Iteration Upon the Active Drag System

A Closed-Loop System for Coast Phase Apogee Control of a Sounding Rocket

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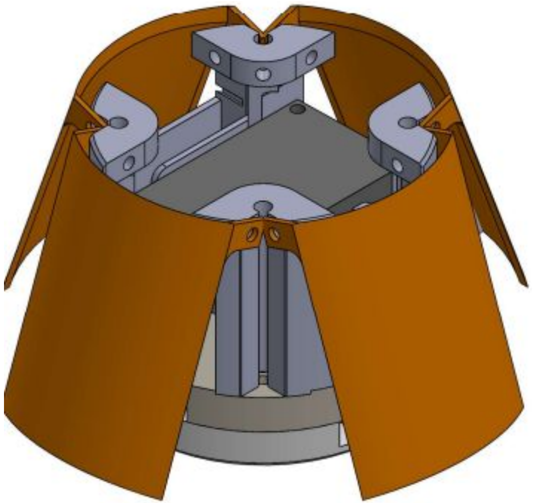
Overview

The Active Drag System (ADS) was developed in response to the Spaceport America Cup's Altitude Accuracy Challenge with respect to the often varying launch conditions.

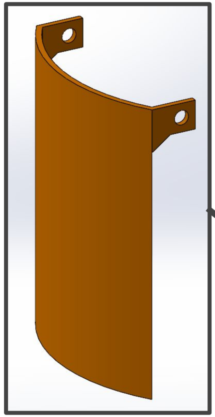
Flap deployment can dynamically alter the drag of the rocket mid-flight.

This is the second major iteration of the ADS with improvements to the mechanical design, electrical design, and a software rewrite from Python on a single-board computer to C++ on a microcontroller.

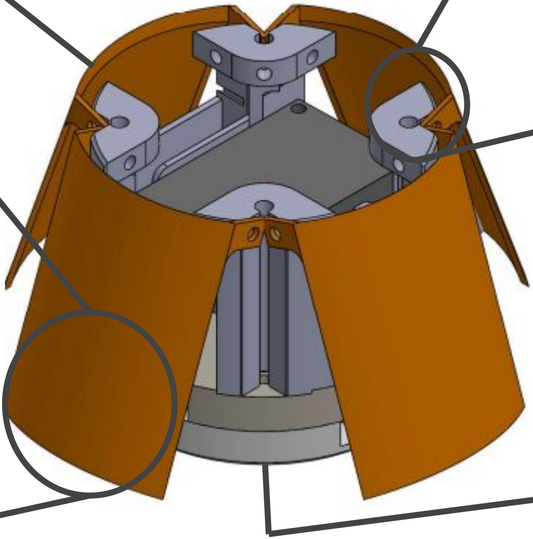


Mechanical Design

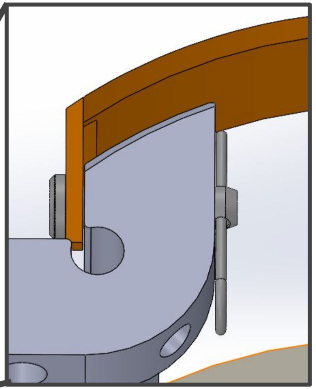
Flap
Each flap has a surface area of 20 in^2. They are made out of carbon fiber.



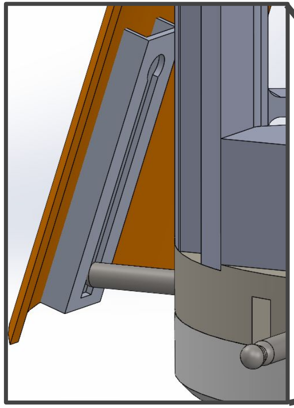
ADS Assembly
The ADS has a diameter of 5.75” and is 5” tall. It weighs roughly 3 lbs. Most of the structure is 3D printed out of ABS plastic.



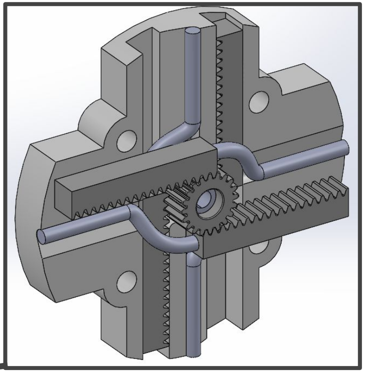
Hinge Pin
Two pins at the top of the flap allow it to hinge around this point. They are held in by an R-clip.



Track and Ball
Mechanism that keeps the flap attached to the actuating pin. Made out of lightweight aluminum.



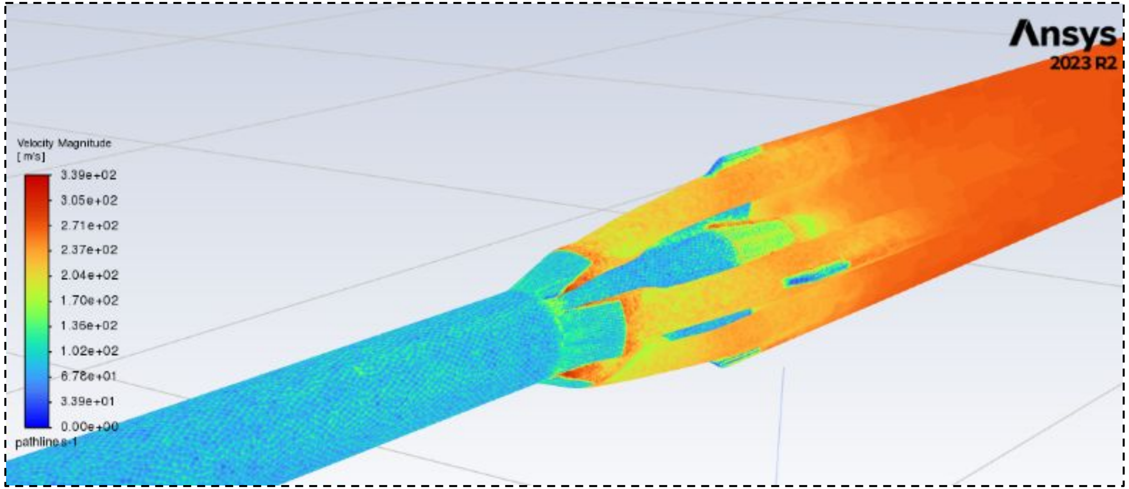
Rack and Pinion
The Mechanism that drives the flap movement. The center gear drives all four pins to move the same amount.



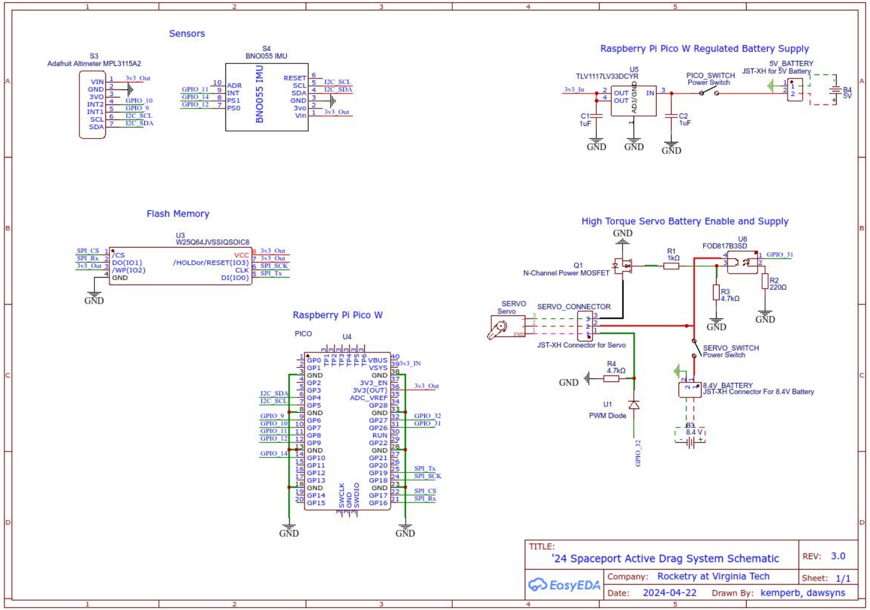
CFD Analysis

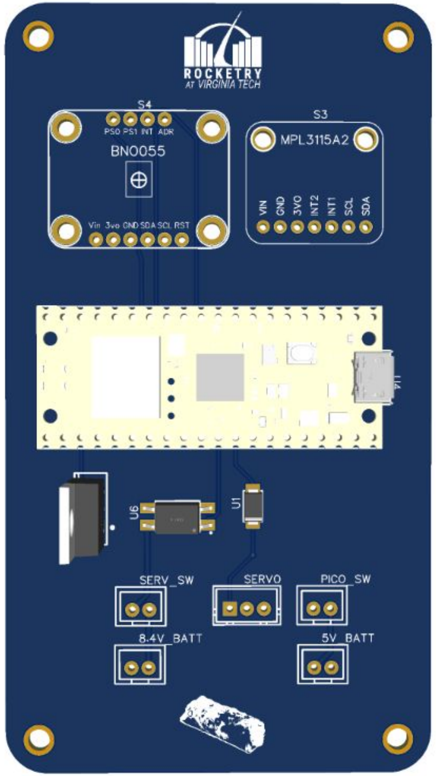
Analysis of rocket's drag in 25% deployment increments from 35 to 280 m/s to form relationship between deployment percentage and additional drag

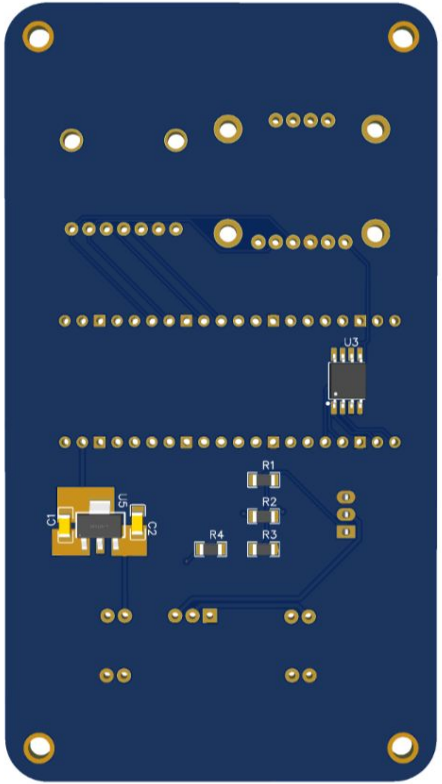
Simulations point to ability to double or even triple rocket's drag with 100% deployment



Electrical Design







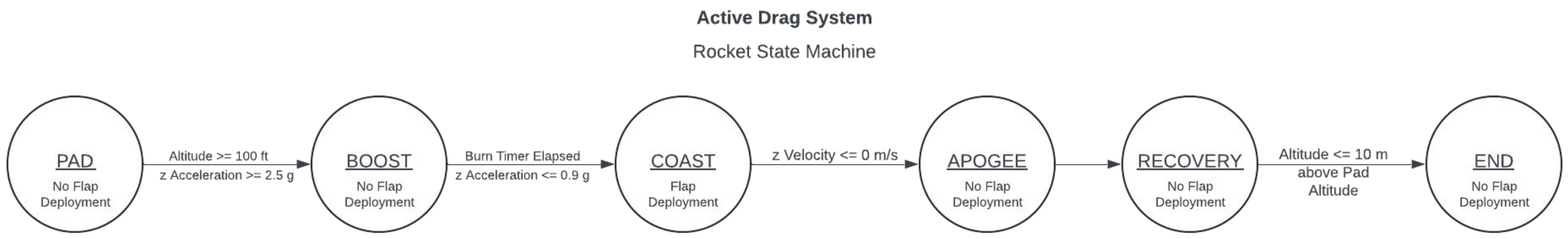
Software Design

Interrupt-based Finite State Machine for flight stage determination

- External Pin from Altimeter Altitude Threshold Interrupts
- Internal Hardware Timer Interrupts

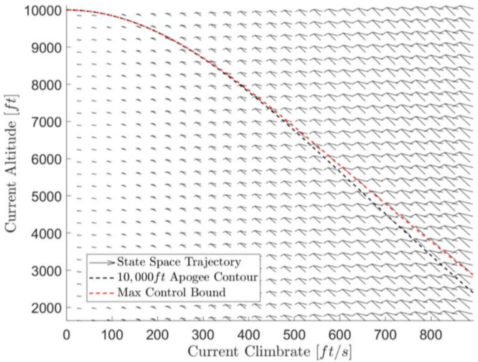
Homegrown Kalman Filter to fuse Altitude with Linear Acceleration Vector

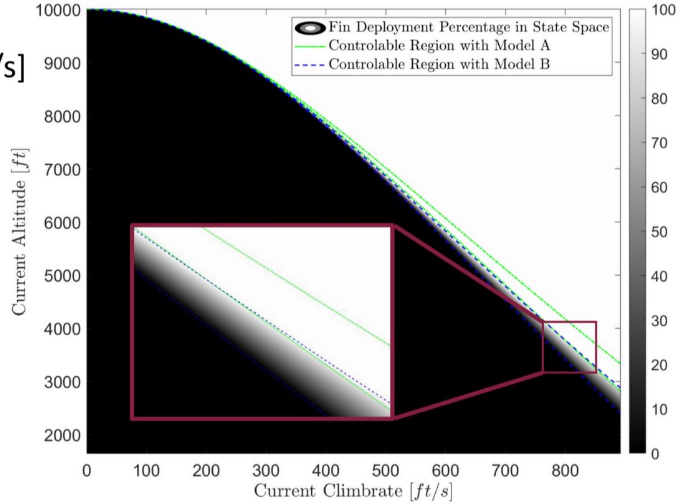
Multi-threaded logging in 32 byte, serialized packages



Model Determination

- State space established
  - [1640 ft, 10000 ft] x [0 ft/s, 892 ft/s]
  - Optimal Cd at 695,877 states





Previous ADS design established state space for Cd and ability to control apogee with respect to:

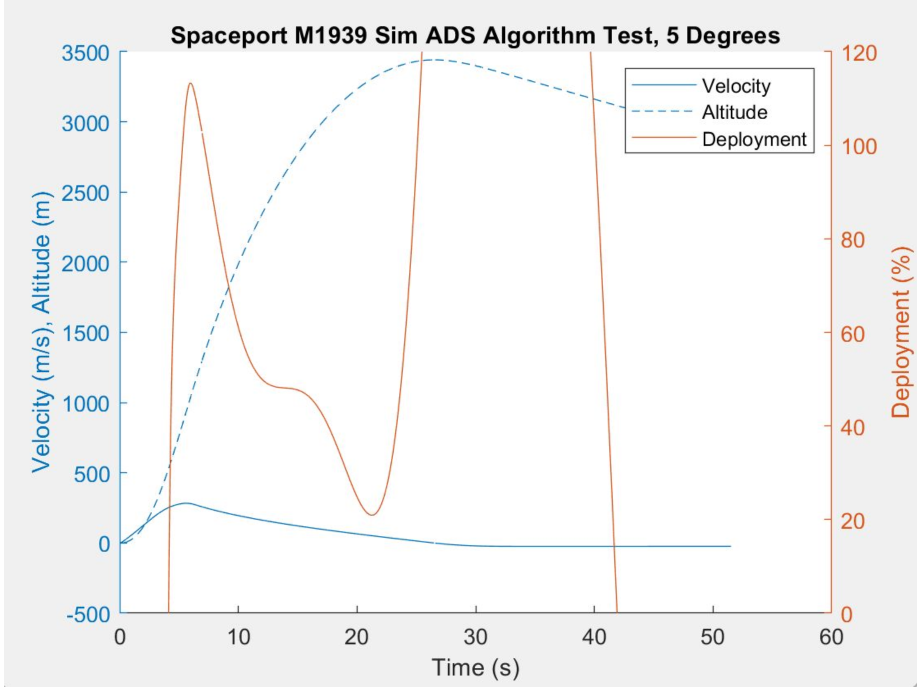
- Constant Air Density Model (A)
- Standard Atmosphere Model (B)

Deployment Percentage

A Linear Polynomial Fit was determined based upon aforementioned model to limit onboard calculations

Deployment percentage output from polynomial where input is:

- Altitude AGL (m)
- Velocity (m/s)



Results

Verification of state machine in February Test Launch

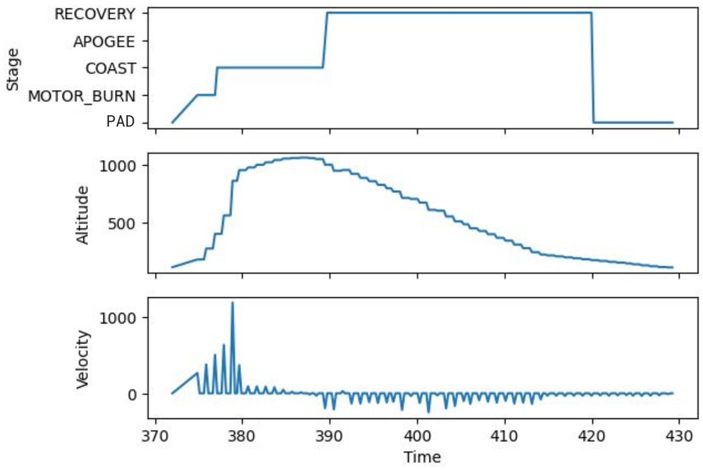
Flap deployment during coast phase

Deployment noticed to be rather slow

- Idle current draw from servo -> battery drain
- Resolved with servo battery enable circuit

Operation without Inertial Measurement Unit (IMU)

Kalman Filter Introduced following Test Launch



Follow-Up Work

- Reduce airframe gaps due to flap installment
- Reduce PCB size and dependence upon COTS breakout boards or development boards
- Refine apogee estimation and deployment percentage algorithm to be moved onboard

Thank you!

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