DESIGNING AND SIMULATING A MODEL ROCKET IN OPENROCKET

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1. INTRODUCTION

Through means of this project, we attempt to make use of OpenRocket to design a rocket capable of launching a CanSat payload to the desired altitude, and also aim to recover the rocket successfully by means of a parachute.

1.1 OPENROCKET

OpenRocket is a free, fully featured model rocket simulator that allows us to design and simulate rockets before building and flying them. It provides amature model rocketeers a reliable toolkit for simulations, through means of a state-of-the-art 6 degrees of freedom flight simulator with more than 50 variables. This robust simulation engine provides rich data to analyse all aspects of the design from stability to thrust curves, with options to plot the simulated data and export it for further processing.

1.2 CANSAT

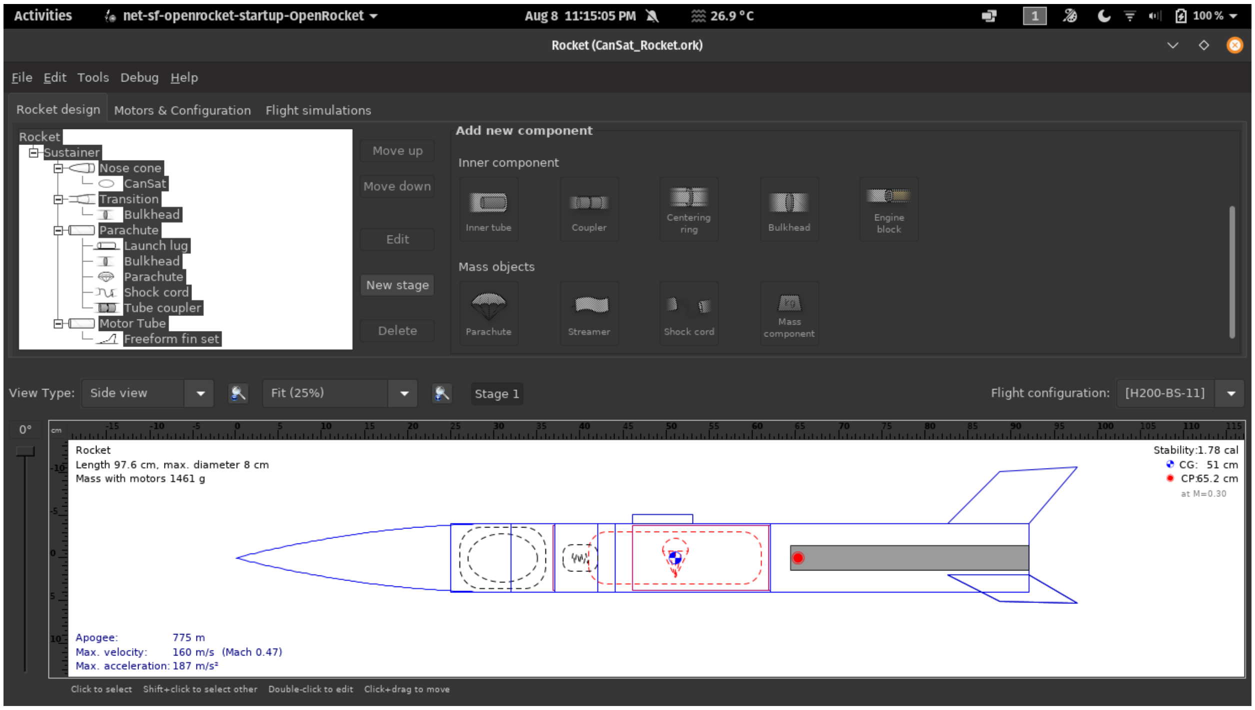
A CanSat is a type of cheap, inexpensive sounding rocket payload used to teach space technology. In CanSat competitions, the payload is required to fit inside the volume of a typical soda can (66mm diameter and 115mm height) and have a mass below 350g. CanSats are equipped with a recovery system, usually a parachute, to limit damage upon recovery and to allow the CanSat to be reused.

2. DESIGN REQUIREMENTS

We are required to design a Model Rocket that is capable of reaching an altitude of at least 750 meters while carrying a payload of 350 gm mass. The maximum allowed rocket length is 1 meter, with a maximum admissible wet mass of 1.5 kilograms. The rocket's inner diameter should be at least 0.07 metre in diameter, to accommodate the payload.

3. THE ROCKET

Taking the above mentioned requirements into account, a rocket has been designed such that its wet mass is 1.461 kilograms with a length of 0.976 metres, diameter of 0.08 metres and an apogee of 775 metres. As we are using a high-power rocket motor, we make use of a “Launch Lug” to provide stability for the rocket prior to and during liftoff. The launch lug works by forcing the rocket to remain parallel to the launch rod, ensuring a smooth, vertical lift off.



(Fig 1 : Rocket Model)

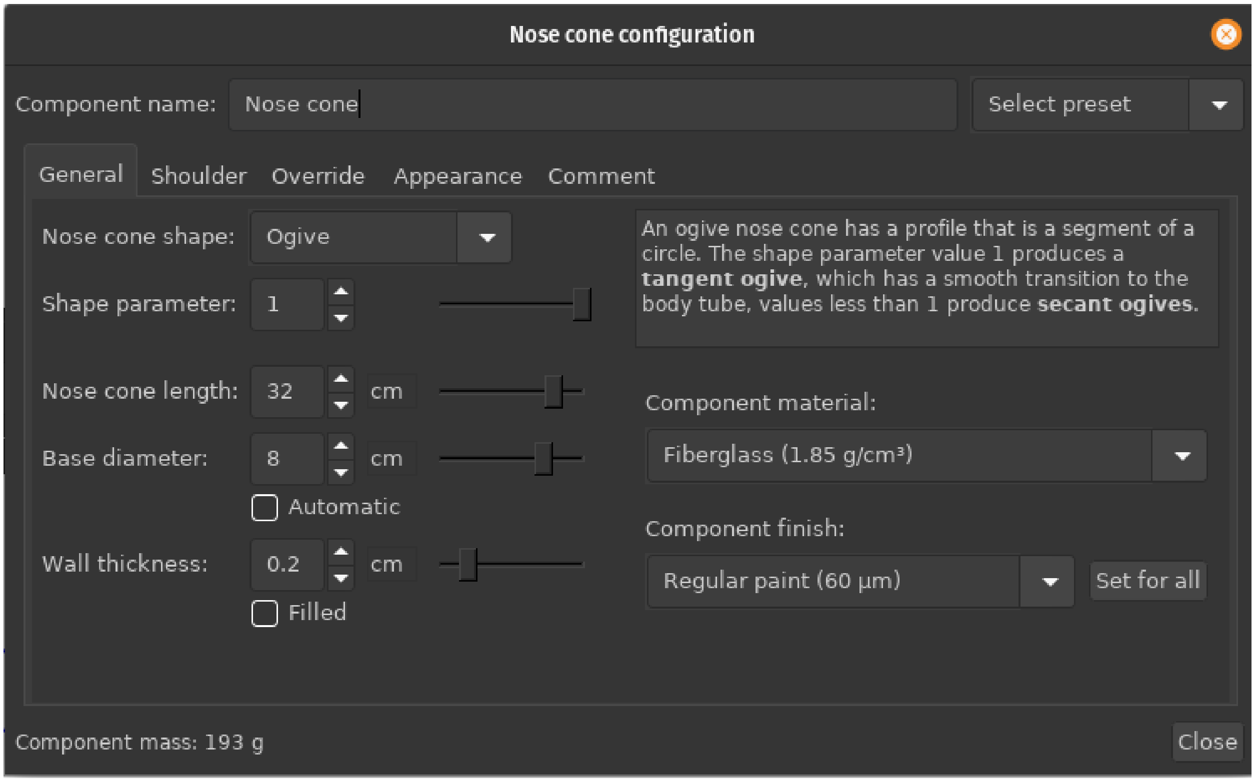
Let’s look at the major sections of the rocket, one by one.

3.1 NOSE CONE

A nose cone is the conically shaped forwardmost section of a rocket. It’s main function is to minimize aerodynamic drag. Here, we make use of an “Ogive” shaped curve for the nose cone. We use this shape because the Ogive nose cone has an arc which meets the body contour smoothly, thereby creating no break in line where the ogive joins the cylindrical body. As a general rule of thumb, the length of the nose cone is taken to be 4 times that of its diameter. In accordance with this rule, the nose cone is designed so as to have an 8 cm diameter and a 32 cm length.

As the rocket will be experiencing accelerations of upto 187 ms^{-2} (approximately 20 g’s) and velocities of upto 160 ms^{-1}, fibreglass has been selected as a suitable material for designing the nose cone. The total mass of the nose cone is estimated to be around 193 grams.

The nose cone is connected to the parachute bay by means of an elastic shock cord, to ensure its successful retrieval.



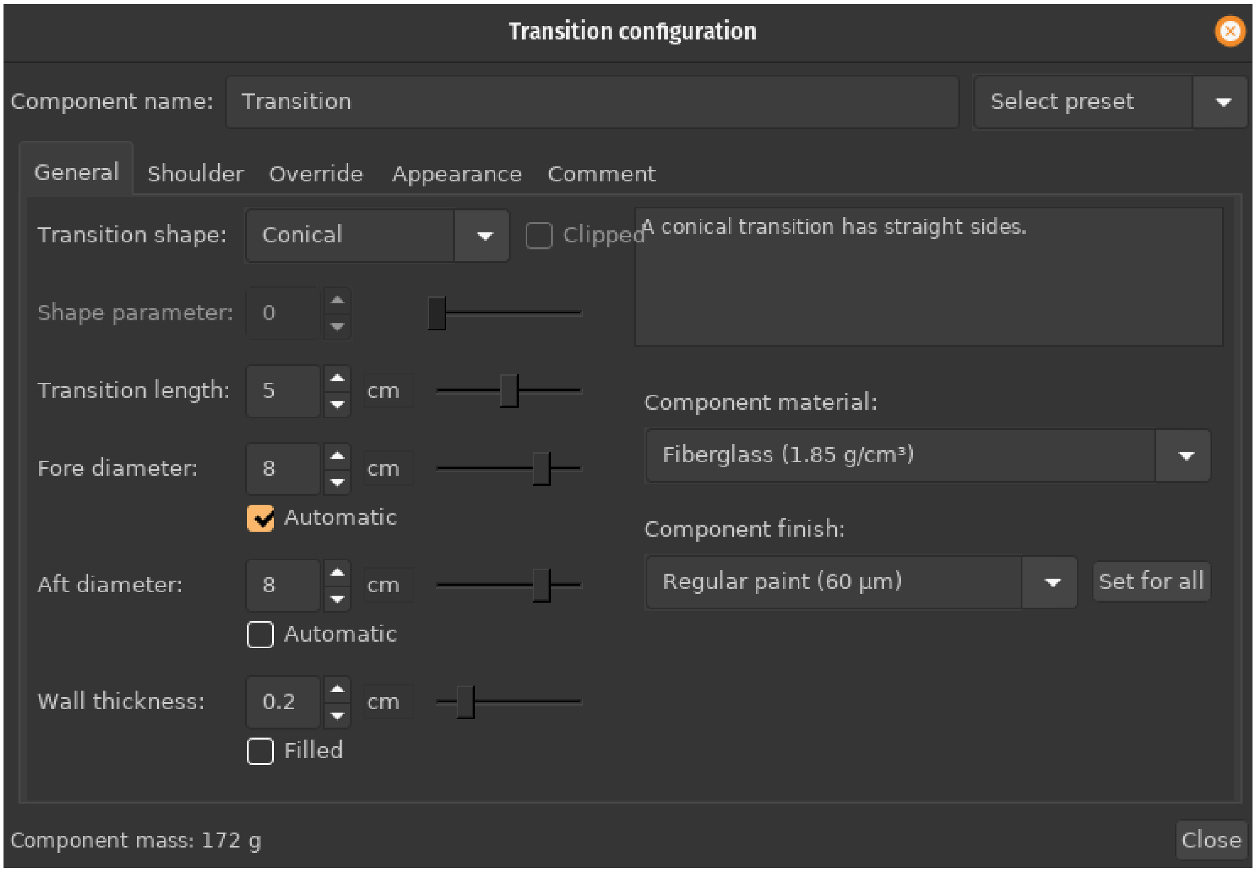
(Fig 2 : Nose Cone Specifications)

3.2 PAYLOAD TUBE

The payload (CanSat) is to be housed inside this section of the rocket. As the rocket nears apogee, a charge will be fired, pushing the payload out of the rocket, hence deploying the satellite successfully. A snug, tight fit is ensured to prevent the payload from experiencing strong vibrational stresses. This is done to prevent damage to the payload, and to prevent electrical contacts from getting disconnected.

Similar to the nose cone, this section is also chosen to be built of Fibreglass, for the same reasons as mentioned above. The payload tube has two shoulders that extend into the nose cone and parachute bay, ensuring it stays properly connected throughout the launch, till the time of payload deployment.

This tube will be split in half by the charge to ensure the payload leaves the rocket smoothly. Hence, it is not designed to be recoverable along with the rest of the rocket.



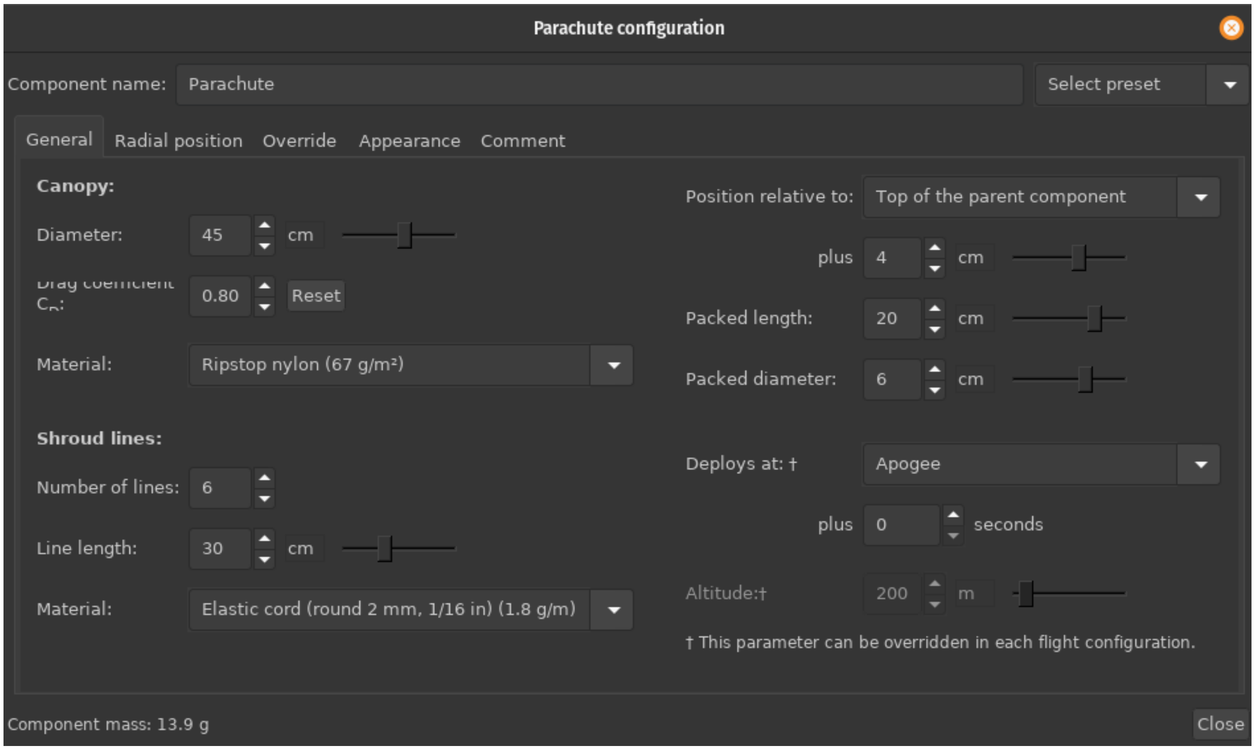
(Fig 3 : Payload Tube)

3.3 PARACHUTE

The parachute is the most essential component of the rocket, right behind the payload. A successful parachute deployment is key to ensuring the rocket's retrievability. Hence, a 45 cm diameter wide parachute with 30 cm long lines has been selected for this purpose. The parachute is made of standard off-the-shelf Ripstop Nylon, to prevent it from tearing under stress.

The parachute is expected to deploy as the rocket reaches apogee. This is done to ensure the parachute deploys when the rocket is at low velocities, in an attempt to minimize tearing. The payload charges are expected to fire at least 5 seconds before apogee, to ensure that the payload has enough time to separate from the main rocket body. This can be accounted for by the flight computer aboard the payload.

As the position of the parachute is close to that of the rocket motor, a layer of insulating material is placed between the two objects to prevent the motor's heat from melting the parachute.

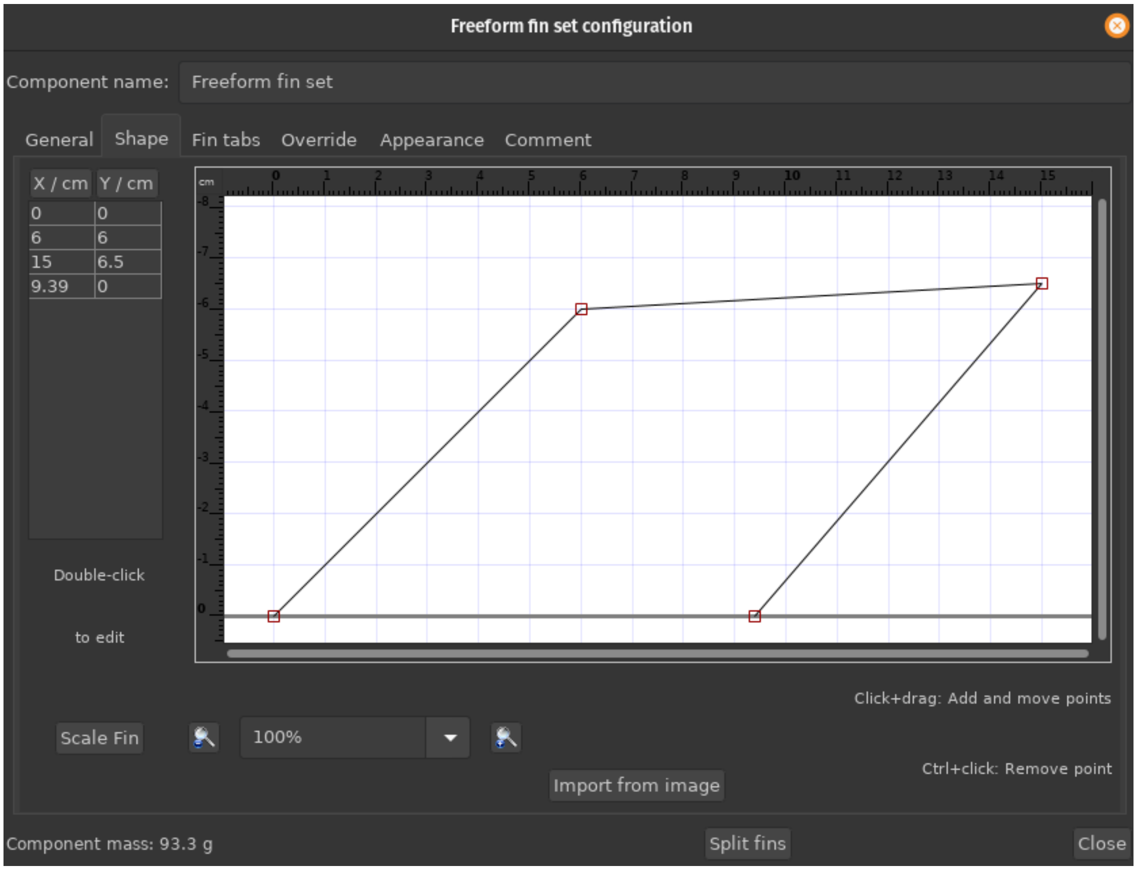


(Fig 4 :Parachute Specifications)

3.4 FINS

Fins are used on rockets to provide stability and control direction. Here, we make use of 3 fins attached to the bottom of the rocket's body. The fin is designed in accordance with the geometry defined in Figure (5). As a general rule of thumb, a model rockets' stability is expected to be between 1 and 2 cal. Lower than 1 cal, and the rocket becomes unstable. Greater than 2 cal, the rocket becomes overstable. Choosing to err on the side of caution, this trapezoidal geometry was designed to provide a stability of 1.78 cal, while also being easy to cut out and make by hand.

Similar to the previously mentioned components, the fins too are made of fibreglass to ensure they do not break easily under aerodynamic stresses, and also because fibreglass will not melt under the heat of the rocket motor.



(Fig 5 :Fin Geometry)

3.5 ROCKET MOTOR

A Cesaroni H200 BS motor is selected to power the rocket. This motor was selected for being a relatively budget friendly ‘H’ series motor. Its properties are as follows:

Total impulse:	261 Ns (63% H)
Avg. thrust:	197 N
Max. thrust:	295 N
Burn time:	1.32 s
Launch mass:	274 g
Empty mass:	138 g
Data points:	13
Digest:	bbba4f23bf36c19027320de7568c6723

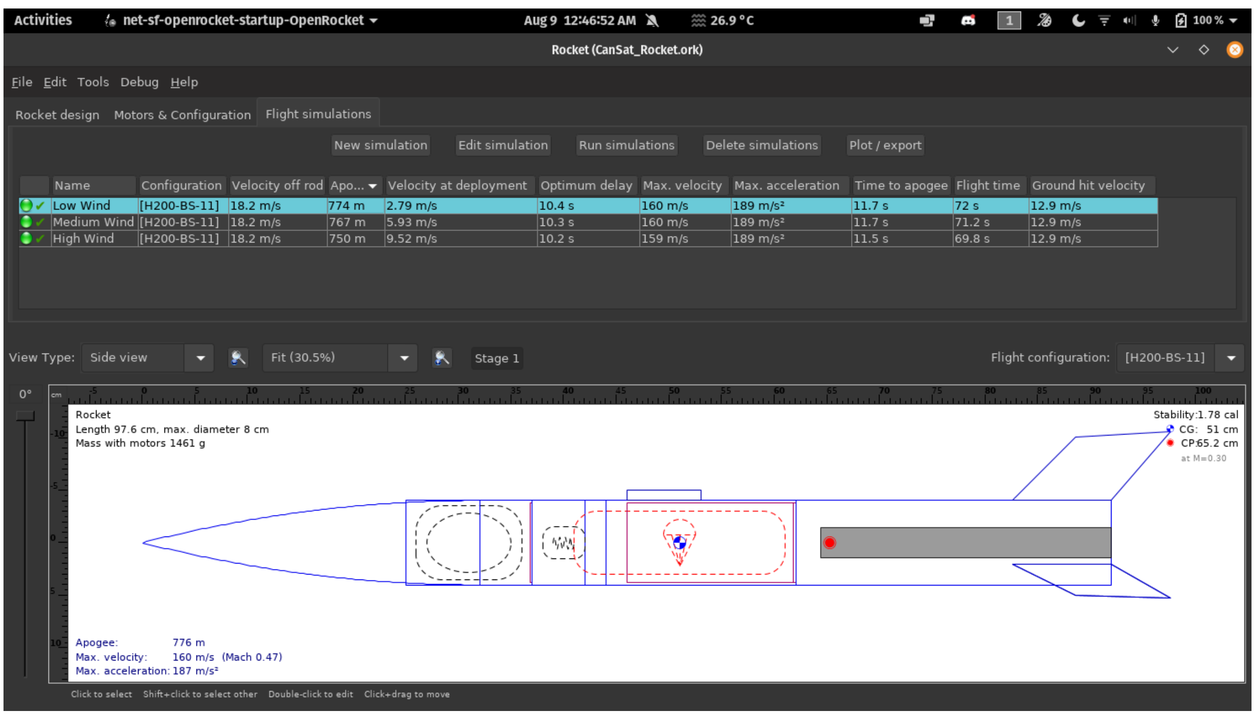
(Fig 6 :Rocket Motor Specifications)

4. FLIGHT SIMULATION

The rocket is simulated under three different weather conditions. They are as follows:

1. Low Wind (wind velocity of about 2 ms^{-1})
2. Medium Wind (wind velocity of about 4 ms^{-1})
3. High Wind (wind velocity of about 8 ms^{-1})

From figure (7), we can see that the rocket reaches apogee at above 750 metres for all three wind conditions. For further interpretations, we make use of the Medium wind velocity simulation.



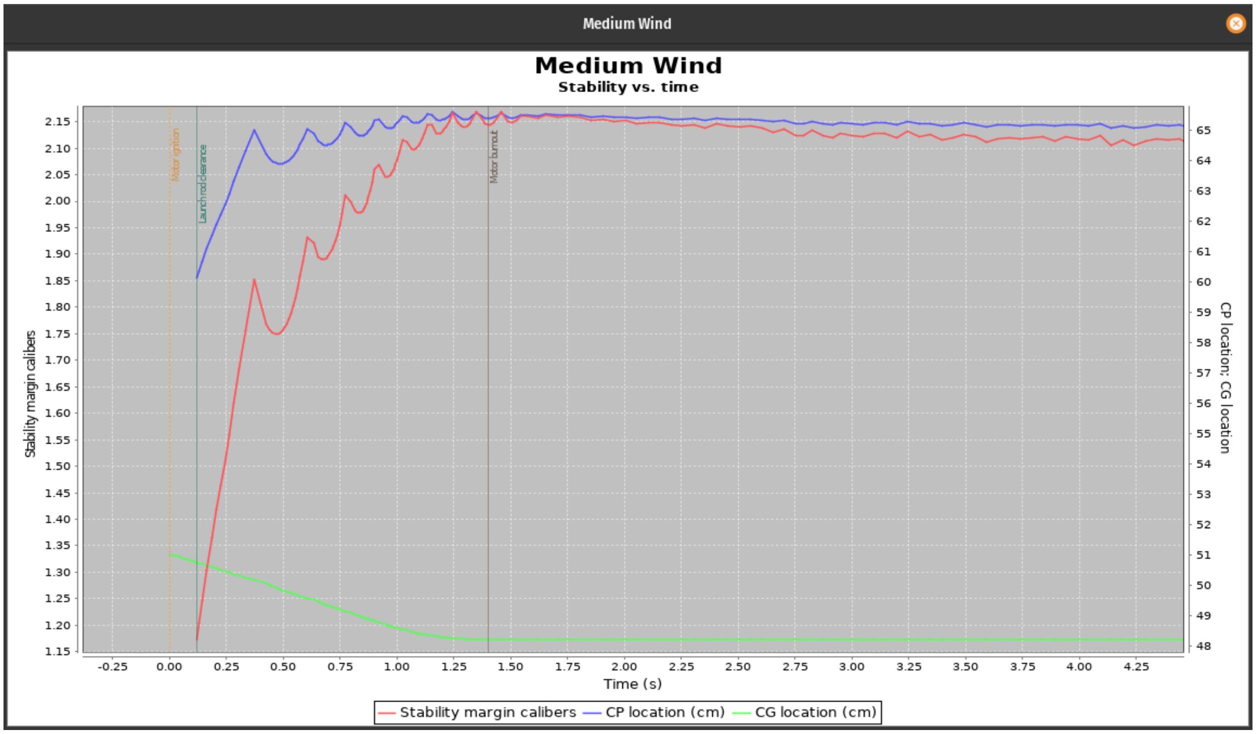
(Fig 7 : Rocket Simulations)

4.1 STABILITY VS TIME

This graph tells us how stable the rocket is as it flies. From this graph, we can make the following inferences:

- The stability margin starts at about 1.15, implying that the rocket is stable throughout the duration of flight.

- The centre of gravity decreases with time, which is expected because the motor's weight decreases as it burns.

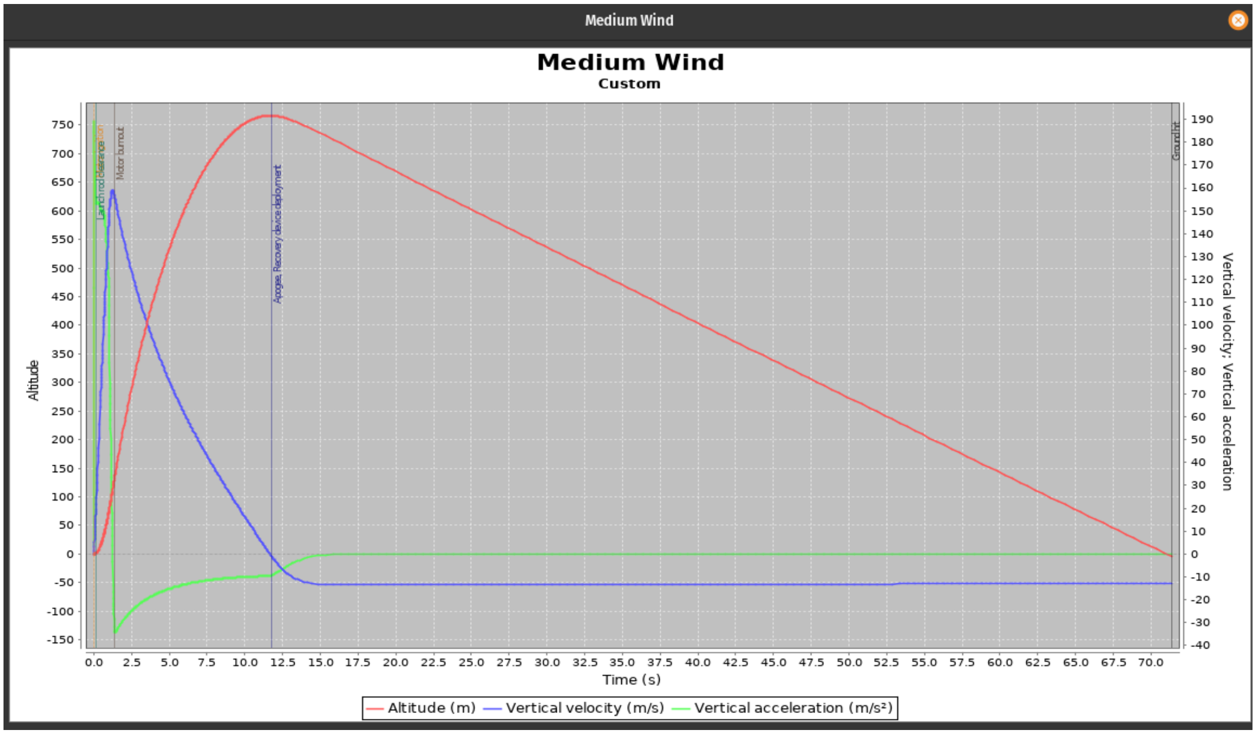


(Fig 8 : Stability vs Time Plot)

4.2 VERTICAL MOTION VS TIME

This graph tells us the altitude, velocity and acceleration of the rocket throughout its flight. From this graph, we can make the following inferences:

- Maximum altitude reached by the rocket is 767 metres.
- It takes the rocket 11.7 seconds to reach apogee.
- The Velocity of the rocket as it leaves the rod is 18.2 ms^{-1}.
- The Velocity of the rocket at the time of parachute deployment is 5.93 ms^{-1}.
- The rocket hits the ground with a velocity of 12.9 ms^{-1}.
- The maximum acceleration experienced by the rocket is 189 ms^{-2}.
- The total flight time comes out to 71.2 seconds.

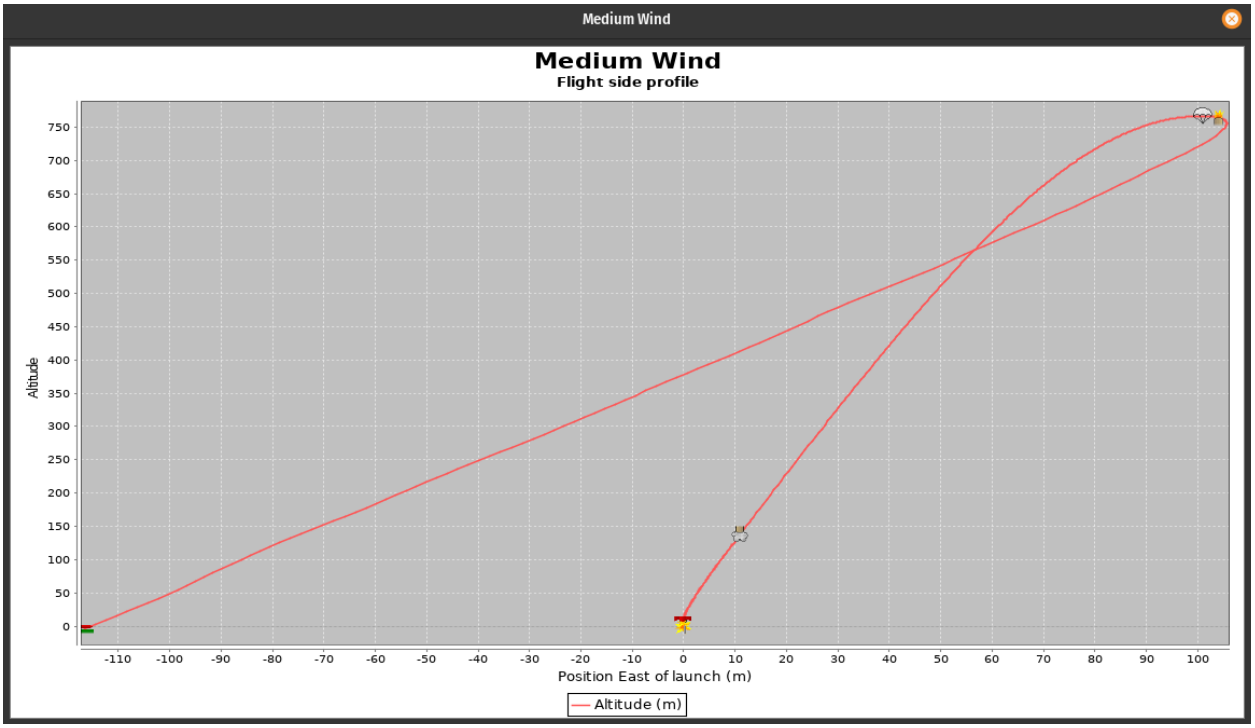


(Fig 9 : Vertical Motion vs Time Plot)

4.3 FLIGHT SIDE PROFILE

This graph tells us the downrange position of the rocket with time. We can make the following inferences from this graph:

- The rocket can be retrieved about 120 metres downrange from the launch location.
- The rocket initially drifts to the west, but finally ends up falling in the east.



(Fig 10 : Flight Side Profile)

5. CONCLUSION

From the above graphs, we can infer that under the simulated conditions, the rocket will deploy the payload nominally, and can be recovered about 120 metres downrange from the launch site.

6. FUTURE WORK

The next logical step after designing and simulating a rocket would be to fabricate one in real life, and try launching it. Hopefully this rocket will fly, one day.

LINKS

- OpenRocket : https://openrocket.info/
- Rocket Model : https://github.com/Naimish240/HighPowerRocket
- Rocket Motor : https://www.apogeerockets.com/Rocket_Motors/Cesaroni_Propellant_Kits/29mm_Motors/5-Grain_Motors/Cesaroni_P29-5G_Blue_Streak_H200