Shrocket The Great

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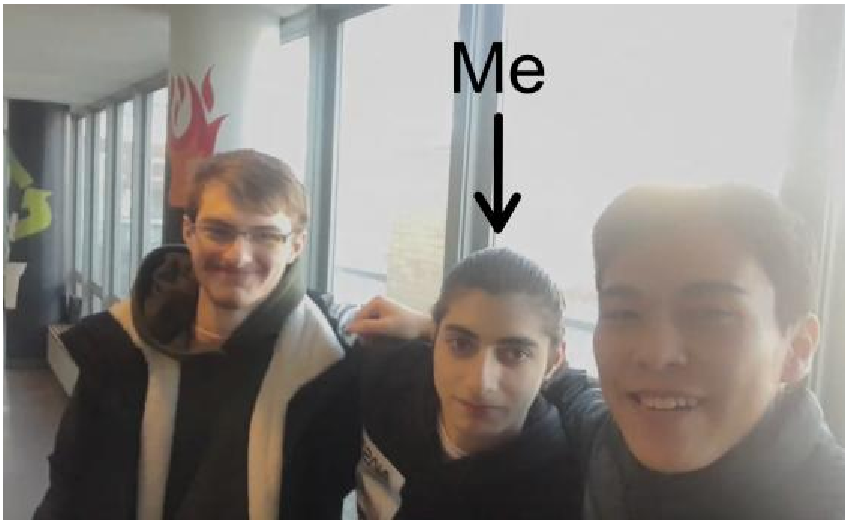
1 Foreword

1.1 What? Who?

This document provides a comprehensive description of the project discussed within my portfolio. It contains more of the technical side of my project, outlining our build, design, Methodology, challenges, etc.

I want to thank my great friends and collaborators, Samuel Angelov and Atai Kydyrov, with whom I worked on a project. They made building this project more memorable, and we learned much from each other.



Moreover, I would like to thank the American Rocketry Challenge for providing us with a generous grant, which we used to build our Rocket.

Additionally, I would like to thank Franklin Delano Roosevelt High School for providing us with a room to work in.

Last but not least, I want to express my gratitude to you, the reader. Thank you for allowing me to share this project, which holds significant meaning to me.

1.2 Why Rocket???

My friends and I wanted to build something that would challenge and enlighten our STEM skills, not only engineering but also Math and Physics. We had ideas for many projects, such as a trebuchet that would throw objects at a great projectile or a solar drone with its remote.

However, nothing stood out to us as much as building a model rocket. This project seemed the most challenging, one that required a lot of theory, engineering, and real-world application of that theory. So we started, and that is where our love for rocketry began.

2 Components

2.1 context

I would like to note that we had limited materials while building this project. Additionally, our school had never done anything related to rocketry before us; therefore, they could not offer much other than a room to build the rocket in. Moreover, we had no experience in building rockets, and we had no mentor to guide us. Nevertheless, we did our best to develop creative solutions for the challenges we faced and learned so much along the way.

2.2 Materials used

All the materials were purchased on the Apogee Rockets website: `https://www.apogeerockets.com/`

Almost all the materials used and their specifications are represented below:
(*Note that the parachute was handmade. Further details on its construction and design will be provided later in this document.)
(*BT stands for Body tube)

Component	Model	Length	width/diameter
Fins	Rising Star Basswood Fins (set of 3)	15.24 cm	7.62 cm
Motor	F50T-6	98 mm	N/A; 76.8 Ns (impulse)
Centering rings	29mm (Thin Wall) to 66mm (BT-80)	0.32 cm	6.44 cm
Bulkhead	Coupler Bulkhead Disk 2.6	0.64 cm	6.28 cm
Inner Tube	29mm x 13" Body Tube	33.02 cm	2.99 cm
Shock cord	Kevlar Cord 1500# (Model 30327)	N/A (2 grams)	0.35 cm
Lower BT	66mm X 18" Slotted Body Tube (BT-80)	45.72 cm	6.6 cm
Transition	Blow Mold Transition BT-70 to BT-80	17.78 cm	6.6 cm
Tube Coupler	AC-56A (BT-70) Coupler	10.16 cm	5.52 cm
Altimeter	AltimeterTwo	49 mm	18 mm
Egg Protection	Vertical Dual Egg Protector BT-70 size	16.51 cm	5.63 cm
Upper BT	56mm x 18" Body Tube (BT-70)	45.72 cm	5.63 cm
Nose Cone	PNC-2.14" (54mm)	24.13 cm	5.74 cm
E-Bay Kit	BT-70 Ebay Kit	N/A	N/A

Note that other materials were also used. However, the above components were the most important for our rocket build. The figure below shows the moment arrival of the components we bought. We were pretty excited to unbox them once they arrived. (see Fig. 1)

Figure 1: Arrival of components

Sometimes, we used some unconventional components that would be part of our rocket, such as Rulers and trash bags. (see Fig. 2) This was mainly because of our limited amount of materials and our trying to create a cheap build so we would fit into our budget. Nonetheless, making such interesting components was fun, which put smiles on our faces.

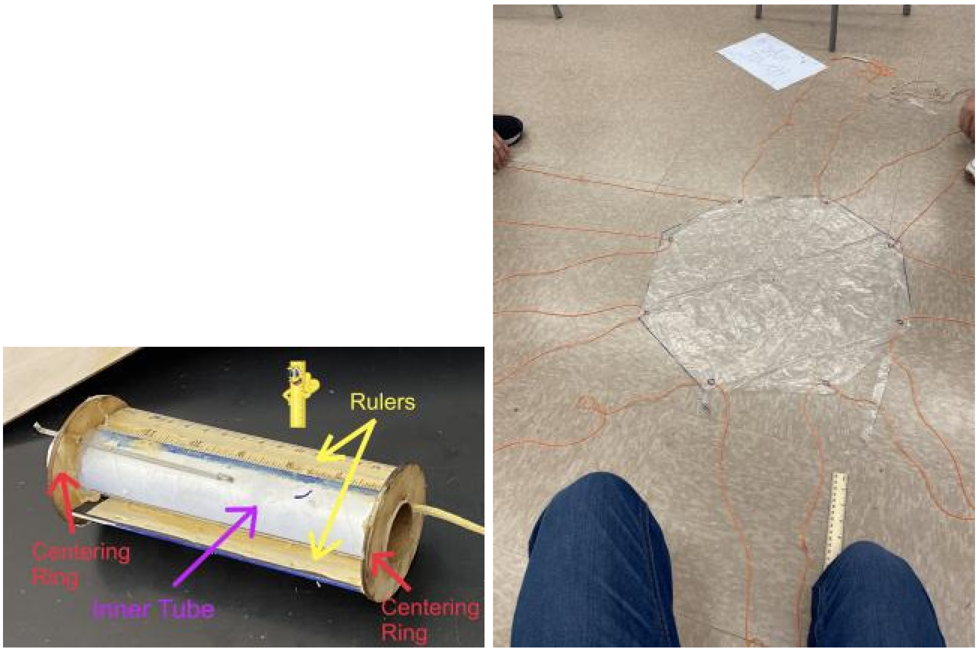


Figure 2: Rulers on Motor mount & trash bag parachute

3 The Build

3.1 Sketches, Theory

Before physically starting the project, we designed our rocket using OpenRocket Software (`https://openrocket.info/`). This software was a precious tool for us. OpenRocket can plot simulated graphs that indicate the rocket's altitude, vertical velocity, and vertical acceleration over time. Therefore, we could predict our rocket's flight results quickly. Using this software, we could know exactly which components to buy. This software especially helped us with picking out the suitable motor for our rocket, as every motor has a different impulse, burn time, etc.

We made multiple designs, as presented below (see Fig. 3):

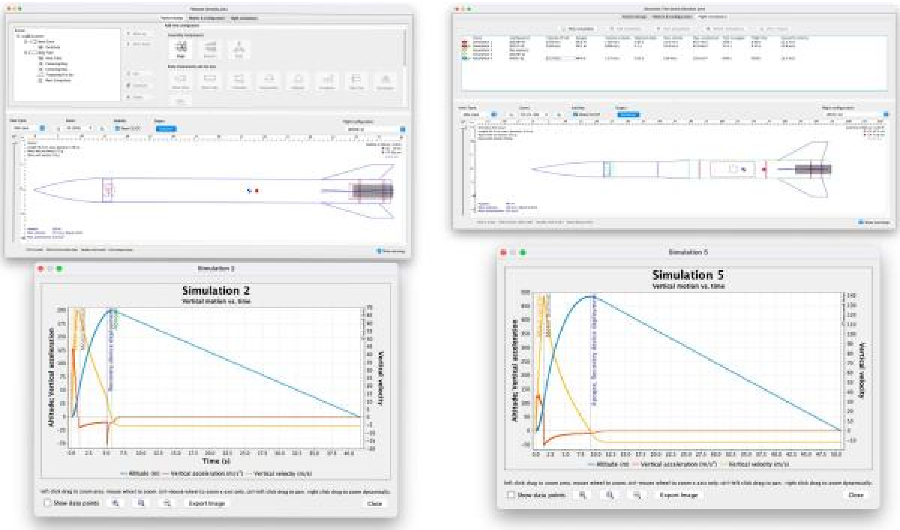


Figure 3: Designs & simulations

Although these designs were not the exact replicas of what we built in real life, they helped us get started by forming the idea in our minds of what we were going to build and where every component would be. More designs can be found on our Github Repository: `https://github.com/atai20/Rocket-kerbals`

3.2 Step by step process of building and Methodology

We started by attaching the fins to the base body tube (BT-80). For this, we used a fin alignment jig (see Fig. 4). At first, we used a hot glue gun. Unfortunately, that did not work well; the findings came off after testing them with slight pressure. After this, we used powerful liquid glue, which worked perfectly. We realized that hot glue would not help us attach components to each other, so we used liquid glue throughout the project.

The primary function of Fins is to decrease the point of Center of Pressure (CP), which has to be below the Center of Gravity (CG). Otherwise, the Rocket will be extremely unstable, maybe even turning around mid-air and accelerating toward the ground while the engine is still running. Which, of course, is unwanted.

Figure 4: Fin alignment jigs

After this, we proceeded by attaching our Analog altimeter to the E-bay, which would be placed in the payload compartment in BT-70. We faced another challenge: We tried attaching the altimeter to the sled using our liquid glue, which was a bad idea. The liquid glue got into the altimeter, breaking it overall. We kept note of this, and after buying a new altimeter, we used tape this time, which attached the altimeter to the sled pretty slightly. We also worked on some straightforward steps, like cutting holes through the bulkheads and the sled (done with a knife) and attaching the E-bay to the coupler (done with the liquid glue mentioned earlier). In the end, the whole process of building E-bay took around 4-5 days.

The whole purpose of E-bay was to measure the maximum altitude the rocket would reach. The altimeter measured a specific altitude at a specific interval. At the same time, the sample switch ensured that the altimeter took multiple measurements of multiple intervals at a particular frequency. This ensured that the altimeter would capture changes in altitude in real-time. Once $\frac{dy}{dt} \leq 0$ the altimeter would display the last recorded value of the altitude.

In the end, our payload looked pretty good (see Fig. 5), and we were pretty proud of how well it worked on the testing day.

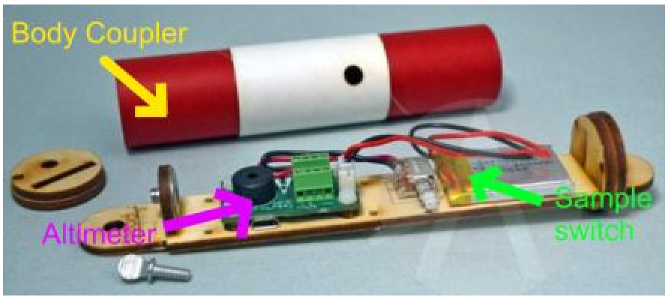


Figure 5: E-bay components

(*Note: I do not own image presented in Figure 4 and Figure 5. the images are owned by Apogee rockets)

After this, we proceeded to construct our parachute. The texture of the parachute was a trash bag (see Fig. 2) in total, our parachute was around 40 centimeters in diameter. We attached the parachute to the broader end of our transition, meaning it would be attached to the BT-80 end (see Fig. 6).

Figure 6: Attachment point of the parachute

Of course, we tested the parachute before concluding that it was safe to attach. Figure 7 shows our multiple tests of the parachute, from running with it to attaching it to a bottle and dropping the bottle from the third floor of our school.

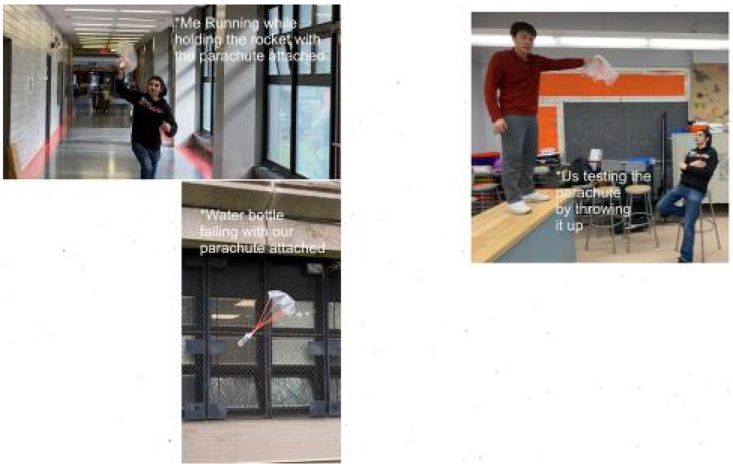


Figure 7: The tests of the parachute

These tests were successful, which made us believe that the parachute would work well. Unfortunately, however, we were deceived; our tests did not simulate the high pressure the parachute would go through during our flight. Because of this, our parachute broke off the Kevlar cords when we launched. That day, we tried to fix the parachute on the spot by using tent fabric on top of our initial parachute, made from a trash bag (see Fig. 8). However, that also failed: it turned out the double-layered parachute was too thick; therefore, it got stuck in our body tube mid-air, not even being able to deploy. By some miracle, the egg still survived, despite the rocket crashing to the ground from the free fall, which did give us one qualifying flight. However, the apparent problem was undeniable: We had to build a new parachute quickly.

Figure 8: Disassembled rocket after launch

That day, I volunteered to build the parachute at home, and we all agreed. The new parachute I made was out of tablecloth. This time, I used a tablecloth as the primary material for the parachute. This time, I attached the parachute to the Kevlar cords using tape. The diameter of the new parachute was relatively same as the diameter of our initial parachute, maybe a centimeter or two larger. The parachute turned out to be highly efficient.

We launched the next day, and the parachute deployed and did its job without a problem, which felt rewarding.

While building the parachute, we also built the motor mount, which consisted of the centering rings, the inner tube, and rulers (see Fig. 2). Why rulers, you may ask? Well, for our launch rod, we used a 1010 rail. Therefore, we would need to attach rail buttons to our rocket. That is where our idea was born: We thought we could kill two birds with one stone by first attaching the rulers in between the two centering rings and then using a rail button and a large screw (which would go through the ruler). Therefore the screw would not only attach the rail button to the rocket but also would act as another source of attachment for the motor mount. Of course, we also glued the centering rings inside the lower body tube.

In the end, this worked out exceptionally well. We had no trouble with the motor mount nor with rail buttons; they held on very well.

I also want to point out that we put the bulkhead between the parachute and the motor. This is because of our motor's built-in function, which is called the ejection charge: Once our motor uses all of its propellant, it makes its final blow by performing an ejection charge, which consists of shooting out the hot gases from the motor (expressly, but not limited to, Carbon Dioxide, Nitrogen, Carbon Monoxide, etc.). These gasses would cause pressure inside the rocket, causing our rocket's lower body tube to separate from the transition. The process I just described is clearly depicted in Figure 9 The bulkhead protected the parachute so that the hot gasses would not damage it, and it succeeded at its job.

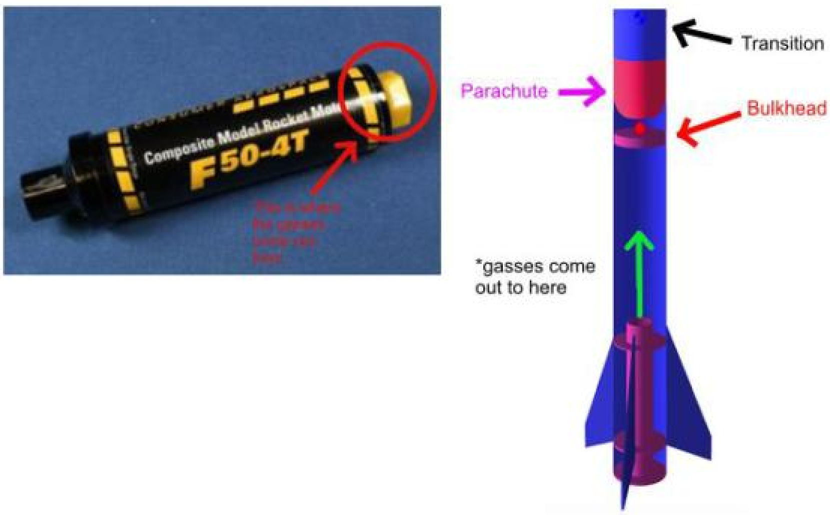


Figure 9: Illustration of ejection charge

The Figure 10 below shows the final build of our rocket

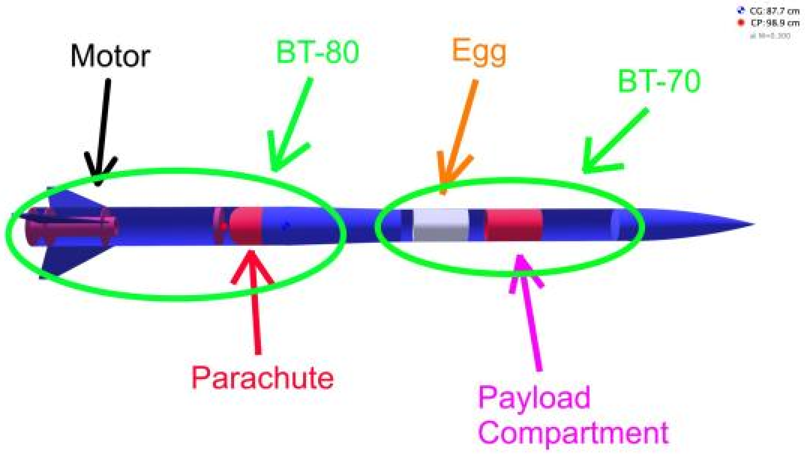


Figure 10: the final build of our rocket

3.3 Rocket specifications

The table below shows the specifications of our rocket as a whole:

Variable	Value
Length	$\approx$ 133.35 cm
Width	$\approx$ 6.6 cm
Weight	$\approx$ 615 grams

4 Flights

4.1 Goal values

Our desired altitude for our rocket to reach was 820 feet, with 43-46 seconds of flight time. With the egg not breaking, of course.

4.2 Flight Specifications

The table below provides an overview of the four flights completed by our rocket:

Flight #	Altitude	Flight time	Qualifying?
Flight 1	$\approx 908ft$	$\approx 25s$	No
Flight 2	$\approx 850ft$	$\approx 23s$	Yes
Flight 3	$\approx 870ft$	$\approx 23s$	No
Flight 4	$\approx 790ft$	$\approx 52s$	Yes

5 Reflections

5.1 Skills developed

This project taught us many skills. One of the most helpful was learning how to use OpenRocket software, which helped us determine which motor would be best for our rocket, what size of parachute we would use, what the weight of our rocket would be, etc., knowing how to use simulation and virtual software such as OpenRocket is essential when building model rockets, so you know what materials you need to buy and how your rocket is supposed to look. I will definitely use OpenRocket for the future model rockets I will build.

Moreover, we learned the engineering behind model rockets, how to build parachutes, how to mount motors, motor classifications, how to deal with E-bay, etc. This gave us the necessary knowledge of rockets/model rockets.

Additionally, we improved our physics and math skills, specifically in Aerodynamics. Even though we did not directly use Tsiolkovsky equations, we did explore them. Moreover, we dug into the Physics behind liquid rocket engines.

5.2 Thoughts

This project was one of the best projects I have ever participated in. We learned so much from each other throughout our journey of building this rocket, which was also a great bonding experience for us. We did not have much materials, experience, or a mentor to work with, but that made our collaborative experience even more memorable and we tried to work with what we had. Every challenge we faced was an opportunity to learn from; every failure was an opportunity to improve our designs, and although we did not qualify to finals, our flights and progress of our rocket's build did feel very rewarding. In the future, I plan to build more model rockets with liquid rocket engines and more features, such as self landing procedure. Moreover, I want my future model rocket to have something unique. Once experienced enough in rocket science, I plan to work on real rockets, specifically engines, which fascinate me; I love their capability and potential.