Rocket Project Report (Team 22)

C. Eure, D. Zaccagnino, and I. Gershkovich
The Georgia Institute of Technology

This rocket project helped us learn how a rocket flies and how the center of gravity and center of pressure affects the flight. Using OpenRocket, we designed a rocket that was stable in flight (center of pressure behind center of gravity), and selected a motor that had enough thrust to reach 125 ft. We decided to cut the length of the body tube to save mass, and place 4 fins at the tail to lower the center of pressure. On launch day, our rocket only reached 93 ft, short of our predicted 122ft in OpenRocket. We believe this happened due to the extra glue mass (not accounted in OpenRocket), our motor data may not have been perfectly accurate, and some drag that OpenRocket may not have simulated. Due to the extra glue in the top of the body tube, we were not able to fit our altimeter all the way in, which resulted in our coupler being very tight. Our rocket did not separate in two halves at apogee, due to the tight coupler, thus the streamer was never deployed. A recommendation for future teams is to take account the mass of the glue and where it is placed, and teams should make sure that the coupler design allows the rocket to separate at apogee.

I.Nomenclature

ρ = density of air

A = Area of the streamer

C_d = Coefficient of Drag

V = terminal velocity of a falling streamer

II.Introduction

In our research, we wanted to design a small model rocket to contain a payload. We aimed for our rocket to reach the Apogee of 125 ft. For our payload, we had a small altimeter to measure the altitude of our rocket. We had to manipulate our design so that we were able to securely and snugly hold our payload inside. We started off with designing our first model through OpenRocket software to get an idea of where our center of mass and center of pressure is located. We ran simulations to pick the correct motor and determine what our predicted results will be. The paper goes into more detail on our OpenRocket simulation, our analysis, and results of launch.

III. Background Research

- Streamers

Throughout our research on streamers, we found the drag force generated by the streamers is calculated with the formula:

Drag Force= $\frac{1}{2}\rho A C_d V^2$. As we know that Drag Force is the same as the gravitational force, which equals to mass x acceleration, once the rocket reaches its terminal velocity, we know that any manipulations we perform with the streamer will not directly affect the drag force, but rather the components for the drag force. We cannot change the density of air as it is a constant, so we are left only with the area of the streamer, coefficient of drag and terminal velocity. From these, we can control the coefficient of drag and the Area of the streamer (independent variables) and the terminal velocity will change with respect to these variables (dependent variable). From the Formula, we can see that as the Area of the streamer and coefficient of drag increase, the terminal velocity would decrease.

From further research, we determined that wider and shorter streamers have higher drag coefficient than the long and slim ones. The reason was the whipping factor. We found that shorter streamers whip around more than longer streamers as they descend. Whipping helps to increase the drag on the streamer, consequently, increasing the coefficient of drag.

- Fins

Throughout our research on fins, we determined that fins help to shift the center of pressure of the rocket further down which ensures that the center of gravity is in front of the center of pressure. Therefore, fins provide the rocket with positive stability and prevent it from pitching to the side and spinning. Mass distribution

- Coupling

As we needed to separate the altimeter from the engine block and have a streamer in between, we needed to create a coupling system. The only coupling systems used for the model rockets we were able to find were simple cardboard inserts that are glued/fixed to one side of the main body tube, with the other part of the tube put over the coupler and either fixed or left loose.

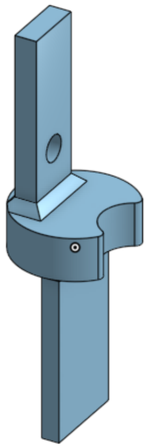
- Engine

Our research on engines mainly included the parameters and simulations performed through OpenRocket.

IV.General Overview of the Design Modification

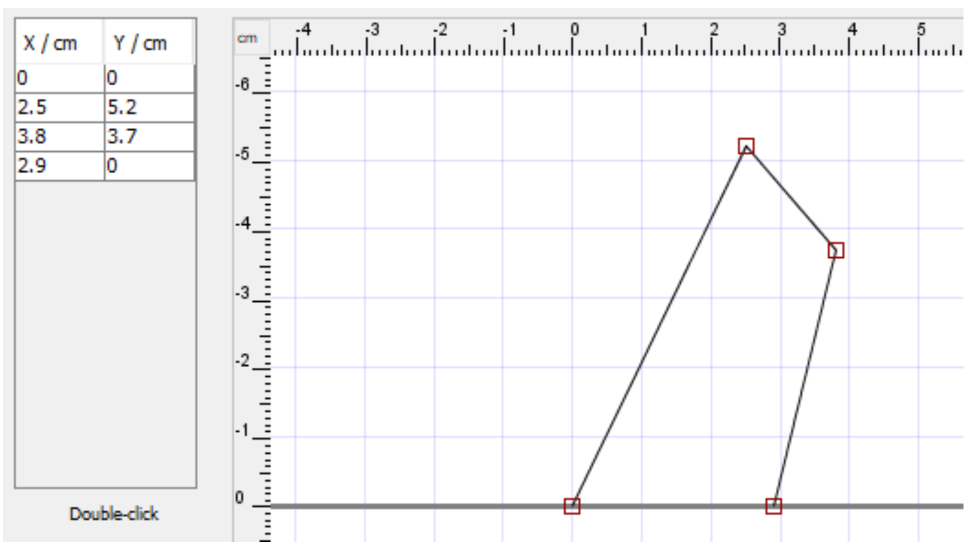
- Altimeter friction holder

To secure the Altimeter, we 3D printed an insert that will hold the altimeter in place and ensure its safety from the gases released from the ejection charge. It would be inserted and turned at the level of the shock cord holder which would provide frictional fixation of both the holder and the altimeter placed right above it. A picture of the CAD is shown below. The hole is a mounting hole for the altimeter. The bottom extension was added for us to grab the holder and rotate it after putting it in the rocket.



- Fins

We have used the original fins provided in the kit. These fins had a tapered swept shape. Fin shape and dimensions:



We decided to go with a four-fin instead of a three-fin configuration to ensure the stability of our rocket at the cost of drag provided by the extra fin. From our simulation in OpenRocket we figured out that our 4-fin design should be able to fly up to a point just slightly below the required 125 ft mark (37.2 m = 122 ft)

Apogee: 37.2 m
Max. velocity: 28.8 m/s (Mach 0.08)
Max. acceleration: 207 m/s²

- Double streamer

Our Original streamer was 3.1 cm wide and 46.5 cm long. This streamer had the length to width ratio of more than 10 and is a long streamer. Consequently, the coefficient of drag of the original streamer would be quite low. To reduce the terminal velocity of the fall, we decided to split our streamer into two smaller streamers of equal length. This would help to increase the whipping of the streamers without affecting the area, hence increasing the C_d and reducing the terminal velocity of our rocket.

- Coupler

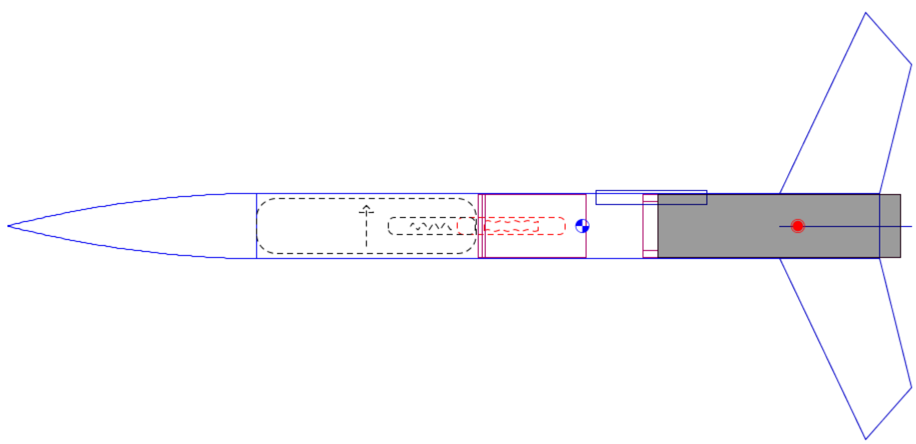
For the coupler, we decided to use the yellow spacer, and cut it down. The coupler was glued to the bottom half of the tube, while the top half was allowed to slide in and out. The streamers and shock cord would be packed in and around the coupler so they would deploy right away when the rocket separates. The pressure when the rocket climbs will be enough to make sure that the rocket will not separate during ascent. The motor ejection charge will push the top half of the rocket off the bottom half, when the motor burns out (close or at apogee).

- Main body modification

We decided to shorten the length of our main body to reduce the mass of our rocket and increase the height of Apogee. From the original 26 cm to 18 cm.

- Engine

We had only two types of motors to choose from: the 1/2A6-2 and 1/2A3-4T. From the simulations in OpenRocket, we figured out that the smaller version of the motor (/2A3-4T) had too much thrust and would put our rocket over the 150 ft mark. Therefore, we decided to go with the 1/2A6-2 motor which should have provided just enough thrust to get our rocket to 122 ft.



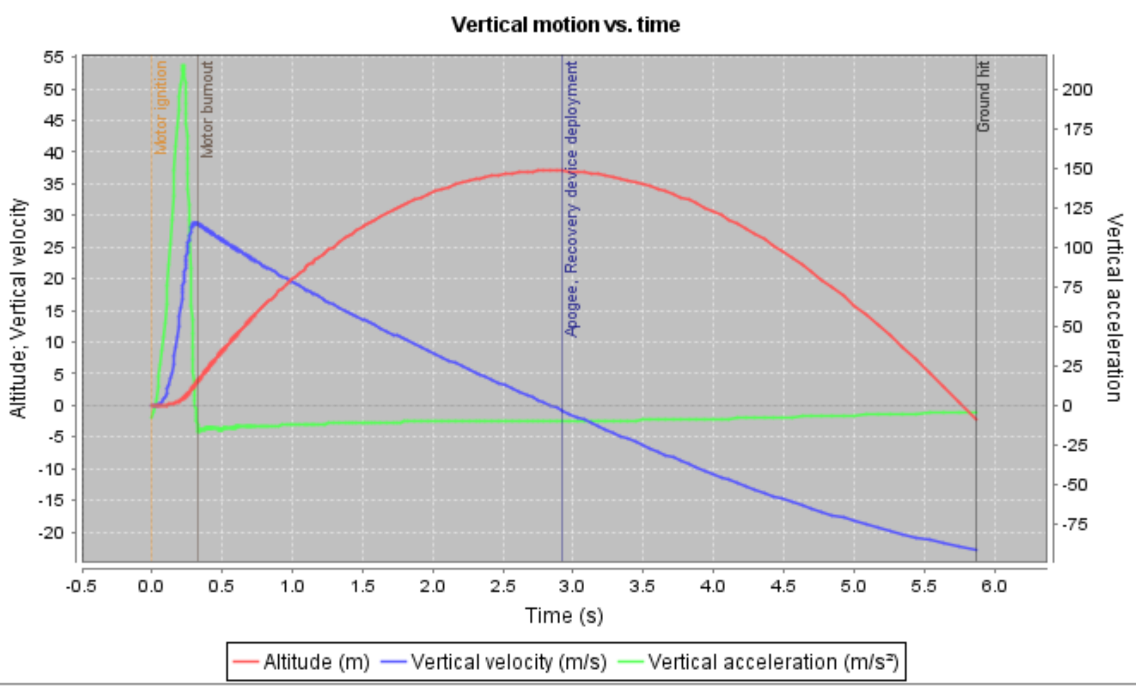
V.Weight and Balance

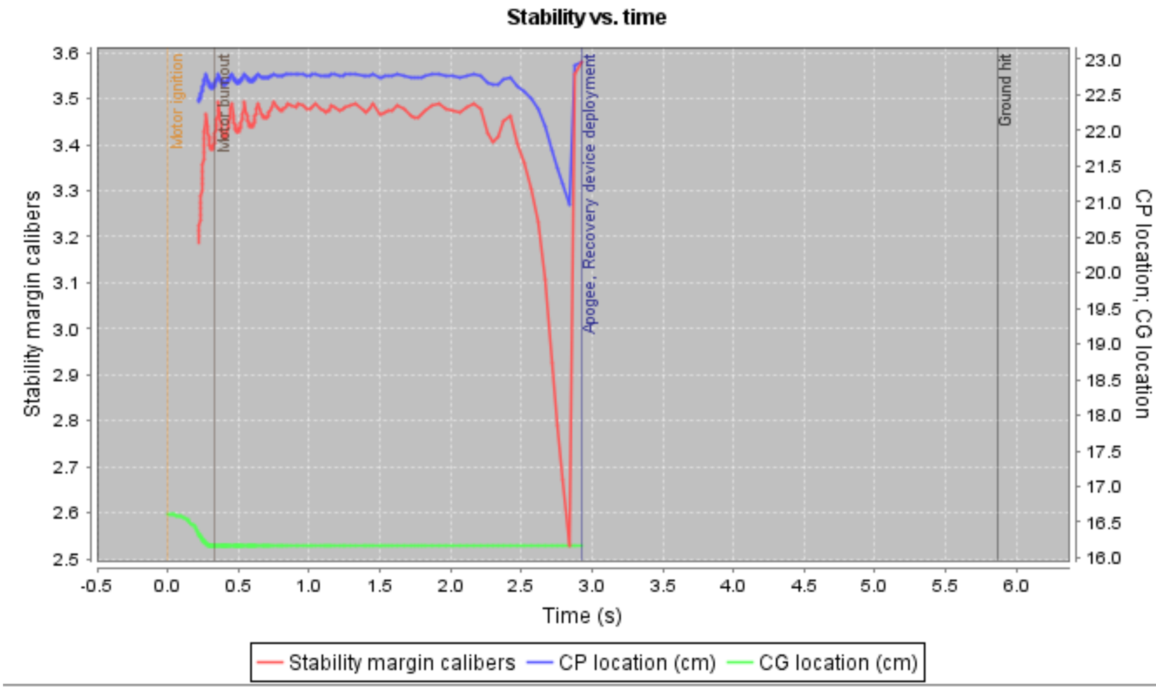
Item	Weight (g)	Location/Length
Body	3.45	7" long
Motor	13.8	Bottom of rocket
Coupler	0.187	5" from bottom
Streamer	0.216	In coupler
Shock Cord	1.94	In coupler
Launch Lug	0.209	2.5" from bottom

Engine Block	0.308	2.75" from bottom
Fins	2.89	At the bottom
Nosecone	4.43	At the top
Altimeter	7.3	5.5" from bottom
Center of Mass	**36.4**	**4" from bottom**
Center of Pressure	**N/A**	**1.5" from bottom**

VI.Design Modification Process

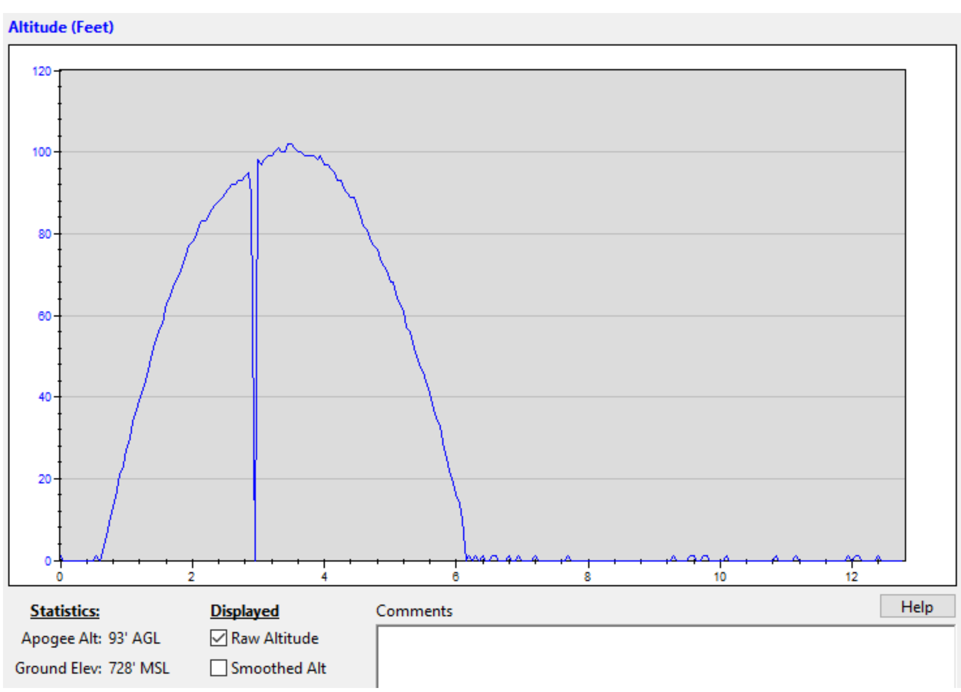
During our design process, we had to make tweaks to our original design. Firstly, we had originally designed a part to help hold our altimeter in securely, but due to a lack of communication with the specified dimensions of the altimeter, we had to unfortunately ditch the part and just stick our altimeter in. It was held in very tightly because it was also connected to our nose cone. We also had added another streamer to our rocket day of the launch. We wanted to help slow down our rocket as much as we could, because we were skeptical about the ability of a streamer to slow down something, compared to a formal typical parachute. We had planned on putting a little bit of glue to help prevent any of our components from moving, but we accidentally added too much, and sliding our components in restricted us from using all the space that we could. The units in the graphs below are in meters, unless otherwise specified.





VII.Test and Evaluation.

Due to the extra glue, we could not fit our altimeter all the way inside to the designated position and, consequently, we had to tightly pack our streamers which caused a lot of friction in the coupler compartment. Due to these factors, our rocket did not separate and therefore, our streamer did not deploy. Our expected altitude was around 120 feet, but we only hit around 93 feet. Probable causes for this were some slightly wrong engine data and some aerodynamic drag that OpenRocket may not have calculated. The extra mass from the glue, which we did not model in OpenRocket could also have impacted our height.



VIII.Conclusion and Recommendations for Further Design Improvements

A recommendation is to spend more time modeling our weight in the rocket and how our streamer and shock cord is fitted and packed in the rocket. Another design recommendation is to design a coupler that works well with the body tube and the inner components of the rocket. We would also recommend gathering more accurate data on the motor, especially burn duration and thrust to make sure it matches what is in the OpenRocket software. We also want to work on being able to work better on paying attention to assembly. We went into a last-minute hiccup with our design because of the inconsistency with the altimeter, so we essentially designed a part that didn't even end up being in the rocket. Thus, by doing that, we wasted time when we could've dedicated it to something worth more like more accurate simulations. Another modification that we could have added was the engine hook as once the ejection charge triggered, instead of pushing the nose of the rocket out, it pushed the engine out.

IX.Appendix

OpenRocket simulations, modeling, and graphs are shown above in the various sections of the paper.

X.Teamwork and Contributions

- Cameron
  - Brought the rocket home and kept it safe while not working
  - Took initial measurements of rocket
  - Organized cloud storage and outlined project
  - Final assembly of rocket
- Ivan
  - Performed preliminary measurements
  - Assembled rocket
  - Organized meetings
  - Performed open rocket simulations
- Dario
  - Performed Openrocket simulations
  - Assembled rocket (Did majority of gluing)
  - Designed altimeter bay

XI.Acknowledgments

The student workers in the Aero maker space answered many of our questions pertaining to the rocket project. Thank you, Dr. Ruffin, for letting us be able to experience and be able to work on this project. This was a fun project, and we wish that it was on a larger scale and to see the other things that we could do, such as the actual manufacturing process.

XII. References

[1] “Peak of Flights Newsletter,” Apogee Components. 2009. https://www.apogeerockets.com/education/downloads/Newsletter244.pdf.

[2] “Model Rocket Fins 101: Purpose, Shape, Size, and Placement,” TheModelRocket. https://themodelrocket.com/model-rocket-fins-101-purpose-shape-size-and-placement/.