Fly Rocket Fly Rocket Report

Student: McNab

Rocket Name: ‘Merica

Date Performed: 9/22/15-11/4/15

Date Submitted: 1/22/16

Partner: Doolittle

Introduction and Initial Research:

Question: Using a 2 Liter bottle, what is the best design for a water rocket in order to achieve maximum distance?

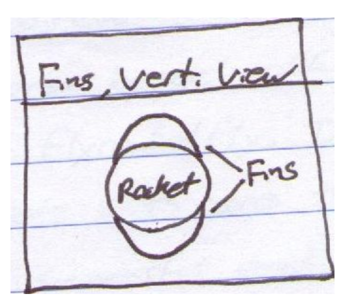
Background: Most of the information that was included on the very first rocket came from general physics knowledge. The nose cone was a result of knowing that it had to be durable to withstand the impacts, and the fins were a result of knowing that more surface area means more correcting ability for the rocket in flight. The research didn't provide any substantial designs for the fins, so the fins that were included on the first rocket were completely pioneered. A plastic sleeve was also included on the end of the rocket, which will be detailed in the section dedicated to the first launch day. The nose cone was attached with duct tape where it met the bottle, the sleeve was duct taped at the seam where it met the bottle, and the fins were attached with vertical strips of duct tape.

Rocket Launch Day 1:

Questions: Will the 3D printed nose cone hold up to the impact of the landing? Will the rocket be stable and fly true with its unique half circle shaped fins? Will the boat tail design be effective?

Background: A nose cone was 3D printed out of plastic because it was guaranteed to be free of most human error, as well as reliable and durable. The half circle shaped fins, as seen in Figure 1, were implemented

Figure 1: 'Half-Circle Fins'



around the idea that the fins with the least air resistance and the most surface area for the air to act upon will increase the rockets “correcting” ability and overall stability.

The extra plastic sleeve on the end of the rocket was modeled off of the design of boat tail bullets, which create a smoother transition for the air when it is leaving the bullet, or in this case the rocket. By using the boattail, the air passing by the rocket would not have to slope down to the nozzle and come in contact with the nozzle, but instead leave the rocket with minimal interference. This would prove to be the key part of this rocket that set it apart from others' rockets. See Figure 2 below for idea.

Figure 2: ‘Boattail Design Element’[1]

Experiment and Analysis: See Figure 3 for distances and pressures on this launch day.

Figure 3: ‘Day One Launch Data’

9/22/15	Test 1	Test 2	Test 3
Distance (Yards)	15	60	94
PSI	70	80	85

[1] "K bullet - Wikipedia, the free encyclopedia." 2011. 20 Jan. 2016 <https://en.wikipedia.org/wiki/K_bullet>

Rocket Construction (Nose Cone): The nose cone was 3D printed with red plastic using CAD software called Inventor. The base diameter was 4.1 inches, the height was 3.75 inches, and the cone thickness was 0.375 inches. The base diameter was solely influenced by the width of the rocket, so that the nose cone would fit right on top of the rocket without any overhang. This hollow nose cone would provide a way to attach weight (in the form of modeling clay) to a forward location on the rocket. The cone was attached to the rocket via duct tape. See Figures 4-5 for CAD drawings.

Figure 4: 'Front View CAD of Nose Cone'

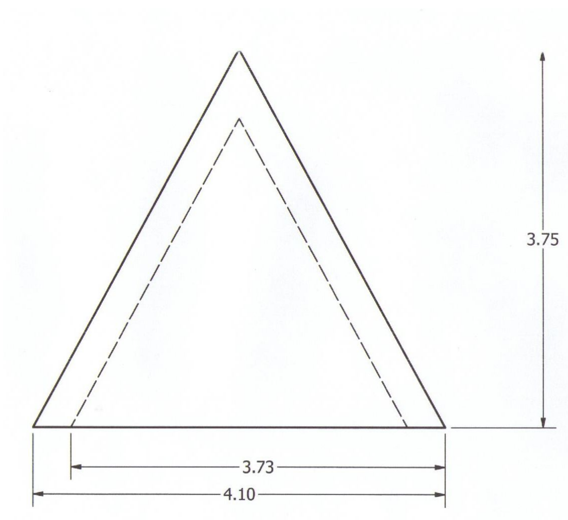
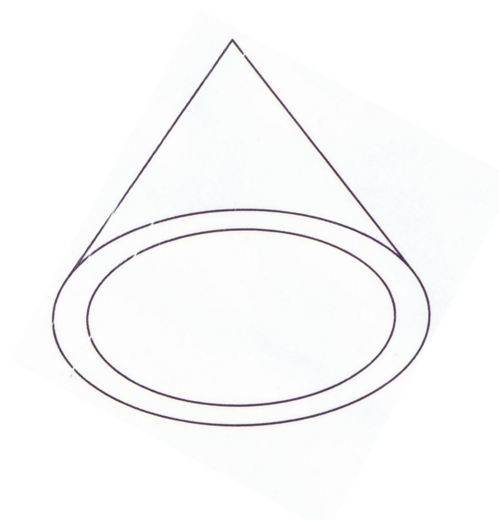
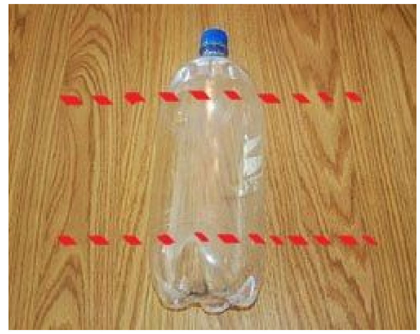


Figure 5: 'Underside of Nose Cone'



Rocket Construction (Boat Tail): The boat tail was made by cutting the "barrel" section of the bottle out and slipping it over the nozzle end of the rocket. The boat tail for this rocket was 4 inches long so that the pin could still be placed on the flat surface of the nozzle, and was attached at the seam with one layer of duct tape. It's crucial to only push the boat tail as far as it will go before dimpling the bottle, because the boat tail is the same diameter as the bottle it is being placed on. As shown in Figure 6, the barrel section of the bottle needs to be cut out and then trimmed down to size.

Figure 6: 'Bottle Cuts for Boat Tail'



Rocket Construction (Fins): The two fins that were used were made with the same process as the boat tail. The barrel section was cut out of a bottle, except instead of being used whole, the barrel was cut in half lengthwise to create two identical half cylinders. The half cylinders were then trimmed down to 5 inches in length and taped along the seams onto the rocket. Refer back to Figure 1 for an overhead sketch of the rocket with fins installed.

Results: The first launch sent the rocket completely vertical because of a lack of weight in the nose cone. At the time, the aforementioned modeling clay way not available, and rocks were used as a substitute when the mistake was brought to light. No official weight is available for this rocket. This mistake was a direct cause of one of the questions asked in the next section, and the main reason why the proper weight for this rocket will be explored.

Rocket Launch Day 2:

<u>Questions</u>: Will adding two extra half cylinder fins add to the stability of the rocket? Will the weight in the nose cone be enough to keep the rocket from losing stability during launch?

Background: All of the information for this launch and the changes to the rocket were taken from the main page of the flyrocketfly[2] website. It is explicitly stated that rockets with more than 2 fins have been very successful and that the mass that works the best in most rockets is 250 grams. This rocket will not be launched at 250g because further testing of this theory is desired, but it should be known that the idea came from the above source. It is better to test multiple weights for a unique rocket instead of assuming that one weight will work the best. Two of the same style fins will be added to the rocket, for the same reason as expressed in the first launch day. Increased surface area means more correcting ability and more stabilization. The fins were also secured in the same manner as before, but with equal spacing for each of the four fins.

Experiment and Analysis: See Figure 7 for distances and on this launch day.

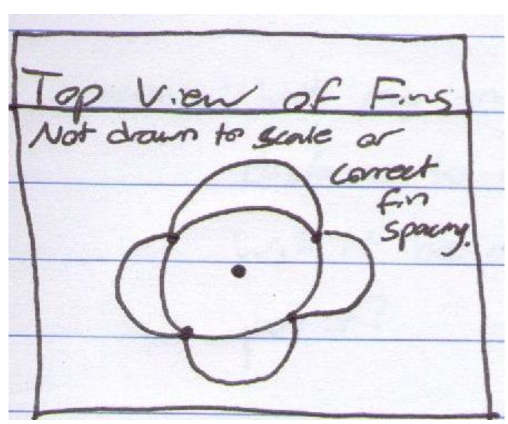
Figure 7: 'Day Two Launch Data'

9/28/15	Test 1	Test 2	Test 3
Distance (Yards)	80	103	130

Rocket Construction (Weight):These launches were performed with 139.6 grams of modeling clay that was packed into the front of the nose cone.

Rocket Construction (Fins): The four fins were evenly distributed on the rocket and attached along the fin/rocket intersection with duct tape. The final product can be seen in the sketch to the right (Figure 8). The boat tail was still in use at this point.

Figure 8: 'Top View of Fins'



[2] http://www.naturalphilosophers.org/rockets/

Results: From this launch day, it was determined that the rocket is very consistent. It has been landing in the same area despite minor changes that were made to the rocket in between launches. The pioneering of new ideas will continue in the rest of the launch entries.

Rocket Launch Day 3:

Questions: Will designing an extended nozzle increase the launch distances? Will the nozzle be able to withstand the internal pressures exerted upon it?

Background: The only change that was made to this rocket was the extension of the nozzle. The nozzle was extended because Mr. Darlington said that “the key to success is in the nozzle.” This led to the experimentation of different nozzle designs through the use of the engineering decision matrix. By extending the nozzle, we would be keeping the water and air in the rocket for a longer period of time, which essentially would extend the time that those forces are utilized and make the rocket go further.

Experiment and Analysis: See Figure 9 for distances on this launch day.

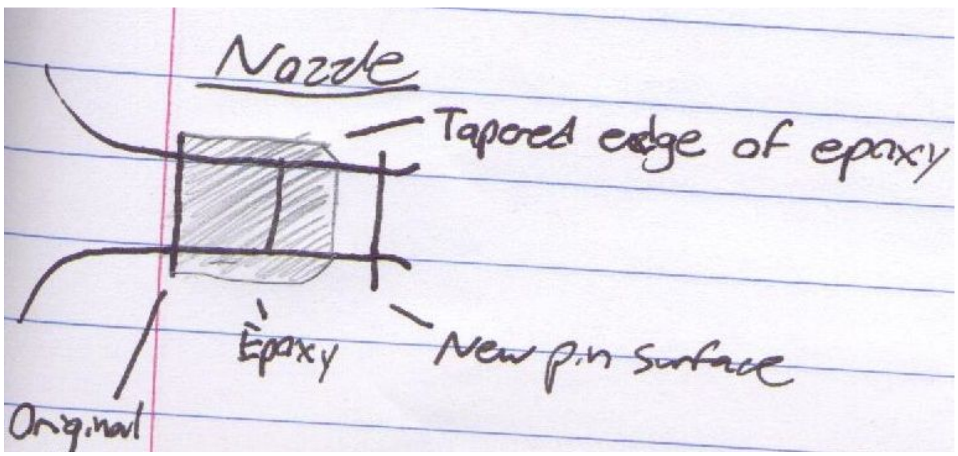
Figure 9: ‘Day Three Launch Data’

10/2/15	Test 1	Test 2	Test 3
Distance (Yards)	100	90	138

Rocket Construction (First Nozzle): The first nozzle design can be seen to the right in Figure 10. This nozzle did not work because it did not fit on the launcher. The nozzle was redesigned and would ultimately become the nozzle that was used on most of the rockets to follow. In order to understand the construction of this nozzle, one must familiarize themselves with the sketch in Figure 11.

Figure 10: 'Failed Nozzle Design'

Figure 11: 'Successful Nozzle Design #1'



Rocket Construction (Second Nozzle): To begin the construction of the nozzle, one must obtain another bottle, two ton (or similar) epoxy, a section of PVC pipe that is the same diameter as the inside of the nozzle, and a large hose clamp. First, the nozzle is cut off of the second bottle about 3mm behind the surface where the pin would've rested. If the cut is made any further backward, the nozzle may not fit inside of the launcher like it should. Next, the new nozzle is placed on top of the original nozzle as shown in Figure 11, and the PVC pipe is slipped into the opening to hold the two together. After that, a strip of plastic is cut from the barrel of a bottle that should be both long enough to wrap once around the nozzle and short enough (widthwise) to be able to pour epoxy into the gap between the plastic and the threaded part of the nozzle. Once the strip is properly dimensioned, it is secured to the original pin surface with a hose clamp. This creates a way to pour epoxy into that space without it flowing completely through. Before the hose clamp is tightened down all the way, the strip should be checked to see if it is completely cylindrical all the way up. In the end, the epoxy should be the same thickness all the way around. Any variation in thickness will cause a weak spot for the nozzle to break at. Then the epoxy is mixed and poured into the created space until there is just enough room for the pin to be able to fit on the new pin surface. Once dry, the plastic strip will peel right off of the epoxy when the hose clamp is removed. There is now a solid mass of epoxy holding the new nozzle onto the original nozzle. The pin should have plenty of room when inserted into this slot. If it is too tight, the pull cord will pull the rocket to the side when launched, and the rocket will fly into the woods. The final product will look like that pictured in Figure 12 below.

Figure 12: 'Successful Nozzle Construction'

Note that with the extended nozzle, a longer boat tail may be utilized. The boat tail was extended for all rockets that were tested that had the new nozzle design, to maximize the aerodynamics.

Results: There were very few successful launches on this day, because the fins of the rocket kept tearing off due to higher velocities. This meant that an accurate observation of the new nozzle wasn't possible, and testing would have to continue in the future. It also meant that new fins were necessary if the rocket were to have successful launches.

Rocket Launch Day 4:

Questions: Will implementing new fins provide added stability and reduced drag? With fins that are now functioning, how does the nozzle affect the distance the rocket travels? What is this rockets sweet spot when it comes to mass?

Background: The fins on the previous rocket tore off mid flight, which prevented a correct assessment of the new nozzle. This led to the design of new fins made out of a unique material given to us by Conor Bradshaw and Caroline Conti.

Experiment and Analysis: See Figure 13 for distances on this launch day.

Figure 13: 'Day Four Launch Data'

10/8/15	Test 1	Test 2	Test 3
Distance (Yards)	149	149	134

Rocket Construction (Fins): The new fins were made out of a material called Corflute (pictured in Figure 14) and is generally used in the production of campaign signs. It is a corrugated plastic, which means that if cut correctly in relation to the rocket, the air will pass right through the fins. Four fins were included on this rocket, each one a 3-4-5 right triangle (inches). It should be known that for this rocket and all rockets that followed, the fins were made of Corflute and were flush with the end of the boat tail. They were secured by taping both sides of the Corflute down onto the surface of the rocket.

Figure 14[3]: 'Corflute'

Rocket Construction (Weight): The weight in the nose cone was also changed slightly, anywhere between 220g and 250g to determine which worked the best. As usual, the weight was in the form of modeling clay packed into the hollow nose cone. After the launches were complete, the ideal mass was said to be 230g. All future rockets would have this same mass.

Results: The fins functioned well, and a solid observation of the nozzle was made possible. After testing, it was concluded that the nozzle was neither helping the rocket nor hurting it, so the nozzle would be included until it was phased out by newer designs. All of the problems with the rocket had been fixed, and this launch day had given us all the information we were looking for. It was time to pioneer another piece of the rocket, or at least study the one aspect of the rocket that would ultimately end up being the key to success.

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[3] https://www.biltongraphics.com.au/products/substrates/corflute

Rocket Launch Day 5:

Questions: What is the boat tail actually doing to the rocket during its flight path? Is the sleeve even beneficial? What is the best design for a nose cone that is both aerodynamic and durable?

Background: At the end of the last launch, Mr. Darlington pointed out that the rocket was going higher and getting more airtime than any other rocket. He said that he thinks it's the sleeve that we have on the end of the rocket, so for this launch the sleeve will be completely isolated and tested. In addition to that, the boat tail was attached to the first rocket with no prior testing or knowledge outside of physics and common sense, so it was beneficial to isolate the sleeve. Two brand new and identical rockets were made for this launch day (one of them had the sleeve and one didn't), so the opportunity was taken to test out a new nose cone design. The 3D printed nose cone had taken a beating over the last few weeks, so it was time to phase it out of use.

Experiment and Analysis: See Figures 15 and 16 for distances on this launch day.

Figure 15: 'Day Five Launch Data (With Sleeve)'

10/15/15	Test 1	Test 2
Distance (Yards)	235	226

Figure 16: 'Day Five Launch Data (Without Sleeve)'

10/15/15	Test 1	Test 2
Distance (Yards)	143	118

Rocket Construction (Nozzle): Both rockets were equipped with nozzles (see Figure 11 and launch day three for more information).

Rocket Construction (Fins): The same Corflute fins that were used on the fourth launch day were used on this launch day (see test day 4).

Rocket Construction (Weight): Both rockets had identical masses of 230g.

Rocket Construction (Nose Cone): The nose cones are the only newly designed rocket parts for this launch. To make the nose cones, one will need two easter eggs, hot glue, duct tape, two bottles, and modeling clay. First, the curved part of the bottles were cut off. They were cut about 6 mm from the nozzle and an inch past the first seam on the barrel of the bottle. This one inch extension is necessary in order to slip the nose cone onto the bottle in the same fashion as the boat tail, without dimpling it. The easter egg was placed on the front most part of the nose cone, centered, and traced so that the nose cone could be cut to dimension. The final cut should be narrower than the circle that was traced so that the easter egg doesn't fall through into the nose cone. The easter egg is then packed with modeling clay and recentered on the nose cone, where it is then hot glued in place at the intersection of the egg and cone. Additional modeling clay should be added to the interior of the nose cone in order to reach the desired mass. The hot glued seam is then duct taped over for added support, and the nose cone is slipped onto the rocket and duct taped at the seam. The nose cones and rockets without fins can be seen in Figure 17 below (also without duct tape around easter egg seam).

Figure 17: 'Nearly Identical'

Results: As can be seen in Figures 15 and 16, the rocket with the

sleeve went much further than the rocket without the sleeve. The rocket without the sleeve struggled to break 150 yards while the rocket with the sleeve was setting class records. The sleeve has now been proven to be the most influential part of the rocket, and would continue to be the most important part until the lab was finished. As for the nose cones, they were completely destroyed. This will lead into launch day 6, with the need to design a new nose cone to capitalize on the sleeve discovery.

Rocket Launch Day 6:

Questions: What is the best possible nose cone design to capitalize on the sleeve breakthrough?

Background: With the failure of the last easter egg nose cones, it was obvious that a new design was needed that was both more aerodynamic and durable. In our research, we found that parabolic nose cones are used for subsonic speeds and more pointed nose cones are for supersonic speeds[4]. Since the rockets are going relatively slow compared to other aircraft, the new nose cone would need to be as parabolic as possible. The same principle was used as the egg nose cones, but instead of eggs on the outside, it was a golf ball protruding out from the inside. This helped to create the most parabolic nose cone possible.

Experiment and Analysis: See Figure 18 for distances on this launch day.

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[4] http://www.aerospaceweb.org/question/aerodynamics/q0151.shtml

Figure 18: **‘Day Six Launch Data’**

10/20/15	Test 1	Test 2	Test 3
Distance (Yards)	190	N/A	N/A

Rocket Construction (Nose Cone): The nose cone was cut the same way as it was for the previous launch day’s nose cones (see launch day 5 for details). From there, a golf ball was fitted to the inside of the nose cone so that it protruded just enough to make a perfect parabolic nose cone. This required drilling the hole in the front of the nose cone until it was the perfect size for the gold ball. Once the size was obtained, the golf ball was sanded down so that it no longer had the dimples that are characteristic of golf balls. This meant the air would pass by the golf ball easier, making the rocket more aerodynamic. There were then two hot glue applications: one strip between the golf ball and the cone on the inside, and one strip where the ball met the cone on the outside. Modeling clay was then packed above the hot glue on the inside until the desired weight was reached. The clay both held the ball in place and added weight. Finally, the hot glue on the outside of the nose cone was sanded down, simply because the hot glue was not there to hold the ball but instead to fill the little gaps between the ball and cone. Four small slits were made at the rear end of the nose cone so that the cone could slip over the rocket to the point where the golf ball was in contact with the bottom of the bottle. This ensured that the nose cone would not cave in upon impact, but instead distribute the force throughout the rocket. The cone was taped at the seam, and the rest of the rocket remained unchanged. Figure 19 shows the completed nose cone.

Results: The rocket was only launched once because the nozzle broke and could not be repaired. The nose cone received little damage, so it was incorporated into the next rocket. The next launch would be dedicated to strengthening the nozzle because it broke, as well as pondering the aerodynamics behind the Corflute.

Figure 19: 'Completed Nose Cone'

Rocket Launch Day 7:

Did Not Launch.

Rocket Launch Day 8:

<u>Questions</u>: What is the best way to redesign the nozzle for strength? Can Corflute fins be created that are both stronger and more aerodynamic?

<u>Background</u>: The last launch day was cut short because of a broken nozzle, so the nozzle would be redesigned and implemented for this launch day. The aerodynamics of the fins are also under question, so Corflute fins would be redesigned to be more aerodynamic.

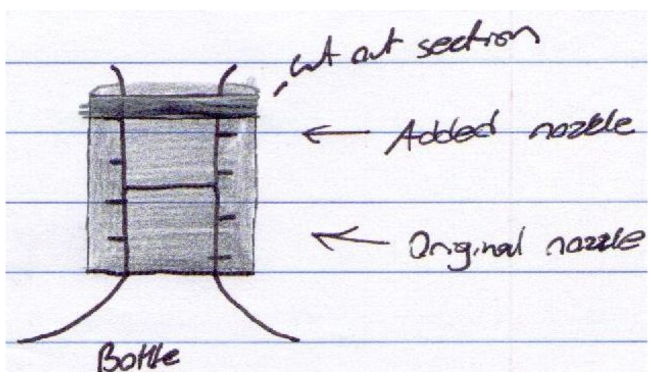
<u>Experiment and Analysis</u>: See Figure 20 for distances on this launch day.

Figure 20: 'Day Eight Launch Data'

10/30/15	Test 1
Distances (Yards)	Approximately 200

Rocket Construction (Nozzle): This nozzle was constructed in the same manner as the nozzles of the past (refer back to Figure 11 and launch day three) with two small changes to increase strength. Instead of stopping the epoxy before the lip that the pin holds onto, the epoxy was poured until it was level with that lip. A dremel was then used to cut out a section right beneath that lip for the pin to go. Figure 21 shows a sketch of the new nozzle.

Figure 21: 'New and Final Nozzle Design'



Rocket Construction (Fins): The same 3-4-5 right triangle Corflute fins would be used for this rocket, but a different duct taping method was used. First and before the fins were even on the rocket, the forward facing surface was covered with duct tape to cover up the airflow holes. The duct tape was applied so that it was perpendicular to this surface before pulling the tape onto the sides of the fin. The excess tape was then trimmed off so that it retained its original dimensions. The four fins were then attached to the rocket with one piece of vertical duct tape on each side, just to hold it in place for the moment.

Figure 22 shows this step. The fins were taped on so that the back of the fin was flush with the back of the boat tail. Next, the fins were taped on even more securely by using the same process that was used to wrap them in duct tape. The tape was applied perpendicular, and ran down the sides of the fin and onto the bottle. This will create an angled pieces of duct tape, which is fine. This is shown by Figure 23 below.

Figure 22: 'Taping Fins Onto Rocket'

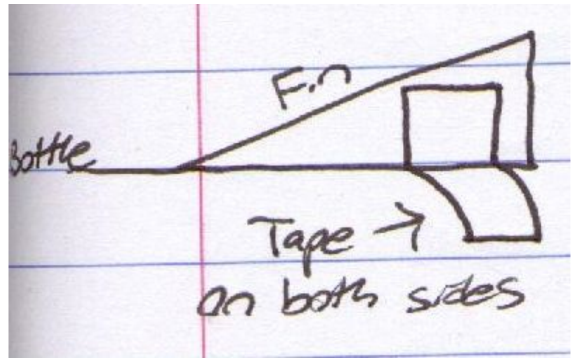
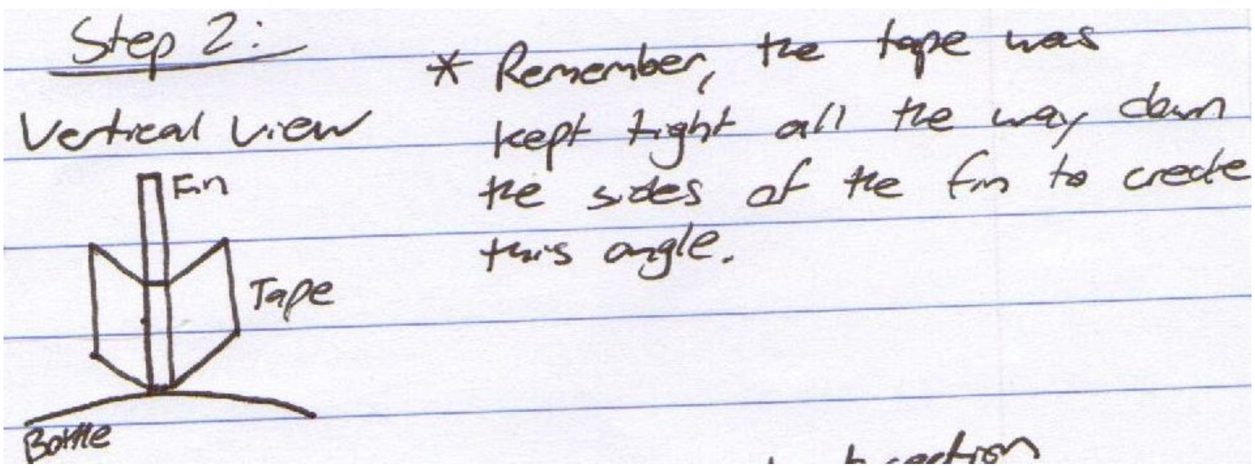
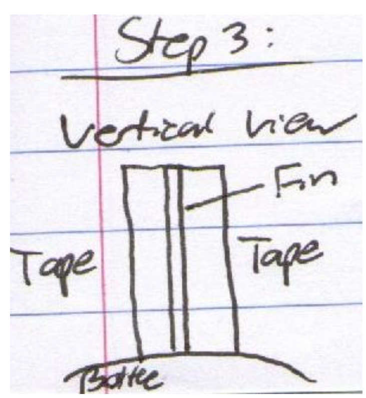


Figure 23: 'Taping Procedure'



Lastly, pieces of duct tape are applied along side of the fins so that the same vertical view in Figure 23 looks like the vertical view in Figure 24.

Figure 24: 'Final Vertical View'



Results: The rocket flew very high and very far, but the slot that was cut for the pin to rest in was too tight, resulting in an offset flight path and a landing in the woods. The rocket was retrieved and fixed so that this issue would not happen again.

Rocket Launch Day 9:

Questions: Is the nozzle really doing anything to benefit the rocket, or is it just adding weight? Will the new and final nose cone design hold up against the impacts?

Background: The nozzle was never isolated and tested like the boat tail was on launch day 5, so it would be beneficial to know if it was improving the distances or just adding weight. Also, the nose cone was redesigned after it failed to survive the tree landing of the last launch day. The new design would end up being the final nose cone design and would be used on rocket day. The rocket being built will be identical to the rocket from launch day eight, except it will have the new nose cone and no nozzle. This will allow for the testing of the nozzle and nose cone at the same time.

Experiment and Analysis: See Figures 25 and 26 for distances on this launch day.

Figure 25: 'Day Nine Launch Data (With Nozzle)'

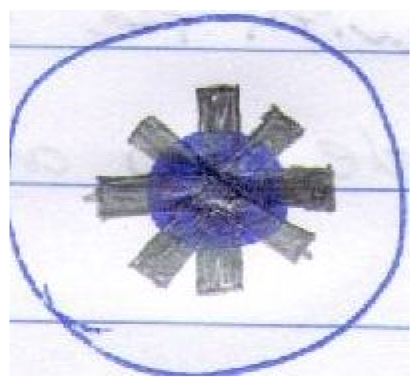
11/4/15	Test 1	Test 2	Test 3
Distances (Yards)	134	149	N/A

Figure 26: 'Day Nine Launch Data (Without Nozzle)'

11/4/15	Test 1	Test 2	Test 3
Distances (Yards)	219	182	210

Rocket Construction (Nose Cone): The Nose cone was built with the same principles as the golf ball nose cone, but with slight variations. Instead of one nose cone, two identical nose cones were cut and placed one inside of the other for added strength. Instead of a golf ball, a large bouncy ball was used. Instead of being held onto the nose cone by hot glue, the bouncy ball had a trench cut into it so that when it was forced into the opening on the nose cone, the plastic would sink into the bouncy ball trench and hold it there firmly. The modeling clay was then packed around it, and the double thick nose cone received two slits so that it could slide onto the bottom of the bottle without dimpling it. Just like the golf ball nose cone, it was pushed back until the bouncy ball was touching the bottle, to increase shock absorption and dispersion. Finally, two pieces of equal length duct tape were torn in half lengthwise and placed over the bouncy ball, as shown in Figure 27, to further increase aerodynamics.

Figure 27: 'Top View of Rocket'



Rocket Construction (Fins): The same 3-4-5 right triangle fins were used for this rocket.

Rocket Construction (Boat Tail): As with all rockets, the boat tail was included.

Results: The rocket without the nozzle was consistently going further than the rocket with the nozzle. This meant that the nozzle would be completely removed from any and all future rockets. Accordingly, the shorter version of the boat tail would need to be utilized. The new bouncy ball nose cone had zero damage to it whatsoever, which meant that this would be the nose cone included in any and all future rockets. The boat tail was also included in all future rockets, as well as the 3-4-5 taped fins that were introduced on launch day 8.

Final Rocket Day Rocket:

The rocket that was built for rocket day and would go on to win the golden rocket was a combination of all of the best discoveries throughout the rocket lab. The rocket had the bouncy ball nose cone (presented on launch day 9) with the taping method presented on launch day 5, the boat tail that was present since the first launch on all but one rocket, and the fins that made an appearance on launch day 4 with the taping method presented in launch day eight. Refer to the aforementioned launch days to receive in depth information about how each part was produced, with measurements, materials, and pictures. These key elements combined their aerodynamic and durability efforts to produce a final winning distance of 245 yards. The final rocket can be seen in Figures 28-30 below.

Figure 28: 'Final Rocket'

Figure 29: 'Final Rocket Cone'

Figure 30: 'Final Rocket Bottom'

Conclusion:

Summary: The single most important lesson that was learned during the design and testing phases was that it is OK to brainstorm ideas instead of always building off of others ideas. The discoveries that were made with these rockets would not have been possible if they were modeled off of other people's ideas. This lesson influenced the final rocket because the key parts were made through the inclusion of ideas that were grounded in reality and backed by physics. As previously mentioned, the final rocket's build can be seen in the "Final Rocket Day Rocket" section above. From there, even more in depth details can be found in their respective locations.

Advice: The best advice that future classes could receive would be not to fear the unknown, and instead face it head on with determination and intelligence. If a new idea or part needs to be made/incorporated in a rocket, then sometimes it's best to come up with your own ideas instead of using others information. That is how breakthroughs are made. This advice would've been very helpful before these rockets were built.

Launch Team:

Radio Operator: The radio operator is responsible for communicating with the downrange radio operator to make sure that the field is clear before launch. After the field is said to be clear, launch protocol begins. This ensures the safety of all rocket owners and the teacher.

Runner: The runner's responsibility is to retrieve the rocket and run it to the next runner in line, in order to get the rocket back to the launch site. You have to wait for the sign man and Hawkeye to get an accurate distance reading before taking the rocket.

Sign man: The sign man's responsibility is to run to the rocket impact site and stand with a sign, so that hawkeye can get an accurate distance measurement.

All three of these positions were held over the course of the rocket lab.