Individual Analytical Analysis

Ejection Charge and Parachute Analysis

By:

AislinnJoy Gacayan

Active Rocket Controls

Team Number: F25toSp26_01

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1.0 Introduction

As the aerospace industry continues to grow and evolve, the research and innovation behind precise maneuvering and advancing technology is critical. The Active Rocket Controls Capstone project focuses on the research, design, and development of a control system that is capable of dynamically adjusting a rocket's orientation and stability. The rocket will utilize fins to induce roll and stabilize about the z-axis.

While conducting the project, it is vital that we ensure all safety regulations are met and that our rocket and systems are maintained following all testing. The analysis conducted in this report answers the following questions: How much ejection charge is required to deploy the parachute? What are the minimum dimensions required for the parachute to safely deliver the rocket back to ground?

2.0 Assumptions and Variables

In order to answer the problem questions, various assumptions and variables are used to perform the necessary calculations.

For the ejection charge calculation, the properties of the black ejection powder, the rocket dimensions, and additional environmental information are needed. The black powder utilized is FFFFg (4Fg), which is the smallest grain type [1]. The gas properties associated with the powder once lit that are needed are the combustion gas constant (R) and combustion gas temperature. These variables have values of R = 22.16 ft-lbf/lbm*R and T = 3307 degrees R [2]. The inner diameter of the rocket that the parachute will sit in has a value of 3.4 inches. The capsule section that will contain the required pressure has a length of about 10 inches. According to a representative from Apogee components, a good range for the desired pressure within this section for model rockets is 10 -15 psi, for this assessment a value of 10 psi will be used [1].

For the parachute analysis, environmental factors and rocket performance data gathered from Rocksim testing are used. The rocket launches will be held in Wickenburg, AZ which has an elevation of around 2,202 feet above sea level (671.17 m). For this analysis, based on the Rocksim results, an additional 4,000 ft will be considered for the maximum altitude reached. The launches will be held from December – March, so the analysis will need to account for colder temperatures. For now, a temperature of 40 degrees Fahrenheit will be used with a standard temperature lapse rate of 0.0065 K/m. For acceleration due to gravity, 9.81 m/s^2 will be used. Utilizing data from the Rocksim test, the total mass of the rocket with an empty motor is around 1,254.85 g. The coefficient of drag (C_d) is 0.75. According to Tripoli's safety code, the descent velocity cannot exceed 35 ft/s (10.67 m/s^2) [3]. Therefore, in order to determine a minimum size of parachute, this analysis will utilize a landing speed of 34 ft/s (10.36 m/s^2). Additionally, it will be calculated for a landing speed of 15 ft/s (4.57 m/s^2), for a safer buffer and comparison.

3.0 Physical Modeling & Schematics

The following will include the dimensions and physical descriptions of the vital components for this analysis.

Figure 1 provides the reference for the sizing of the capsule where the pressure is calculated for. This is to include the diameter and length.

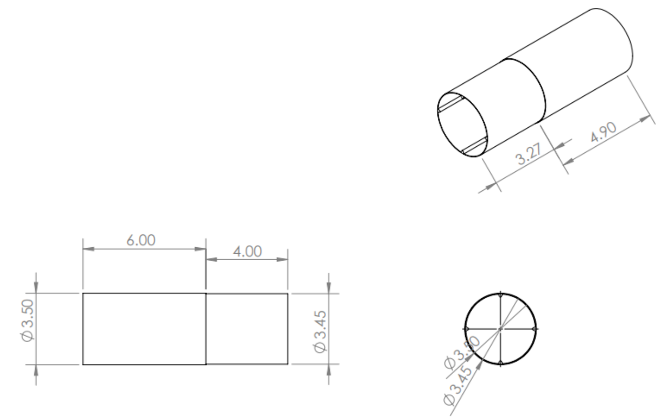

Figure 1: Capsule Sizing

Figure 2 provides a Rocksim modeling of the rocket. This image also includes distribution of mass and overall rocket sizing information.

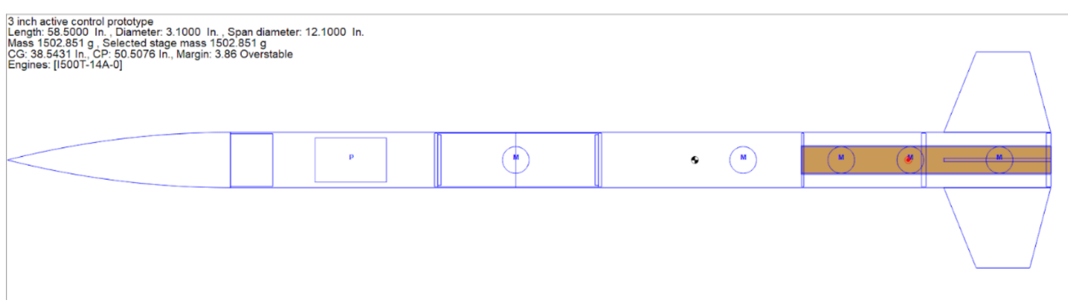

Figure 2: Rocksim Rocket Model

Figure 3 provides the Rocksim test results given the rocket from figure 2. It provides a prediciton of flight data that will be used for the analysis.

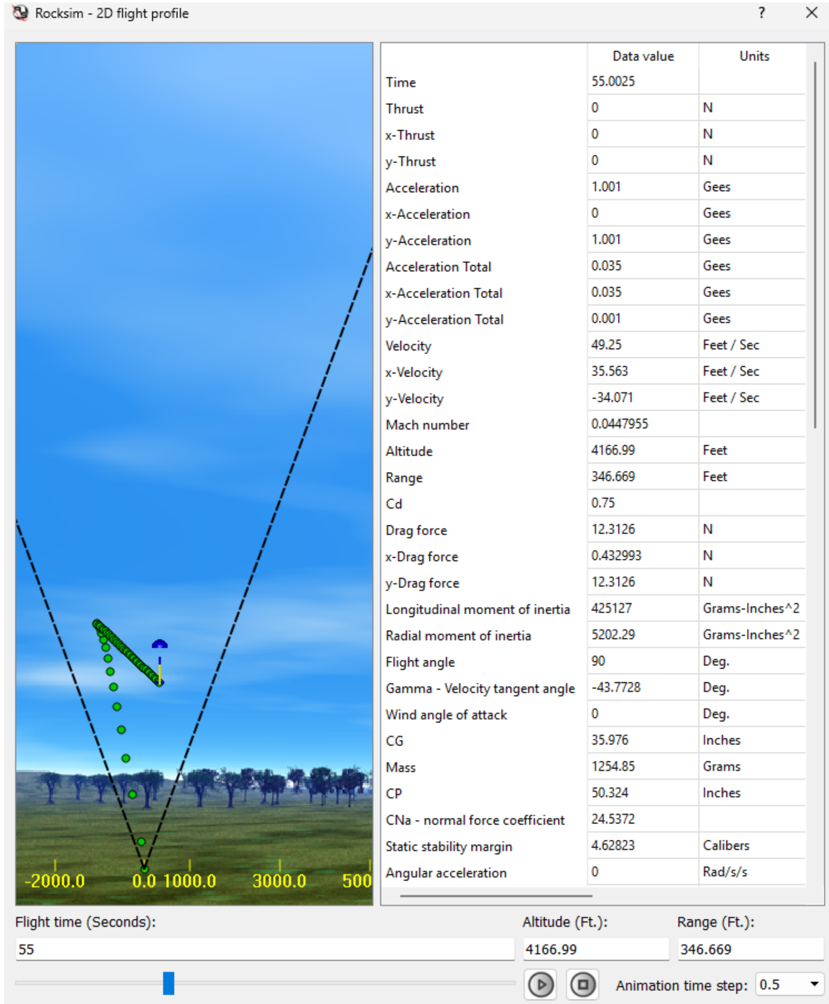

Figure 3: Rocksim Test Results

4.0 Calculations (reference sources equations came from, label all equations and describe)

Black Powder Ejection Charge

The first equation that needs to be determined is the volume of the capsule where the pressure will be. That can be determined by multiplying the area of section and multiplying it by the length as seen in equation 1.

$$V = \frac{\pi}{4} * D^2 * L \tag{1}$$

To find the mass of the black powder needed, the ideal gas law can be used. That can be determined by multiplying the desired pressure by the volume obtained from equation 1, and then dividing it by the product of the combustion gas constant and combustion gas temperature. A unit conversion of 1 lbm = 454 grams and 12 in = 1 ft will be used to ensure the final value is in grams.

$$m = \frac{PV}{RT} \quad (2)$$

To determine the force that will result from the amount of black powder used, the desired pressure can be multiplied by the area.

$$F = P * \frac{\pi}{4} * D^2 \quad (3)$$

Parachute Sizing

Before the area can be determined, environmental factors such as temperature, pressure and air density must be taken into account. Equations 4 - 6 will be used to determine the standard temperature, pressure, and density for conditions during the launch in Wickenburg, Az.

$$T = T_0 - \alpha * h \quad (4)$$

$$P = P_0 (\frac{T}{T_0})^{\frac{g}{R*\alpha}} \quad (5)$$

$$\rho = \frac{P}{RT} \quad (6)$$

To determine the area needed for the given factors, this can be found by multiplying 2 by the acceleration due to gravity and the mass of the rocket with an empty motor and dividing it by the density at the given elevation multiplied by the coefficient of drag and the descent velocity squared. [5]

$$S = \frac{2*g*m}{\rho*C_d*V^2} \quad (7)$$

For a parachute that is round, the diameter can then be determined using the following relation.

$$D = \frac{4*S}{\pi} \quad (8)$$

5.0 Results and Discussion

Black Powder Ejection Charge

Using equation 1, the volume of the pressurized section is 90.79 in^3. From equation 2, the minimum amount of black powder needed for an ejection pressure of 10 psi is 0.469 grams. From equation 3, the ejection force for the given variables is 90.79 lbf.

According to Apogee components' information on ejection charges, for a single use motor that is around 38 mm, the ejection charge is normally around 1.3 grams of black powder. However, for the friction fitted nose cone we will utilize, the ejection force that will result from the amount of black powder use is more than enough. The force simply needs to be larger than the force of friction from the nose cone. This can also be tested on the ground for validating the calculations. Using a more conservative amount that meets the desired objectives will allow for better resource allocation.

Parachute Sizing

Using equations 4-6 the following values were found:

T = 275.9 K

P = 80576.77 Pa

ρ = 1.018 kg/m^3 = 1018 g/m^3

From equation 7, the minimum area required in order to meet a descent velocity of 34 ft/s (10.36 m/s^2) is, 0.301 m^2. The area resulting from a desired landing speed of 15 ft/s (4.57 m/s^2), is 1.55 m^2. The associated diameters being 0.38 and 1.97 m respectively.

This is important as the larger the parachute is, the harder it will be to fit inside the fuselage with the other components such as the housing module for electronics. Having the room to be a little more conservative with the parachute sizing while also maintaining safety standards and ensuring the structure and parts of our rocket are well maintained during testing will be beneficial when improving the design.

6.0 Conclusion

The analysis provided within this report are vital to safety and maintenance considerations for the active rocket controls capstone project. Using mathematical relations and consideration of environmental conditions as well as the Tripoli launching safety code, values were found for both the amount of black powder needed for an effective ejection charge as well as recommended parachute size. The analysis provided results that will allow the group to be conservative with it's resource management as smaller amounts were calculated for and found to still be effective.

References

[1] I. Apogee Components, “Advanced construction videos : Apogee rockets, model rocketry excitement starts here,” Advanced Construction Videos : Apogee Rockets, Model Rocketry Excitement Starts Here, https://www.apogeerockets.com/Advanced_Construction_Videos/Rocketry_Video_337 (accessed Nov. 22, 2025).

[2] “Black powder sizing,” Info Central, https://info-central.rocketlabdelta.com/recovery/black-powder-sizing/#:~:text=This%20is%20the%20simplest%20case%20for%20a,in/ft%20to%20get%20in%20terms%20of%20inches.) (accessed Nov. 22, 2025).

[3] “Tripoli Rocketry Association Safety Code ,” unified safety code - Tripoli Rocketry Association, https://www.tripoli.org/safetycode#:~:text=A%20rocket%20shall%20be%20launched,12%2D5.1 (accessed Nov. 22, 2025).

[4] I. Apogee Components, “Apogee components - Aerotech 38mm HP SU DMS motor - H100W-14A,” [81295] - $58.84 : Apogee Rockets, Model Rocketry Excitement Starts Here, https://www.apogeerockets.com/Rocket-Motors/AeroTech-Motors/38mm-Motors-Single-Use/Aerotech-38mm-HP-SU-Motor-H100W-14A#faqs (accessed Nov. 22, 2025).

[5] Apogeerockets, https://www.apogeerockets.com/downloads/PDFs/Peak-of-Flight-Newsletter-Rocket-Plans.pdf (accessed Nov. 23, 2025).