Iteration Upon the Active Drag System

Precision Apogee Control of a Sounding Rocket

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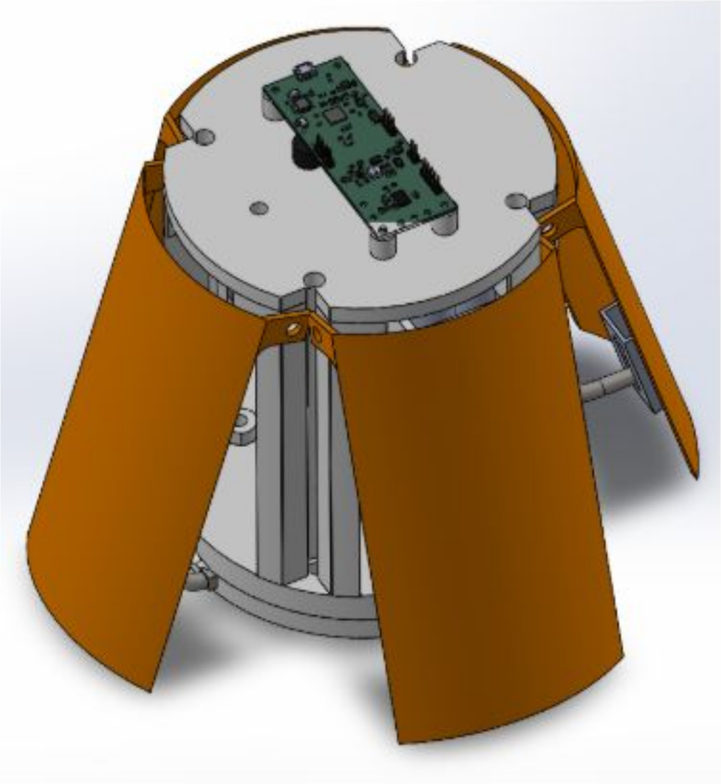
ROCKETRY
AT VIRGINIA TECH

Overview

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

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

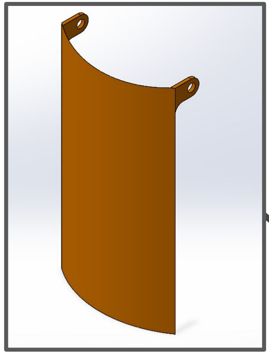
This is the third major iteration of the ADS with improvements to the mechanical design, electrical design, and the integration of a real-time operating system.



Mechanical Design

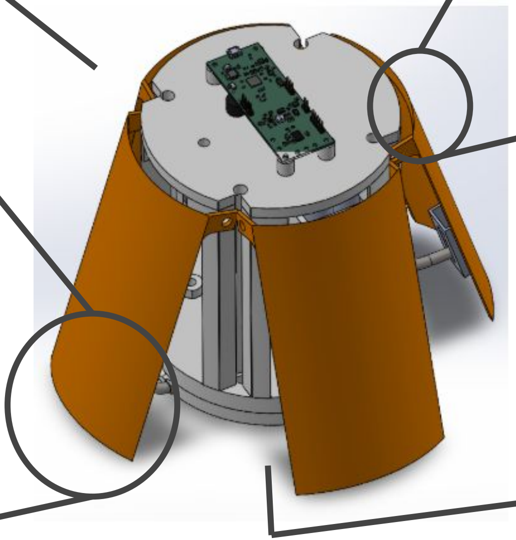
<u>Flap</u>

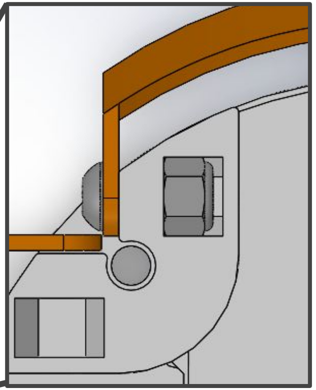
Each flap has a surface area of 40 in^2. They are made out of carbon fiber.



<u>ADS Assembly</u>

The ADS has a diameter of 5.75” and is 7” tall. It weighs roughly 3 lbs. Most of the structure is 3D printed out of ABS plastic.



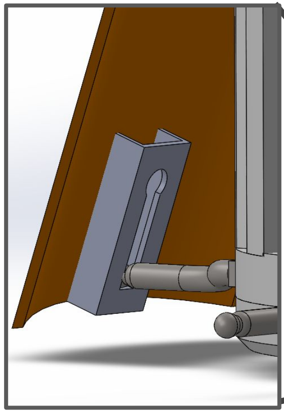


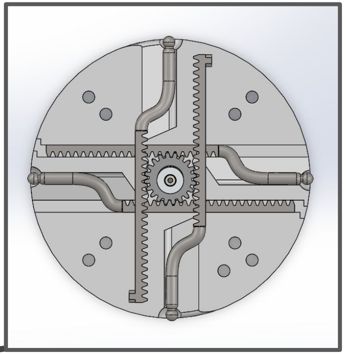
<u>Bolt and Lock Nut</u>

A lock nut is epoxied to the columns where a bolt can secure the flap to the assembly, acting as a hinge.

<u>Track and Ball</u>

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





<u>Rack and Pinion</u>

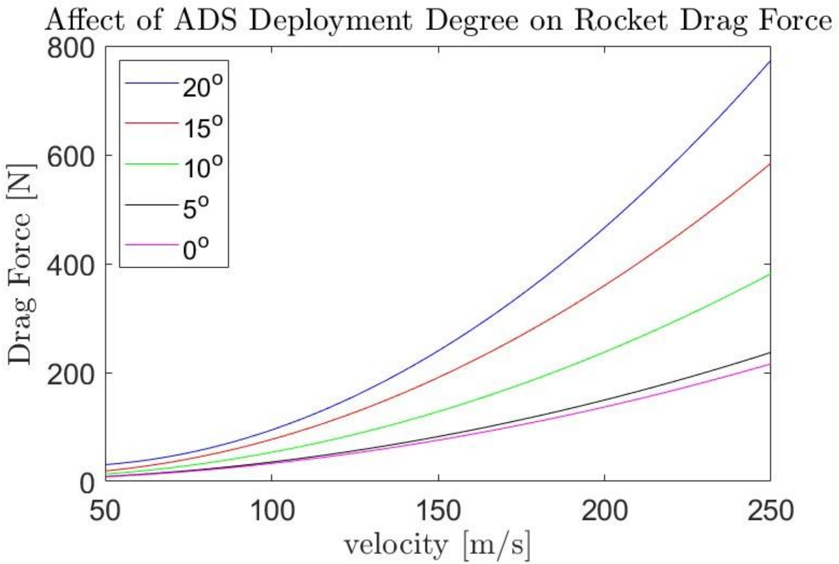
The mechanism that drives the flap movement. The center gear drives all four pins to move the same amount.

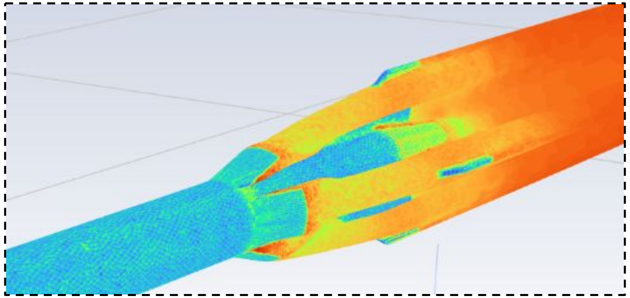
CFD Analysis

Analysis of rocket's drag force conducted using Ansys Fluent.

CFD simulations were run in 25% ADS deployment increments over an air velocity range of 25 m/s to 250 m/s.

An equation was generated using the CFD results to relate the rocket velocity, rocket drag force, and ADS deployment percentage.



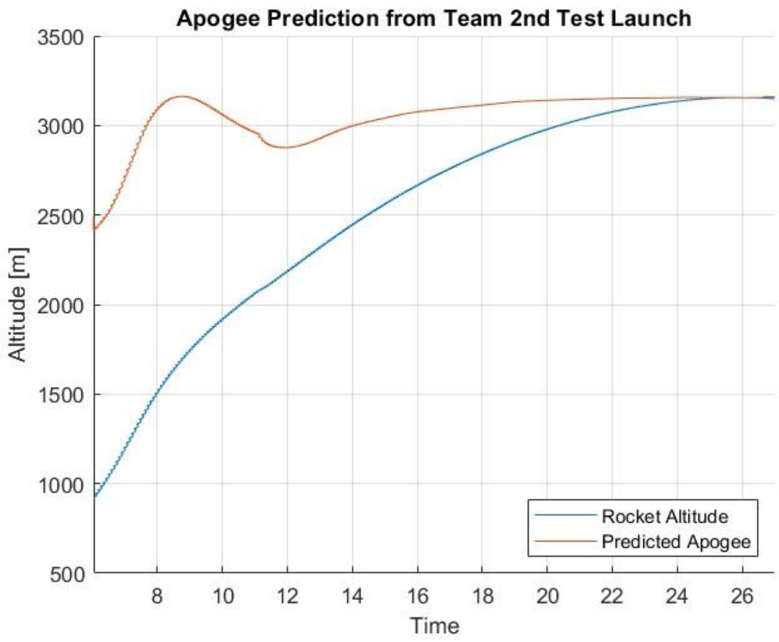


Apogee Prediction

$$Predicted\ Apogee = Altitude - \frac{Mass * Velocity^2}{2 * Drag\ Force} \ln\left(\frac{g}{g + \frac{Drag\ Force}{Mass}}\right)$$

Model assumptions:

- Vertical flight
- Constant air density
- Only valid during rocket's coast phase

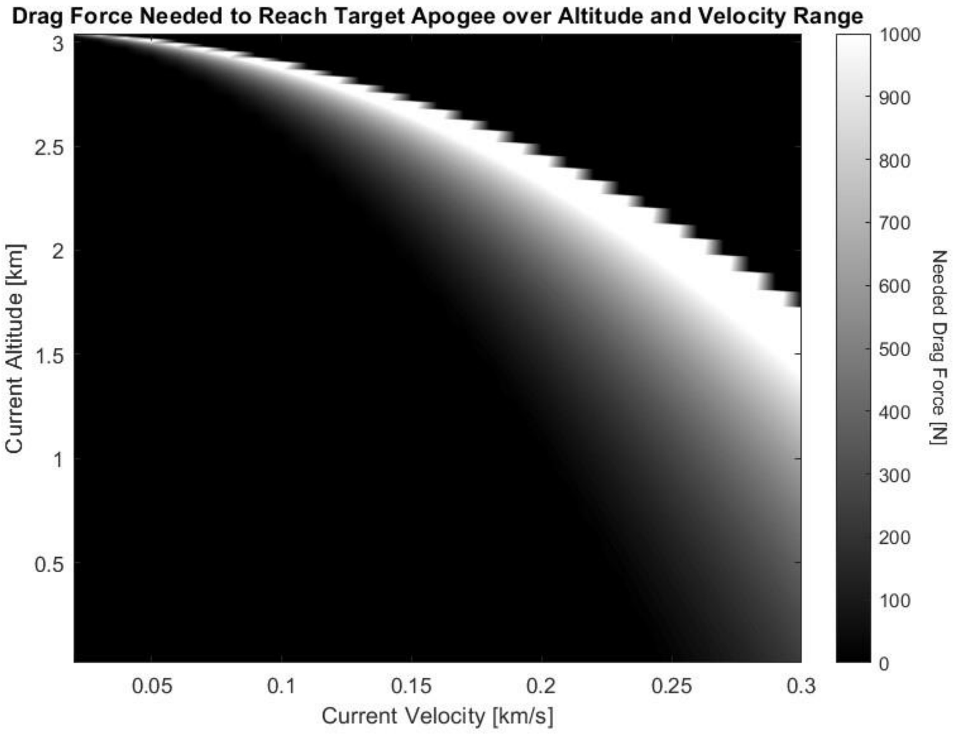


Required Drag Force

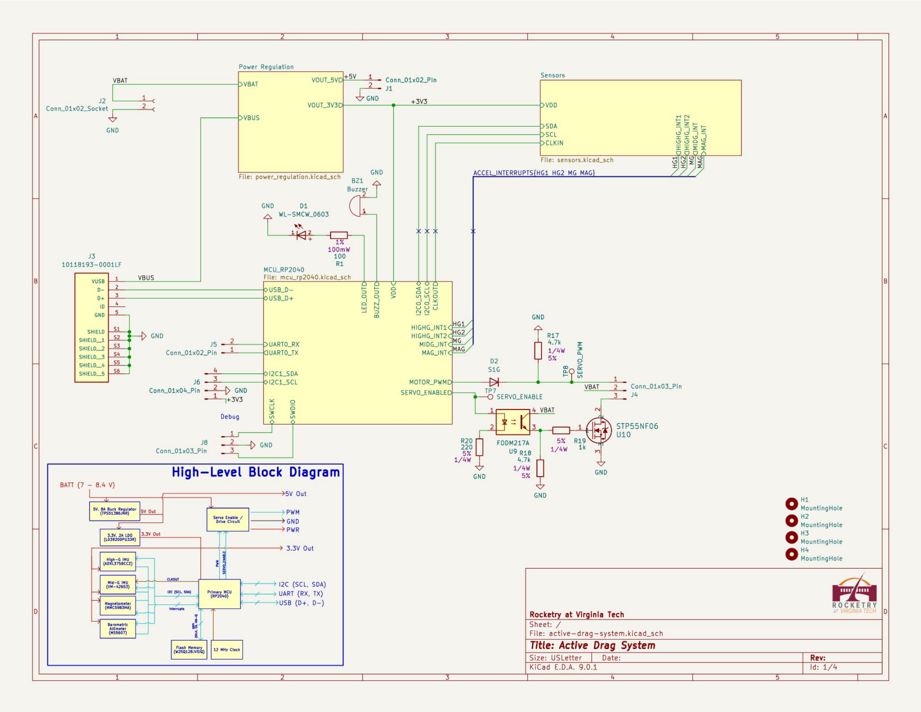
Solved apogee prediction equation numerically in MATLAB over possible velocity and altitude values.

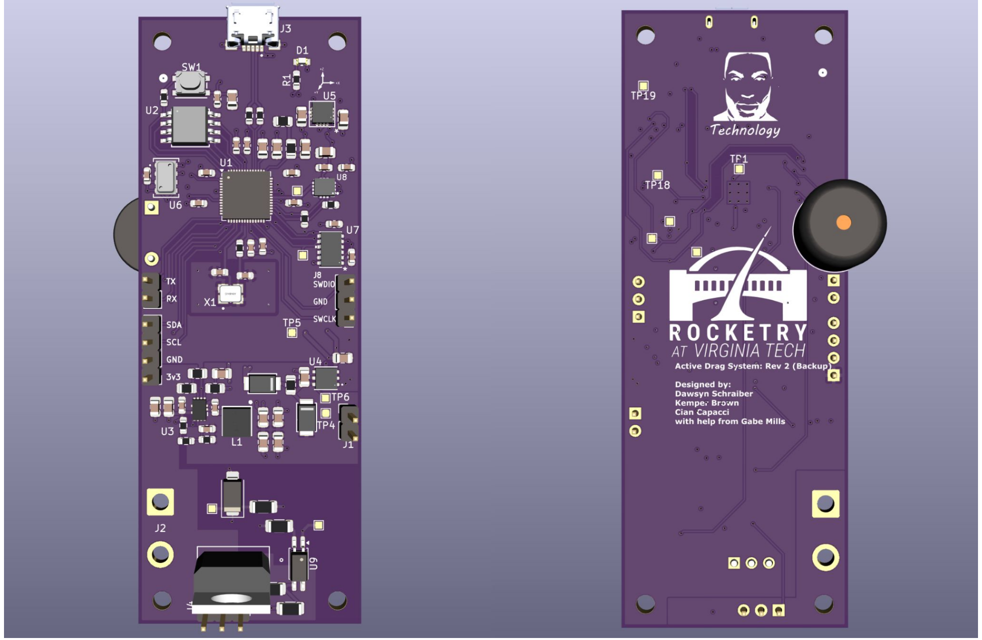
Fitted a surface to solved equation values to create equation that inputs current rocket velocity and altitude and outputs needed current drag force to reach target apogee.

The needed drag force is then input into the relationship found from the CFD to determine what ADS deployment % is needed.



Electrical Design





Software Design

Interrupt-based Finite State Machine for flight stage determination

- External Pin from Accelerometer and IMU Threshold Interrupts
- Altimeter Driver Altitude Interrupts
- Internal Hardware Timer Interrupts

Fixed point Kalman Filter to fuse barometric altitude measurement with vertical acceleration to obtain state vector with velocity and altitude estimation

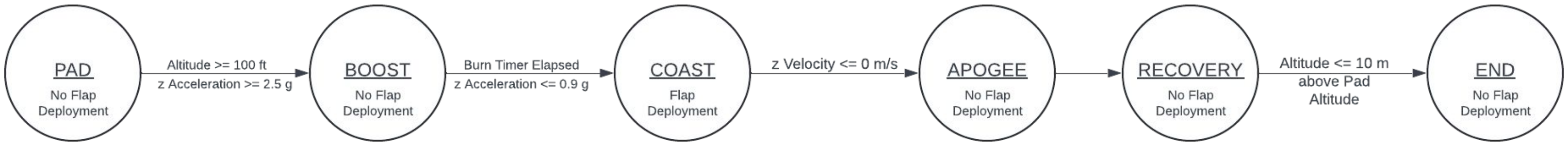
- Barometric altimeter weighted more at lower velocities (~160 m/s) whereas acceleration weighted more at higher velocities

Multi-threaded logging in 64 byte, serialized packages at 100 Hz

- Circular buffer to log 2 seconds prior to launch

Active Drag System

Rocket State Machine



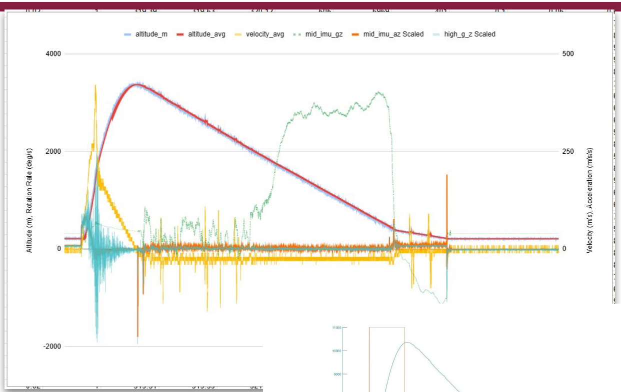
Results

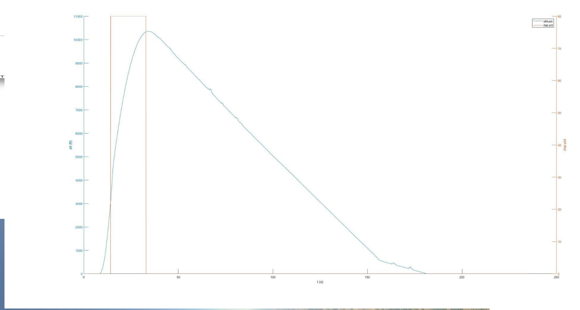
Verification of state machine in April Test Launch

Flap deployment during coast phase

Operation without Inertial Measurement Unit (IMU)

Kalman Filter introduced following Test Launch





Follow-Up Work

- Reduce airframe gaps due to flap installment
- Refine apogee estimation and deployment percentage algorithm to be moved onboard

Thank you!