OpenRocket Simulations

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Table of Contents

1. Purpose
2. OpenRocket
3. Rocket Model - Launch 2 (Current Version)
4. OpenRocket limitations and troubleshooting
5. Launch 2 Expected Altitude, Vertical Velocity, Vertical Acceleration
6. Launch 2 Expected Lateral Displacement

1. Purpose

The purpose of this document is to be familiar with OpenRocket and understand how using it is beneficial in analysing a rockets expected behaviour during its flight.

2. OpenRocket

OpenRocket is a great tool for simulating rocket designs. The software is free uses java as its engine (i.e. the program uses java to function). OpenRocket is a rocket simulator that simulates the theoretical expected behaviour of a model rocket such as its altitude, vertical velocity and vertical acceleration. The model rocket can be designed in the software to be any style and shape as well as including the specific volume, dimension, material type for any part of the rocket. The feature that distinguishes OpenRocket from other free rocket simulators is that any rocket motor can be placed in a specified position within the rocket and the simulation will base the rockets behaviour on the rocket motors impulse etc. Useful information can be found on the OpenRocket wiki.

3. Rocket Models

- 3.1 Launch 1

The specifics of the rockets dimensions, mass, structoral composition etc are found in Rocket documentation.

The OpenRocket simulation file can be found in Launch_1.ork.

- 3.2 Launch 2 (Current Version)

The rocket to be used in launch 2 is as shown in figure 2 below

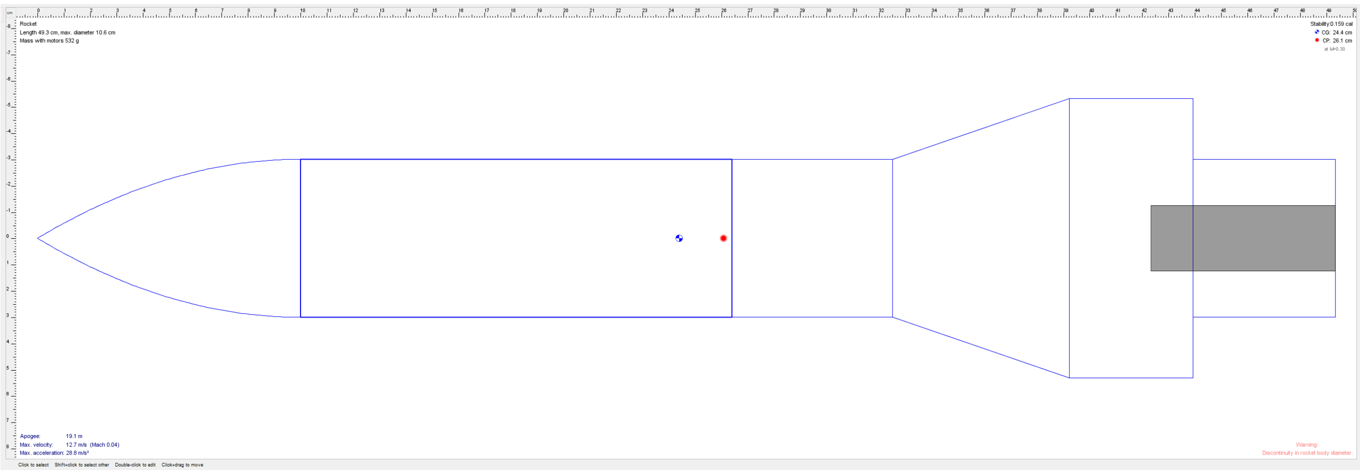

Figure 2: Model of rocket used in Launch 2 in OpenRocket

The specifics of the rockets dimensions, mass, structoral composition etc are found in Rocket documentation.

The OpenRocket simulation file can be found in Launch_2_rev_1.ork.

- 3.2.1 Launch 2 (First Version)

The initial rocket to be used in launch 2 is as shown in figure 2 below

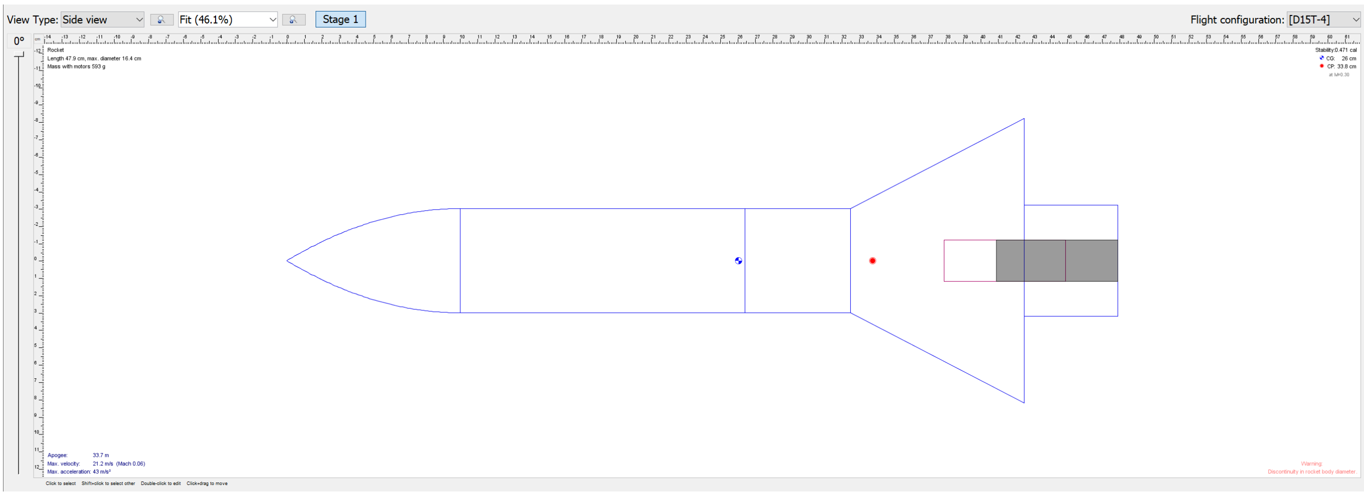

Figure 3: Model of rocket used in Launch 2 in OpenRocket

The specifics of the rockets dimensions, mass, structoral composition etc are found in [Rocket documentation.]

The OpenRocket simulation file can be found in [Launch_2.ork].

4. OpenRocket limitations and troubleshooting

There are some subtle differences between the model rocket and the physical rocket which is solely due to the software limitation of OpenRocket. For the rocket used in launch 2, the only difference is the location of the rocket motor. OpenRocket wasn't able to shift the position of the rocket motor a few mm inward of the rocket which is why the rocket motor is sitting right at the end tip of the rocket. That being said, this compromise should not alter the rockets simulated behaviour by a large factor but to the positional difference being in the mm range.

The software at times can freeze or produce non-logical simulations. If this is the case, then try re-running the simulation. If problems still persist then restart the OpenRocket software.

5. Simulated Altitude, Vertical Velocity, Vertical Acceleration

- 5.1 Launch 1 Expected Altitude, Vertical Velocity, Vertical Acceleration

The best way to observe the expected behaviour of the rocket is to run the simulation for several different possible rocket motors. Currently, the gimbal is capable of holding C - D class rocket motors. Figures 2,3 represent the expected altitude, vetical velocity and vertical acceleration over the rockets active flight for class C11, D12 rocket motors respectively. Note that all of these figures are generated directly from OpenRocket and are under a constant 2m/s wind speed from the east which is specified in the software in the model. The wind speed shouldnt affect these 3 properties but is mentioned for clarification purposes. !
[Launch_1_Rocket_Landing_Var_Wind](2018_Avionics_Project/Rocket CAD/Launch1 10kmh Wind Simulation.png) *Figure 4: Simulation of rocket using a D12-5 rocket motor*

- 5.2 Launch 2 Expected Altitude, Vertical Velocity, Vertical Acceleration

The best way to observe the expected behaviour of the rocket is to run the simulation for several different possible rocket motors. Currently, the gimbal is capable of holding C - D class rocket motors. Figures 2,3 represent the expected altitude, vetical velocity and vertical acceleration over the rockets active flight for class C11, D12 rocket motors respectively. Note that all of these figures are generated directly from OpenRocket and are under a constant 2m/s wind speed from the east which is specified in the software in the model. The wind speed shouldnt affect these 3 properties but is mentioned for clarification purposes.

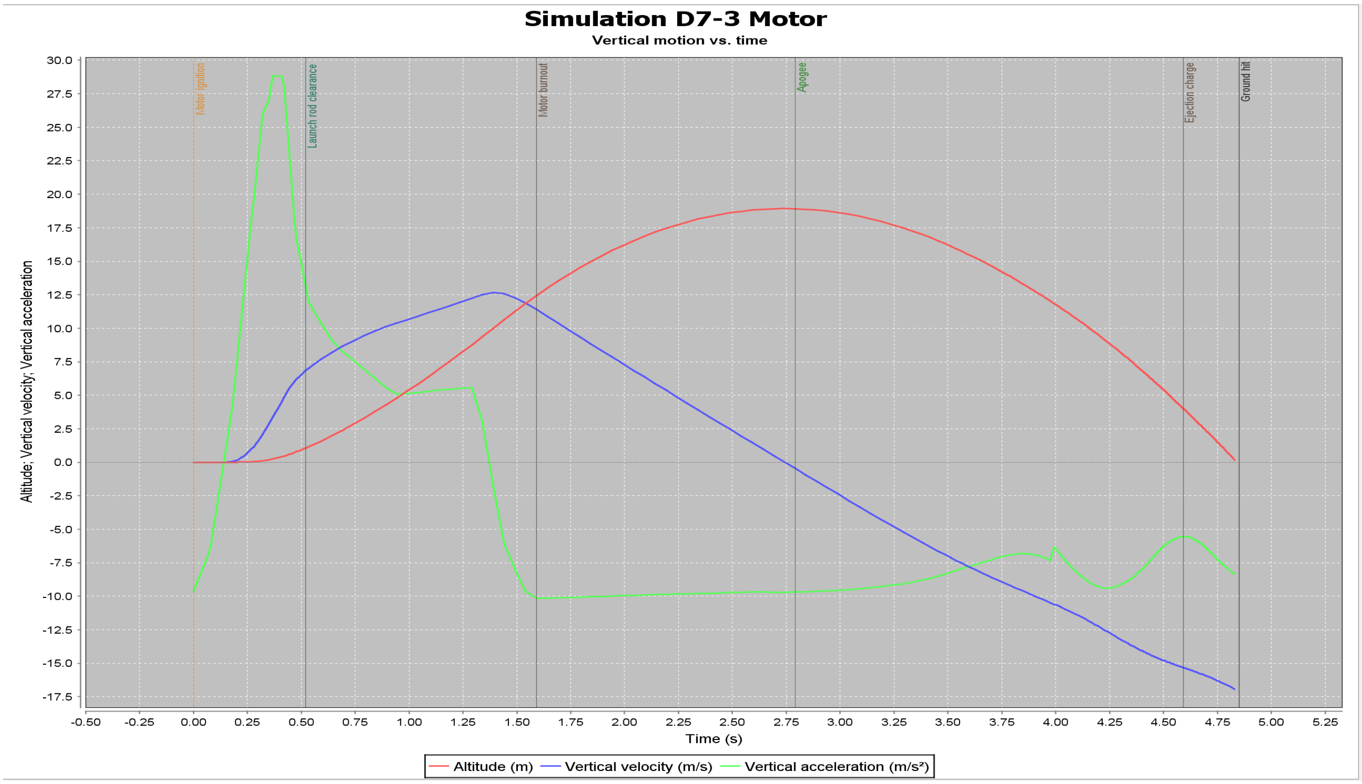

Figure 5: Simulation of rocket using a D12-5 rocket motor

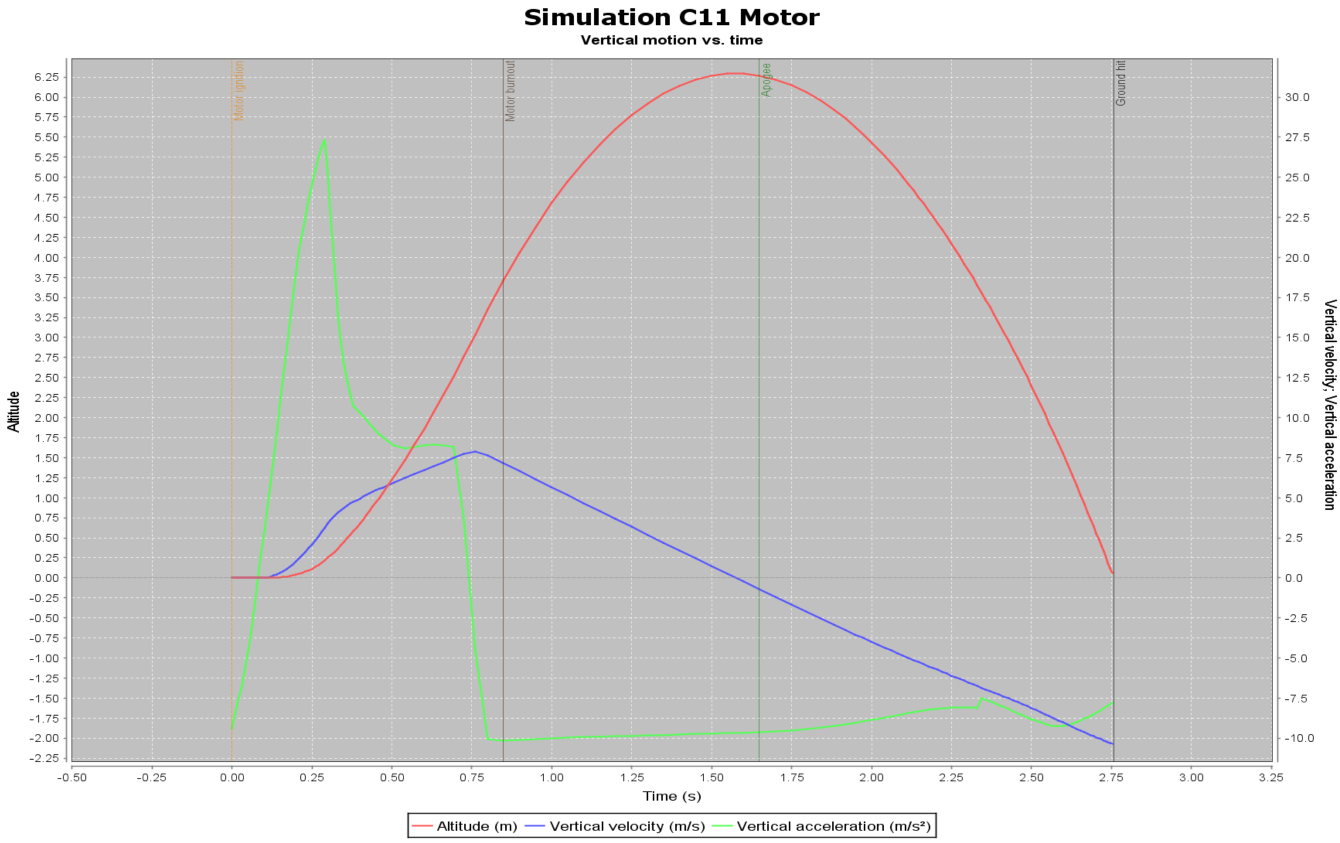

Figure 6: Simulation of rocket using a C11 rocket motor

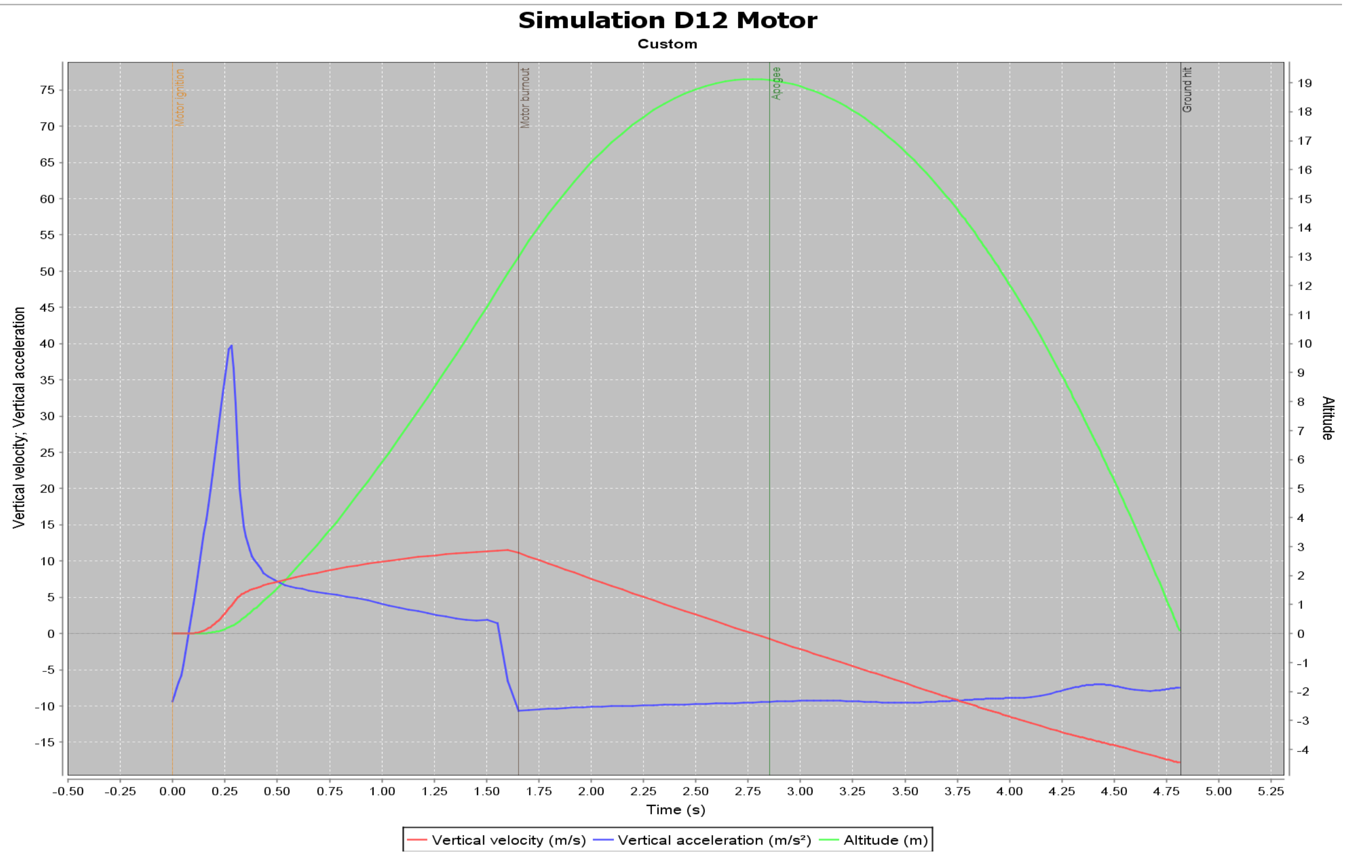

Figure 7: Simulation of rocket using a D12 rocket motor

6. Launch 2 Expected Lateral Displacement

Lateral displacement is the displacement between the landing of the rocet and its launch point. The main issue with running these simulations is that the displacement value will not be the same especially when the wind speeds are not constant. So Monte-Carlo simulations were performed using OpenRocket and the information was fed into MATLAB. The MATLAB file used to analyse the Monte-Carlo data is Expected_Launch_2_Rocket_Land_Dist.m. Figures 4,5 below is the outcome of the Monte-Carlo simulations. MATLAB computes the calculations for windspeeds of v_{wind}=7.2km/h and v_{wind}=25.2km/h for each rocket motor as well noting the uncertainty in the landing displacement from launch point. The uncertainty is represented by the max and min displacement for each windspeed in the figures below.

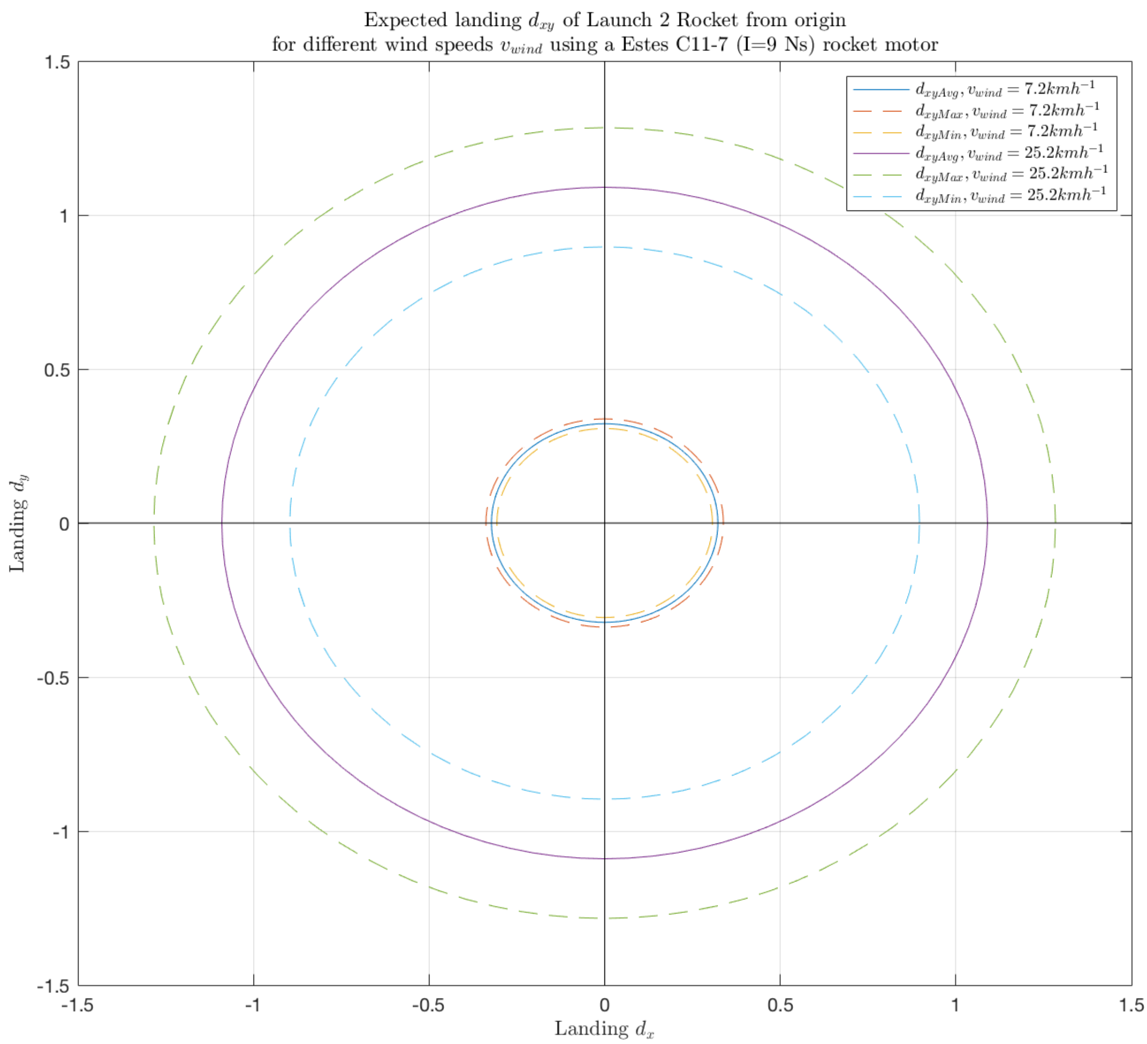

Figure 8: Landing displacement of rocket with Estes C11-7 rocket motor for various windspeeds

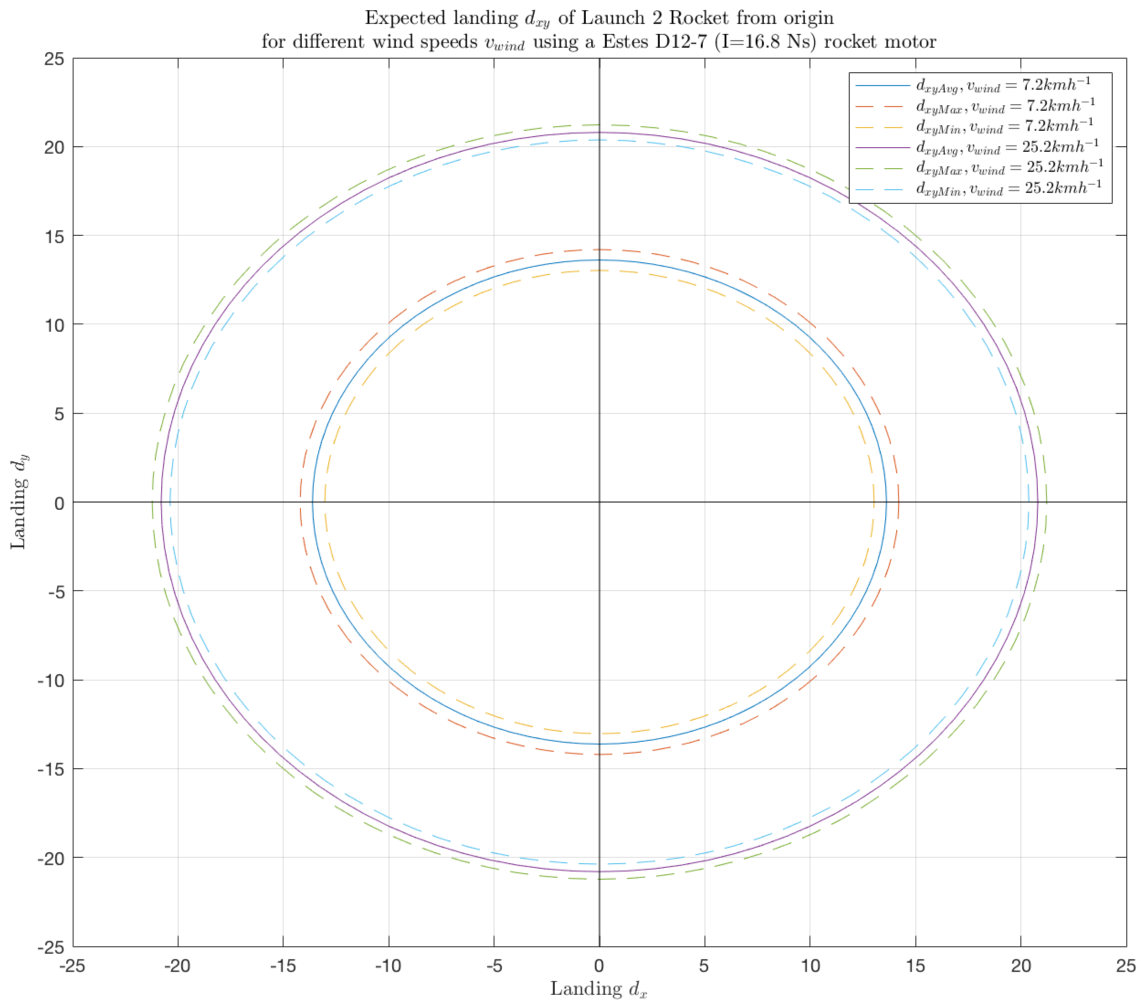

Figure 9: Landing displacement of initial rocket model with Estes D12-7 rocket motor for various windspeeds

As can be seen, the displacement of the rockets landing from its launch point increases drastically as the rocket motor increases in 1 class size. That being said, due to the difference in the motors impulse for both classes, the uncertainty for a C class motor is greater than D class. That being said, it is safe to say that using a C class motor would result in a shorter landing displacement than a D class motor which is to be expected. For slow wind speeds, both the C and D class motors are acceptable whereas for medium/high windspeeds, the class C motor would still be suitable while the class D motor would not.

The figures do not take into account the dngular displacement of the rocket which is done on purpose as the rocket has the possibility of landing in any region spanned by its launch radius. Instead, the anglular displacement for any part in any of regions can be calculated simply as follows

Let $land_{pos} \in \mathbb{C}$. By treating $y \in \Im, x \in \Re$, (i.e. by treating the figures as a Argand diagram) then $\phi = \frac{ln\left(\frac{land_{pos}}{r}\right)}{i}$ where $r = \sqrt{d_x^2 + d_y^2}$ and ϕ is the angular displacement in radians.

The 2 wind speeds (7.2km/h and 25.2km/h) are the low and annual average windspeeds in the Wellington region. If the rocket is to be flown in a different region/country, the parameter 'East_Wind_Speed' in the MATLAB file Expected_Launch_2_Rocket_Land_Dist.m can be altered. Also note that although the wind is being simulated from the east, figures 4,5 provide a radial span of the expected landing displacement of the rocket.