PROVIDENCE ~ SEA PERCH ~ CORPORATION

MOTHER OF PROVIDENCE REGIONAL CATHOLIC SCHOOL

NEMO FINDER 5000

PSPC

Providence SeaPerch Corporation Design Notebook

Mother of Providence Regional Catholic School

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Team Name: Providence SeaPerch Corporation

School Name: Mother of Providence Regional Catholic School
School District: Archdiocese of Philadelphia

PSPC is a fictitious corporation and is used here as the team name for the team from Mother of Providence Regional Catholic School competing in the 2016 Greater Philadelphia Sea Perch Challenge.

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1. http://www.aoe.vt.edu/programs/undergrad/navaleng/
2. http://www.bls.gov/ooh/architecture-and-engineering/marine-engineers-and-naval-architects.htm
3. http://www.seaviewsystems.com/questions/what-is-an-rov/
4. https://en.wikipedia.org/wiki/Remotely_operated_underwater_vehicle
5. Bouyancy for Middle School Learning Module downloaded from http://www.phillyseaperch.org/learning-modules.html
6. Vectors Learning Module downloaded from http://www.phillyseaperch.org/learning-modules.html
7. https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_navigation/cub_navigation_lesson02_activity1.xml
8. Electric Circuits Middle School Learning Module downloaded from http://www.phillyseaperch.org/learning-modules.html
9. Motors Learning Module downloaded from http://www.phillyseaperch.org/learning-modules.html
10. Crane Salvage Mission document downloaded from http://www.phillyseaperch.org/mission-overview.html
11. http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess
12. Mike Wright, Magnetool, Inc., 505 East Elmwood Avenue, Troy MI 48083; 248-588-5400
13. http://electronics.stackexchange.com/questions/32798/can-silicone-sealant-be-used-to-insulate-and-waterproof-electronic-components
14. http://forums.planetchristmas.com/index.php?/topic/50265-silicone-caulk-and-electrical-connections/

Section II: Naval Engineering Research

The Virginia Tech website states that Naval Engineering is “a field of study and expertise that includes all engineering and sciences as applied in the research, development, design, construction, operation, maintenance and logistic support of surface and subsurface ships, craft, aircraft, and vehicles (manned and autonomous) used by the Navy for the Nation’s defense.”(1) Besides naval engineering, marine engineering and naval architecture also involve designing, building and maintaining all kinds of ships and their internal systems.(2) Naval and marine engineers would be most interested in designing and using remotely operated underwater vehicles or underwater ROVs.

Underwater ROVs are often used to observe underwater environments and to do underwater research for many reasons. Underwater ROVs can stay underwater for a very long time, can be tracked, and can carry cameras and other equipment.(3) Underwater ROVs can be used to sample the water, to test water temperature, density and clarity or to recover artifacts from shipwrecks.(4)

The main engineering theories and principles that Providence Sea Perch Corporation (PSPC) researched and used for the design and manufacture of the remotely operated underwater vehicle, the Nemo Finder 5000 (NF5000), were buoyancy, vectors, electric circuits, electric motors, and electromagnetism.

Buoyancy:

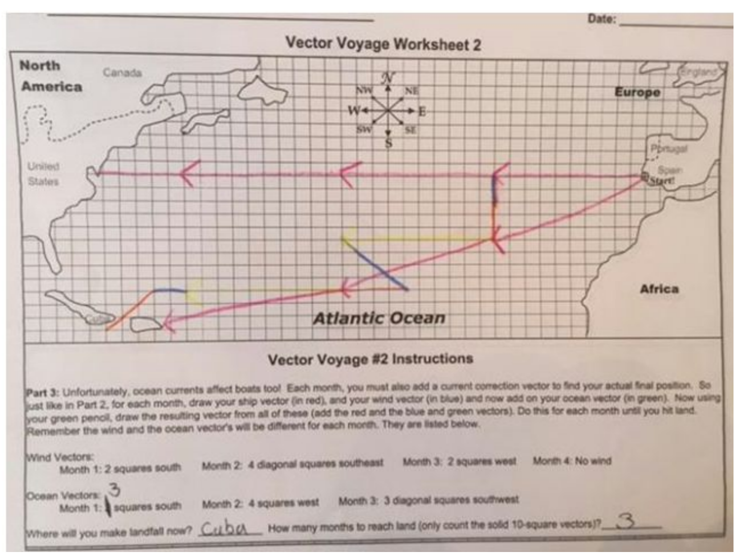
Buoyancy was a very important principle for the entire PSPC team to understand. Buoyancy is what causes something to either float or sink depending on how buoyant that item is.(5) Buoyancy is what makes an underwater Remotely Operated Vehicle (ROV) properly maneuverable in the water without sinking or floating. When something is positively buoyant it will tend to float. If something is negatively buoyant it will tend to sink. If the object is neutrally buoyant it will neither sink nor float when put into a position surrounded by water. To get positive buoyancy simply add extra floatation devices to the ROV. To make an ROV more negatively buoyant, add extra weight, called ballast, to the ROV. To acquire neutral buoyancy you would have to balance out the weight and the flotations, meaning that you can't have too much weight but you can't have too many floats either.

PSPC team members participated in a buoyancy activity in which modeling clay was placed on the end of a cap of a pen. The weighted pen cap was inserted in a bottle of water so that air would be trapped under the cap and the bottle was sealed . Whenever the sides of the bottle were depressed, the cap would sink. Whenever the bottle was released, the cap would float to the top. This showed that buoyancy depends on pressure which is important to understand when designing an ROV which will move in deep water.

Vectors:

A vector is a quantity that has both magnitude and direction.(6) For example a car can be going 45 miles an hour but it can also be going 45 miles an hour north. This makes a difference because now it has a direction. Another example is a traditional wind speed map on weather reports. The arrows of different sizes show wind speed and direction and are vectors. Acceleration and force are also vectors, since when you're applying a force on an object you're pushing (or pulling) it in a certain direction. Fields are also vectors such as gravitational or magnetic fields.

PSPC team members did a vector worksheet activity(7) as part of our research on vectors. On the worksheet, we determined where a ship would travel if it were not affected by the force of the wind or currents and then show how it would travel if it was affected by different wind and current forces acting in different directions - vectors.



Electric Circuits:

Electric circuits are what transport electrons from one place to another. When electrons move in a wire, or conductor, it is called current flow. The current (i) is the number of electrons to pass a set point in a certain amount of time and is measured in Amperes. The resistance (R) is the measurement of how difficult it is for an electron to flow through a material. The unit for resistance is the Ohm (Ω). In a circuit, potential energy is often referred to as voltage (V). The relationship of these three things can be described using Ohm's law. The equation for Ohm's law is $V=iR$ and it can be used to design circuits.(8)

It is important to understand electric circuits when designing an ROV because the ROV will probably use electricity to power its thrusters. Electric circuits will be needed to operate the thrusters and any other electrical devices that the ROV might use.

Electric Motors:

Electric motors change electrical energy into magnetic energy, and then into rotational force. The electric motor is made up of the stator, rotor, commutator, brushes and terminals. The stator is most often a permanent magnet or row of magnets lining the edge of the motor casing. The rotor is inserted into the stator, which is usually made of copper wire coiled around an axle. When current is applied to the coil of wire, a magnetic field is created. The magnetic field interacts with the field of the stator, and the axle begins to spin.(9)

PSPC team members completed and activity in which we made our own small motors with magnets and small coils of wire. It was very exciting when our Lead Electrical Engineer, Theresa, first got hers to spin! Some people had a really hard time making their little motor work but eventually we all got them to work.

When designing an ROV it is important to understand how motors work because the ROV will probably use some sort of motor as part of the thrusters. Motors are very useful for making propellers turn which is a great type of thruster to use for an ROV.

Electromagnetism:

Electromagnets are a type of magnet in which the magnetic field can be turned on and off. Electromagnets are usually made from a large number of closely spaced turns of wire, a coil, that create a magnetic field when electricity flows through them. The wire is usually wound around a magnetic core. The magnetic core concentrates the flow of the magnetic field, the flux, so the magnet is more powerful. Electromagnets are different from permanent magnets because the strength of the magnetic field can be controlled by changing the amount of electric current in the winding. An electromagnet needs an electric current flowing through the winding in order to maintain the magnetic field.(10)

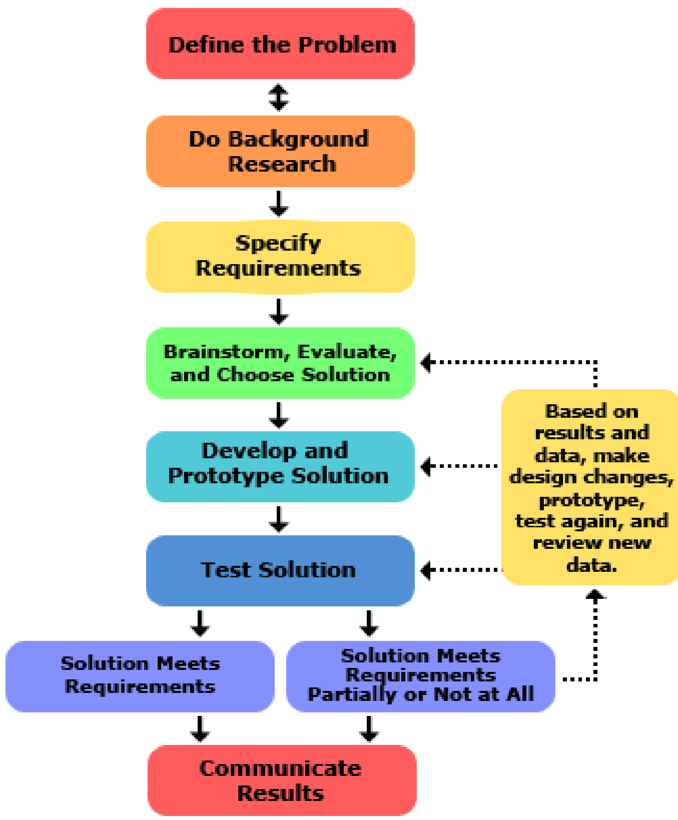
Electromagnetism is not normally important to understand when designing a standard ROV however, the NF5000 was designed to meet the specific mission requirements of the Navy to retrieve small metal objects and then drop them in a collection container. Electromagnets are able to do this task easily.

Section III: Design and Engineering Process

Section A. Design

1. **Process:**

The process used to manufacture and design a final product is known as the "Engineering Design Process." The Design Process starts with defining a problem or requirement. The next step is to brainstorm, evaluate, and choose a solution. Then a prototype solution is developed and tested. If the first solution fails, a new solution is tested. This is repeated until a successful solution is found.(11)



http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess

A example of how PSPC met a requirement using the Engineering Design Process is to have neutral buoyancy. Neutral buoyancy was important on the PSPC Nemo Finder 5000 (NF5000) because this year's mission required the NF5000 to have neutral buoyancy at a greater depth.

The PSPC Design Team (DT) thought that plugging the ends of the two top PVC pipes would be a reliable and reasonable way to provide additional floatation. The DT tested this hypothesis and it seemed to work so they decided to implement the idea as a design modification.

Another way PSPC used the Engineering Design Process was to meet the mission requirements. When the mission of navigating a maze and picking up small metal objects was first defined, the PSPC team discussed ways to modify the vehicle in order to be able to accomplish the mission. Once all the ideas were evaluated, we selected an electromagnet as the most important modification.

Our advisor, Mrs. Lehman, purchased 3 small electromagnets of varying powers and we did a preliminary test. When we did this test, we learned that it did not give us enough information in order to decide which electromagnet to use on the NF5000 so we designed another, more accurate, experiment.

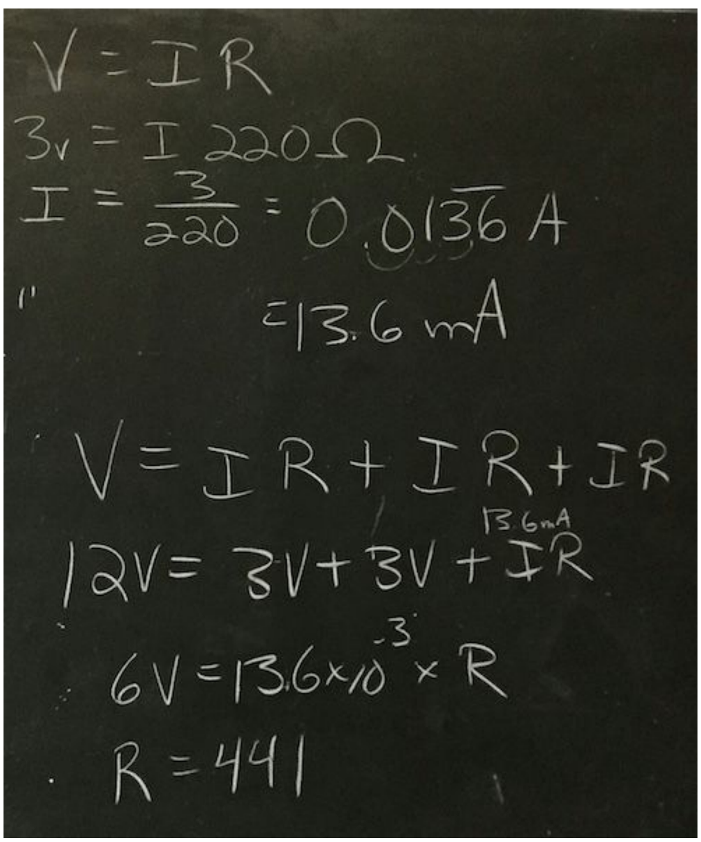
After the second electromagnet experiment, the PSPC team discussed the results. There was not much difference between the magnets in terms of reach but reach was definitely shown to be a function of the strength of the magnet. There was no difference in water or air. Because of how much of a difference in weight there was between the electromagnets, we chose not to use the strongest. We were worried that the weakest would not be able to hold the metal object against the pressure of moving it through the water to the collection container so we chose not to use that one either. That is how the PSPC team used the Engineering Design Process to help design the electromagnet part of the NF5000 and select the medium power electromagnet.

2. Theories

The PSPC team used its research about buoyancy to make the Nemo Finder 5000 neutrally buoyant. Neutral buoyancy is needed for the NF5000 to be able to move up and down through the water with ease, without stressing the motors too much, and also to be able to retrieve items and move them to the collection area. PSPC also used knowledge gained about the effect of pressure on buoyancy to change the flotation for the NF5000 so that it would be less affected by the deeper water than an ROV with just pool noodles for floats.

Vectors are an important engineering theory because the maneuverability of the ROV depends on the force vectors created by the thrusters (and water currents, if any). If the weight of the Nemo Finder 5000 plus the payload was equal to the thrust of the motors, the ROV wouldn't be able to move up in the water. PSPC also needed to make sure the NF5000 thrusters were properly positioned so the thrust vectors they made wouldn't make it spin in circles unless the operator wanted it to!

Knowledge of electric circuits was critical for assembling the basic controls for the motors and for designing the electromagnet modification. After making sure to select an electromagnet that would work with a 12 volt battery, the PSPC electrical engineers, with the help of the advisory



consultants, solved the problem of adding an electromagnet and LED lighting to the NF5000 by using Ohm's law. First they calculated that the 3V LEDs which were designed to be used with 220 ohm resistors would need 13.6 mA of current. To use two 3V LEDs with a 12V battery, they calculated that 441 Ω of resistance would be needed. PSPC decided to use two 220 Ω resistors in series with the two LEDs to create the lighting that would activate when the electromagnet was turned on. In addition, they determined that the electromagnet would need to be placed in a parallel circuit with the LEDs and resistors. Testing of this circuit will take place next week when the switch is installed in the control box, shown at right being assembled.

Knowledge of electric motors was important in the design of the NF5000 because it is designed to use three electric motors as part of its three thrusters. Using an understanding of both electric circuits and electric motors, PSPC built the NF5000 to operate with an electric circuit using a 12 volt battery, a control box, wires, and three electric motors with propellers, shown at left being assembled. The potential energy is provided by the battery. The control box acts as a switch in our circuit. By pressing different controls we can control not only which motor turns on, but which direction the motor spins. By changing the polarity of the magnet in the stator, we can change the direction the rotor spins. Because the electric motors use electricity for power and are made with lots of metal, it is crucial to waterproof the motors. The motors in the NF5000 are waterproofed using electrical tape, toilet bowl wax, and film canisters.

The PSPC team members studied electromagnets and used them in the design of the NF5000. After determining that the NF5000 would use an electromagnet to get the scattered objects, PSPC engineers performed experiments to test the reach of three different electromagnets. The reach is the distance from which a certain magnet can pull certain objects. The holding power of the electromagnets was also verified to make sure they would be able to carry small metal objects through the water.

Our engineering team researched many engineering principles but one of our most efficient ways to research very specific information was to consult with experts. PSPC was able to consult with Mike Wright at MagneTool in Troy, Michigan(12) to see if the electromagnet was waterproof. The PSPC team used the knowledge he shared to make the design for mounting the electromagnet much simpler than the one we first thought of using. After online research, PSPC learned that some silicone caulk could corrode the wire and solder of the LED circuit and should not be used to protect a circuit.(13, 14) PSPC engineers then reached out to the manufacturer of the specific caulk they wanted to use and were told by the product engineer that GE Silicone II was the right caulk to use because it has a neutral cure that won't corrode the wires of the LED circuit.

3. Design Modifications

PSPC used the basic SeaPerch design with seven modifications.

a. Implemented Modifications

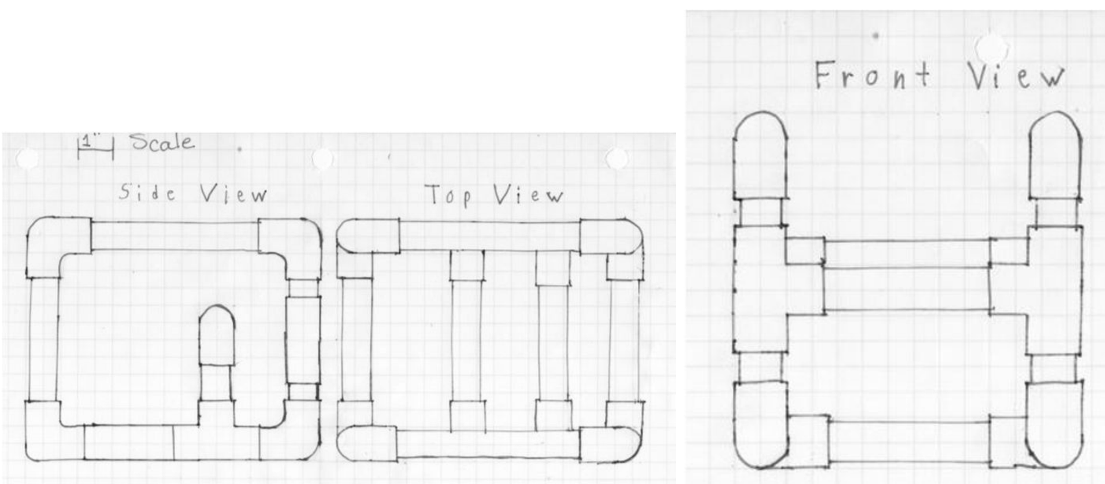
i. PSPC Assistant Materials and Structures Engineer (AMSE), Ian, thought it was a good idea to take off the back lip of PVC Pipe on the original design so that the final product would weigh less and be smaller and therefore be more maneuverable. The AMSE and other team members felt this would help to compensate for the extra weight of the electromagnet. They also felt that resulting stability issues would be offset by the proper placement of the electromagnet as stabilizing ballast.

ii. PSPC Lead Electrical Engineer (LEE), Theresa, knew about the mission assignment to retrieve small metal objects. This called for some sort of magnet. But, she also knew we needed to drop the metal objects again so that meant we needed a magnet that could turn off, which is an electromagnet. The Design Team couldn't come up with any other reasonable way to accomplish the mission so they chose to modify the NF5000 to use an electromagnet. The electromagnet had to be attached to the NF5000 somehow so they implemented a bar near the middle of the structure to which to attach the electromagnet and not affect the way the thrusters work or throw it off balance.

iii. The Design Team (DT) came up with adding a bar in between the two front support rods to better balance the SeaPerch, make it sturdier, and make it easier to maneuver into panels to depress them.

iv. The PSPC DT discussed all of the possible requirements for the NF5000 and decided that a smaller, more compact vehicle would make for an all around better design for maximum performance. It was important to lose some weight because the electromagnet was going to be heavy and it was also important to be small to be able to maneuver easily in the maze.

A scale drawing of PSPC's NF5000 with structural modifications:



v. The PSPC DT knew that pool noodles can compress in deeper water and would provide less floatation which could prevent the NF5000 from being properly neutrally buoyant during the obstacle course. To help provide floatation which would not be affected by the deeper water, the PSPC DT decided to seal the ends of the top two structural PVC pipes on the NF5000.

vi. The Lead Materials and Structures Engineer, Gabe, and the Lead Project Manager and System Engineer, Cole, had both piloted an ROV in a pool in last year's SeaPerch competition. They felt it would be helpful to make the NF5000 a bright color so that it would be easier to see against the bottom of the pool. The PSPC team chose to paint the NF5000 bright orange.
vii. The LMSE and LPMSE also thought it might be hard to tell when the electromagnet of the NF5000 was directly over each metal object. The Lead Electrical Engineer, Theresa, agreed to design lights to add with the electromagnet.

b. **Not Implemented Modifications**

i. The DT came up with a very good design for a SeaPerch that was flat, but decided that they wouldn't have enough time to make a new one if the design failed, so the DT decided to test it over the summer and, if it works, use it next year.
ii. The DT thought about making a bar below the vertical directional thruster to hold the electromagnet but determined it was a bad idea to implement because it could interfere with the performance of the thrusters.

Section B. Experimentation

PSPC experimented with three different sized electromagnets. The first test of the electromagnets was to put a half-inch steel ball on the lab table about 6 inches away from the electromagnet. Then alligator clips were attached to the leads on the electromagnet and then to the 12 volt battery. One at a time, each electromagnet was slowly moved toward the ball until it began rolling across the table toward the electromagnet. This was fun but didn't tell us much so we designed a more accurate experiment for the electromagnets.

For the second experiment, we used the metal object specs on the Crane Salvage Mission document from the Philly SeaPerch website to make our own metal objects as close to the specs as we could. We designed the experiment so that the electromagnet would be mounted on a lab stand above the metal object starting at about 6 inches above the object. The electromagnet was lowered by increments and turned on. If it didn't make the metal object move, it was turned off and lowered again.

The purpose of this experiment was to test the reach of each of the magnets when picking up the object, which in this case, was a metal piece about 17.5 grams. The goal was to find the smallest magnet that would work well for picking up the piece of metal and moving it without the metal falling off. First, each electromagnet was tested outside of the water in air. Then they were tested to see what happened when the electromagnet and metal object were placed in water because we thought the water might affect the magnetic field. The same results were obtained in both water and air. After discussing the results of these tests we chose the medium sized electromagnet. This magnet was more powerful than the small one but lighter than the biggest one.

PSPC also tested the thrusters. After we put them together we tested each thruster to make sure it spun in both directions and to see if we could feel some air flowing behind it. When the controller was finished and installed, we tested to make sure that the control buttons controlled the correct motors. Both of the experiments led to making sure our ROV, the Nemo Finder 5000, worked and was capable to complete our mission.

PSPC performed concept validation testing for the sealing of the PVC bars as an additional flotation device. The empty and unsealed PVC tubes sank but the ones with the ends sealed with silicone caulk floated.

PSPC will be conducting additional validation testing of the NF5000 in water over the next three weeks. We will be putting the NF5000 in different depths of water to test the buoyancy and ballast of the ROV. We want to check the NF5000 buoyancy in depths of over five feet to make sure it is still neutrally buoyant and easy to maneuver. The PSPC team will be doing further testing of the electromagnet once it is attached to the switch and then again in the water to make sure that everything works the way it should. Obviously, we will fix any problems that come up as a result of this testing.

Section IV: Naval Scenario for Sea Perch

PSPC has designed several remotely operated underwater vehicles for use in a variety of applications. The Nemo Finder 5000 was specifically designed to retrieve small metal objects, fit into small spaces, and be highly maneuverable.

The NF5000 would be a perfect tool to use if there was a small bomb in the harbor. The NF5000 is small and easy to transport to the location of the bomb. If the bomb is in a hard-to-reach place, the NF5000 would be able to get there because of it's maneuverability. It is also very durable, so it won't be damaged if it bumps into things. The electromagnet on the NF5000 would be attracted to the small metal components of the bomb. The Ordinance Disposal Team has talked with us about this type of mission and seems very enthusiastic.

PSPC has the expertise to scale up the NF5000 so that it can also be used by the Coast Guard or private companies for retrieving black boxes or other salvage from sunken vessels. Increasing the strength of the electromagnet could be done by getting a larger electromagnet and adding more powerful thrusters.

Section V: Teamwork

Section A. Team Participant List

The Providence SeaPerch Corporation consists of 8 student team members in grades 6 and 7.

Ella Bellace, Grade 6
Cole Clancy, Grade 7
Theresa Haas, Grade 7
Gabe Lehman, Grade 7
Maeve McMahon, Grade 6
Leah Moyer, Grade 6
Kyle Taylor, Grade 7
Ian VanDam, Grade 7

Section B. Team Responsibilities

To split up all of the responsibilities, the PSPC Adviser, Mrs. Lehman, reviewed the SeaPerch slides and discussed all of the jobs, the jobs' responsibilities, and what the jobs encompassed. Our instructor wrote all of the jobs' names on the board. To officially decide which team member would get which part, we volunteered for the parts we wanted, and if there was more than one team member who wanted that particular part, we went over the responsibilities again and based the decision on which team member had more experience. Team members were eager to step in and help another team member with their responsibilities if they were needed. Team member responsibilities are as follows:

Lead Project Manager and System Engineer (LPMSE)- Cole Clancy
Assistant Project Manager and System Engineer (APMSE)- Gabe Lehman
Lead Materials and Structures Engineer (LMSE)- Gabe Lehman
Assistant Materials and Structural Engineer (AMSE)- Ian VanDam
Mechanical Engineer (ME)- Maeve McMahon
Lead Electrical Engineer (LEE)- Theresa Haas
Assistant Electrical Engineer (AEE)- Leah Moyer
Lead Technical Writer (LTW)- Maeve McMahon
Presentation Design Team (PDT)- Kyle Taylor and Ian VanDam
Team Spirit Coordinator (TSC)- Ella Bellace

Section C. How Our Team Worked Together

Our team tried hard to work together all of the time because, as everyone knows, working as a team is a hard thing to accomplish. Because the SeaPerch mission came out a little late, our team started by working on subsystems. The design team members, structural engineer, and system engineer helped work on the construction of the motors. The team worked together to decide on the modifications of our system, the Nemo Finder 5000. Our team worked together on building all the various parts of our SeaPerch and on making decisions for how to improve our SeaPerch.

When choosing our mascot, Ella Bellace, Team Spirit Coordinator, held tryouts where the whole team could see and be involved. After everybody had tried out, the team voted on who would take the role of being our mascot. We all wrote our choices down on pieces of paper, and then counted the votes. AMSE Ian VanDam won. When choosing a name for both the SeaPerch ROV and the company, we also held a team vote. Whenever one name got the fewest number of votes, it was disqualified. Once we finally came to a conclusion, the name of our company became Providence Sea Perch Corporation. Our ROV name became the Nemo Finder 5000.

Even though the jobs were divided up, there were always people who wanted to do some of the actual construction so we often worked together on those tasks. With the activities and experiments, we always did those together so we could all learn and because it was fun! Once the mission came out, everyone was part of the discussion about how we were going to modify our ROV so it could accomplish the mission. We tried to make sure we listened to everyone's ideas. Overall, our team got along very well and we learned a lot as we worked together.

Section D. Challenges and Lessons Learned

One of the problems we ran across is that our Team Spirit Coordinator and Technical Writer were part of a musical festival. These team members had many practices required for this festival which interfered with school and our weekly SeaPerch meetings on Tuesdays from 3-5 PM. The critical sections these team members participated in had to be delayed. To resolve this problem, the team delayed the mascot try-outs until the entire team was available. The team used Google Docs so that all team members could share the design notebook until Maeve McMahon, the team's Lead Technical Writer, was available.

Another problem we faced was having the wrong measurements for some of the modified structural pieces of the Nemo Finder 5000. One half of our submarine would not fit with the other. We resolved this problem by cutting some of our PVC pipe shorter to make the two sides fit together and we learned that it is better to make the drawings and part lists before cutting the pieces.

The biggest lesson learned by the team is that one person can't do all of the work. SeaPerch is like a giant science project that is nearly impossible to complete on your own. Working with a team makes the job easier to complete, as opposed to completing the SeaPerch on your own.

Teamwork was one of our biggest factors of success, along with our motors working on the first test.   Last year, it took many sessions to get the motors to work. This year, our motors worked on the first test, allowing us to focus on other things. Working as a team allowed us to do more than one job at once. It was a big part of us being able to be successful.

Section VI: Bill of Material

Section A. List of All Material Used

SeaPerch Kit Items

Quantity	Part Description
1	Sealed lead acid battery- 12V, 7AH
1	Sealed lead acid battery charger
1	Wax Bowl Ring
6	Tie Wraps
3	Waterproofing die cut set for motors
1	Sea Switch control box kit
2	Pool Noodle- 5”
1	50 ft. 350 Mhz cat 5e Stranded cable
1	Velcro Cable tie
3	Film Canister
1	18 Awg speaker wire
3	12 VDC motor 0.7A- shaft diameter “0.091”
1	Solder- 60/40 rosin core
3	Propellers- plastic ⅛” shaft size
3	Propeller shaft threaded coupler
1	Alligator clips (set of 2)
1	Black alligator clip insulator
1	Red alligator clip insulator

1	Butyl Rubber Tape- 1.5”x3” (Monkey Dung)

3	Nylon-insert hex locknut 4-40 - stainless steel
3	Threaded insert Tee nut

4	Tee joints
8	Elbow joints
2	6.5”x 1/2 “ PVC pipe
4	4.5” x ½” PVC pipe
4	2” x 1/2 “ PVC pipe
6	1.5” x ½” PVC pipe
2	2.5” x ½” PVC pipe
2	5” x 1/2 “ PVC pipe

Purchased or Donated Items

Quantity	Description	Price
1	½” PVC pipe Tee joint ($2.76/10)	$0.28*
2	½” PVC pipe Triple joint	$1.18
1	12 oz. Orange spray paint can (Rust-Oleum)	$3.87
2	Red 3V LED Lights ($12.99/300)	$0.04*
2	Resistors (220 Ω) ($5.39/100)	$.05*

1	Clear Silicone Caulk	$3.98

Section B. Receipts

Starred items in the Bill of Material were already owned by the team or were donated. An old receipt was found for the LEDs but store price quotes were used for the tee joints and resistors instead of receipts.

LOWE'S

LOWE'S HOME CENTERS, LLC
116 WEST TOWNSHIP LINE RD.
HAVERTOWN, PA 19083 (610) 526-6168

\- SALE -

SALES#: S3169RS1 F985651 TRANS#: 11789170 03-12-16

315490 1/2-IN SCH40 SIDE OUT ELB 2.36
2 @ 1.18

SUBTOTAL: 2.36
TAX: 0.14
INVOICE 04470 TOTAL: 2.50
CASH : 20.00
CHANGE: 17.50

STORE: 3169 TERMINAL: 04 03/12/16 08:26:27
\# OF ITEMS PURCHASED: 2
EXCLUDES FEES, SERVICES AND SPECIAL ORDER ITEMS

More saving.
More doing.

700 REED ROAD MARPLE, PA 19008
STORE MGR: KELLY GREEN (610)356-3927

4181 00056 84188 03/10/16 03:02 PM
CASHIER SELF CHECK OUT - SCOT56

098168421343 4X4-8 #2PT <A> 8.17
4X4-8FT #2 PT
032247568331 MGPOTTING <A>
32QT MIRACLE GRO POTTING MIX
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24"X36" GALV STEEL FLAT SHEET
611942090691 PVCSIDEOUTEL <A>
1/2" PVC SIDE OUTLET EL SXSXFPT
2@0.98 1.96
611942038335 1/2 M ADAPTR <A>
1/2" PVC MALE ADAPTER SXMPT
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707392696603 FENCE BRKT <A> 0.47
FB24Z 2"X4" 20GA ZMAX FENCE BRACKET
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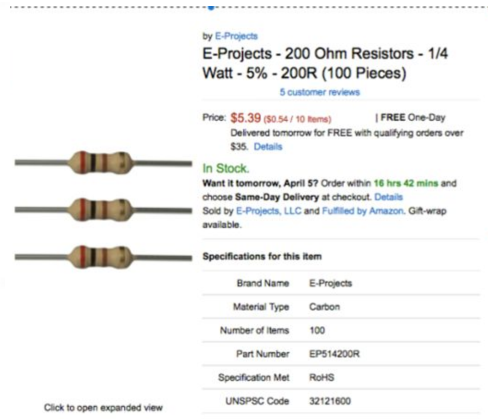
1/2"X6" ACID BRUSH
020066187121 2X RLORANGE <A> 3.87
PAINTERS TOUCH 2X GLSS REAL ORANGE
032076890215 6" LGHPHNTCAT <A> 5.48
10A MAINTAINED PUSH-BUTTON SWITCH
032628156051 THREAD SEAL <A> 3.56
2OZ THRD SEALANT W/PTFE REAL TUFF
071691434702 SPRMPRFLPD <A> 5.97
RUBBERMAID SPRAY MOP REFILL PADS
098268338995 25' POLY <A>
3/8ODX1/4IDX25' POLY TUBE
2@6.78 13.56
077027002841 GECLEAR TUBE <A> 3.98
GE SILICONE II K&B CLEAR 2.8OZ

SUBTOTAL 77.19
SALES TAX 4.63
TOTAL $81.82
XXXXXXXXXXXX6569 DISCOVER 81.82
AUTH CODE 01002P/9563281 TA



amazon.com

Final Details for Order #103-2321643-5037020

Print this page for your records.

Order Placed: November 24, 2015
Amazon.com order number: 103-2321643-5037020
Order Total: $0.00

Shipped on November 25, 2015

Items Ordered	Price
2 of: *3mm and 5mm Assorted Clear LED Light Emitting Diodes 5 Colors Pack of 300* Sold by: CO-RODE (seller profile) Condition: New	$12.99
1 of: *microtivity IL111 5mm Diffused Red LED w/ Resistors (Pack of 30)* Sold by: microtivity (seller profile) Condition: New	$5.49

Item(s) Subtotal:	$31.47
Shipping & Handling:	$0.00

Total before tax:	$31.47
Sales Tax:	$0.00
Rewards Points:	-$31.47

Total for This Shipment:	**$0.00**
Total paid by Rewards Points:	**-$31.47**

Shipping Address:
Curtis Lehman
462 Woodcrest Lane
Media, PA 19063
United States

Shipping Speed:
Two-Day Shipping