Fly Rocket Fly

Black Hawk and Velocity 9

November 30th, 2016

Velocity 9-244 Yards

Black Hawk-257 Yards

Purpose

The question posed in this project is one that could inspire future physicists, mathematicians, and aeronautical engineers. The two liter soda bottle is common place in many households and seen regularly in gigantic stacks in grocery shops. This humble amalgamation of petroleum products seems unassuming at first glance but the potential of such a bottle is so much greater than you can see. The question posed is how far can this flimsy bottle be launched similar to that of a rocket. This is your mission. To make a bottle rocket like the world has never seen. Using just water and pressure to power these behemoths of engineering, many great discoveries will be made. Through numerous days of grueling testing you will refine your rocket. Fiddling with a great deal of variables to surmount the greatest distance with your rocket.You will complete extensive research on the subject and become experts on bottle rocketry. Gather your wits and prepare for liftoff.

Literature Review

Mass: Mass is one of the most important factors when designing a rocket with the goal being distance. According to past year's students there needs to be a balance between to light of a mass and too heavy of a mass. If you have a mass that is too light there will be a great deal of acceleration off the launch pad but the rocket will get heavily influenced by wind and overall have a shorter launch. If you use too heavy of a mass then the rocket will not receive enough acceleration off the launch pad to get anywhere noteworthy. Finding the correct balance for your rocket is essential. A good starting point of mass would be around 350 grams and adjust that according to rocket performance. Another consideration to make regarding mass would be to put a ballast in your rocket that would allow for the changing of the mass easily and you could even test various masses on the same testing day. Ballast location is also important because in order to achieve the best balance in your rocket the ballast has to counteract the fins and work in equilibrium. The nose cone is most likely the best place to have your ballast located to sort of pull the rocket and keep it on a true path.

Nose Cone: Traditional nose cones that are of a cone shape are most likely not the best option to put on the top of your rocket. Cone shaped items like a funnel or a small sports cone are typically not the best route to take as it limits aerodynamic potential of your rocket. Parabolic or spherical shaped cones consistently outperform traditional cones. This is the type of nose that was used on the space shuttles and is a proven shape to provide the least air resistance. The most efficient shape that we currently know of is the "Von Karman Ogive". This is a sort of an ellipse shape similar to that of a bullet.

Fins: One of the most important things to consider when deciding on what design to give your fins the first step is to figure out your desired material. The best fin material would be very rigid and not breaking on impact would be a pretty big plus. Another variable to consider is how easy the material is to work with. If you are fumbling around during the manufacturing portion then your fins will be of a lesser quality. A material that we found to be very successful was vinyl siding or something similar. The next step is a fin design. There are numerous variations of fin design ranging from a simple triangle on the back of the rocket to more complex curved fins that require careful measurements. The fins that we used were rectangular in nature but hugged the back of the rocket where it curved into the nozzle. We chose this sort of fin design due to the fins being farther back allowing for a more even center of gravity. With this design we could get the fins just about as far back as possible while allowing it to be as stable as possible.

Fastening: In order to hold our rocket together we used a multitude of fastening agents. One of the tapes that we used was glass strapping tape. This tape is similar to packing tape however it has a mesh imbedded in it to make it more structurally sound. We used this tape to cover seams and for just general structural stability. Another tape that we found very useful was Gorilla Tape. It is a brand of duct tape that is exceptionally strong, we used this to attach our fins as well as our nose cone. At the heart of our rocket is PL Premium glue. This is the glue that we used to hold our spliced bottles together. At the insertion point of the bottles this was used to prevent slippage and breakage. We also used this glue in a sort of reinforcement band around this seam as an extra layer of protection against a break. All of these performed very well especially the glass strapping tape which provided a good deal of extra structural strength.

General Lessons: There are a few general lessons in bottle rocketry to be learned from this project. The one that I personally believe to be the most important is to keep testing with different variables. Finding the correct balance between all of your variables is what will make your rocket be a record breaker.This is why it is essential to keep on testing and trying new and different things to find out what your ideal balance is. Another lesson that I learned well from this project is to keep it simple. Often times a very ambitious rocket will fall flat because it was so complex and harder to make. A very simple but well made rocket will most likely out perform an overly complex one. I'm not saying don't be creative but it is essential to know and have the fundamentals down before you go onto bigger things.

Splicing: Splicing bottles can be a very tedious and difficult process if you don't know the proper way join two bottles. The first step is to clean the bottle from all glue wrappers and cap rings. Then you cut the bottle along the bottom line. Then put 3cm of water in a saucepan and heat it to about 72C and leave the bottle in for 20seconds. As it starts to steam turn off the heat and press a bottle and press it evenly on the bottom of the saucepan. You should take it out every few seconds until it fits snugly into the bottom of another bottle. Once you get a solid and snug fit then you can apply a coat of PL Premium or your preferred glue. Give this time to dry according to your glue. Then as the glue is dry cut a small band of bottle so that it fits around the seam where the bottle is joined. Then use glue to attach this to the bottle. This will provide more structural integrity for the seam to make sure it does not break.

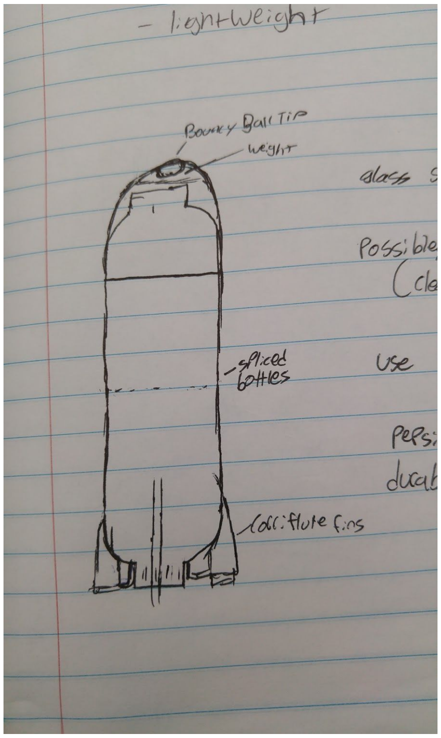

Figure 1

Sciencelearn. sciencelearn.org.nz/Contexts/Rockets/Science-Ideas-and-Concepts/Rocket-aerodynamics. Accessed 19 Dec. 2016.

Apogeerockets. www.apogeerockets.com/technical_publication_16. Accessed 19 Dec. 2016.

Testing and Development

Mission #1: 2016-September 30th

Mission #1: Preparation- In order to prepare for this day a rocket had to be manufactured. In order to create the design in Figure 1 two bottles needed to be spliced together. Four 1-liter bottles and two 2-liter bottles needed to be joined together. In order to do this the bottles first needed to be stripped of all labels and adhesives. All of the bottles were cut along an existing line near the bottom of the bottles. The next step to joining the bottles was to ensure a snug fit between bottles. To do this one bottle was placed in 3 cm of water at around 72C for about 20 seconds. This shrinks the bottle allowing it to fit into another bottle. Then in order to ensure a snug fit the bottles were pressed against a hot pan so the edges would curl. Then about 2 centimeters of the inside of the not shrunken bottle was sanded to allow for a good gluing area. The outside of the shrunken bottle was then applied with PL Premium glue and fit inside of the non shrunken bottle. This was then repeated to the other bottles.The joined bottles need time to dry so they will not be prepared for this mission. A blank bottle will be tested in place of the rockets.


Figure 2

Misson #1: Results- The flight of this rocket was very erratic as the moment that it came off of the launcher it did a loop and slammed into the ground. We found that fins for stability are possibly the most important part of a rocket

Angle	Pressure	Water	Distance
45 Degrees	110 Psi	1 Liter	22 Yards

Figure 3

Mission #1: Recommendations- Adding various components to the rocket is of utmost importance .

Mission #2: 2016-October, 4th

Mission #2: Preparation- After the rockets have dried more structural support needed to be added. In preparation for this mission a strip of of PET plastic from a spare bottle was added. A 3 cm strip was cut out of a bottle identical to the bottle the rocket is made of. This was then glued to the seam using PL Premium glue. Since the glue added circumference to the bottle and another PET strip was glued to the stream. This reinforcement was able to dry in time for this mission and the rocket will be launched. The two stage rocket will not be launched on this day due to difficulties securing two separate joined bottles. Fins were also manufactured for the rocket. These fins are made out of tapered cedar wood. This material is hoped to have a rigid enough structure for the fins to operate effectively. This is a small sketch of the fin design showing dimensions used in the fins. The weight that we have for this mission is 351 grams.

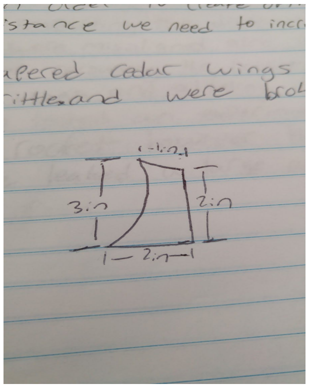

Figure 4

Mission #2: Results-As the rocket left the launcher it made a flight pattern similar that of an exponential curve gaining significant altitude. After reaching the top of its ascent it began to fall into a tailspin

Angle	Pressure	Water	Distance
45 Degrees	120 Psi	1.2 Liter	85 Yards

Figure 5

Mission #2: Results- We concluded that the tailspin was due to the relatively small wings that were on the rocket. They also turned out to be very brittle and actually broke on impact with the ground. We will need to figure out a more sturdy material that can take more of a beating. We also thought about reducing weight and seeing what sort of affects that this could have on the rocket.

Mission #3: 2016-October, 6th

Mission #3: Preparation- As preparation for the launch of day 3 brand new fins were fashioned. These fins were made of vinyl siding because this material would be very sturdy yet flexible allowing it to take hits as it lands. This is the largest part of testing that will be done on this day. The dual chamber rocket that was manufactured earlier will be prepared for launch. The portion of this that will be tested is the connector piece used to connect the two rockets.

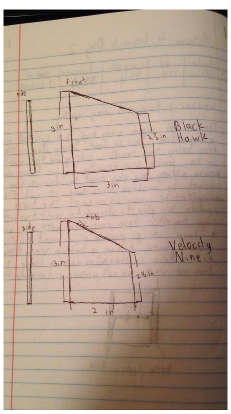

Figure 6

Mission #3: Results- Velocity 9 was a failure as the connector piece between the two chambers leaked a significant amount of water making it impossible to launch.

Angle	Pressure	Water	Distance
32 Degrees	135 Psi	1 Liter	205 Yards

Figure 7

Angle	Pressure	Water	Distance
41 Degrees	134 Psi	1 Liter	238 Yards

Figure 8

Mission #3: Recommendation- A launch angle that is closer to 45 degrees seems to be optimal for this rocket as opposed to a 32 degree angle. This could have impacted the distance of the launch negatively. The new fins may have been misaligned slightly. This could also have negatively impacted the overall distance achieved and is something that needs fixing for the next mission. For Velocity 9 work will need to be done on a more stable and waterproof connector piece due to the leakage that occurred. A Tornado Tube is a possible solution for a viable connector piece.

Mission #4: 2016-October, 13th

Mission #4: Preparation- For this launch day the fins were re-aligned on Black Hawk. The main variable that is being tested on this day is the mass of the rocket. The mass has been increased 20 grams since last launch and the effects will be recorded.

Mission #4: Results-

Angle	Pressure	Water	Distance
45 Degrees	140 Psi	1 Liter	247 Yards

Figure 9

Mission #4: Recommendation- After recovering the rocket from the field it was found that the nosecone was irreparably damaged. A new nose cone will have to be constructed while taking into account how much damage the previous one received. It is believed that because the rockets upwards trajectory and it's landing almost vertically is why the nose cone broke the way it did. Another factor that could have influenced the breakage is the added mass. Another note to make about the flight of the rocket is that it was quite wobbly and not straight. It can be concluded that the fins will need to be revised further to get it on a straight path.

Mission #5: 2016-October, 19th

Mission #5: Preparation- There was no change in any parts of the physical rocket for this mission. the main testing area for this mission is to see how the different volumes of water affect how the rocket performs. The intent is to observe if a larger amount of water counteracts the added weight that comes along with adding the water. The design being used has a much larger fuel storage capacity than other traditional rockets which allows for more fuel storage.

Mission #5 Results-

Angle	Pressure	Water	Distance
41 Degrees	135 Psi	2 Liters	202 Yards

Figure 10

Angle	Pressure	Water	Distance
41 Degrees	130 Psi	1.625 Liters	200 Yards

Figure 11

Mission #5: Recommendation- Using a larger amount of water seemed to lower the overall distance that the rocket travelled. According to figure 11 using 2 liters of water reduced the distance considerably from the last mission. It seems that using the added weight from the water impacted the distance more than the extra fuel. A possible reason that the second launch did not yield accurate results relating to water level as the nose cone was severely damaged from the first launch. This does however provide some useful data relating to the nose cone design. It is clear that the current design is not adequate because of the last two mishaps. In conclusion a new nose cone should be designed or alternatively we can replace the nose cone after each launch.

Mission #6: 2016-October, 25th

Mission #6: Preparation- In preparation for this mission a new nose cone had to be made. Because of the previous launch the nose cone was irreparably damaged and needed to be replaced. The weight located in the nose cone was also changed for this mission. Velocity 9 will also be launched on this day to test the new connector piece.

Mission #6: Results- Black hawk performed very well on this launch. This could be because the change of weight in the nose cone. Velocity 9 was also successfully launched however it performed worse than what was expected. The flight pattern was parabolic but went toward the ground quite quickly. This could be due to the top heavy nature of the rocket and is something to be considered.

Angle	Pressure	Water	Distance
40 Degrees	Max Psi	1 Liter	257 Yards

Figure 12 (Black Hawk)

Angle	Pressure	Water	Distance
40 Degrees	130 Psi	1 Liter	107 Yards

Figure 13 (Velocity 9)

Mission #6: Recommendation- Something that could be done to prepare is to create more nose cones for Black Hawk. Another large portion that could be done to aid in Velocity 9 is working on the weight distribution. Due to the uneven nature of the weight distribution the flight was short and abrupt. If this is changed to a more even distribution it may improve the possible distance.

Mission #7: 2016-October, 27th

Mission #7: Preparation- To prepare for this launch two new nose cones were created for Black Hawk. The hope is that these nose cones will last longer than other nose cones but we will have a few backup. However the Black Hawk was not launched on this day because Velocity 9 needed a good deal of testing to perfect. Velocity 9 was launched twice with the first launch trying to focus one liter of water in the top portion of the rocket to try and prolong fuel life.

Mission #7: Results-

Angle	Pressure	Water	Distance
40 Degrees	135 Psi	1 Liter	0 Yards

Figure 14 (Velocity 9)

Angle	Pressure	Water	Distance
40 Degrees	135 Psi	1 Liter	128 Yards

Figure 15 (Velocity 9)

Mission #7: Recommendation- It was found that focusing the water in the top portion of velocit 9 would not be an effective strategy. Instead of funneling fuel and lowering its usage it made the rocket much too top heavy and it ended up falling off of the launcher. The water also just flowed back into second chamber which would have produced the same result as just filling the second chamber. For the second launch only one third of the water was added to the top chamber and the rest to the bottom. This was shown to be the most optimal way to launch Velocity 9 while utilizing both chamber. It may have something to do with a more even weight distribution right after the launch. Black Hawk was not launched on this day to allow maximum time for perfecting Velocity 9.

Mission #8: 2016-October, 31st

Mission #8: Preparation- To prepare for this mission the weights of both Black Hawk and Velocity 9 were reduced slightly. This is the main area of testing for this mission. Another preparation executed was the creation of a buffer area between the main body and the ballast of Black Hawk. The goal of this buffer is to absorb some of the landing and protect the main body of the rocket. This elongated the nose cone considerably so the impacts will have to be observed.

Mission #8: Results-

Angle	Pressure	Water	Distance
45 Degrees	135 Psi	1 Liter	219 Yards

Figure 16 (Black Hawk)

Angle	Pressure	Water	Distance
45 Degrees	135 Psi	1 Liter	244 Yards

Figure 17(Velocity Nine)

Angle	Pressure	Water	Distance
47 Degrees	135 Psi	1 Liter	196 Yards

Figure 18 (Black Hawk)

Angle	Pressure	Water	Distance
47 Degrees	135 Psi	1 Liter	186 Yards

Figure 19 (Velocity 9)

Mission #8: Recommendation- On the first launch of Black Hawk the rocket sustained a good amount of damage and performed poorly compared to other launches. Some possible causes of this are the buffer or the change in weight or even a combination of the two. On the second launch the reinforcing bottle ripped and crinkled some of the base bottle. A possible cause of this is the buffer which sent back more force than expected causing the bottle to crinkle. Velocity 9 went a fair distance for both launches however the nose cone sustained serious damage. This could be difficult to fix since we ran out of 1 liter bottles. This is something that must be considered and repaired for the next mission.

Mission #9: 2016-November, 2nd

Mission #9: Preparation- For this mission the main portion of preparation went into the nose cones. Bothe rocket's nose cones needed to be completely replaced in order to be ready for launch. A 1 liter bottle was able to be sourced and the nose cones were replaced. For this mission the main testing area will be mass again. It seems that this is one of the most important variables to consider when launching.

Mission #9: Results-

Angle	Pressure	Water	Distance
45 Degrees	135 Psi	1 Liter	207 Yards

Figure 20 (Velocity 9)

Angle	Pressure	Water	Distance
45 Degrees	135 Psi	1 Liter	160 Yards

Figure 21 (Velocity 9)

Angle	Pressure	Water	Distance
45 Degrees	135 Psi	1 Liter	218 Yards

Figure 22 (Black Hawk)

Angle	Pressure	Water	Distance
45 Degrees	135 Psi	1 Liter	220 Yards

Figure 23 (Black Hawk)

Mission #9: Recommendation- Comparing this mission's distance with previous launch distances it can be concluded that something we changed likely negatively impacted our distances. It is most likely the change in mass because that was the main variable changed. In order to launch on the next mission a new nose cone will have to be constructed for Black Hawk as it sustained too much damage to be usable again.

Mission #10: 2016-November, 4th

Mission #10: Preparation- this mission was used mostly to make sure we had functioning rockets for Rocket Day. This was imperative because both rockets had sustained some amount of damage that may hinder the launches. The launches that were completed on this mission were mostly to make sure that the rockets were in functioning order for Rocket Day.

Mission #10: Results-

Angle	Pressure	Water	Distance
45 Degrees	110 Psi	1.6 Liters	211 Yards

Figure 24 (Black Hawk)

Angle	Pressure	Water	Distance
45 Degrees	110 Psi	1.4 Liters	187 Yards

Figure 25 (Velocity 9)

Mission #10: Recommendation- one thing to make note of on this mission is the rockets launched fairly well despite the lower PSI. The main work that needs to be done to the rockets is prepping them for Rocket Day. A coat of paint and designs still need to be added to the rockets in order to be launched at Rocket Day. Another portion that needs to be done is assuring that all fins, nose cones and ballasts are proper before the launch on Rocket Day.

Rocket Day

Conclusion

Perhaps the most important lesson learned through the entirety of testing and development was that each and every variable really matter. For instance changing the weight in your nose cone slightly could throw off your flight. It could affect how well the fins you have work at keeping your rocket stable. Water levels will have a similar effect because of the weight as well. Another important lesson that I learned throughout testing and development is that properly sizing fins is one of the most important things to do but also one of the most difficult things. I learned very early on that if your fins aren't near perfect your rocket could end up in a tailspin hurtling towards the ground.

The body of the first rocket, was made of two 2-liter bottle. This is the Black Hawk The second rocket was made out of 4 1-liter bottles. This is Velocity 9. The same general process was used to create both rockets but Velocity 9 did not get completed until well after Black Hawk. The reason for this was the trouble of connecting two spliced rocket fuselages reliably. We ended up ordering a tornado tube to connect the two pieces. In order to create the rockets the bottles were first stripped of all labels. After the labels were removed all adhesives must be removed as well. Then, two 2-liter bottles, and four 1-liter bottles were all cut along a line on the bottom of the bottles that was already there. The next step to splicing the bottles to form a solid body is to ensure that one bottle fits snugly inside of the other bottle. To do this one of the 2-liter bottles and two 1-liter bottles were submerged in 3cm deep water heated to 72C for 20 seconds bottom side down. This shrunk the plastic to ensure a snug fit. Then, in order to create a smoother edge on the shrunken bottles the edge was pressed to a hot pan so it would curl inward. Then the outside of the shrunken bottle was sanded along with the inside of the regular bottle. They are sanded about two centimeters up from the bottom edge on each. This made a rough surface that is good for glues as it allows it to fit in between the cracks and adhere more completely. A generous amount of PL Premium glue was applied to the outside of the shrunken bottle. The bottles were then fitted together keeping in mind to keep them as straight as possible. The three separate body assemblies were then left to dry overnight. After drying two more 2-liter bottles were cut similarly as well as removing the heads so they fit over the bottles. These were added as an extra supporting layer for the rocket. These were secured using glass strapping tape. Then as an extra structural measure glass strapping tape was added over these supporting bottles for maximum pressure resistance. Then the fins were attached to Black Hawk using Gorilla tape. See figure 26 for final fin designs that were used. After the fins were attached a 2-liter bottle was cut about ¾ the way up from the bottom to be used as a nose cone. The head of the bottle needed to be removed to make room for our bouncy ball nose. Using the bouncy ball as guidance the cut was made to allow about half of the bouncy ball outside of the nose cone. The bouncy ball was secured with modeling clay. Varying amounts of clay was used depending on how massive the rocket needed to be. This was secured to the rocket using Gorilla tape. It simply fit over the bottle and was ready to be secured. The only variation in steps between Black Hawk and Velocity 9 is the connection of the two chambers for Velocity 9. Using a tornado tube both chambers were connected by using the threading that already exists on the bottles. Another 1 liter bottle was cut to go over where the tornado tube was connecting the two chambers. Gorilla tape was also used to attach this to the main body of the rocket. The final step in creating these rockets was the paint job. A The Flash inspired color palette was used for the painting of Velocity 9 see Figure 27. For the painting of Black Hawk a color pallet of black and silver was chosen with a central symbol. See Figure 28.

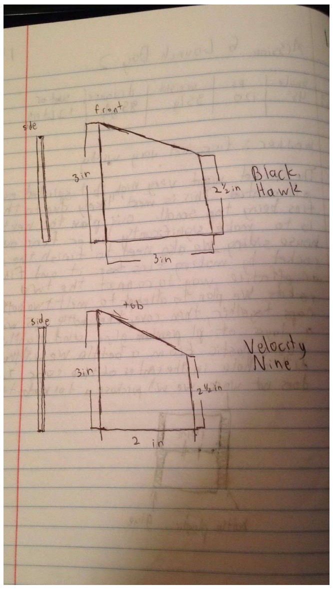

Figure 26

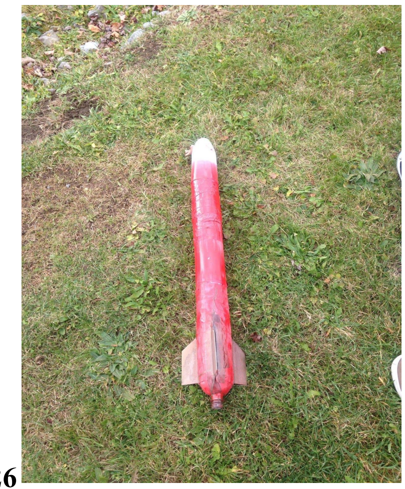

Figure 27

Figure 28

One piece of advice that I wish I had before starting this project was to take your research very seriously. This goes for the literature review as well.The more research you have built up prior to actually building the rocket will only help you.The more information you have beforehand the better. Knowing how to do rocket science before trying to do rocket science is very valuable.

Launch Team

My role of the launch team was to provide fuel for the rockets. This included filling the coolers we had at either the water truck or at a sink. After retrieving water from the source I had to fill the rockets with the desired amount of fuel. We had 1 liter jugs that were used to measure and , for the most part, rockets only used 1 liter. I used a funnel in order to fill rockets with ease from these liter jugs. If the water in the cooler were to run out it was my job to refill them to continue fuelling. This role of the launch team is invaluable as rockets could not get off the ground with their fuel source.