Water Bottle Rocket Project

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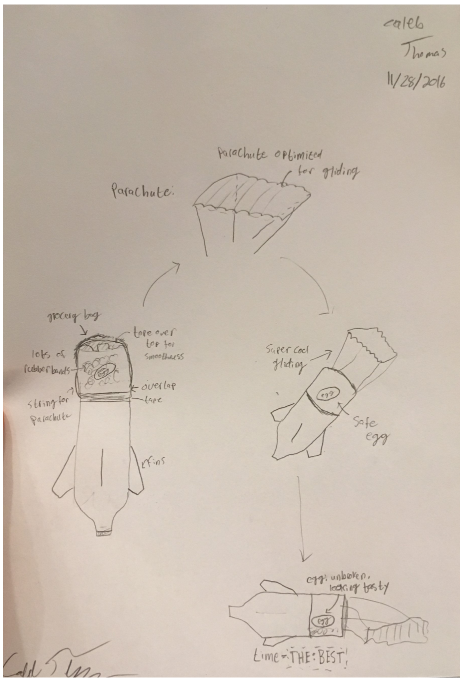
1 Introduction

We were tasked with building a water bottle rocket using two 2-liter soda bottles, duct tape, a cardboard box (in place of posterboard), glue, rubber bands, and string. The pressure vessel is made out of a single 2-liter plastic bottle, and the structural integrity was unaltered.

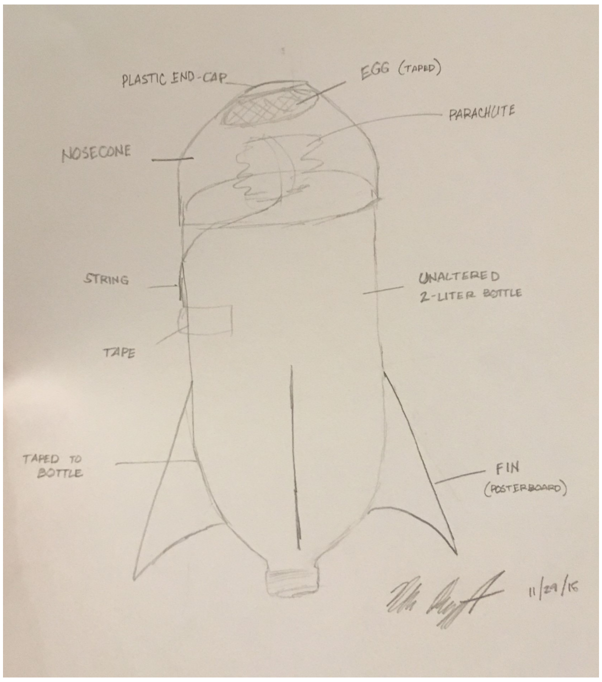
The goal of this project was to design a water bottle rocket that has the longest flight time and carries a payload (egg). The water rocket will be loaded up to a maximum of 60 psi at the launch. The time aloft will be recorded in tenths of second, and the timing begins when the rocket separates from the launcher and stops when the system touches the ground or comes to rest on another object.

2 Possible Designs

We each came up with an individual design before meeting, shown in Figure 2 After collaborating, we realized that our initial ideas were similar, but each missed some key components. One of our designs has a good holding cell for the egg, but not a very good parachute system. We determined that the other had a better parachute system, but an inferior egg placement. So, our final concept was created by taking the best of each design and putting them together.



(a) Concept Design 1



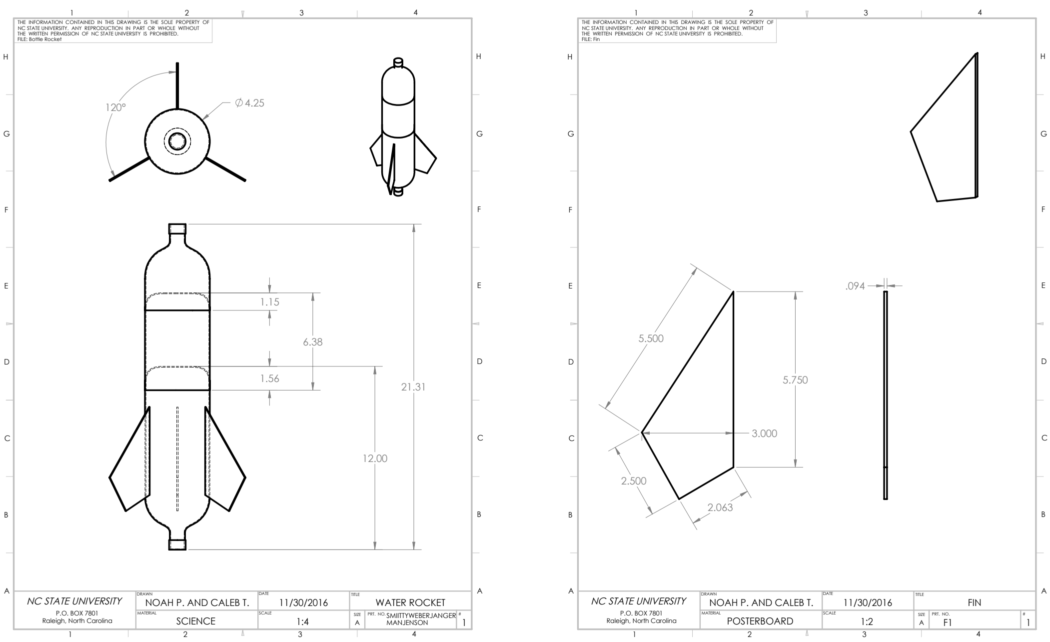
(b) Concept Design 2

Figure 1: Initial Ideas

3 Final Design

We decided to have a final design that incorporated some key components from both of our initial concept drawings. The egg will be contained under a cap on top of the rocket, and the parachute will be contained in a section between the fuel cell and the egg that will theoretically come off as the rocket begins it's decent. The upper section with the parachute and the egg should completely detach from the rocket at the decent. The egg will be placed in a bed of rubber bands (and not not adhered to by the tape), in an effort to dampen any jarring the rocket receives.

To make the parachute, we used part of a target shopping bag. We cut the largest circle possible from the shopping bag possible, which ended up being ≈ 13 inches in diameter. We attached 12 shroud lines to the rocket with string each ≈ 20 inches long. Those were then tied together at the far end and taped to the interior of the cap.



(a) Overall Design

(b) Fin Specifications

Figure 2: Final Design

4 Tuning Concept by Experimentation

After initial construction of the rocket, we had to perform some tests and modifications.

4.1 Parachute Test

To test the parachute that we put on the rocket, we launched the rocket (by throwing), on one of the upper stories of Talley. This test was very useful. From it, we were able to determine the most reliable method of wrapping the parachute. As it turns out, we achieved the most success with parachute deployment when the parachute was folded into smaller and smaller triangles, and then rolled the parachute in its shroud lines. This test confirmed that our parachute was able to successfully unravel and that the upper section of the rocket was able to detach from the pressure vessel.

4.2 Stability Test

To test the stability of the rocket (as suggested in the lecture notes), we tied a string around the body of the rocket at the center of gravity and swung the rocket about in a circle. The nose of the rocket pointed in the direction of motion, demonstrating that our rocket is stable and the center of gravity is above the center of pressure. However, we did not do the test with the egg loaded or with the water in the pressure vessel. That would definitely lower the center of gravity.

4.3 Watertight Test

We needed to test the watertight properties of the pressure vessel to gauge whether or not it would hold the water at pressure. To do this we simply partially filled the vessel with water, wiped it dry, and shook it up. No water was found leaking or on the exterior of the vessel after this experiment, so we concluded that the vessel was watertight enough.

5 Expected Rocket Performance

Here we use the equations as given in the given in the Soda Bottle Water Rockets article (cited below), to predict the performance of the aircraft.

Soda bottle water rockets Kagan, David and Buchholtz, Louis and Klein, Lynda, The Physics Teacher, 33, 150-157 (1995), DOI:http://dx.doi.org/10.1119/1.2344175

We used MATLAB to solve the equations simulating the flight of our rocket. Our estimations are as follows:

Maximum Height:	45.58 m
Maximum |Velocity| :	29.84 m/s
Time Elapsed:	6.87 s
Propellant Emptied at:	5.23 s
	0.95 m
	28.21 m/s

When calculating the values for the height, speed, and airtime of our rocket, we started the process in excel. The values we got were interesting, and the velocity of the craft increased exponentially as the water left the tank however, the rocket only flew 9.8 meters by our calculations. Based on research, we knew that the rocket was supposed to reach approximately 77 feet, well above the number excel gave us. Determined to confirm our calculations, we switched to MATLAB. MATLAB gave us a calculation on the other end of the spectrum, telling us the rocket would reach a height of approximately 155 feet, nearly double what we expected, and stay in the air nearly 7 seconds. However, using an online simulator, we got similar results as to those MATLAB calculated. After much deliberation and reviewing of our code, we finally agreed that our numbers were found correctly, and that they were actually somewhat reasonable. This was confirmed when we cross referenced calculations with other another group, who had arrived at a similar performance analysis to ours.