Air Brakes for High Power Rocket

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Introduction

The objective of this project is to design an air brake system that can be implemented on a Level 3 rocket capable of reaching a target altitude of 10,000 feet. This air brake system is autonomously controlled to change the speed of the rocket through the air to ensure the rocket reaches a target altitude between 10,000-10,100 feet.

Problem

The goal of the Spaceport America Cup is to engineer, manufacture, and launch a Level 3 rocket using commercial off-the-shelf components. The rocket is required to deliver a 4.4 lb. payload to an apogee of 10,000 feet.

Specifications Table

Metric	Value
Diameter	6.17 in
Length	2.115 in
Weight	4 lbs
Material	PAHT-CF

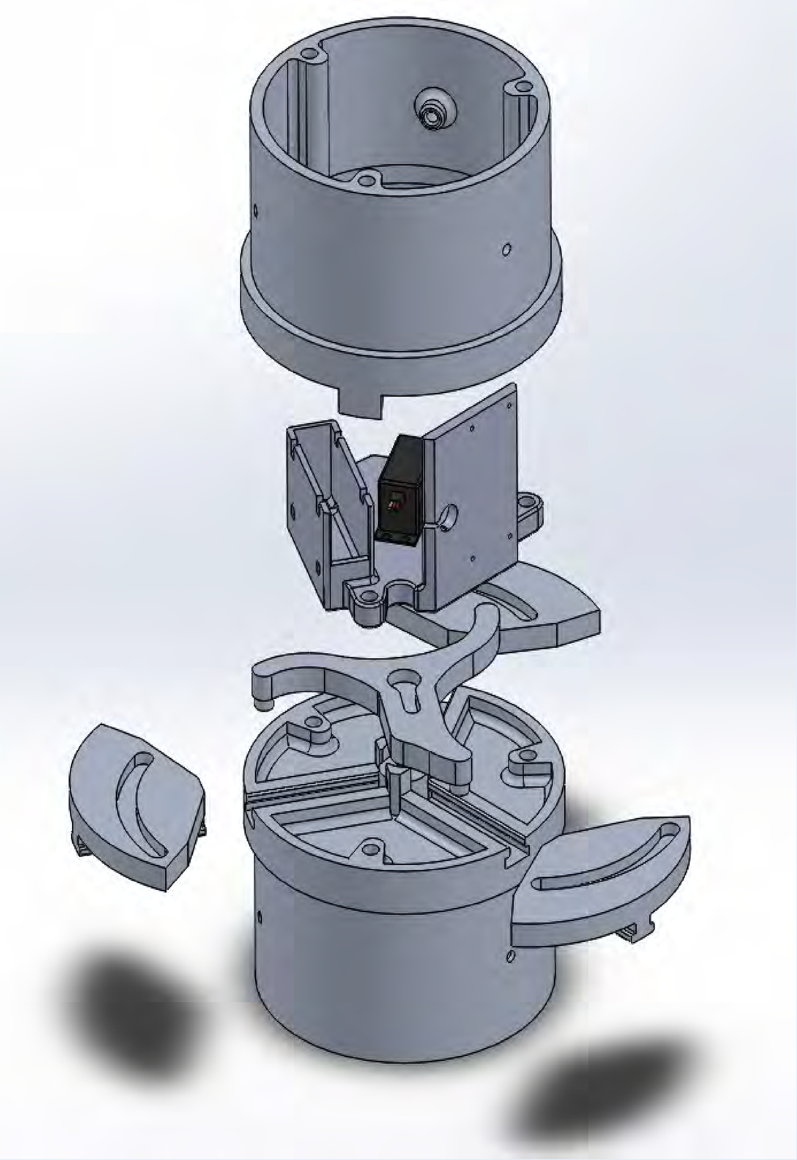
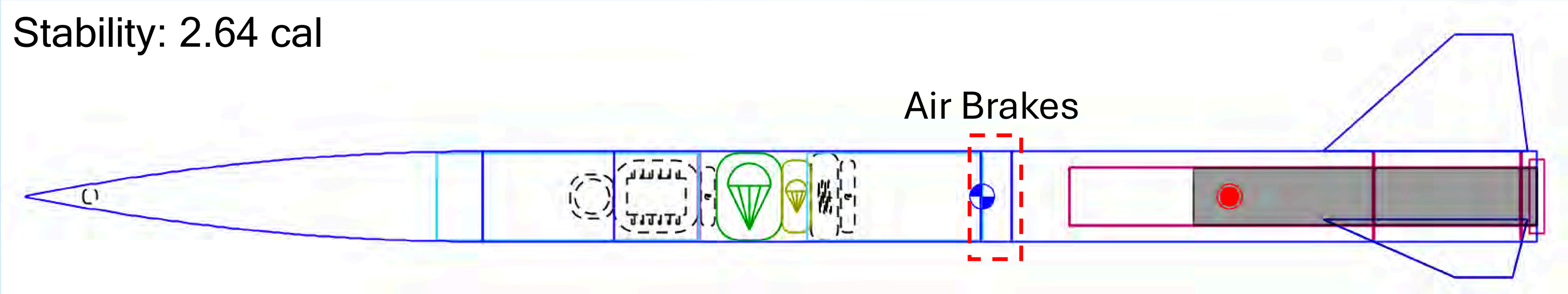


Figure 1: Exploded view of Level 3 air brake assembly

Aerostructure Schematic



Schematic design of the Level 3 rocket from OpenRocket. Center of pressure is denoted by ◉ and the center of gravity is denoted by ⊕. These metrics are used to determine the stability of the rocket during flight. A stability greater than 1.4 is ideal for the rocket to maintain its trajectory. The section of the exposed air brakes is outlined by the dashed red box.

Methods

By analyzing the dynamics of the rocket, it was determined linear feedback control would be sufficient for controlling the height of the rocket. To use linear feedback control, the drag force acting on the rocket was approximated as a natural damper. Root locus techniques were used to determine preliminary gains for the controller and then tuned based on flight simulation results.

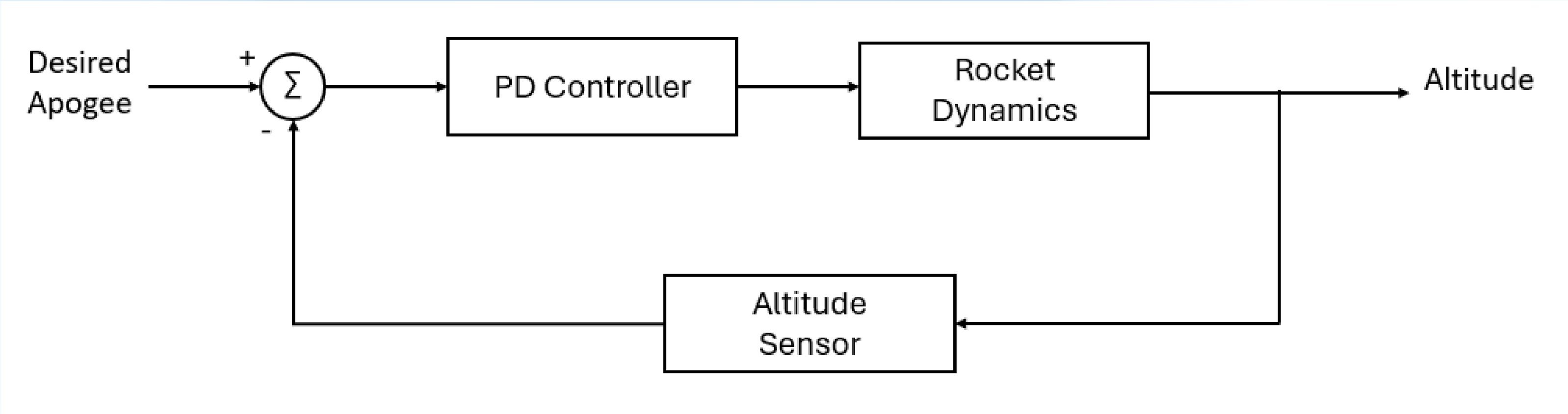


Figure 3: Block diagram of feedback control loop of the rocket system

CFD Results

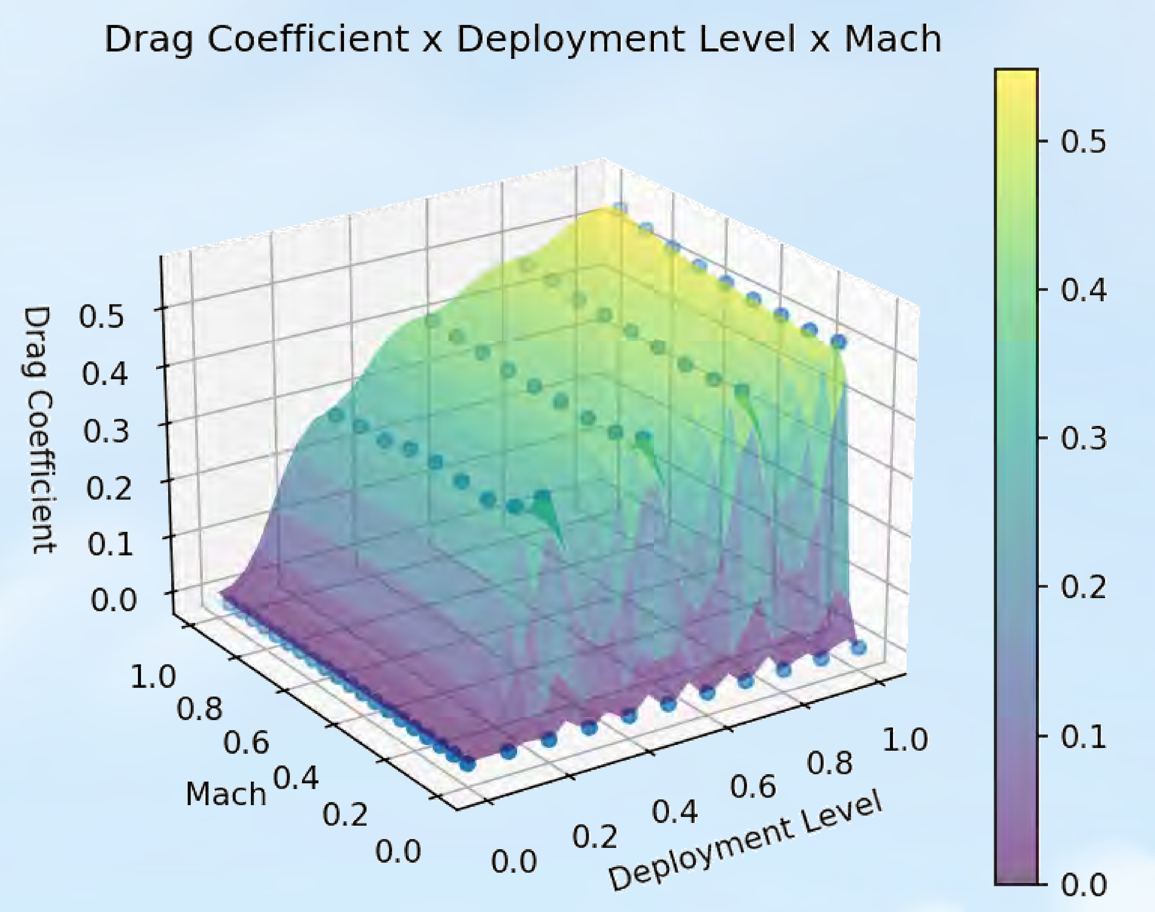


Figure 4: Plot of drag coefficients for just the Level 3 air brake assembly at different deployment levels and Mach numbers

Given the drag force, the microcontroller controlling the air brake deployment level interpolates drag coefficients using bilinear interpolation to output a desired drag force by the brakes. To determine these drag coefficients for different speeds and air brake deployment levels, CFD was performed using SolidWorks Flow Simulation.

Simulation Overview

To ensure the rocket reaches its target altitude, we simulated the flight with and without air brakes for a M2400 motor. These simulations allow us to predict the rocket's behavior and validate the effectiveness of the feedback control system before launching.

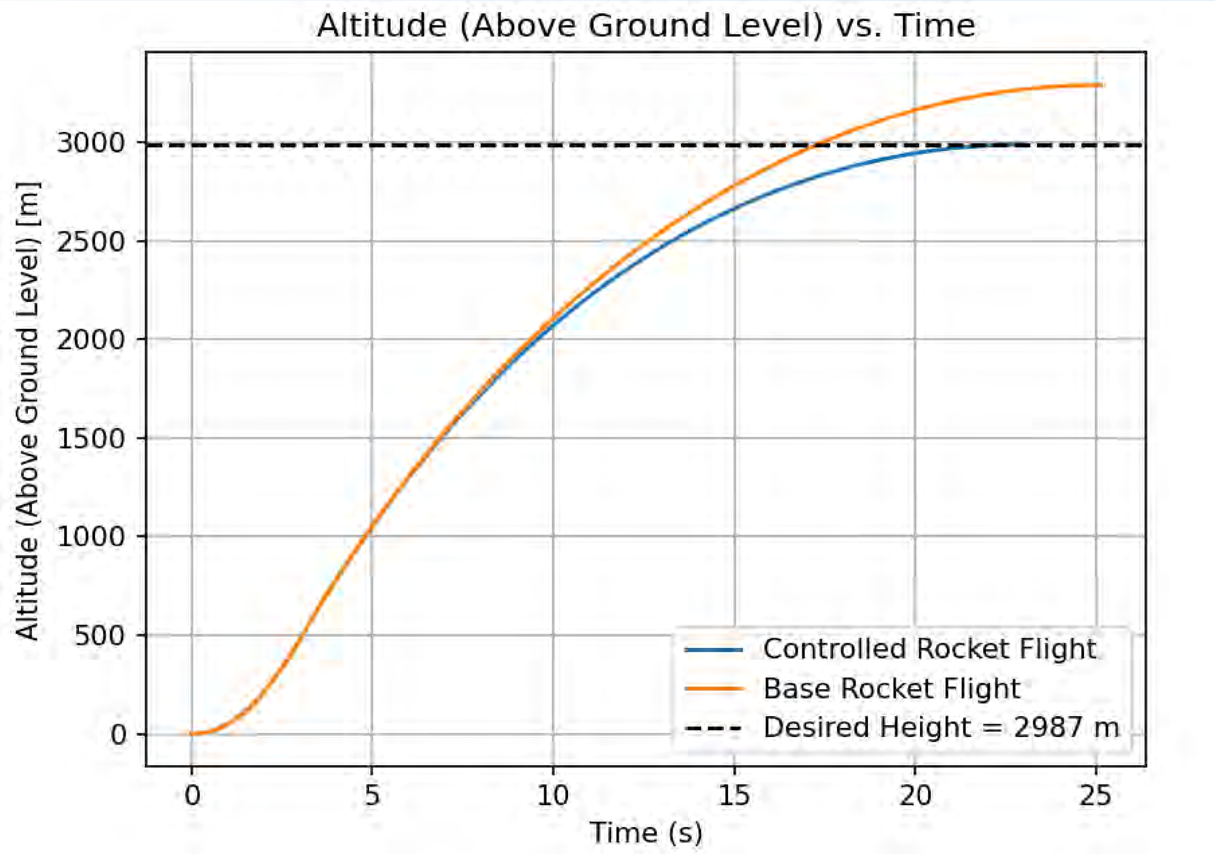


Figure 5: Plot comparing the simulated altitude vs. time of the Level 3 rocket flight for the base rocket with no air brakes deployed and a flight with controlled air brakes

Simulated vs. Experimental Results

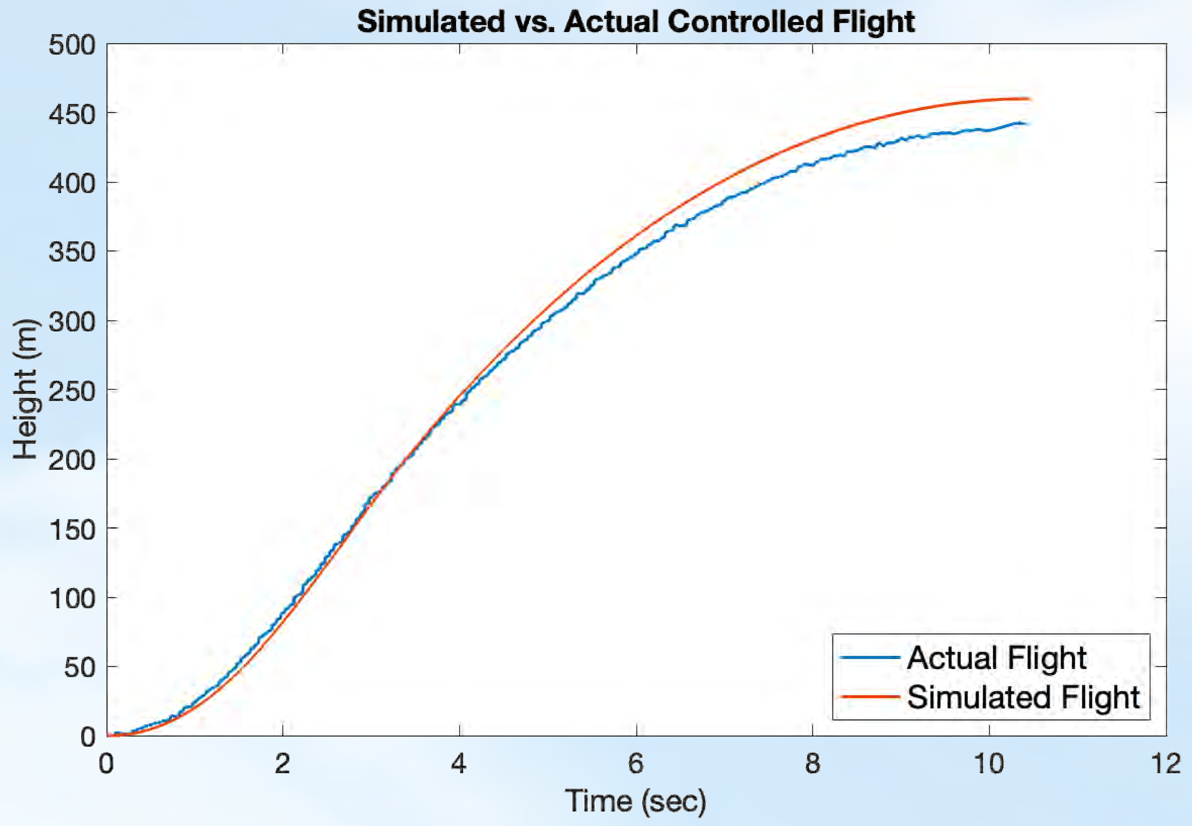


Figure 6: Simulated and experimental flight trajectories of the Level 3 rocket using feedback-controlled air brakes

Conclusion

The design, simulation, and testing of the air brake system demonstrated its ability to autonomously control the altitude of a Level 3 high-power rocket. Using feedback control and CFD-based drag data, the system will consistently guide the rocket to an apogee near the 10,000-foot target.