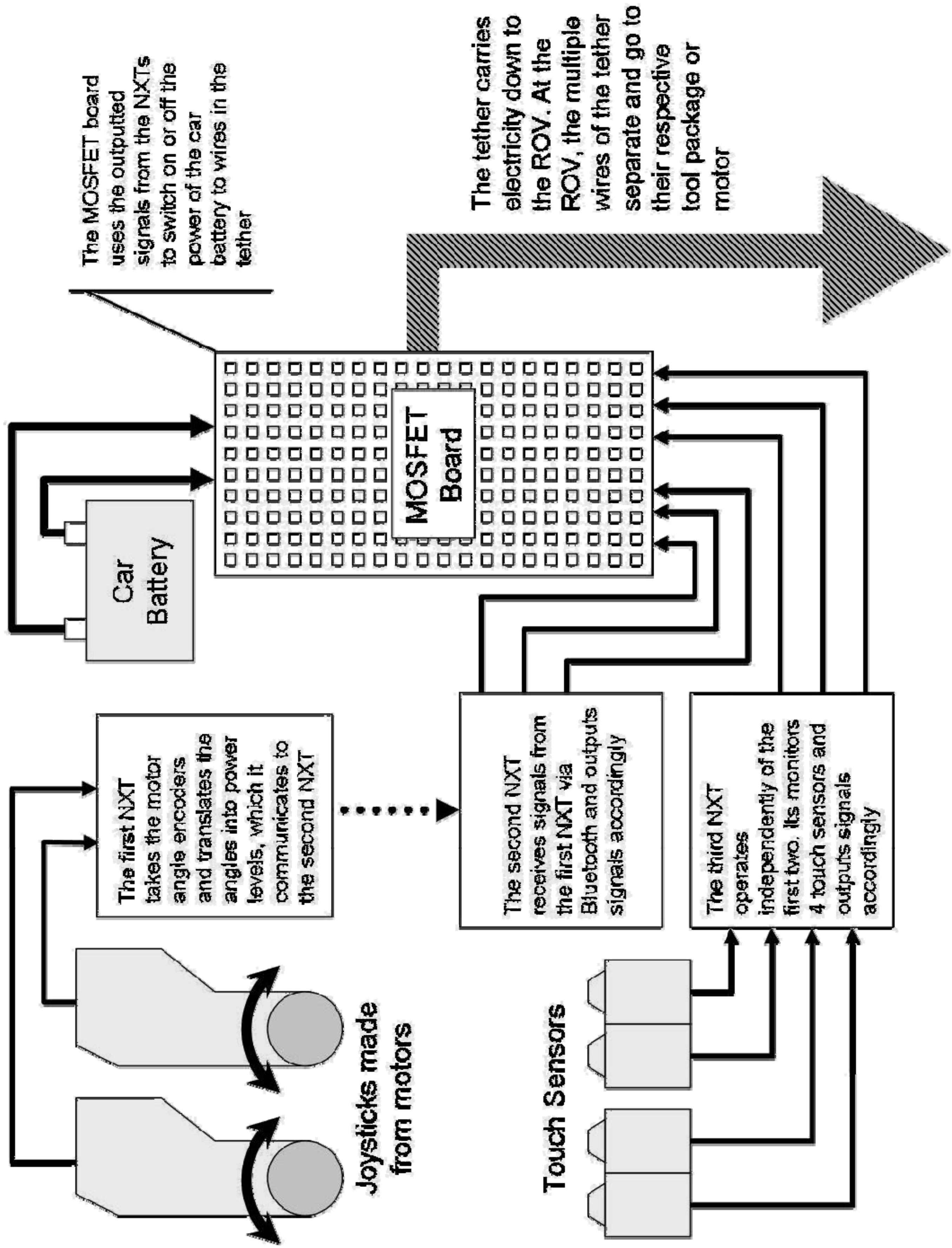
The physical controller itself is constructed out of Legos. To control the drive motors, a two joystick system is used (see ***Picture 8***). Each joystick controls the power level of the motors on one side of the ROV. The joysticks are made of motors and use the motor angle encoders to measure movements made on the joysticks by the drivers. The software then converts these angle readings into power levels. Also, a touch sensor on the top of each joystick serves as a vertical motor control, with the left trigger moving the ROV down and the right trigger moving the ROV up. All of these sensors and motors are connected to an NXT that is integrated with the joysticks.



*(**Picture 8**: Wireless joystick controller)*

This NXT communicates wirelessly via Bluetooth to another NXT connected to the MOSFET boards. This NXT actually outputs the power levels that control the motors. A third NXT connected to the MOSFET boards runs independently of the other NXTs and uses touch sensors and buttons on the NXT to run the three current peripheral packages (the gripper, the spinner, and the suction sampler). A general controller flowchart can be found in ***Diagram 3*** (full program in the ***Appendix***).

The advantage of using the Lego NXT is the high flexibility of the system. In accordance with TNP's goal of modularity, the physical controller and its software can be quickly modified for whatever tool package is needed to complete a task. Also, the joysticks are wireless, allowing for the driver to operate easily without the constraints of wires. A final advantage goes along with the robot's bi-directionality. By simply pressing a button on the joystick NXT, the NXT's programming will adjust the outputs so that the back of the ROV becomes the "front". In another words, the drivers can switch



*(**Diagram 3**: General controller flowchart)*

their attention to the back camera and use the joysticks normally. This feature allows pilots to effectively and easily drive in either direction.

Design Rationale: ROV Tasks

Because of TNP's modular design, the Lincoln Group had no problem quickly installing attachments to the ROV's frame to create a robot capable of all the tasks MATE has assigned it. Also, because of the focus on simplicity of design, many of TNP's tools have multiple functions.

Task 1: Removing the riser pipe

To complete task one, the ROV must secure a line to the U-bolt on the top of the riser pipe, remove the Velcro from the riser pipe to simulate cutting it, and then lift the riser pipe clear of the working area. To affix a line to the U-bolt, we designed a prong shaped tool which is inserted into the U-bolt and has spring loaded arms that expand wider than the width of the U-bolt, thus preventing it from coming out of the constriction. Previous designs included using a carabineer, but the method of attaching a line is still in testing and development. A line is connected to this tool that runs to the surface. This tool is partially affixed to the ROV with Velcro that is loose enough to be pulled of by the ROV once the tool has been attached. The task of removing the Velcro from the riser pipe is completed by the ROV using its gripper (see ***Picture 9***).

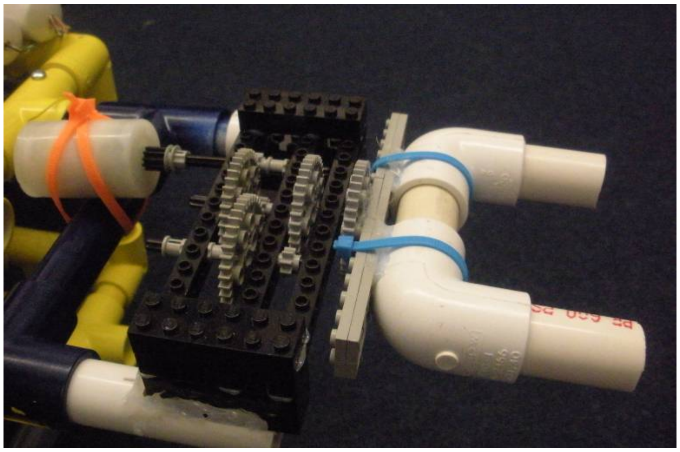
*(**Picture 9**: Gripper tool package)*

The gripper, the ROV's most universal tool consists of a hook shaped static prong, and a hook shaped moving prong that is rotated by a motor via a set of worm gears. The worm gears serve two functions: to provide adequate torque for the gripper, and to keep the gripper in its position when the motor is off. The gear ratio of the spinner is 576 to one, meaning it takes 576 rotations of the motor to rotate the axle holding the fingers one time. This substantially increases the torque of the gripper.

To power tool packages like the gripper and spinner (discussed in the next section), a potted hobby motor was used (one can be seen in the left side of ***Picture 10***). The motor itself is a simple DC hobby motor. To waterproof it, it was placed in a pill case with petroleum jelly in the bottom and potted with canning wax. This setup provides a cheap, small motor perfect for use in tool packages.

Task 2: Closing the well valve

For task two, the ROV must retrieve a PVC tee from the top kill manifold, and then deliver it to the well site. It then must rotate a valve three times to close it. Finally, the ROV must deliver a cap to the top of the riser pipe. The tee is retrieved and delivered using the ROV's gripper tool. To rotate the wellhead's valve shut, a special tool package was developed called the spinner (see ***Picture 10***).



*(**Picture 10**: Spinner tool package)*

This tool consists of two PVC prongs that can be rotated about a center point by a potted DC hobby motor via a gear set. This gear set provides a 125 to one ratio which increases the torque that the tool can provide, allowing it to turn the valve. After turning the value, the ROV's gripper is used to deliver the cap to the top of the riser pipe.

Task 3: Collecting specimens

In order to complete Task 3, the Lincoln Group tried several solutions. Task 3 was to collect one of each of the 3 specimens so that further testing could be done on them. In order to do this the Lincoln Group used some tool packages already in place. The gripper can be used to pick up anything within its reach, usually crabs and glass sponges. We also built a modified lift for the sea cucumbers. This is designed to scoop the cucumbers into the gripper, or at least give the ROV a way to carry the cucumbers back to the surface. Tool packages for collecting specimens are at this time still in development in order to take the current working system and make it more effective.

Task 4: Collecting a sample of saltwater

For task four, the ROV must navigate to a predetermined depth and collect a sample of saltwater from a vertical pipe with a flexible container attached to it. To navigate to the correct distance, the ROV has a simple, inexpensive depth sensor. It was constructed by connecting a piece of thin tube to a three quarter inch (1.9 cm) PVC cap. The cap and tube was filled with water that had been dyed with red food coloring. Then a piece of latex was secured over the open end of the PVC cap. The tube is situated on the ROV so that it is in view of the camera. On the other end of the tube, there is a syringe that can be used to adjust the red fluid's position in the tube. The tube is easily calibrated with markings made on the tube.

*(**Picture 11**: Nozzle leading to the suction sampler, held in the gripper)*

To remove the sample from the site, the ROV delivers a nozzle (see ***Picture 11***) that it holds in its gripper. This nozzle is an inverted funnel with plumber's putty inside of it as well as a piece of latex that forms a seal with the tube of the sample site. This nozzle is connected to the collection reservoir. The collection reservoir is a clear plastic bottle with two tubes coming into the top of it. One of the tubes is long, and runs to the bottom of the container. This tube is attached to the nozzle. The shorter tube is connected to a centrifugal vacuum pump. In this way, the denser sample is deposited at the bottom of the bottle. This bottle is visible to one of the ROV's cameras so that it can be determined when an adequate sample has been collected.

Safety

The safety of TNP was a top priority for the Lincoln Group. To decrease the chance of injury while the ROV is in use, the team's thrusters have been placed in motor shrouds that prevent a person from carelessly harming themselves or the propeller. Also, to prevent electric shock, TNP's main line contains a 20 amp fuse. Our Lincoln Group has also developed a safety checklist that follows to eliminate some of the human error involved in ROV operation.

- Leave battery unclipped while not in use
- Check the bolts on the motors to make sure they are tight before every mission
- Check the propellers to make sure they will not come off before every mission
- Do not touch the ROV while the motors are running
- Drivers should inform the entire team before they start the motors

Budget

ROV			
Quantity	**Item**	**Unit Cost**	**Total**
11	1/2" PVC Elbow	$0.28	$3.08
22	1/2" PVC T	$0.28	$6.16
10	1/2" PVC Cross	$0.98	$9.80
10	1/2" PVC Three Joint	$1.44	$14.40
310	1/2" PVC Pipe (per cm)	$0.13	$40.30
4	1.25" end cap	$1.25	$5.00
65	1.5" PVC Pipe (per cm)	$0.83	$53.95
8	2.0" PVC Pipe (per cm)	$0.60	$4.80
96	3.0" PVC Pipe (per cm)	$1.11	$106.56
2	1/2" screw in plug	$0.76	$1.52
10	1/2" Clear PVC Pipe (per cm)	$0.09	$0.90
3	West Marine 500 GPH Bilge Pump	$12.99	$38.97
4	Johnson 1250 GPH Ultimate Bilge Pump	$29.99	$119.96
75	Zip Ties	$0.02	$1.50
65	CAT5E Wire for Tether (per foot)	$0.20	$13.00
130	14 Guage Wire for Tether (per foot)	$0.27	$35.10
130	16 Guage Wire for Tether (per foot)	$0.22	$28.60
1	Water Bottle for floatation	$7.00	$7.00
2	Camera	$40.00	$80.00
2	Lights	$5.99	$11.98
1	Funnel	$2.00	$2.00
10	Rubber tubing (per foot)	$0.29	$2.90
2	Hobby motors	$2.97	$5.94
1	Water Bottle for Sucker	$2.00	$2.00
1	Legos for tool packages	$5.00	$5.00
	Total	**$600.42**	

Grand Total	**$1,337.98**

Controller and Interface			
Quantity	**Item**	**Unit Cost**	**Total**
6	Bread board	$5.00	$30.00
12	P chan mosfet	$1.81	$21.72
12	N chan mosfet	$1.43	$17.16
24	1/2W Resistor	$0.41	$9.84
6	1/4W Resistor	$0.15	$0.90
6	NEC Quad optoisolator	$1.84	$11.04
24	Fast Recovery Rectifier diode	$0.64	$15.36
3	NXT controllers	$149.99	$449.97
2	servo motors for joystick	$19.99	$39.98
5	wires for NXT	$3.33	$16.65
1	Various parts for controller	$5.00	$5.00
6	touch sensors	$19.99	$119.94
	Total	**$737.56**	

Total Final Budget for 2011			
Quantity	**Item**	**Unit Cost**	**Total**
8	Plane Tickets to Houston	$400.00	$3,200.00
3	Hotel Rooms x 5 nights	$500.00	$1,500.00
1	Travel to Alpena for Regional	$300.00	$300.00
4	Alpena Hotel Rooms x 1 nights	$90.00	$360.00
1	Rover/Controller Costs	$1,337.98	$1,337.98
	Total Cost for ROV and Trips		**$6,697.98**
1	Income from Summer Camps	$500.00	$500.00
1	Donation from DynaLab	$1,100.00	$1,100.00
1	Donation from IHG	$300.00	$300.00
8	Money Raised by students	$575.00	$4,600.00
1	Carry-over from last year	$250.00	$250.00
	Total Income		**$6,750.00**
	Final Balance		***$52.02***

Troubleshooting Technique

Since the control and design of the ROV worked in previous years, the Lincoln Group aimed to use the same design. However, the majority of the problems came from the control system. Just before the team was ready to practice the mission with the ROV, the old PS2 controller system broke. Luckily, the team was able to use three NXTs to drive the ROV. One NXT was used as the actual analog controller, which allowed drivers to still have the analog control of the robot that the PS2 controller allowed. This NXT wirelessly communicated with a second NXT via Bluetooth. The Lincoln Group was quickly able to overcome the loss of a control system and gained a new one that is much more modifiable and is also wireless.

Another problem that the team encountered was the shrouds on the motors. The team knew that there would have to be a flow to the motor in order for the ROV to move at a fast speed, but also would need to be safe. To fix this problem, the team built shrouds out of PVC pipes that had holes cut out of the pipe. In the end, there was only enough PVC to keep the shroud together and to attach to the motor, maximizing water flow. Since the openings were so large, the team decided to put plastic chicken wire around the shrouds for the safety of anyone touching the ROV.

A third problem came from the adjustable water bottle on the top of the ROV that provided buoyancy. As seen in ***Picture 1*** and the picture on the cover of the report, a plastic water bottle was originally used. However, the bottle was discovered to be ineffective at depth. To solve this problem, an aluminum bottle was used instead and is currently being tested.

Challenges

Throughout the process of building TNP, the Lincoln Group has faced a few technical and non-technical challenges. As all team members are high school students, many have alternate commitments to sports, clubs and other after school activities. The various activities have conflicting time schedules that have made it difficult for the Lincoln Group to meet consistently as a large group. To help with this issue, meetings were held right after school for anyone who was not involved in another activity that day, but meeting days were also held over the weekends to be more available for everyone. Having this flexible schedule allowed the team to retain more members and get work done even with small groups when not everyone could meet.

Yet even more than the interpersonal challenge of keeping a team together, the Lincoln Group has faced challenges in the technical realm. At the beginning of the project, the ROV was maneuvered by a PS2 controller that was developed the previous year, but the system failed due to unknown electrical problems. The team was then challenged to come up with an alternate method of control. The new method of control was designed using Lego NXTs and took innovations from the team members to get the physical and electronic components of the controller up to par with the previous controller. The physical controller was made to emulate the previous PS2 controller by building joysticks out of Legos and it turned out to be an adequate substitute.

<table>
<tr><th></th><th colspan="8">Schedule</th></tr>
<tr><th></th><th colspan="8">Month</th></tr>
<tr><th></th><th>November</th><th>December</th><th>January</th><th>February</th><th>March</th><th>April</th><th>May</th><th>June</th></tr>
<tr><td>Houston Fortney</td><td>Waterproof Connectors</td><td>Waterproof Connectors & Electronics</td><td colspan="2">Electronics</td><td>Build Barometer and Suction Sampler</td><td>Final Prep for Competition</td><td>Improve ROV& Tool Packages</td><td>Pool Deck Supervision</td></tr>
<tr><td>Eric Schumacher</td><td rowspan="11">Brainstorm</td><td>Mission Specific Designs</td><td colspan="2">Build Tool Packages</td><td colspan="4">Driving</td></tr>
<tr><td>Ainsley Baum</td><td colspan="2" rowspan="4">Build ROV</td><td>Research</td><td colspan="2">Driving</td><td>Improve ROV& Tool Packages</td><td>Presentation / Poster</td></tr>
<tr><td>Adam Motsinger</td><td>Build Tool Packages</td><td>Rules</td><td>Discuss Rules With Team</td><td colspan="2">Driving</td></tr>
<tr><td>Chris Chang</td><td colspan="2">Research</td><td>Final Prep for Competition</td><td>Improve ROV& Tool Packages</td><td>Pool Deck and Tether Management</td></tr>
<tr><td>Jordan Zink</td><td rowspan="4">Build Tool Packages</td><td>Build and Design Controller</td><td>Debugging Controller Software</td><td>Improve Controller</td><td>Data Analyst/ Mission Supervisor</td></tr>
<tr><td>Nathan Hammonds</td><td colspan="2">Financial Stat Tracking</td><td>Tether Management Practice</td><td colspan="3">Parts and Cost List</td></tr>
<tr><td>Jeff Chen</td><td colspan="2" rowspan="4">Build ROV</td><td>Tether Management Practice</td><td colspan="2">Tether Practice</td><td>Tether Management</td></tr>
<tr><td>Zach Koors</td><td>Research & Poster</td><td>Poster</td><td>Driving Practice</td><td>Photographer</td></tr>
<tr><td>Sanchi Arora</td><td rowspan="2">Research</td><td colspan="4" rowspan="2">Poster</td></tr>
<tr><td>Katie Sharkey</td></tr>
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(***Diagram 4***: *Schedule*)

Future Improvements

After a year-long effort of development and testing, the Lincoln Group has learned many things, including ideas that we can apply to our future ROV. There are many things we want to improve on our ROV, including our cameras and water-proof connectors.

The camera is one of the most important devices on a ROV, since it enables the controller to see the objects and responsd to it appropriately. For our future ROV, we want to use a camera with a wider field of vision than is granted by the current security cameras. A possible solution is to attach the cameras to servos, which would allow us to turn the cameras while underwater. An interesting idea we are considering is to control the camera's angle by using a head-mounted controller that moves the camera when the driver turns his/her head.

Another area we want to improve on our future ROV is to design a better way to hold our water-proof connectors onto our ROV frame. Currently, they are simply zip tied randomly to the side of the ROV. In the future, we will create a more secure and organized housing to hold the connectors.

Skills Gained

Throughout the process of building TNP, the Lincoln Group has learned many things. Through its never-ending quest to improve itself, it has transformed from being just another Underwater Robotics team to being exceptional. The team this year has learned much about innovation and risk taking. When previous designs failed, such as the ROV controller, instead of becoming discouraged, the team started immediately working on a new method of control. The same was true in terms of approaching tasks for the competition. If the first method of solving the task did not work, new ideas were explored as soon as possible. In the face of adversity, the Lincoln Group never gave up.

Along with these skills, the Lincoln Group has also acquired many interpersonal skills. The team learned how to compromise on ideas. If disagreements arose, team members would try both approaches to a problem if possible, and if not, they would vote on which design they liked the most. This approach prevented most bickering about the ROV's design since everyone had a voice and felt as if they could contribute to team decisions.

Reflections

Sanchi Arora: Communications

As a first year member, Underwater Robotics taught me about engineering, critical thinking, and team work. Before Robotics, I wasn't exposed to building structures strategically and thinking outside the box to build different devices. Underwater Robotics taught me how to look at details in regards to building devices and the ROV itself. Greater than that, Underwater Robotics taught me the importance of teamwork and that many people can achieve greatness by working together.

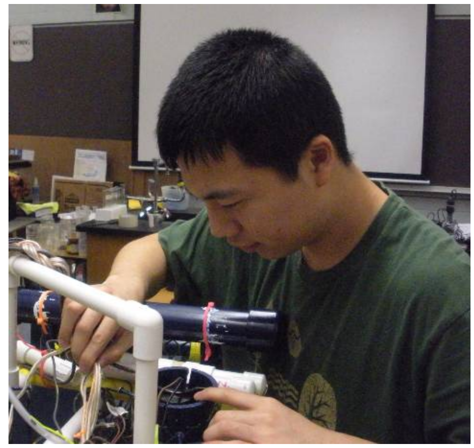
Ainsley Baum: Pilot

Since this was my second year on the team, I knew what to expect coming in. However, I was not ready for how different this year was going to be with the waterproof electrical connections and the new members. I was happy to work with the future leaders of the team, as well as help further the betterment of the ROV. I am very happy with my choice to be on the team again, and I am glad that I was able to help with building and teaching the younger members how to do things that they have not yet done with robotics.

Chris Chang: Research

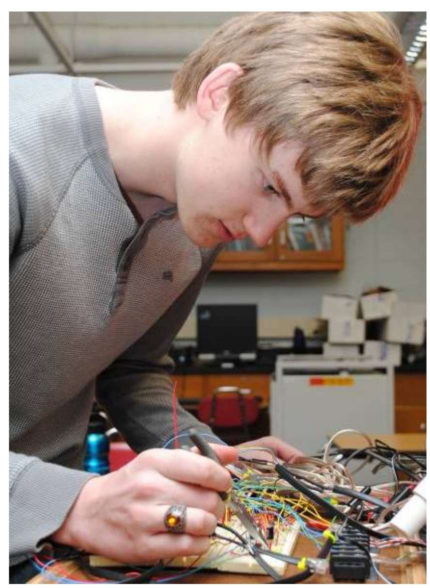
The last several months I spent working on our Underwater ROV have been a fantastic experience. The best part for me has been being able to work with other students that share similar passions. I learned a vast amount of information through them that certainly has taken me to a higher level. Next year, I feel confident that I can lead the next team to equal or greater heights.

Jeff Chen: Builder



This is my first year on the Underwater Robotic Team. I am glad that I joined this team because this has been a fun and rewarding experience for me. On the Underwater Robotic Team, I can use the knowledge I learned in class and apply it to the ROV we are building. I am the tether manager in our team, and I learned many things about the tether and its importance. I also learn more about the oil spill and how it was fixed. All in all, it was a great experience for me.

Houston Fortney: Electronics



I learned much from participating in this experience. I learned about developing something until it works as well as you would like it to. This was especially true of our approach to collecting the sample of saltwater. We went through many different methods and prototypes. Finally we created a device which worked reliably at a very low cost. This experience taught me a lot about perseverance and troubleshooting. Furthermore, this experience has inspired me to pursue the many more ideas I have for underwater robotics.

Nathan Hammonds: CFO, Tether Manager

Being on the Underwater Robotics team has been a rewarding experience for me. I learned a lot more about what it means to be on and contribute to a team. I also learned more about how an underwater ROV operates and the occasional problems that can arise in the designing and building of an underwater ROV. I enjoy the collaboration of ideas between teammates because it is interesting to hear the opinions of my peers, and hearing the team argue can be amusing. I plan on being on the underwater ROV team next year because of the rewarding experience that I had this year.

Zach Koors: Builder

This is my first year joining the team and I have thoroughly enjoyed my time with the team. Throughout my time while being involved in the Underwater Robotics Team I have gained a lot of experience and learned a lot of useful information. I have mainly been involved in building the frame and specifically the shrouds for the propellers. I have also been following around our team leader, Houston Fortney, to learn about the electronics involved in controlling the ROV so that next year when I am a senior I will be able to replicate them. He has been the main team member behind the electronics in our ROV, and hopefully I and some other members will be able to take his place next year.

Adam Motsinger: Builder, Pilot

I contributed to building some of the tool packages for TNP, along with knowing all of the rules of the competition. I was in charge of sharing the rules with my teammates to make the sure the mission was done right, and that the ROV met all the requirements. I am also taking on the role of driving TNP in the actual mission. I have learned many things through my experience on the underwater robotics team, from knowledge on the ROV itself to learning how to be on a team. This was my first year on the team, and I am very glad I made the decision to join. This unique opportunity gave me the chance to experience engineering in the real world, and get a sense of how a future job could be like for me.

Eric Schumacher: COO, Pilot

I had two overarching jobs this year in the Lincoln Group. I was the Chief Operations Officer which meant that I basically made sure everyone knew what they had to do, and also made sure everyone was doing it. While I took pride in this job and also in my help to build some of the tool packages, the role I consider most important is that of pilot. I spent extensive hours practicing the mission and developing my driving technique. Since our ROV requires 2 pilots, I had to create a partnership with another pilot. Doing this built a great sense of comradery into the team as we all had to work together to complete the mission. The thrill of a successful mission is almost unrivaled, and it is a thrill I enjoyed sharing with the rest of my team.

Katie Sharkey: Communications

Being a first year member of the underwater robotics team, I came in not knowing much about the process or the team. Now, at the end of the year, I have learned a lot about working as a team and getting work done efficiently by the deadline. Though I was not able to contribute much due to other school commitments, I was happy to be able to help however I could and be part of such a great team. I enjoyed learning to use some of the tools for building the ROV and getting to research about the Deepwater Horizon oil spill and help put together the poster for the competition.

Jordan Zink: Programmer, Editor

Through both of my years of involvement in Underwater Robotics, I have acquired a lot of knowledge about the general construction of robots. While the project specifically dealt with an Underwater ROV, many of the techniques we learned can be extrapolated to other robots. Prior to this project, I did not build with materials other than LEGOs and knew very little about electronics. While building the ROV, I learned to create different things with PVC. Also, I learned much about soldering and controllers, especially making controllers out of materials like Legos. Most importantly, I have learned that things don’t have to be perfectly precise and correct. Things will still work even if they are not exactly accurate. Breaking my previous mindset of precision has been hard, but this ROV has allowed me to do so. Overall, I feel as if I have widened my horizons by participating in this project.

Acknowledgements

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On a more personal level, the Lincoln Group would like to thank Matt Gardener for answering all the forum questions on-line at the ROVER site, and for Sarah Waters and all of her staff in helping us feel welcome at the Great Lakes Regional Competition in Michigan. We would also like to thank the family of each team member for all of their encouragement. Moreover, the entire team wishes to thank its advisor Fred Donelson, who put in countless hours to help lead the team to success and whose moral support has guided the team even through its toughest times.

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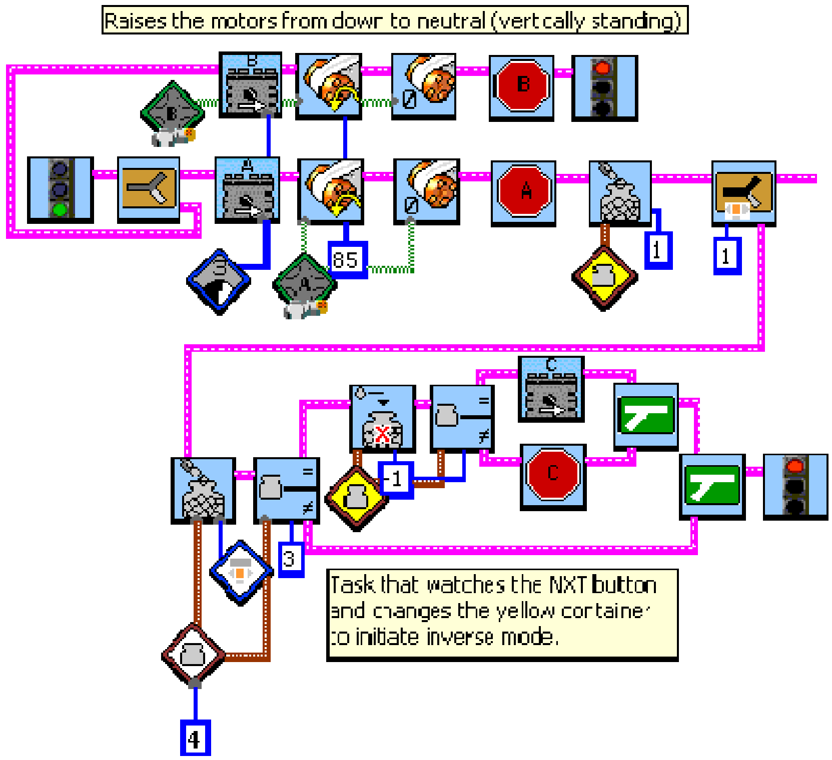
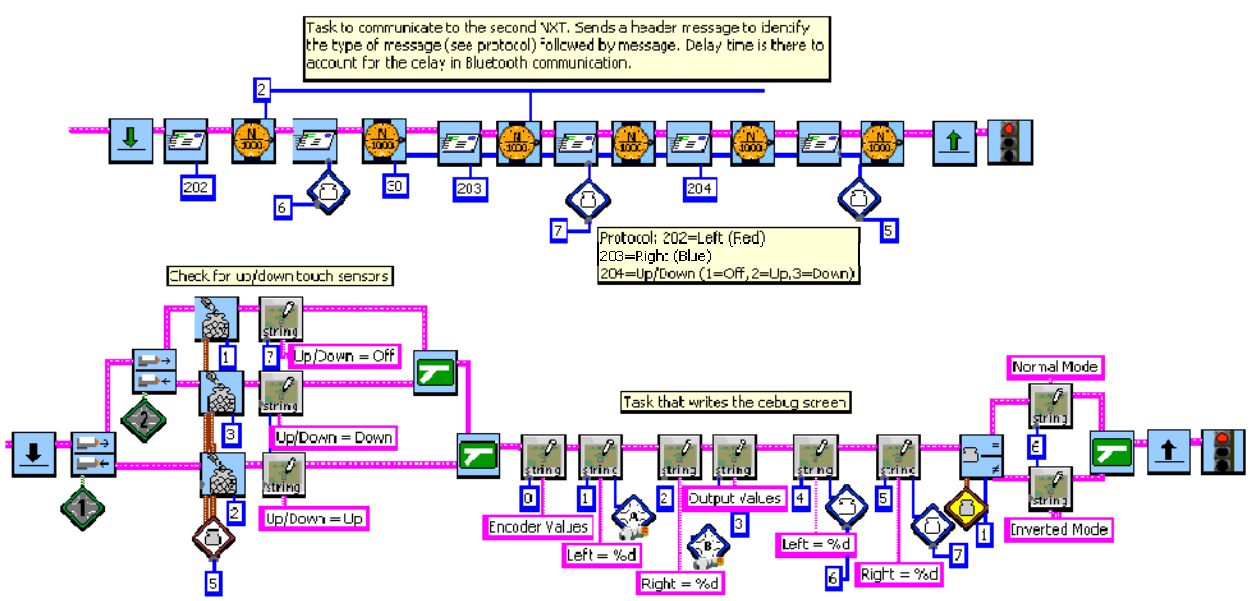
Appendix

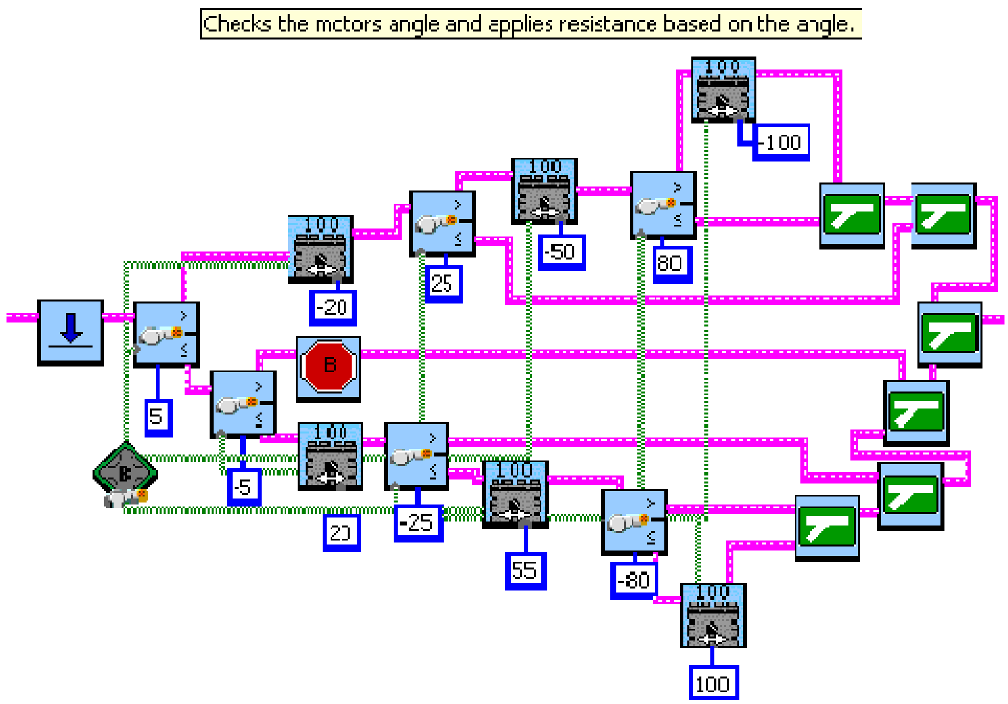
Control Program – Programmed by Jordan Zink in RoboLab, 2011

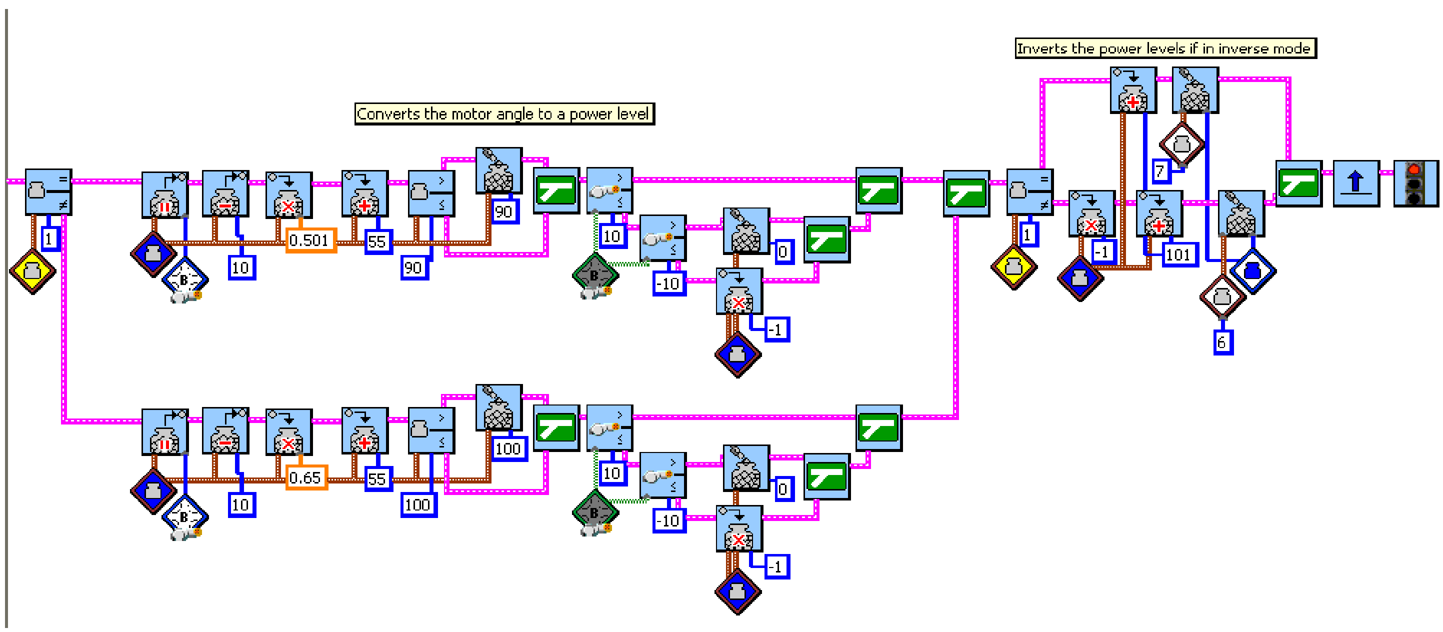
Master Drive NXT Part 1



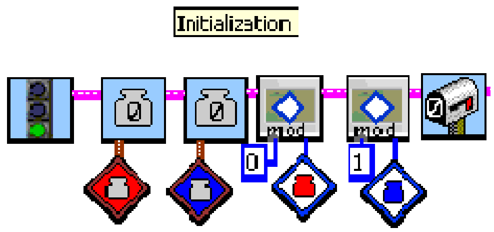


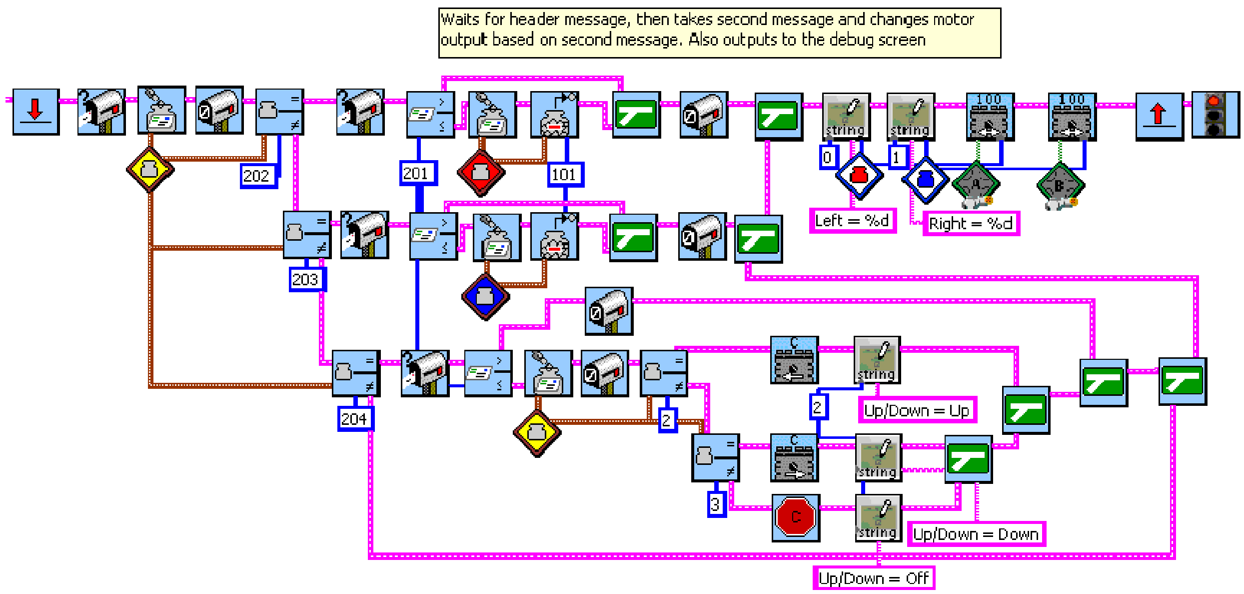
Appendix
Master Drive NXT Part 2





Appendix
Slave Drive NXT





Appendix

Tool package NXT Code