All I need is just some space!

Does the volume of a pressure vessel affect the height and hangtime of a bottle rocket?

Questions/Problem:

If the volume of a pressure vessel of a bottle rocket is decreased by half, the same rocket is exactly 2x smaller in size than the other and, the weight of the 1L rocket is 2x smaller than the 2L bottle rocket then the height and hangtime will be the same.

Hypothesis:

Research

- Science Olympiad:
  This researcher has been building bottle rockets powered only by water and air for three years now. In addition, this researcher has won many medals at the state and regional level in Science Olympiad.

- NASA Water Rocketry:
  This researcher gained some knowledge upon reading this article on water bottle rockets. The article showed how and why the bottle rockets worked and how they compared to the NASA rockets.

- US Water Rockets:

- This site guided this expert through the main building parts such as the nosecone of the bottle rocket. In addition, the website stated how to take precaution when launching a bottle rocket.

- Robert Youngs:
  Robert’s website majorly contributed to this analyst success in making the design of the rockets and the fin design.

Variables

Controlled variables

- 400 ml of water in the 1L and 800 ml of water in the 2L rockets
- The launches at 415 KPA
- The total weight of the 1L and 2L rockets
- The 5 cm triangle fins 1L and the 10 cm triangle fins for 2L rockets
- Pressure vessel
- Nosecone
- Launcher

Independent variable

- Volume of the bottle rocket (1L or 2L)
- Size of the 1L and 2L rockets

Dependent variable

- Height of the bottle rocket
- hangtime of the rocket (the time the rocket is in the air)

Experiment Control

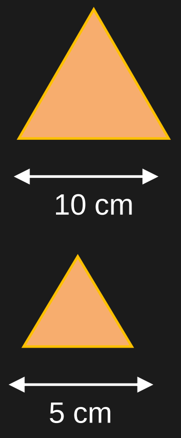
This scientist's experimental control is the 2 Liter bottle rockets. In this case I am testing if the 1L bottle rocket will achieve the same hangtime and the same altitude as the 2L bottle rocket. In addition, the 2L bottle rocket will have the same features and will be built from the same martial. Thus, eliminating variables that would cause a failure in this experiment.

Test Group

The test group in this science experiment is the 1L bottle rockets. This is because this scientist is testing the if the 1L bottle rocket will get the same results as the 2L bottle rocket. However, the 1L bottle rocket will be 2x smaller in size and in weight.

Materials

Materials	Quantity
1L bottles	4
2L bottles	4
Equilateral triangle fins with the side length of 10 cm made from cardboard	6
Equilateral triangle fins with the side length of 5 made from cardboard	6
T8 fluorescent light covers (one should be cut in half)	3
Ping Pong balls	6
Plastic Easter eggs	6
Paper	5
CA or Super Glue 8 oz.	1
Plastic Beaker 100 mL	1
Estes Altitrak	1



Materials (Cont.)

Materials	Quantity
10 cm pieces of Masking Tape	6
5 cm pieces of Masking Tape	6
Ruler	1
Bottle caps	6
Safety Goggles	1 pair for each person
Gloves	1 pair for each person
Safe surface to glue on	1
Water	Around 3 gallons
Clay	2000 grams
Hot Glue Sticks	10
Hot Glue Gun	1
Scissors	1
Aqua Port II Water Rocket Launcher	1
Pen/Pencil and Sharpie	1
Deluxe Port Pump II	1
Measuring Tape (20 Meters)	1

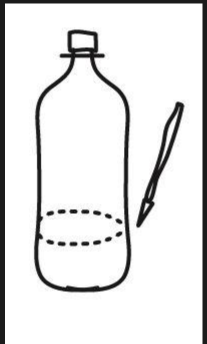
Procedure

Step 1

- Let the glue gun heat while preparing your materials for building the bottle rocket.

Step 2

- First, take 2 of both the 1L and 2L bottles and cut 10 cm from the nozzle to where you should cut. Do this for both bottles, in total there will be 4 bottles cut. This will be the nosecone for the bottle rockets. below.



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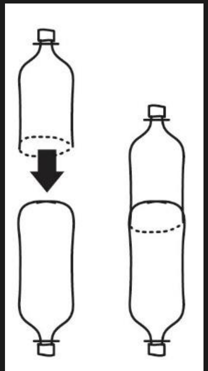
Step 3

- Tape the nosecones to the top of the uncut 1L and 2L bottles and align the nosecone to the bottle to make a perfect cylinder. As shown below.



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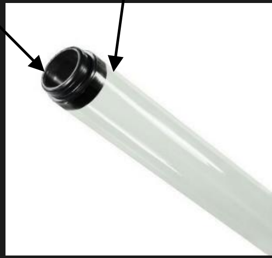
Step 4

- After, prepare your gluing surface, put the safety gear on and, get the T8 fluorescent light covers (nosecone tubes). There should be two 1.2 m (4 ft) and, two 0.6 m (2 ft) long tubes. Now take the manual and the 2 plugs at each end and keep both the manual and plugs aside. We will need them later on. Apply CA to the edge of 1 side of the nosecone tubes. Do this for all 4 tubes.

Glue there

Plug



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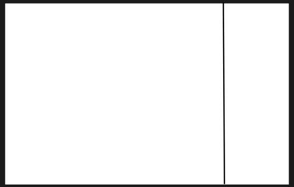
Procedure (Cont.)

Step 5

- From now you have very little time until the glue dries onto the nosecone tubes. Quickly take 1 bottle cap from the bottles and insert it into the one side of the nosecone tube. The cap should fit snug. After, push the cap into the nosecone tube until the edges of both the cap and the nosecone tube are flush. Do this for all 4 nosecone tubes.

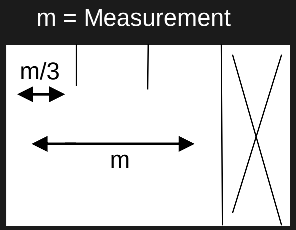
Step 6

- Set the nosecone aside to dry. Mean while roll 1 sheet of paper around the 2L bottle and mark the meeting point of the edges of the paper. Do this for the 1L bottle too.



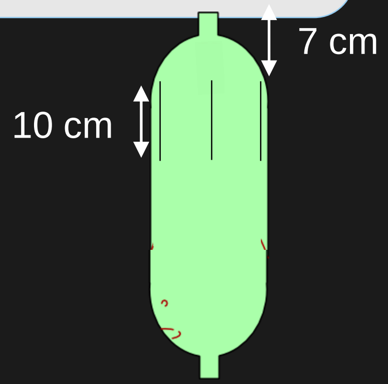
Step 7

- After completing the marks on both papers. Measure the distance from the paper edge to the point marked. Then, divide the distance by 3. Now mark those 3 points. Also, label the paper used for the 2L rocket “2L” and, label the 1L rocket “1L”.



Step 8

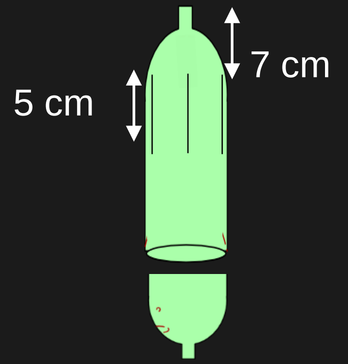
- Roll the “2L” paper back onto the 2L bottle rocket and make the marks 7 cm from the nozzle of the bottle rocket. Then, slide the paper roll up about 10 cm and mark it again. Now connect the marks so the three lines are parallel to each other. Do this for all ONLY on the 2L bottle rocket.



Procedure (Cont.)

Step 9

- Roll the "1L" paper back onto the 1L bottle rocket and make marks 7 cm from the nozzle. Then, slide the paper roll up about 5 cm and mark again. Now connect the marks so all the lines are parallel to each other. Do this for all the marks ONLY on the 1L bottle rockets.

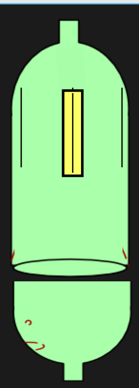


Step 10

- Now take one black end plug and CA it to the other side of the tube. Now CA the other side of the black plug and place the ping pong ball on top. In addition, CA the inner edge of the plastic egg. Then place it on top of the ping pong ball. As seen below.

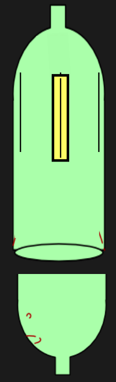
Step 11

- Put the nosecone tube aside to dry. At this point there should be a total of 4 bottle rockets with fin lines marked. Take the 10 cm pieces of masking tape and tape it in the center of the fin line (line marked on the bottles). Like this. Do this ONLY for the 2L bottles.



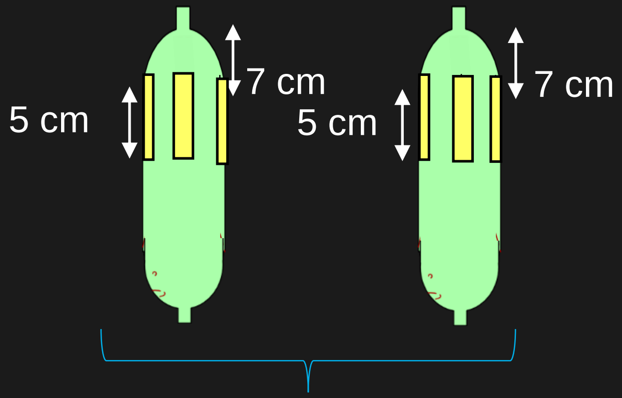
Step 12

- Furthermore, take the 5 cm pieces of masking tape and tape it in the center of the fin line (line marked on the bottles). Like this. Do this ONLY for the 1L bottles.



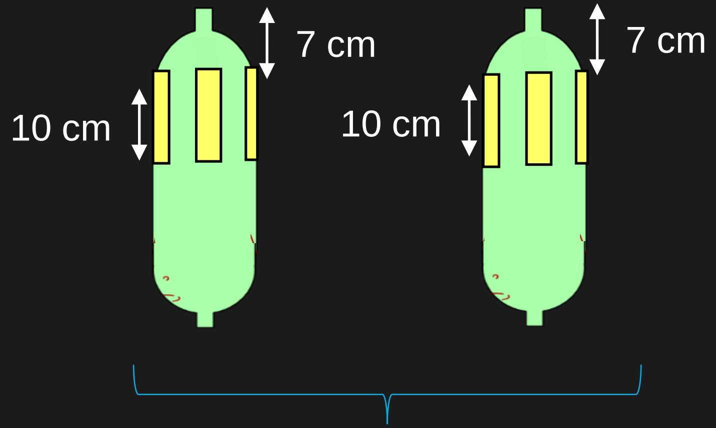
Quick Check

1L Bottle Rocket

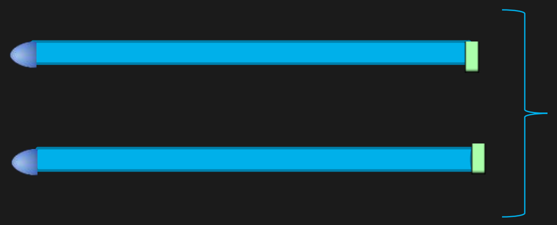


Bottle Rockets

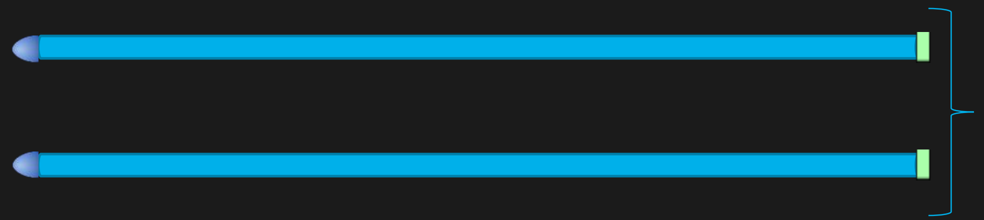
2L Bottle Rocket



Bottle Rockets



.6 m (2ft)
Nosecone Tubes



1.2 m (4ft)
Nosecone Tubes

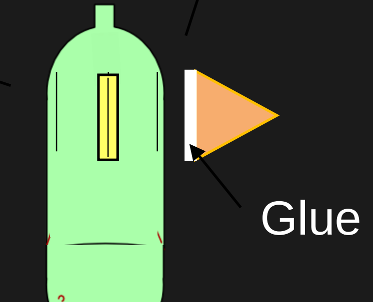
Procedure (Cont.)

Step 13

- Moreover, ready the hot glue gun for use, take the 10 cm fins and use the hot glue gun to glue 1 side of the fin to one piece of tape (the tape that is covering the fin lines) on the 2L bottle rockets. This piece of tape will insure that the bottle’s integrity will not be altered, in other words it won’t explode on the launcher. Do his for all fins marks ONLY on the 2L bottle rockets.

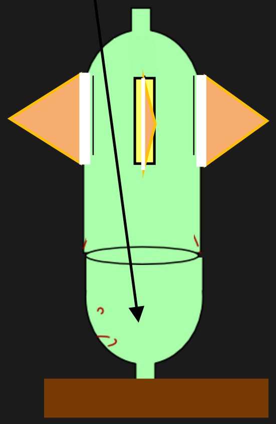
Step 14

- Afterwards, take the 5 cm fins and hot glue 1 side of the fin to one of fin lines on the tape. Do his for all fins marks only on the 2L bottles.



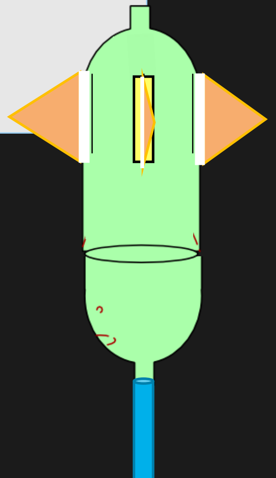
Step 15

- Let all the bottles dry for 5 minuets on the cut bottle, previously referred as the nosecone.



Step 16

- After letting the bottle dry, screw the end of the nosecone tube to the nosecone. The long ones 4ft should go on the 2L and the short ones that you cut in half should (2ft) should go on the 1L rockets Shown below.



Fine-tuning

Step 1

- Now take the all the rockets and weigh them on a scale. The 2L rockets should be half the weight of 1L rockets.

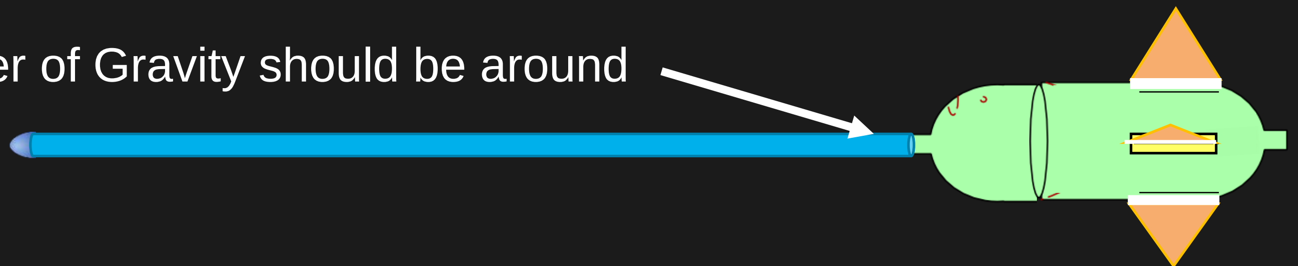
Step 2

- If the 1L rocket is not half the weight of the 2L rocket then you should add mass to make the 2L rocket twice as heavy as the 1L rocket. In my case I added clay to easily “fine-tune” the rockets.

Step 3

- I added clay all around the rocket to make sure the Center of Gravity[1] would not change as much.
- Center of Gravity[1] - The point on a object where both sides are equally balanced.

Center of Gravity should be around



Launching

Step 1

- Set the AquaPort II Water Rocket Launcher and the Deluxe Port Pump II up so its in ready to lunch. It should look like this.

Step 2

- Add 800 mL of water only to 2L rockets and add 400 mL of water to only the 1L rockets.

Step 3

- Then put the bottle rocket onto the rochet launcher. Shown below.

Step 4

- Pump the Deluxe Port Pump II till the gauge reads 415 KPA. Then pull the trigger and time at the same time. After stop timing when it touches the ground.

Measuring Height

Step 1

- After setting up the launcher, roll a measuring tape 20m away from the center of the launcher.

Step 2

- Have a person stand at the end of 20m with the Estes Altitrak.

Step 3

- To operate the Estes Altitrak hold the trigger when the rocket is lunched and point the device at the rocket while in flight at its highest altitude. When the rocket reaches the highest altitude release the trigger.

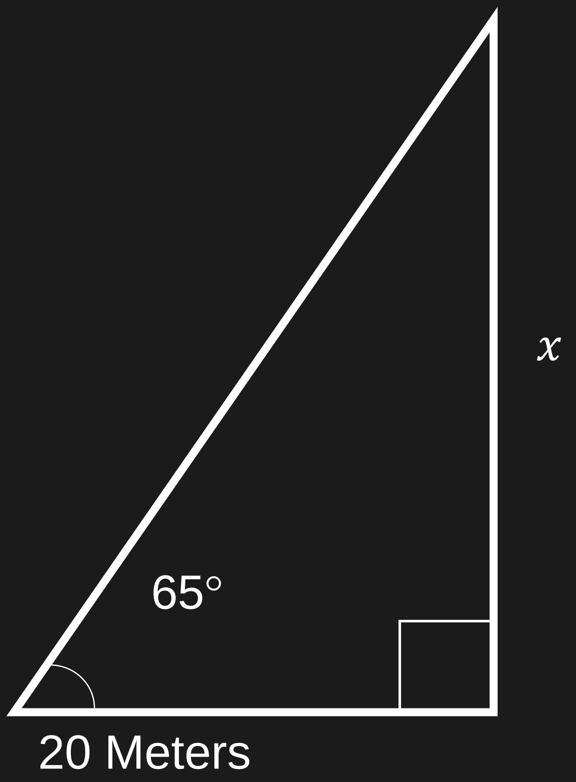
Step 4

- Then record the angle of on the Estes Altitrak and the distance you are away from the launcher (20 m).

Measuring Height (cont.)

Step 5

- Now use TAN to solve for the height. Say the angle was 65°.



$$\tan(65) = \frac{x}{20}$$

$$x \cong 10.7\ Meters$$

Data Table

	Water	Wind	Time of Day	Height	Hangtime
#1 1L	400 mL	N 5 KM/H	2:15 pm 11/18/16	57.5 Meters	13.02 Seconds
#2 1L				55.98 Meters	12.57 Seconds
#1 2L	800 mL			51.45 Meters	12.74 Seconds
#2 2L				52.03 Meters	12.39 Seconds
#1 1L	400 mL	NW 13 KH/M	3:35 pm 11/19/16	56.18 Meters	13.05 Seconds
#2 1L				57.63 Meters	12.64 Seconds
#1 2L	800 mL			51.23 Meters	13.18 Seconds
#2 2L				53.89 Meters	12.73 Seconds

Data Table (Cont.)

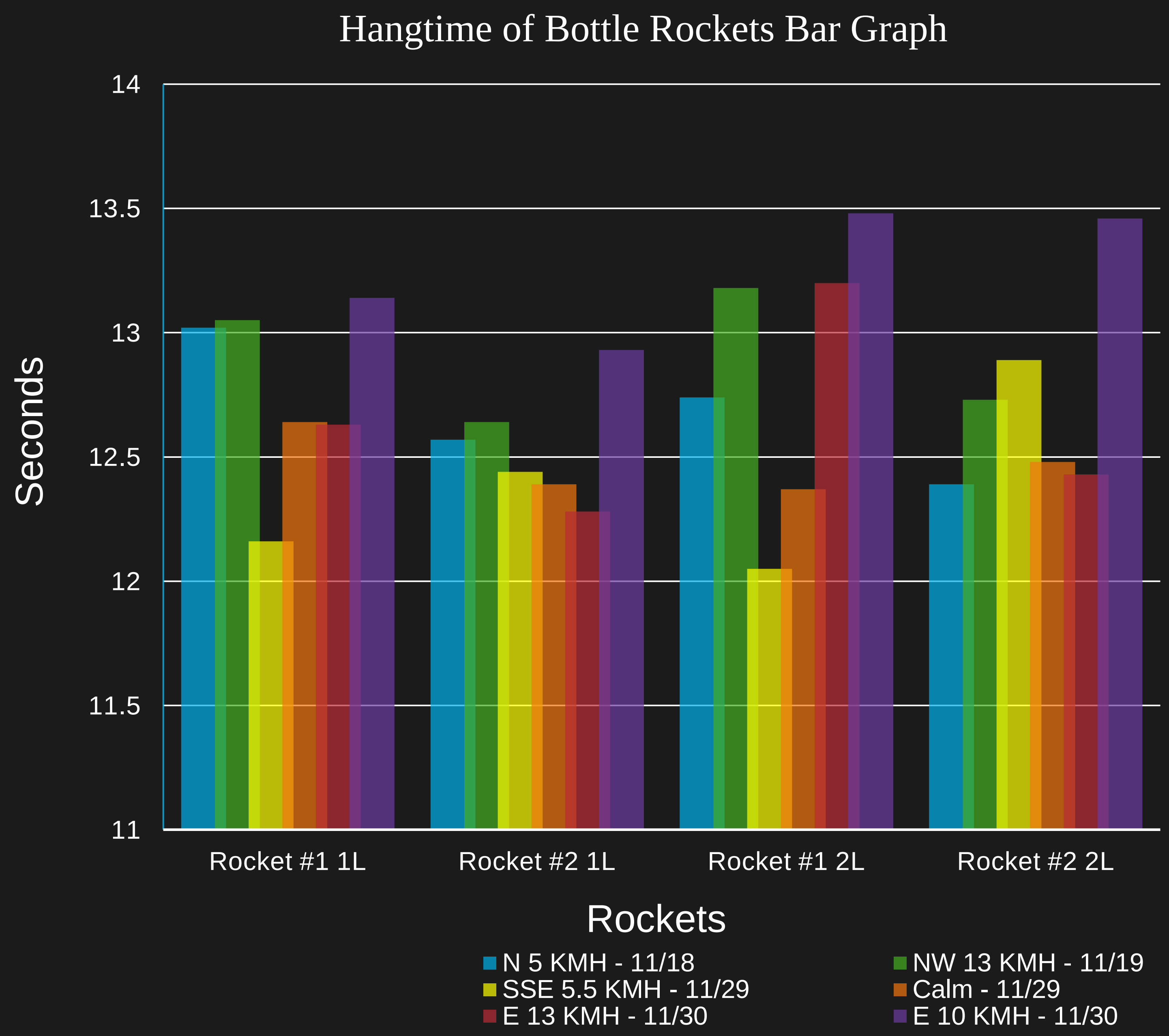
	Water	Wind	Time of Day	Height	Hangtime
#1 1L	400 mL	SSE 5.5 KM/H	3:10 PM 11/29/16	58.08 Meters	12.16 Seconds
#2 1L				54.91 Meters	12.44 Seconds
#1 2L	800 mL			57.44 Meters	12.05 Seconds
#2 2L				54.27 Meters	12.89 Seconds
#1 1L	400 mL	Calm	3:40 PM 11/29/16	52.83 Meters	12.64 Seconds
#2 1L				56.42 Meters	12.39 Seconds
#1 2L	800 mL			59.68 Meters	12.37 Seconds
#2 2L				52.28 Meters	12.48 Seconds

Data Table (Cont.)

	Water	Wind	Time of Day	Height	Hangtime
#1 1L	400 mL	E 13 KM/H	3:20 PM 11/30/16	52.27 Meters	12.63 Seconds
#2 1L				52.76 Meters	12.28 Seconds
#1 2L	800 mL			51.83 Meters	13.20 Seconds
#2 2L				52.35 Meters	12.43 Seconds
#1 1L	400 mL	E 10 KM/H	3:40 PM 11/30/16	54.83 Meters	13.14 Seconds
#2 1L				53.05 Meters	12.93 Seconds
#1 2L	800 mL			54.37 Meters	13.48 Seconds
#2 2L				53.85 Meters	13.46 Seconds

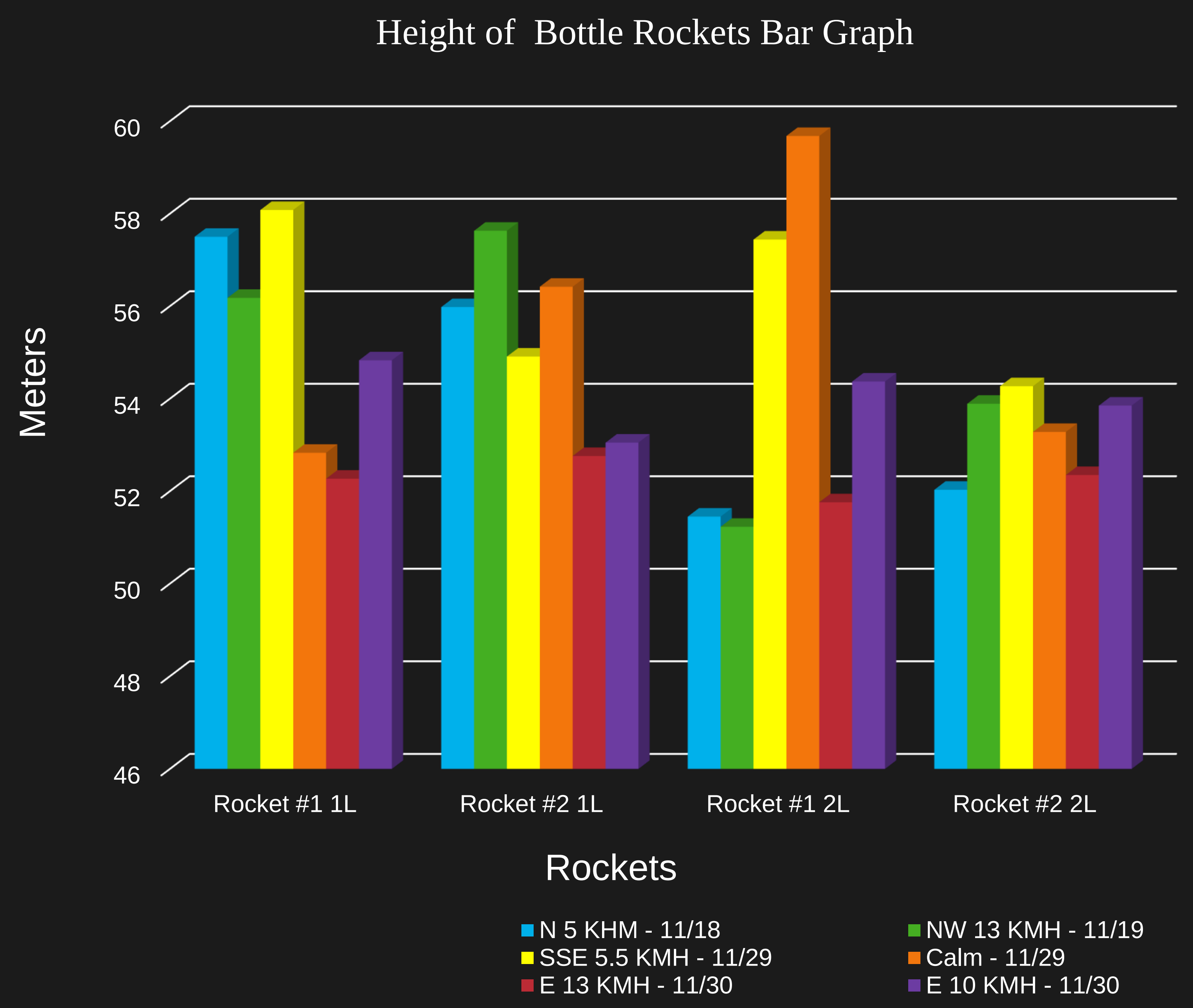
Data/Observations

An analysis of this graph, allows this scientist to say that the rockets times are consistent among other rockets on the same day. Rocket #1 1L times were between 12.16 – 13.14 seconds. Rocket #2 1L times were 12.28 – 12.93 seconds. Rocket #1 2L times were 12.05 – 13.48 seconds. Rockets #2 2L times were 12.39 – 13.46 seconds. Hence, the times did not change dramatically. Thus, supporting my hypotheses.

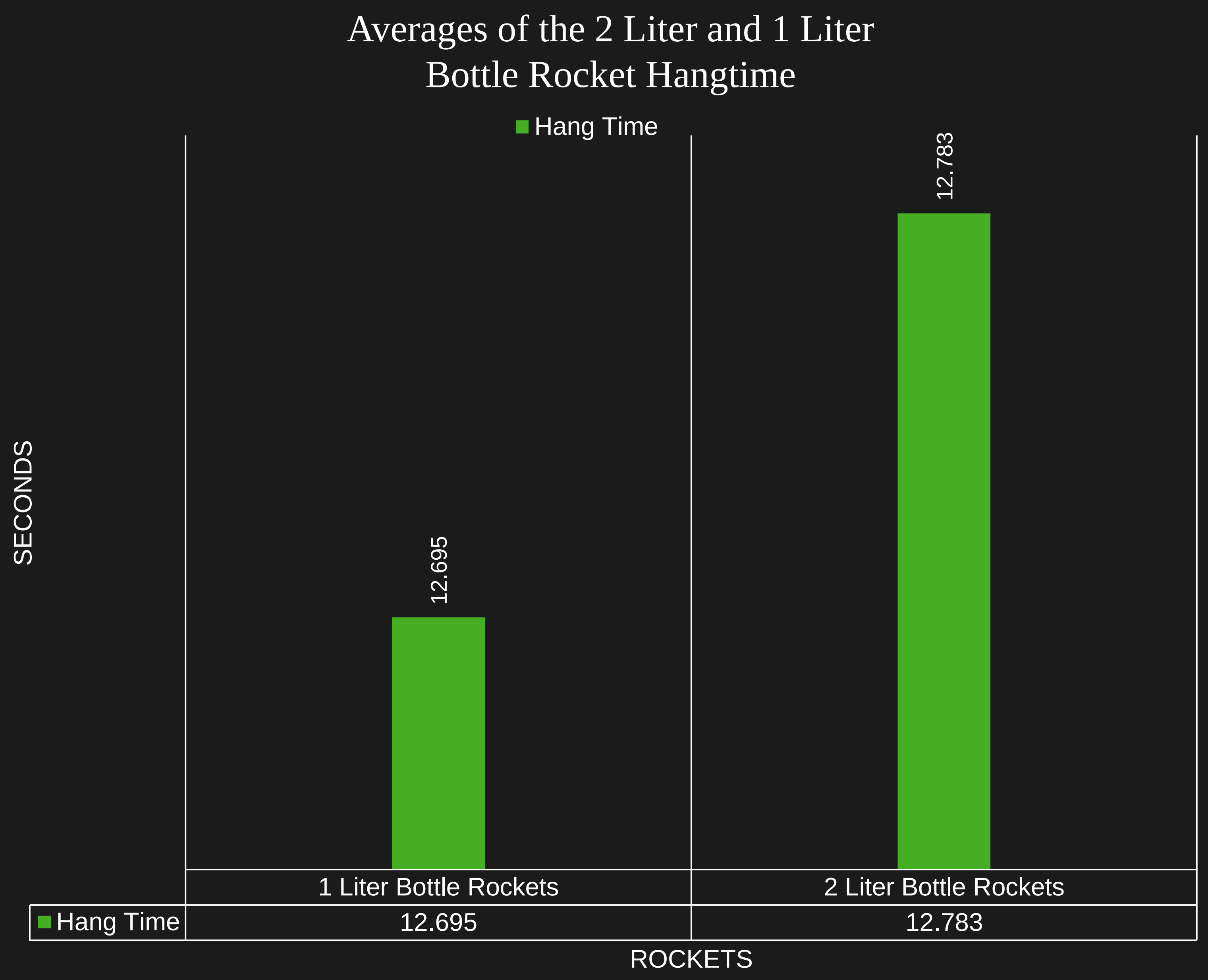


Data/Observations (Cont.)

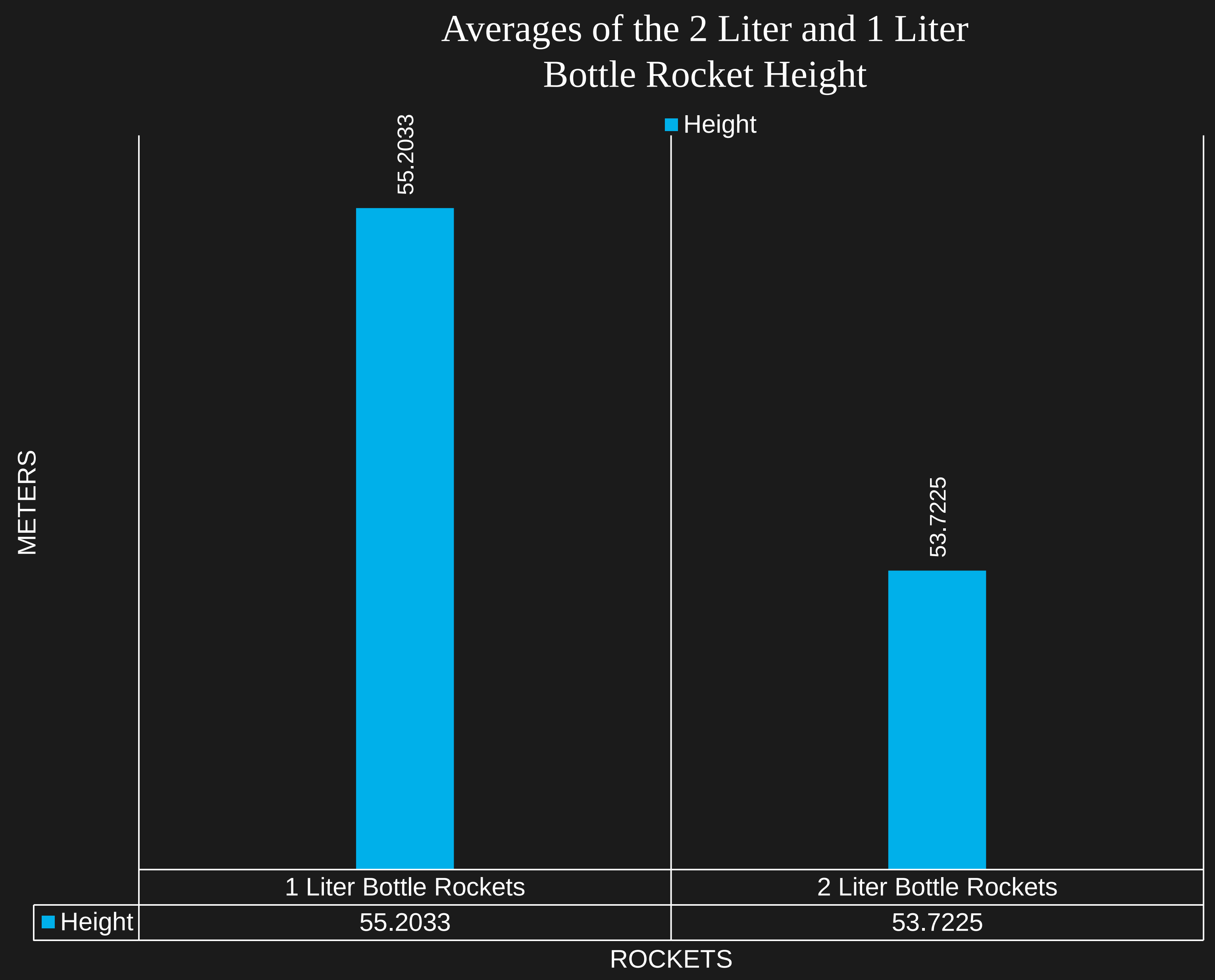
An analysis of this graph, allows this scientist to say that the rockets heights are consistent among other rockets on the same day. Rocket #1 1L height was between 52.27 – 58.08 meters. Rocket #2 1L height was 52.76 – 57.63 meters. Rocket #1 2L height was 51.23 – 59.68 meters. Rockets #2 2L height was 52.03 – 53.89 meters. Hence, the times did not change at all dramatically.



Data (Cont.)


Averages of the 2 Liter and 1 Liter Bottle Rocket Hangtime
Hang Time
SECONDS
12.695
12.783
1 Liter Bottle Rockets
2 Liter Bottle Rockets
Hang Time
12.695
12.783
ROCKETS

Data (Cont.)


Averages of the 2 Liter and 1 Liter Bottle Rocket Height
Height
55.2033
53.7225
METERS
1 Liter Bottle Rockets
2 Liter Bottle Rockets
Height
55.2033
53.7225
ROCKETS

Conclusion

In conclusion, this scientist has discovered if the volume of a rocket is decreased by 1/2 and the same rocket is exactly 2x smaller in size and weight, then the height and hangtime of the rocket will be the same. This is shown through the data this scientist has collected, Rocket #1 1L times were between 12.16 – 13.14 seconds. Rocket #2 1L times were 12.28 – 12.93 seconds. Rocket #1 2L times were 12.05 – 13.48 seconds. Rockets #2 2L times were 12.39 – 13.46 seconds. Hence, the times did not change at all dramatically, this time range would be considered great despite the variables. Furthermore, this scientist can say that the rockets heights are consistent among other rockets on the same day. Rocket #1 1L height was between 52.27 – 58.08 meters. Rocket #2 1L height was 52.76 – 57.63 meters. Rocket #1 2L height was 51.23 – 59.68 meters. Rockets #2 2L height was 52.03 – 53.89 meters. Thus, from the data this scientist has collected, this scientist has accepted that his hypotheses is correct. Some errors that might have caused some various in time and height may include the constant speed of pumping and the inaccuracy of the pressure gauge. Moreover, the fins could have been placed to far up which may have cause an unstable flight leading to a decrease in hangtime.

If this scientist were to do his experiment again he would use a wind tunnel to check that the stability for all rockets would match and the CPP was the same for all. Moreover, this scientist would use 4 of the same bottle rocket launchers to launch his rocket, eliminating variables such as wind gust, rain, etc. Next year this expert could test if the spin of a bottle rocket affected the height, velocity, and hangtime of a bottle rocket.

Photos Experiment

Bottle Rockets

Launcher

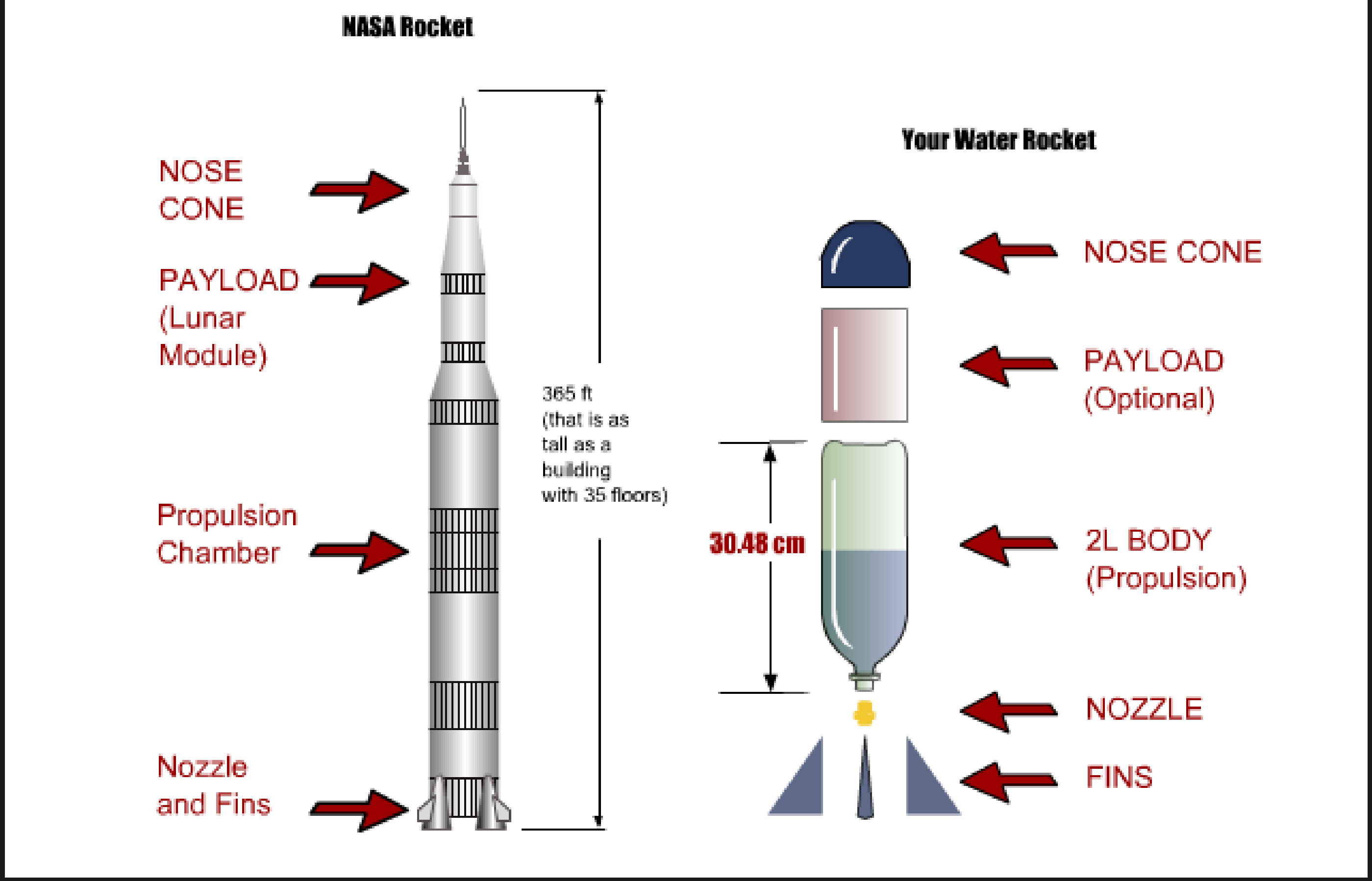
Risk, Safety & Cautions

- Safety glasses
- The chance of the rockets exploding on the launchpad
- The launcher tipping over and firing towards a person
- Inhaling the fumes of CA
- Use common sense

Pro Tips

- Stiff fins are the best fins. Flexibility decreases the effectiveness of a fin.
- Place the grain of the fin perpendicular to the bottle. This will make the fin stiffer and stronger.
- "Swing Testing" is a quick way to determine if a rocket has reasonable stability. This test is done by tying a string around the rocket at its Center of Gravity and swinging the rocket around.
- Fins cause very little drag and do not weigh very much. A non-stable rocket that is flying sideways is creating a lot of drag. Non stable rockets have a lot of problems with pre-deployment of their parachute.

NASA Rocket vs Water Bottle Rockets



This experiment could help the NASA rocketry team design a more effective, reliable, and affordable way of space travel.

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Thank You!

Do you have any questions?