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THE ASCENT AND DESCENT OF

WUSHOCK STARDUST

AND THE SHOCKERS FROM MARS

AE 528/628

SENIOR DESIGN

2019 – 2020

Mentor

Dr. Steve Klausmeyer

"THE STARS ARE NEVER FAR AWAY"

- DAVID BOWIE

THE MISSION

THE COMPETITION

2020 Spaceport America Cup
Intercollegiate Rocket Engineering Competition [IREC]
Category: 10,000 ft COTS [Commercial Off-The-Shelf]

THE MISSION

Fly an 8.8-pound payload on board our rocket, WuShock Stardust, to a precise altitude of 10,000 ft and return it safely to the ground.

THE GOAL

- Be the first Wichita State team to compete in the world’s biggest rocket competition.
- Have fun!

THE PLAN

Design our rocket to overshoot the target apogee, and then have it activate the Active Drag System [ADS] to slow it down during flight.

THE ROCKET

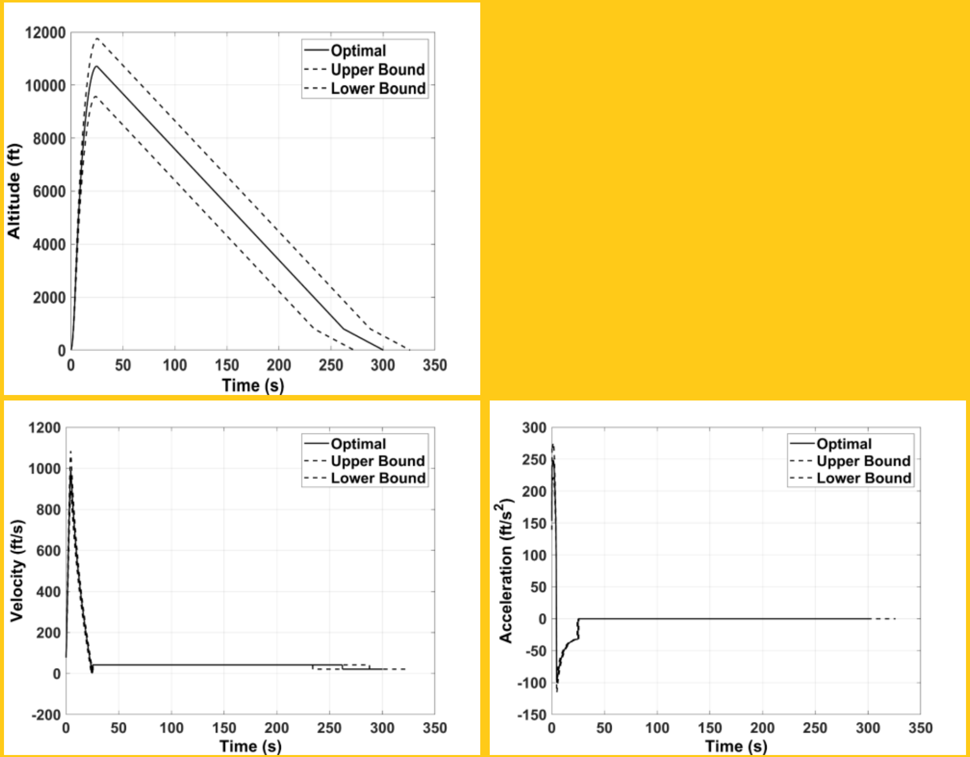
Total Rocket Height	118 in
Total Liftoff Weight	57.1 lb
Rocket Body Diameter	6 in
Liftoff Stability Caliber	2.7
Liftoff Thrust-Weight Ratio	8.5
Motor Designation	M2000R
Average Thrust	450 lb
Total Impulse	2,072 lb-s
Primary Airframe Material	Fiberglass

Apogee With Airbrakes	10,006 ft
Apogee Without Airbrakes	10,715 ft
Max Velocity	990 ft/s
Max Mach Number	0.89
Max Acceleration	250 ft/s^2
Liftoff Velocity	81 ft/s
Ground Hit Velocity	21 ft/s
Main Deployment Altitude	800 ft
Total Flight Time	300 s

AERODYNAMICS

We decided to use a 5:1 Von Karman nosecone due to its high fineness ratio and availability. We chose a 48-inch Drogue Parachute to deploy at apogee and slow the initial descent phase while minimizing wind drift; and a 96-inch Main Parachute to deploy at 800 feet above ground level to ensure a safe ground hit velocity for the rocket.

We built our own trajectory modeling tool in MATLAB to simulate the rocket's altitude, velocity and acceleration over the course of the flight. The tool's capabilities were validated using flight data from other WSU rocket projects.

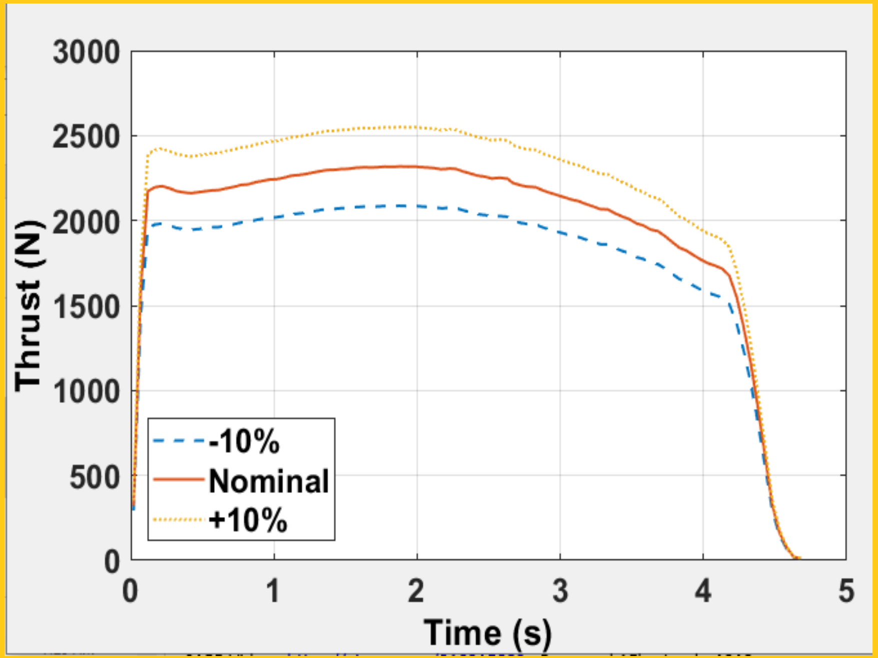


Plots of altitude, velocity and acceleration, respectively, versus time during the rocket's flight, including parachute events and landing. Bounds account for up to 10% variation in motor performance.

PROPULSION

We chose an Aerotech M2000R motor for the following reasons:

- Neutral thrust profile simplifies calculations.
- High thrust-to-weight ratio at liftoff ensures rocket stability off the launch rail.
- Quick burn time allows for longer coast phase, giving more usable time to the ADS.
- Single-port nozzle is more efficient than multi-port ‘medusa’ nozzles used in some motor designs
- Standard 98-millimeter motor hardware can be borrowed from the Wichita State Rocket Club, reducing the cost of otherwise highly expensive components.

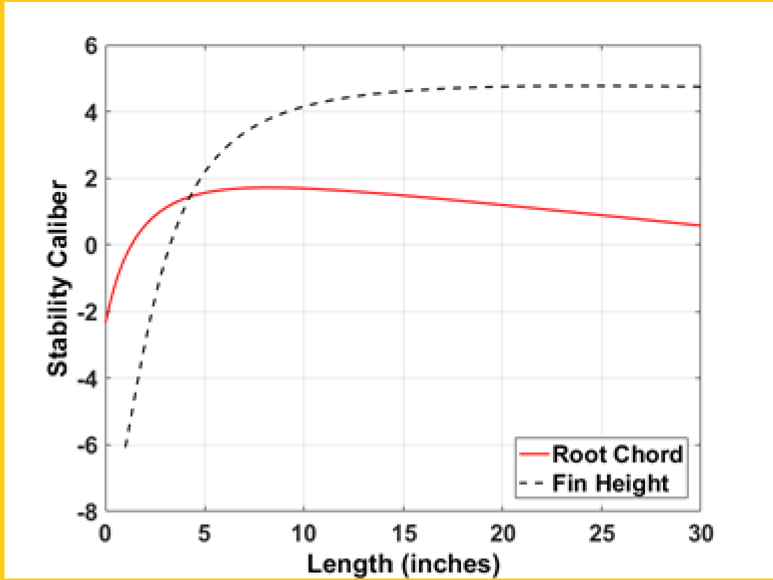


Plot of thrust versus time, accounting for up to 10% variation in motor performance.

STABILITY AND CONTROL

We decided to make our four fins right triangles to simplify design and manufacturing. By varying fin root chord and height, we were able to manipulate the rocket's center of pressure.

Coupled with the rocket's center of gravity, we were able to settle on the stability caliber. We aimed for a stability caliber above 2 for flight safety, but below 6 to avoid weathercocking, which could have had a significant impact on our apogee.



Plot of varying fin geometry lengths versus rocket stability caliber

STRUCTURES

We chose to use filament-wound fiberglass as our primary airframe material. As a composite material, this will distribute loads in instances of site damage in order to deter crack propagation.

We examined various forces acting on the rocket during flight, including compressive stress due to liftoff, tensile stress due to chute deployment, the effect of ground impact on the fins, and airbrake deployment effects, to ensure all components are capable of being safely recovered after the flight.

Our payload, which was designed to mimic the weight and dimensions of a 3U CubeSat, is made from steel tubing and affixed securely inside the nosecone coupler.

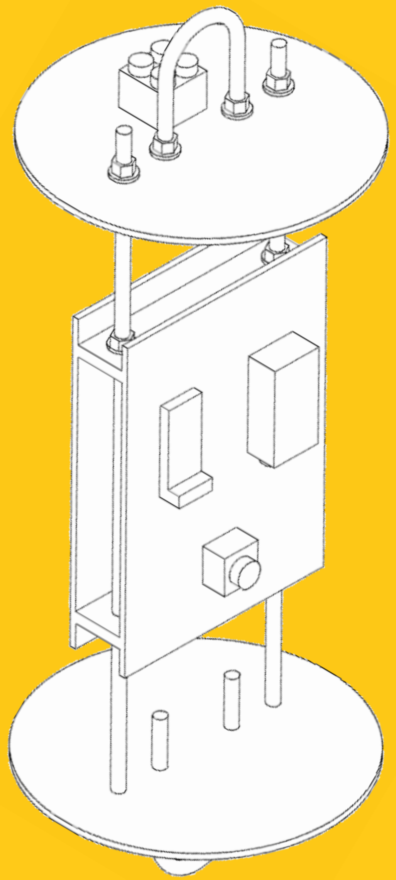
Our body tube is slotted for our fins, which are bonded to the motor mount within the aft tube using epoxy. A blend of epoxy and chopped carbon fiber is used to create fillets along the joint where the fins and the body tube meet.

AVIONICS

Parachute deployment is handled by a dual-redundant avionics sleigh which includes two entirely separate systems of altimeters, batteries, switches, wiring and ejection charges.

The Telemetrum altimeter handles the primary deployment charges; it also has a GPS function, which allows for flight tracking and rapid recovery. The Raven altimeter handles the backup charges. Both altimeters collect flight data. We elected to use two different altimeters to reduce the potential for failure during flight.

Since the avionics sleigh is not a loadbearing component, we decided to build it out of plywood to keep the rocket's weight down. The bulkheads are made of fiberglass.



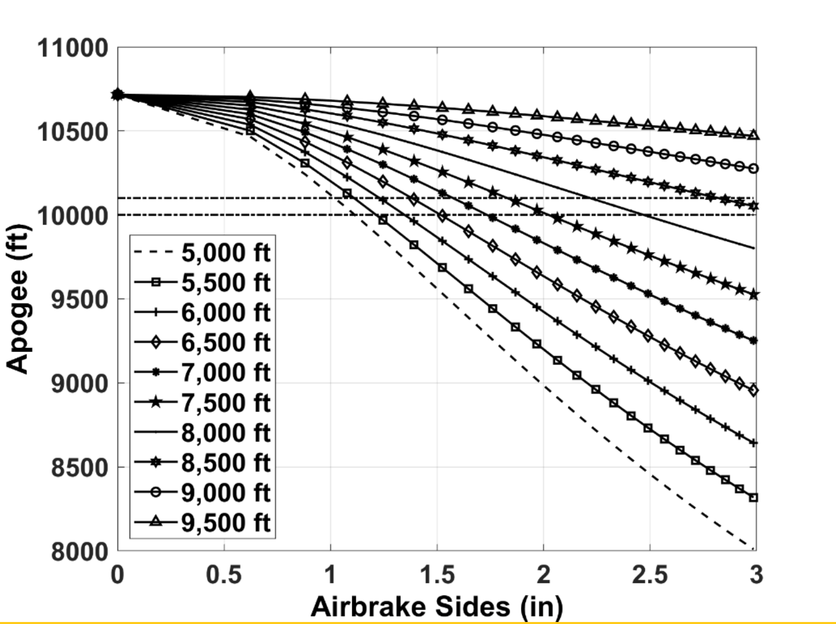
ACTIVE DRAG SYSTEM

Our Active Drag System [ADS] makes use of a rack and pinion system, with a gear on a servo driving four flat blades (known as ‘airbrakes’) out of the rocket body perpendicular to the flow in order to increase drag and slow the rocket down. We came up with a sizing plot to size the airbrakes based on the target apogee.

A system made up of an Arduino Uno, an IMU and a pressure sensor evaluate the rocket’s behavior during flight and use this information to control the servo and, by extension, airbrake deployment, in order to ensure the rocket hits the target apogee.

Initially, the system’s target apogee is set at 10,100 ft, which is slightly higher than the competition goal. The system’s target apogee changes to 10,000 ft as the rocket approaches the goal. This strategy gives the ADS clearance to adjust and fine-tune airbrake deployment should unexpected events that affect the trajectory occur, such as wind gusts or variations in motor performance.

We modeled the ADS in action using SIMULINK.



Airbrake sizing plot: plot of apogee versus airbrake side lengths while varying deployment altitudes.

ACTIVE DRAG SYSTEM

Launch (system starts time with positive acceleration)

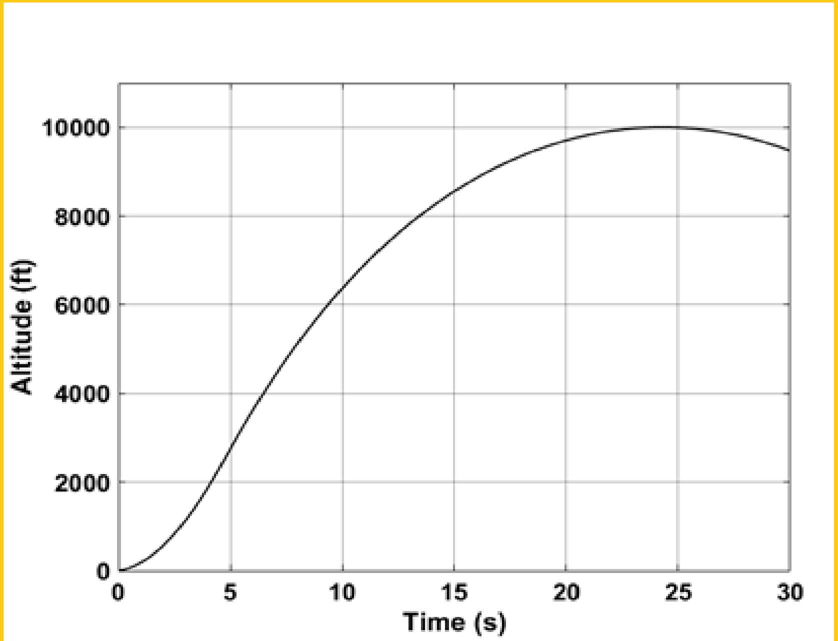
Feedback loop after 10 seconds (ensures complete motor burnout prior to airbrake deployment)

Desired altitude minus current altitude (Desired set to 10,100 feet until 800 feet where it switches to 10,000 feet)

PID controller

ADS

Rocket Altitude



Plot of altitude versus time using the controller and the ADS in SIMULINK.

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WSU CORE Lab – Research Assistant [Nanosats]

Wichita State Rocket Club

- Propulsion Team Lead
- Executive Board Member [3 years]

Tripoli Rocketry Association Rocket Certification

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B.S. in Aerospace Engineering, minor in Physics

US Air Force – Aerospace Maintenance [7+ years]

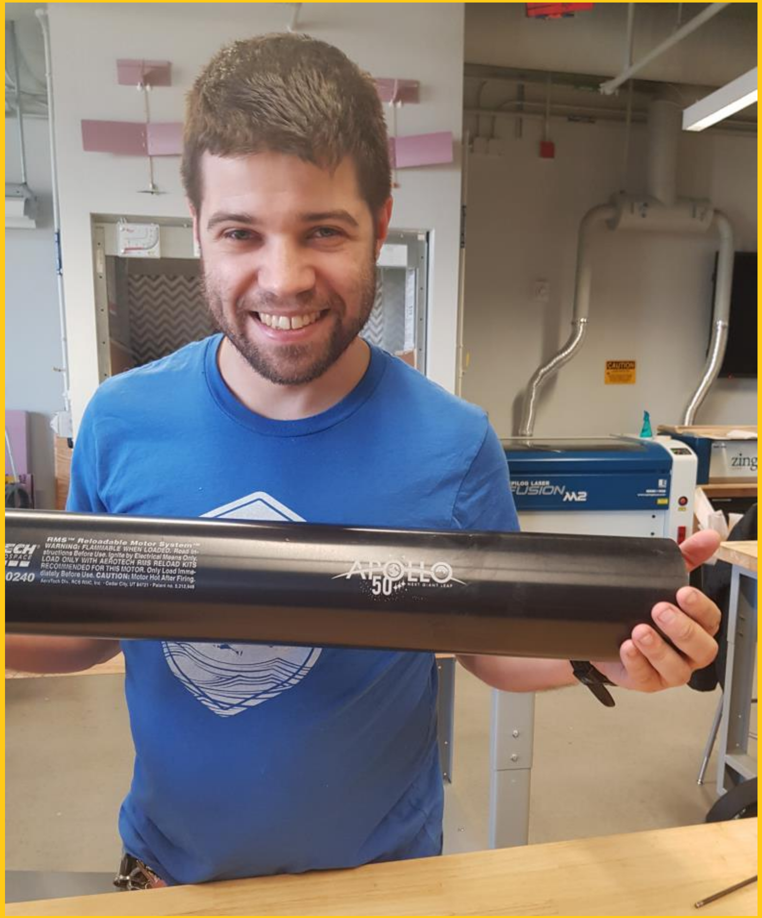
Internships

- National Institute for Aviation Research [NIAR]
- Aerospace Systems & Components
- GE Aviation

Wichita State Rocket Club

- Stability & Recovery Team Lead
- Executive Board Member [2 years]

Tripoli Rocketry Association Rocket Certification



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B.S. in Aerospace Engineering
Minors in Management and Mathematics

WSU MADLab – Research Assistant

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- Presenting author on 2 published papers
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Wichita State Rocket Club

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Special Thanks

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K.L.O.U.D.BUSTERS, Inc.

Wildman Rocketry

Wichita State University

WSU College Of Engineering

Wichita State Rocket Club

Bryan Cline