2.1.4 Aerodynamic Design

Team Name: Rocket Masters
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Class: Principles of Engineering(POE)
Period: 7
Date: January 8, 2019 - January 28, 2019

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Design Brief

Client/Target Consumer: Nitro Planes, is looking to manufacture a series of toy projectiles, that can be sold with a launcher, that ensures it goes the longest horizontal distance.

Designers: Aarya Dharm, Khushi Gupta, Donna Prince

Problem Statement: The toy projectile, the company would like to sell, must fly the highest lateral distance, using a launcher with 60-75 PSI.

Design Statement: Design, build, and test a prototype that is made completely of paper, and is able to fly the greatest horizontal distance.

Criteria and Constraints:

- Only use paper and tape can be used
- Body diameter must fit over ¾" PVC pipe
- Body length between 10"-15"
- Wingspan less than 24"
- Launched at specified psi with provided rocket launcher
- Angle of launch determined by team
- Lastly, you may use any material approved by your instructor to build the prototype

Deliverables

Team:

- Design Brief
- Team Photo
- Total of 6 different rocket designs
- Description of each rocket, and modifications, with summary (with key differences and what features were tested)
- Make a recommendation for the final product
- Data table-initial velocity, launch angle, time, horizontal & vertical distance (note theoretical & experimental when stating values)
    - XY-scatter plot of horizontal displacement versus vertical displacement - include proper labels/titles & trendline

Individual (Items must be in Notebook):

- Design Brief
- Team Norms/ Consequences
- 2 clearly annotated brainstorming sketches
- Table of measurements
- Calculations for Initial Velocity
- Conclusion Questions

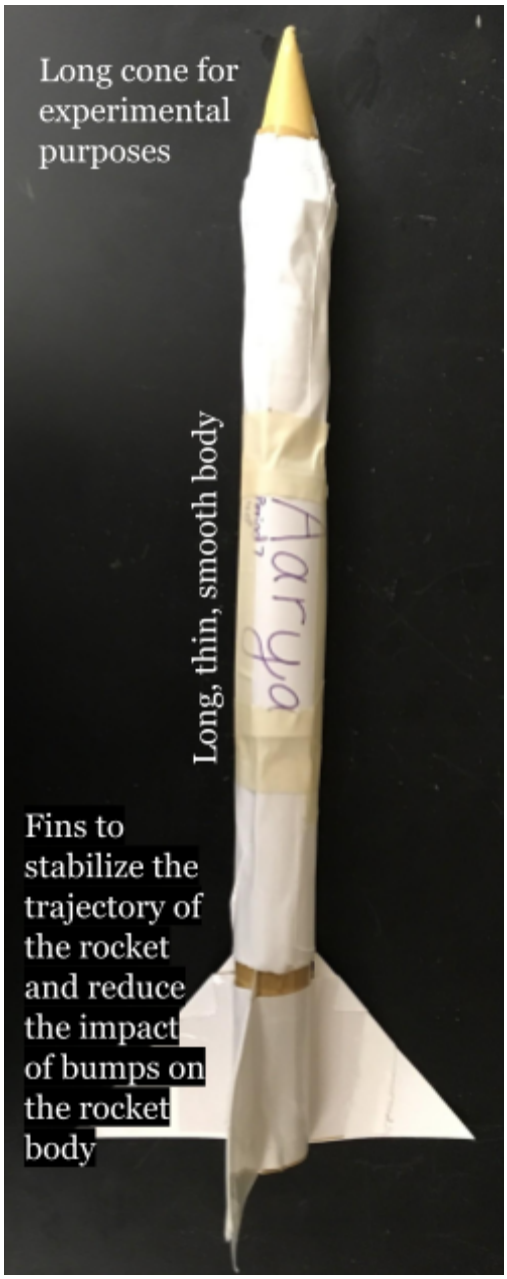
Total Data (Experimental Data)

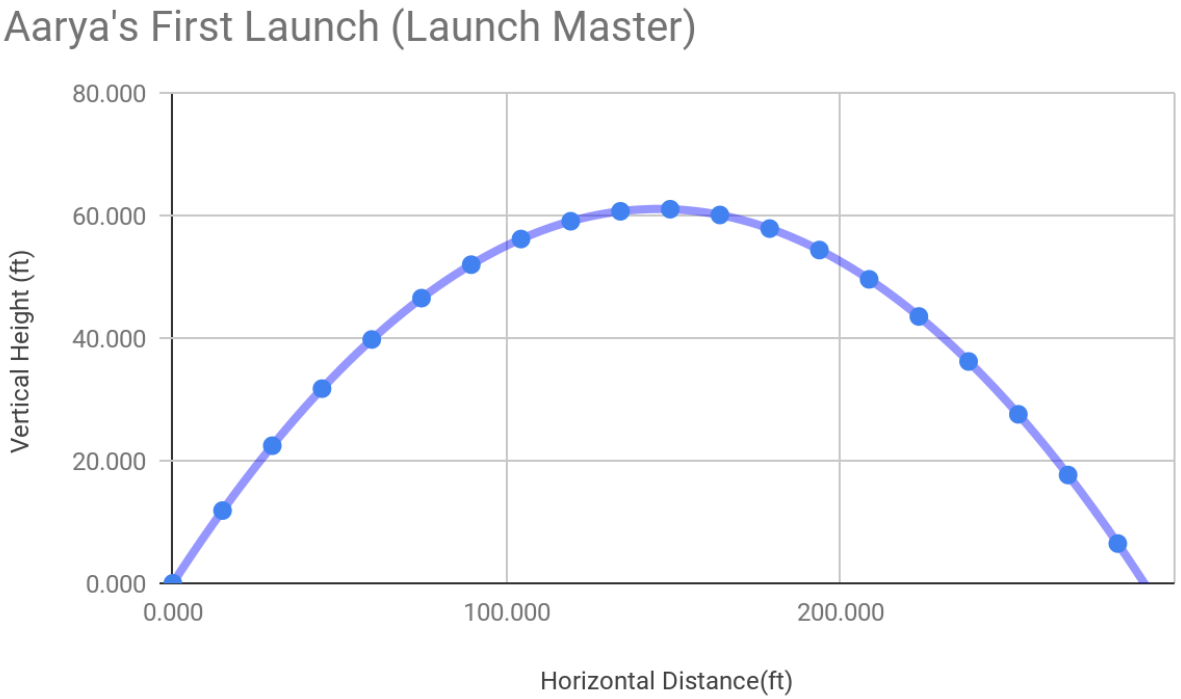
Launch Day 1				
Rocket Name	Angle (degrees)	Distance Traveled (yards)	Time in Air (seconds)	Initial Velocity (feet/sec)
Tape Master(Donna Prince)	45	67	3,33	n/a
Tape Master 1(Donna Prince)	45	68	3.33	114.26
Launch Master (Aarya Dharm)	40	94	4.03	n/a
Launch Master 1 (Aarya Dharm)	40	97	4.11	97.24
Cone Master(Khushi Gupta)	35	11.5	1.08	37.77
Launch Day 2				
Rocket Name	Angle (degrees)	Distance Traveled (yards)	Time in Air (seconds)	Initial Velocity (feet/sec)
Tape Master (Donna Prince)	45	71	3.39	n/a
Tape Master 1 (Donna Prince)	45	75	4.4	120
N.E.T (Aarya Dharm)	45	45	3.09	65.73
The Bride (Khushi Gupta	40	43	2.56	64.73

Aarya's Rocket #1 (Launch Master)

Rocket Description: This rocket has a thin body so that it grips the tube tightly enough to create pressure for the launch but not too much that it explodes or reduces the force given to launch the rocket. I tried to make the rocket body as smooth as possible in order to reduce drag and make it more aerodynamic. For the first rocket, I tested this sample size cone which I would change for the second rocket and observe the changes. Since I have made a rocket before, I knew that the fins would help keep the rocket in a straight path and the air resistance would not have much more of an impact on the trajectory of the rocket. Additionally, there are about three layers of heavy duty duct-tape around the body to give it some weight and some stability while flying. I launched the rocket at 40^{O} so that it is close enough to the theoretically best angle but it can glide on the air and travel farther.

Time	Theoretical X-distance (ft)	Theoretical Y-distance (ft)
0	0.000	0.000
0.2	14.898	11.861
0.4	29.796	22.442
0.6	44.694	31.743
0.8	59.592	39.764
1	74.490	46.505
1.2	89.388	51.966
1.4	104.286	56.147
1.6	119.184	59.047
1.8	134.082	60.668
2	148.980	61.009
2.2	163.878	60.070
2.4	178.776	57.851
2.6	193.674	54.352
2.8	208.572	49.573
3	223.470	43.514
3.2	238.369	36.175
3.4	253.267	27.556
3.6	268.165	17.657
3.8	283.063	6.478
4	297.961	-5.981
4.2	312.859	-19.720
4.4	327.757	-34.739
4.6	342.655	-51.039





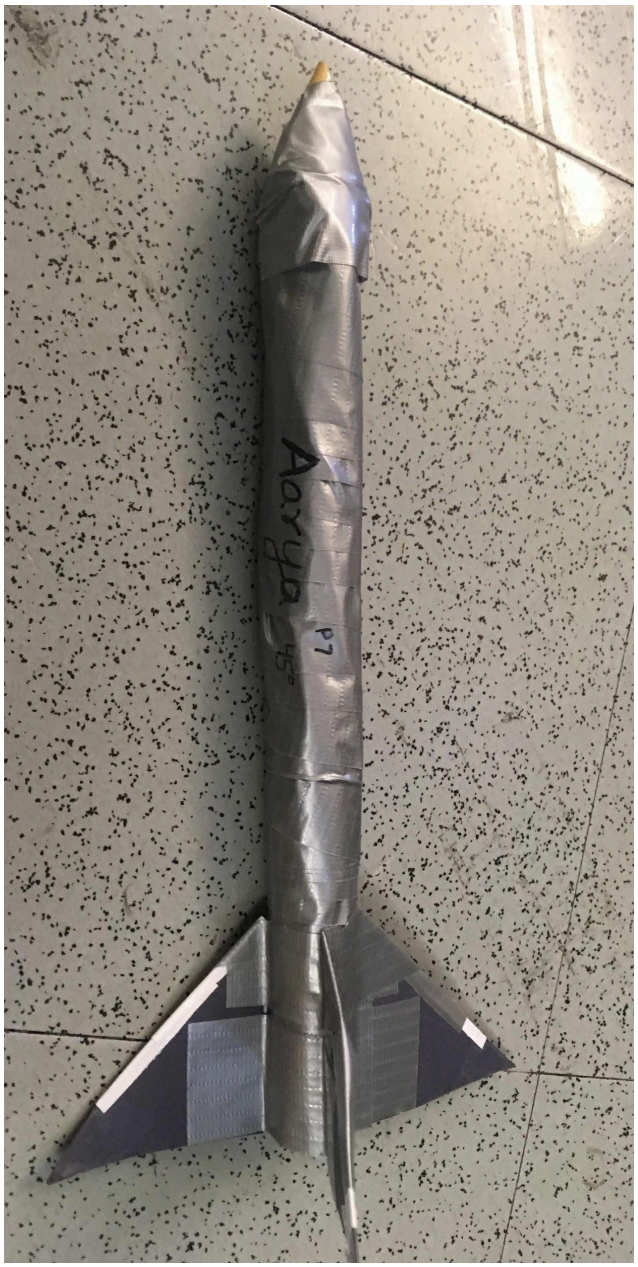
Theoretical Initial Velocity: 97.24 ft/sec
Experimental Distance: 97 yards
Angle: 40^{O}
Experimental Time: 4:03

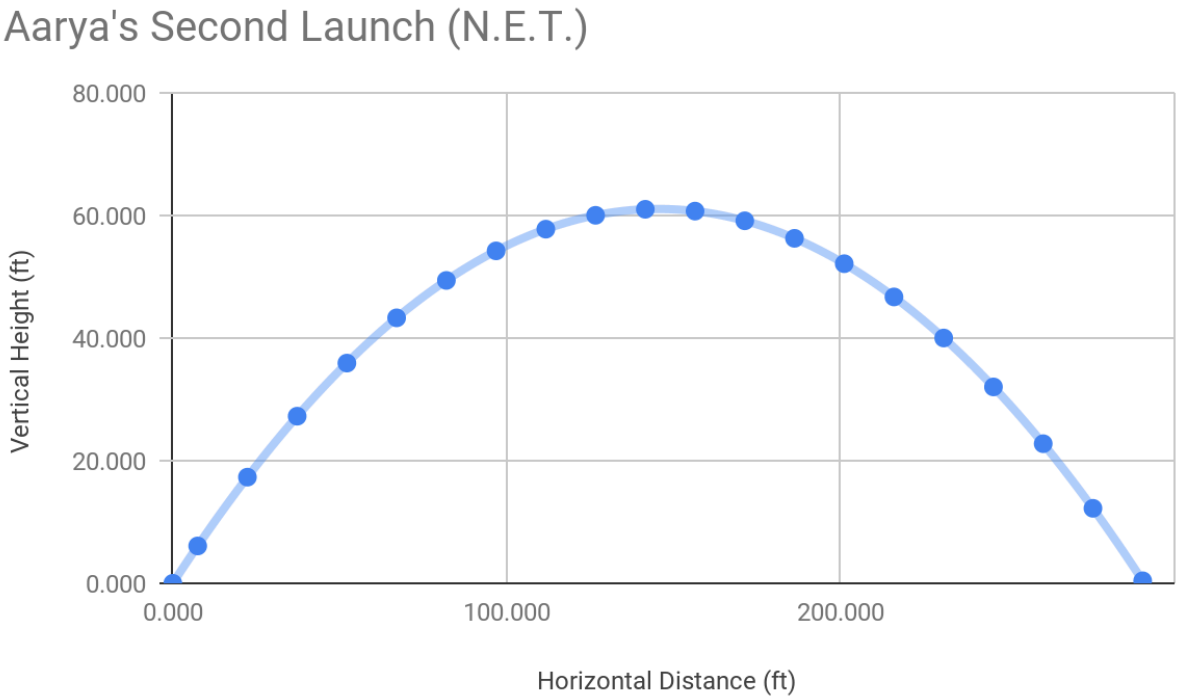
Recommendation: I would recommend this rocket pretty much as it is since it did go far in the experiment and the science behind the design is secure as well. However, to further improve the efficiency of the rocket, try to make the body of the rocket smoother in order to reduce even more drag. Additionally, make the cone a little bit longer to again reduce wind resistance, as a flatter cone would be hitting the air straight on and would not be able to cut through the air as well.

Aarya's Rocket #2:

Rocket Description: This rocket was built off of the previous rocket and therefore has the same tightness as the previous one in order to maximize the force being used for flying. To experiment the size cone, I made a flatter cone. This did not work out well because the flat cone increased drag and therefore reduced distance. For this rocket, the fins were bigger which may have helped however on this rocket there were not executed well and therefore slowed the rocket down. There were also additional layers of duct tape around the body, making it heavier and decreasing the initial velocity.

Time	Theoretical X-distance (ft)	Theoretical Y-distance (ft)
0	0.000	0.000
0.1	7.449	6.090
0.3	22.347	17.311
0.5	37.245	27.252
0.7	52.143	35.913
0.9	67.041	43.294
1.1	81.939	49.395
1.3	96.837	54.216
1.5	111.735	57.757
1.7	126.633	60.018
1.9	141.531	60.999
2.1	156.429	60.700
2.3	171.327	59.121
2.5	186.225	56.262
2.7	201.123	52.123
2.9	216.021	46.704
3.1	230.920	40.004
3.3	245.818	32.025
3.5	260.716	22.766
3.7	275.614	12.227
3.9	290.512	0.408
4.1	305.410	-12.691
4.3	320.308	-27.070
4.5	335.206	-42.729





Experimental Initial Velocity: 65.73 Experimental Distance: 45 yards
Angle: 45^{O} Experimental Time: 3:09

Recommendation: I would not recommend this rocket at all since it did not travel far during the experiment, and the science behind the rocket is sound in the fact that it will not work. Instead, the projectile should be lightweight, smooth, and well executed with no areas for the air to escape into.

Khushi's Rocket #1 (Cone Master)

Description

This prototype features a cone, a basic body, fins, and a pressure cap. It is the structure of these parts which makes it unique. The cone is made out of cardstock to make it sturdy and comes to point to allow it to be hypothetically, more aerodynamic. The body is made out of cardstock, and then reinforced with packaging tape to make it sturdy as well to make sure the paper is not so thin so that the rocket explodes when it is launched. There are four fins placed approximately equidistant from one another to perform as stabilizers when the rocket is in the air. The pressure cap inside the rocket is to help the air push evenly upward, as well as protect the cone from exploding. The rocket's experimental performance was different from its hypothetical. The rocket, while seemingly primed for flight, hypothetically should have been able to reach a maximum distance of about 42 feet, which is 14 yards. The rocket instead went 11.5 yards. There was also a difference in the time. My theoretical time was 1.35 seconds, but my experimental time was 1.08. This may have been due to wind which was not taken into account. Another factor is poor construction due to lack of time. The time difference may have also occurred due to the fact that that we may have not recorded the proper time or mistimed it. The poor construction resulted in the wrinkles in the tape as well as weak fins, all of which affect how aerodynamic the flight was. I would not recommend this design because even theoretically the rocket would have not performed that well, only going a distance of 14 yards. This rocket could, however, to be modified for better performance by making the fins more sturdy with tape, as well as being careful to create a smooth body by preventing any wrinkles when using tape.

Experimental Values

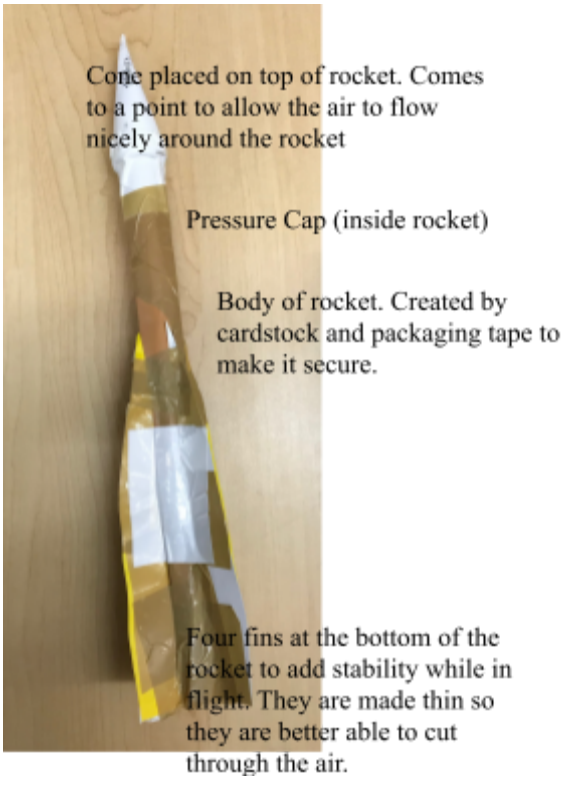
Rocket Name	Angle (degrees)	Distance Traveled (yards)	Time in Air (seconds)	Initial Velocity (feet/sec)
Cone Master(Khushi Gupta)	35	11.5	1.08	37.77

Theoretical values under that constraints of the following information:

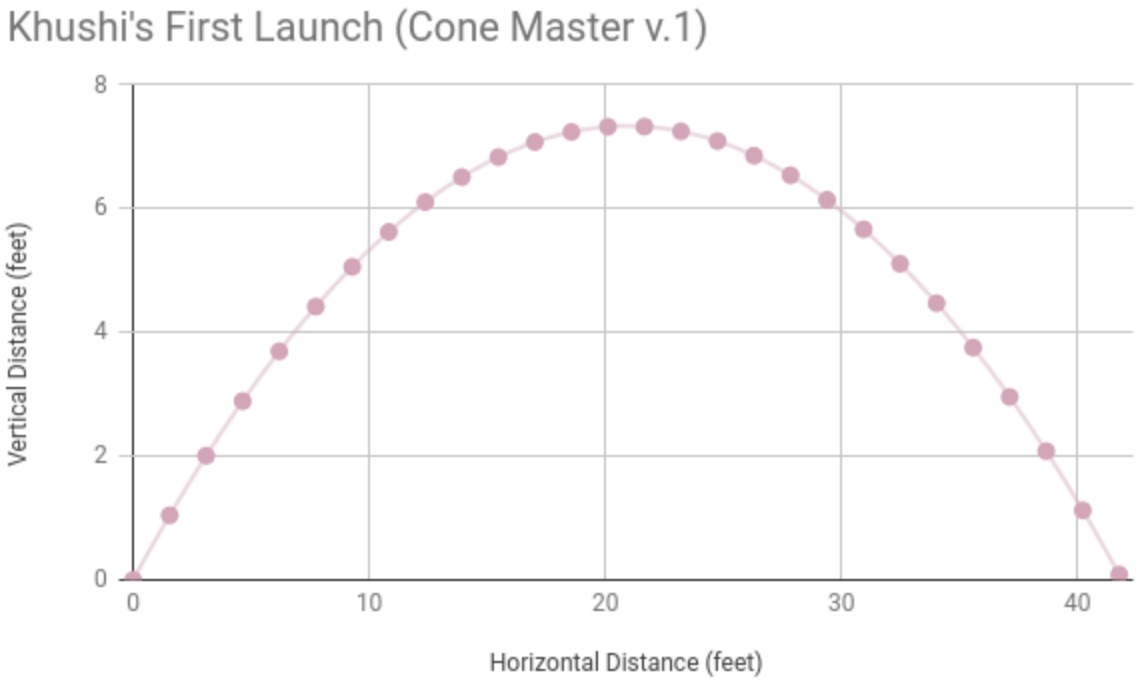
Experimental Initial Velocity: 37.77 ft/sec

Angle: 35°

Time	Theoretical x-values	Theoretical y-values
0	0	0
0.05	1.546968636	1.0431991
0.1	3.093937271	2.0063982
0.15	4.640905907	2.8895973
0.2	6.187874543	3.6927964
0.25	7.734843178	4.4159955
0.3	9.281811814	5.0591946
0.35	10.82878045	5.6223937



0.4	12.37574909	6.1055928
0.45	13.92271772	6.5087919
0.5	15.46968636	6.831991
0.55	17.01665499	7.075190101
0.6	18.56362363	7.238389201
0.65	20.11059226	7.321588301
0.7	21.6575609	7.324787401
0.75	23.20452953	7.247986501
0.8	24.75149817	7.091185601
0.85	26.29846681	6.854384701
0.9	27.84543544	6.537583801
0.95	29.39240408	6.140782901
1	30.93937271	5.663982001
1.05	32.48634135	5.107181101
1.1	34.03330998	4.470380201
1.15	35.58027862	3.753579301
1.2	37.12724726	2.956778401
1.25	38.67421589	2.079977501
1.3	40.22118453	1.123176601
1.35	41.76815316	0.08637570132


Khushi's First Launch (Cone Master v.1)
Vertical Distance (feet)
8
6
4
2
0
0
10
20
30
40
Horizontal Distance (feet)

Khushi's Rocket #2 (The Bride)

Description

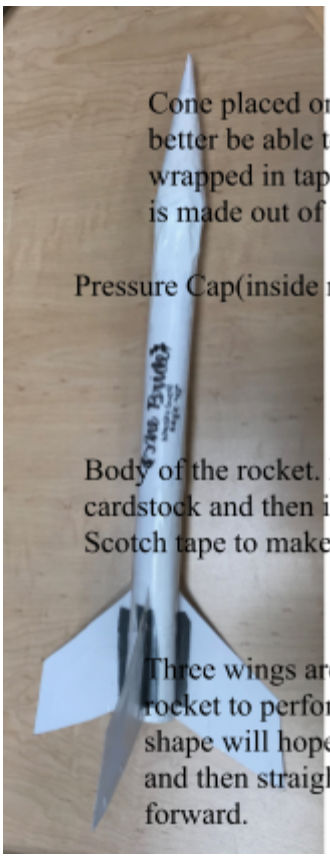
This rocket is slightly different from the previous. Firstly, the main difference is in the smoothness. The body and the overall structure of the rocket is better designed to be smooth. I also increased the length of the cone to allow it to be able to cut through the aire better. Another difference is in the amount of wings. I instead decided to use three wings instead of four to determine to effects of the amount of wings as stabilizers. The last difference is between the shape of the wings. The last fins were made out of thin paper and featured a different design. This time I decided of more rigid wings with a firm shape instead of a curve. This would theoretically allow the air to flow around the wing and then downward, allowing it to thrust the rocket forward. The rocket hypothetically should have been able to reach 130 feet which is about 43.33 yards. In reality the rocket had also travelled 43 yards. In this case my hypothetical and experimental values were very similar as the theoretical time was 2.56 seconds versus 2.6 seconds. This may have been due to lack of wind or other external factors allowing this rocket to perform as predicted. Taking this into account, I would recommend this rocket based on the fact that it performs as hypothetically predicted and was able to launch farther than my previous rocket. However, overall based on the distance the rocket was able to travel I would not recommend it, because it was still unable to travel as far as the other rockets tested in our group. This rocket could be further improved upon by still making the wings for rigid. While these wings were still less prone to bending, they still were very light and quite flexible. A better material could be cardboard which is more firm and resilient against wind.

Experimental Values

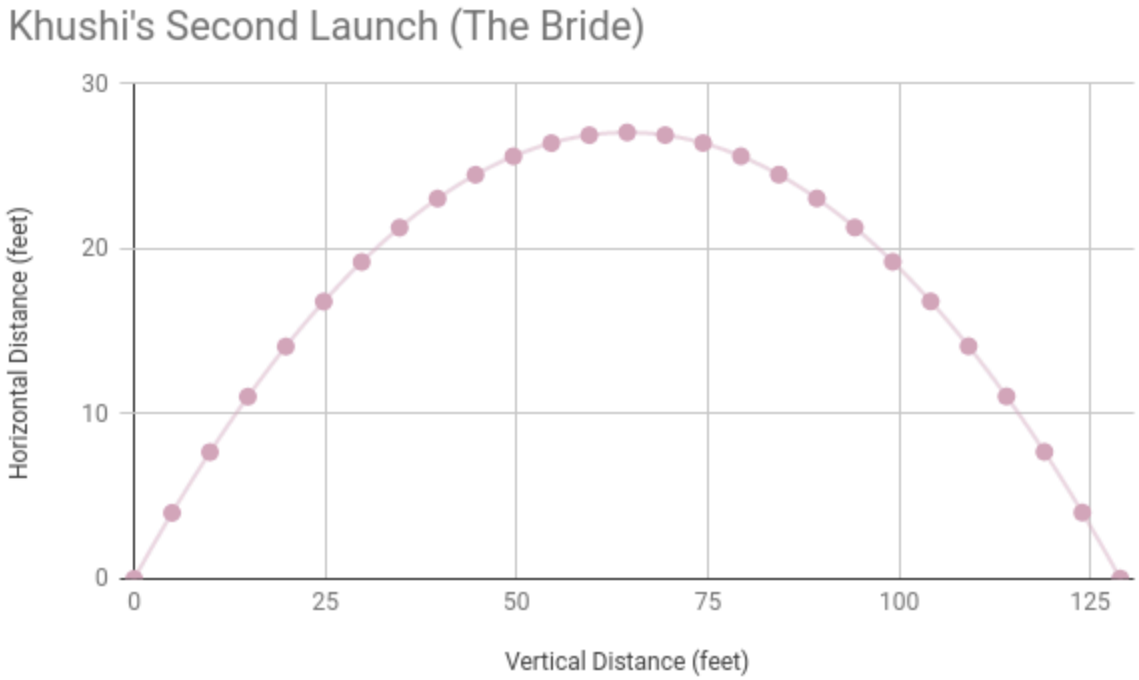
Rocket Name	Angle (degrees)	Distance Traveled (yards)	Time in Air (seconds)	Initial Velocity (feet/sec)
The Bride (Khushi Gupta	40	43	2.56	64.73

Theoretical values under that constraints of the following information:
Experimental Initial Velocity: 64.73 ft/sec
Angle: 40°

Time	Theoretical x-values	Theoretical y-values
0	0	0
0.1	4.95860568	4.000764198
0.2	9.917211361	7.681528395
0.3	14.87581704	11.04229259
0.4	19.83442272	14.08305679
0.5	24.7930284	16.80382099
0.6	29.75163408	19.20458519
0.7	34.71023976	21.28534938



0.8	39.66884544	23.04611358
0.9	44.62745112	24.48687778
1	49.5860568	25.60764198
1.1	54.54466248	26.40840617
1.2	59.50326816	26.88917037
1.3	64.46187384	27.04993457
1.4	69.42047952	26.89069877
1.5	74.3790852	26.41146296
1.6	79.33769088	25.61222716
1.7	84.29629657	24.49299136
1.8	89.25490225	23.05375556
1.9	94.21350793	21.29451975
2	99.17211361	19.21528395
2.1	104.1307193	16.81604815
2.2	109.089325	14.09681235
2.3	114.0479306	11.05757654
2.4	119.0065363	7.69834074
2.5	123.965142	4.019104938
2.6	128.9237477	0.01986913503



Donna's Rocket #1

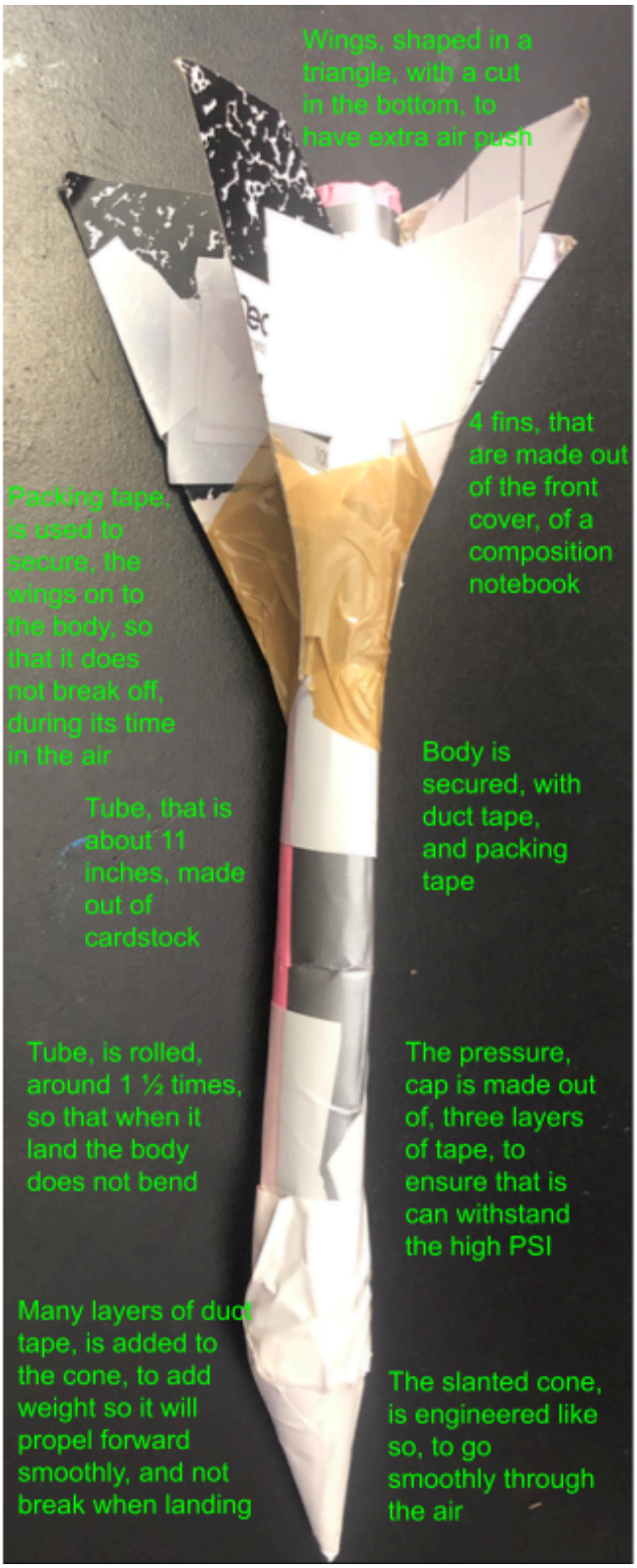
Experimental Initial Velocity: 114.26 ft/sec
Experimental Distance: 68 yards
Angle: 45^{O}
Experimental Time: 3.33 Seconds

Experimental Values

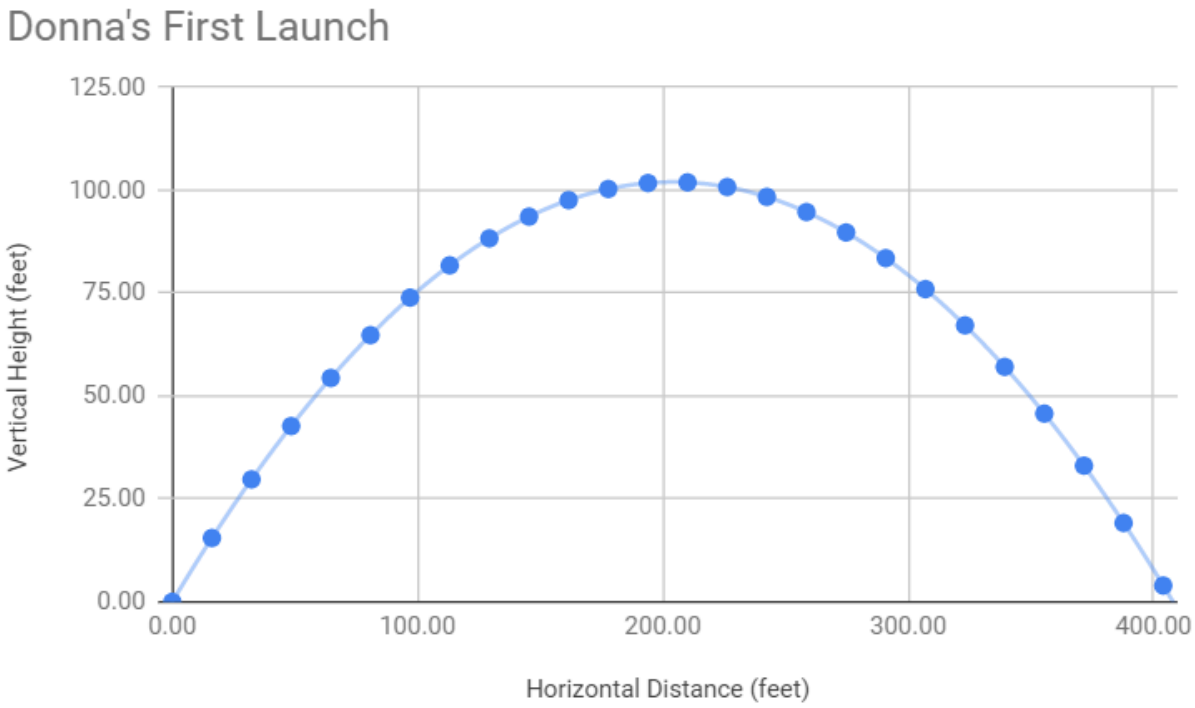
Angle (degrees)	Distance Traveled (yards)	Time in Air (seconds)	Initial Velocity (feet/sec)
45	68	3.33	114.26

Theoretical Values

Time	x	y
0	0.00	0.00
0.2	16.16	15.52
0.4	32.32	29.76
0.6	48.48	42.72
0.8	64.64	54.40
1	80.79	64.79
1.2	96.95	73.91
1.4	113.11	81.75
1.6	129.27	88.31
1.8	145.43	93.59
2	161.59	97.59
2.2	177.75	100.31
2.4	193.91	101.75
2.6	210.06	101.90
2.8	226.22	100.78
3	242.38	98.38
3.2	258.54	94.70
3.4	274.70	89.74
3.6	290.86	83.50
3.8	307.02	75.98
4	323.18	67.18
4.2	339.33	57.09
4.4	355.49	45.73
4.6	371.65	33.09



4.8	387.81	19.17
5	403.97	3.97



Description:
The first rocket, that I created had a tube made out cardstock paper, that was about 11 inches long. The pressure, cap was made out of about 3 layers of tape, to ensure that it can withstand the high PSI, provided from the launcher. There are four wings, that are in a triangular, with small cutouts at the bottom, to provide additional push for the rocket. Another important, aspect was balancing out the weight on the rocket, since the wings weighed more, I had to add more tape to the cone, to make sure the weight does not pull down the rocket. Overall, this rocket when in flight went 68 yards, in 3.33 seconds, launched with a PSI of 60. The rocket, unlike others, did have a turbulent flight, as the weight was not exactly balanced, and the cone was not sharp, allowing it to cut through the air. Comparing the 3.4 second mark of the theoretical value, stated that the rocket would cover 86.18 yards, while the rocket only made it to 68 yards. Reasons of why this outcome may have occurred, was due to winds, more drag due to weight, launching at a lower PSI. In addition, this was the second time the rocket was launched, so the rocket had some damage. I would not recommend this rocket, as it weighed too much, and was quivering throughout the entire time, it was in air. Given the results, of this rocket, I would recommend using three wings, instead of four, as many of the rockets that used three wings, were able to go a longer distance, in a faster time. Another modification, I would make is changing the cone structure, to make longer so that it can cover a larger distance, in a shorter time. Nitro Planes, should not invest in this rocket, as it can go off, the course, and land up in a different location that the user may have not been predicting. Another reason this product, should not be taken up by the company, is due to its weight, and lackluster quality, as the rocket suffered damages, just

from the first launch, and therefore, since children would use the toy many times, it should not be manufactured.

Donna Rocket #2

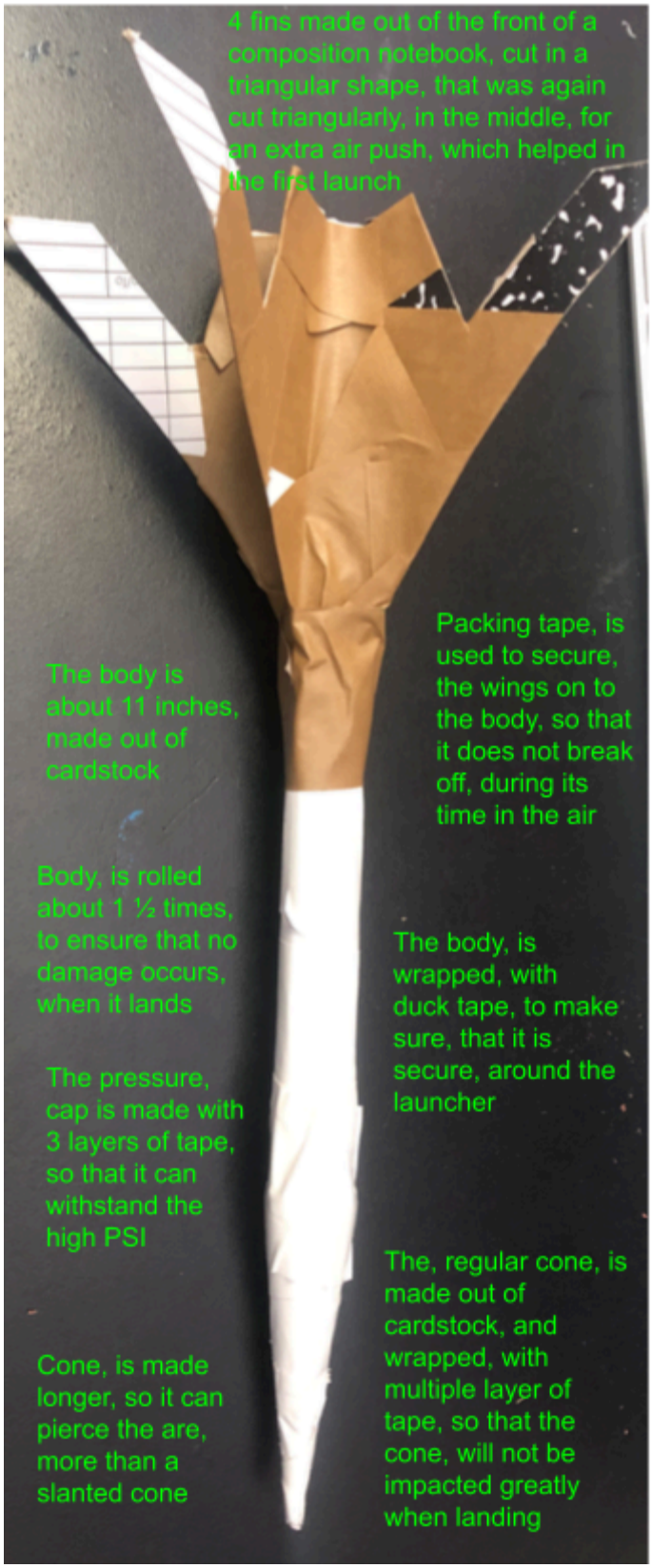
Experimental Initial Velocity: 120 ft/sec
Experimental Distance: 75 yards
Angle: 45^{O}
Experimental Time: 4.40 Seconds

Experimental Values

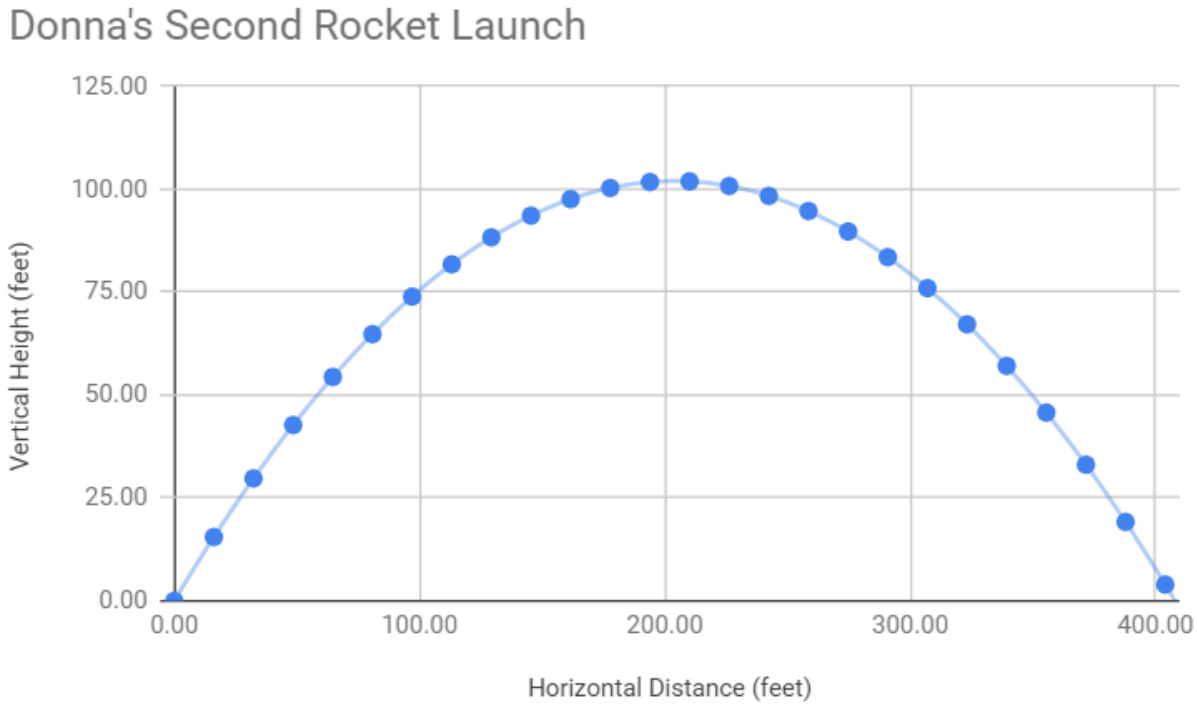
Angle (degrees)	Distance Traveled (yards)	Time in Air (seconds)	Initial Velocity (feet/sec)
45	75	4.40	120

Theoretical Values

Time	X	Y
0	0.00	0.00
0.2	16.97	16.33
0.4	33.94	31.38
0.6	50.91	45.15
0.8	67.88	57.64
1	84.85	68.85
1.2	101.82	78.78
1.4	118.79	87.43
1.6	135.76	94.80
1.8	152.74	100.90
2	169.71	105.71
2.2	186.68	109.24
2.4	203.65	111.49
2.6	220.62	112.46
2.8	237.59	112.15
3	254.56	110.56
3.2	271.53	107.69
3.4	288.50	103.54
3.6	305.47	98.11
3.8	322.44	91.40
4	339.41	83.41
4.2	356.38	74.14



4.4	373.35	63.59
4.6	390.32	51.76
4.8	407.29	38.65
5	424.26	24.26
5.2	441.23	8.59
5.4	458.21	-8.35



Description:
The second rocket, that I created had a tube made out of cardstock paper, that was about 11 inches long. The pressure, cap was made out of about 3 layers of tape, to ensure that is can withstand the high PSI, provided from the launcher. There are four wings, that are in a triangular shape, with another set of triangles cut out in the middle of the wings, to provide additional push for the rocket. This time the wings, did not weigh as much as before, therefore, less tape was used around the the cone of the rocket. Overall, this rocket when in flight went 75 yards, in 4.40 seconds. This rocket, compared to the first one was not as turbulent when flying, and was able to fly smoothly. Comparing the 4.40 second mark of the theoretical value, stated that the rocket would cover 124.24 yards, while the rocket made it to 75 yards. Reasons of why this outcome may have occurred, was due to launching at a higher PSI, of 75. I would recommend this rocket, as it was able to cut through the air better, and go smoothly. Given the results, of this rocket, I would recommend using a longer cone, to make the rocket go even faster, and maybe reduce the length of the body. Another way to improve this rocket, is to use, cardstock paper, instead of a

composition notebook cover, as it can reduce, the weight that causes drag. Overall, the rocket went far, smoothly, which would be an important, aspect when launching a toy rocket, so that it appeals, to the children. Another reason, Nitro Planes, should manufacture this is rocket, is due to precision, as it will go straight, and not move away from the approximate location, the user would assume it would land.