University of New Hampshire
College of Engineering and Physical Sciences

UNH SEDS

Department of Mechanical Engineering
Authors: Charlie Nitschelm, Kevin Bucher, Nick Clegg, Reilly Webb
Advisor: Dr. Todd Gross

SEDS USA

Project Overview

To design, manufacture, and launch a high-powered, multi-stage rocket for the SEDS University Student Rocketry Competition

- Goals
  - Design a high-powered engine class rocket to achieve **maximum altitude**
  - Implement a comprehensive recovery system that results in a fully reusable rocket
- Constraints
  - Total combined engine impulse must not exceed 640.0 N-s
  - Must have *at least* two propulsion stages

Research Aerodynamic Theory

Check Integrity with Finite Element Analysis

Optimize Rocket Dimensions

Improve Aerodynamic Models

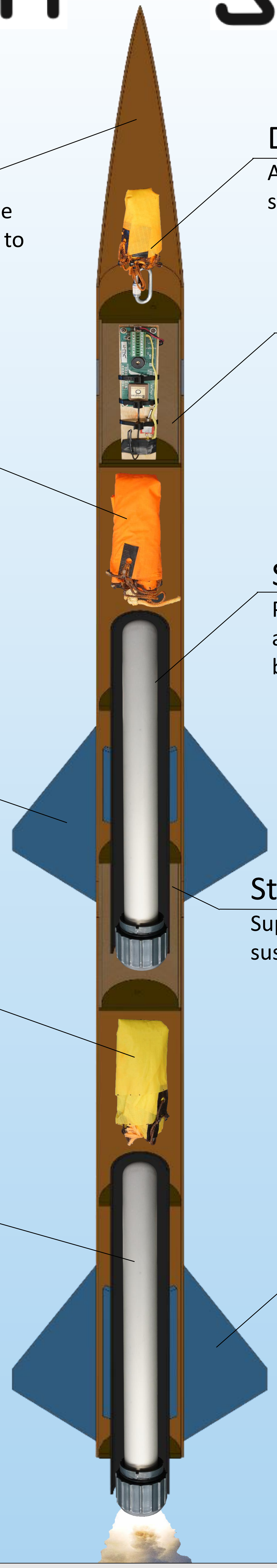
Rocket Improvement Cycle

Manufacture and Assemble

Launch and Gather Data

Improve Field Launch Techniques

Improve Manufacturing Techniques



Custom Nose Cone
A carbon fiber nose cone that houses the drogue parachute and connects directly to the electronics bay

Drogue Parachute
A small parachute deployed at sustainer apogee

Electronics Bay
Houses the TeleMega GPS and controls both parachute deployment and sustainer ignition

Sustainer Parachute
A larger main parachute that slows the sustainer to a safe landing speed

Sustainer Engine
Propels the rocket to max altitude after booster burnout; 1.7 second burn time

Forward Fins
Provides stability to the sustainer after stage separation

Staging Coupler
Supports stage separation at sustainer ignition

Booster Parachute
A large parachute to slow the booster to a safe landing speed

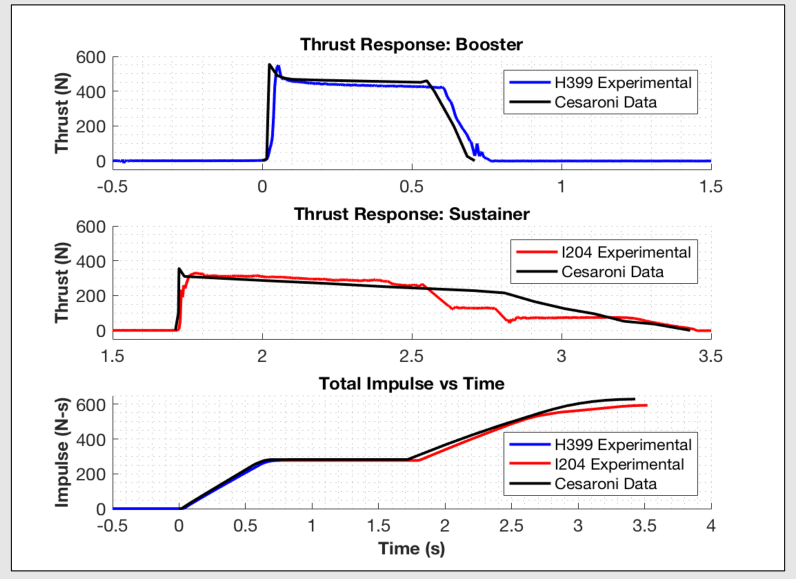
Booster Engine
Initiates flight with a 0.7 second burn time

Aft Fins
Provides stability to the rocket before stage separation

Propulsion

- A Static Test Fire Rig was designed and manufactured to test the propulsion characteristics of each engine and to verify total engine impulse stays below 640.0 N-s

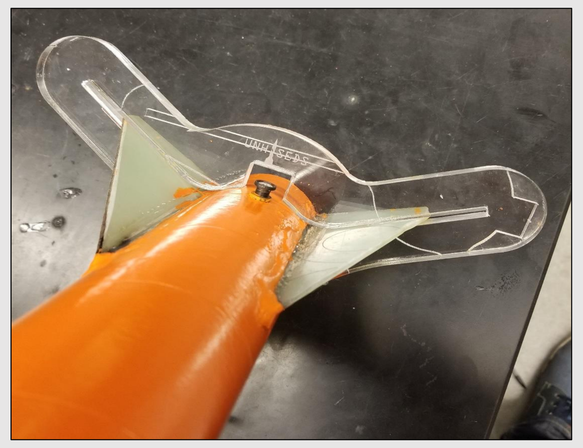
	Reported Max Thrust	Measured Max Thrust	Reported Total Impulse	Measured Total Impulse
Booster Engine: Cesaroni H399	545.8 N	549.6 N	282.2 N-s	277.1 N-s
Sustainer Engine: Cesaroni I204	356.8 N	329.7 N	347.7 N-s	322.7 N-s



- Data acquisition was performed using the custom test rig, a 150 lb load cell, and NI SignalExpress software
- Results were verified by comparing to official data reported by the engine manufacturer

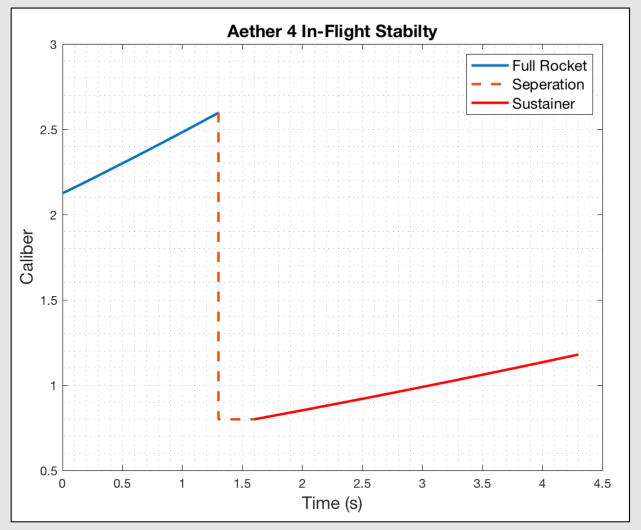
Manufacturing

- A laser cut fin alignment tool was designed to keep fins in place during the epoxy curing process
- Many components are assembled from scratch such as the nosecone, fins, ignition leads, ejection charges, and launch pad



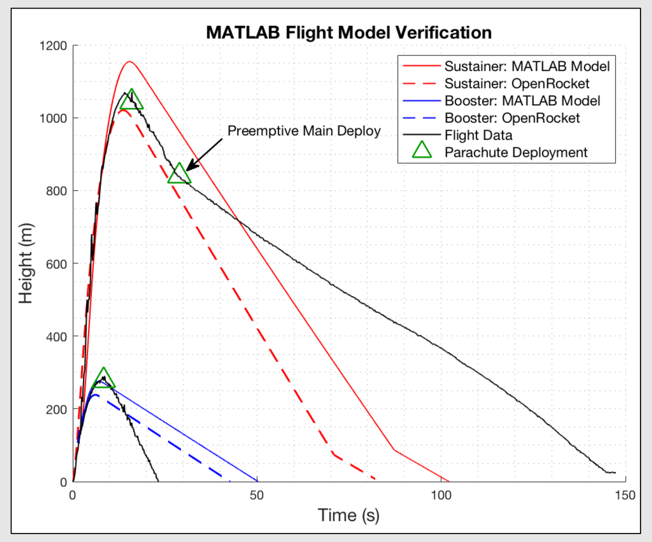
Launch Simulation

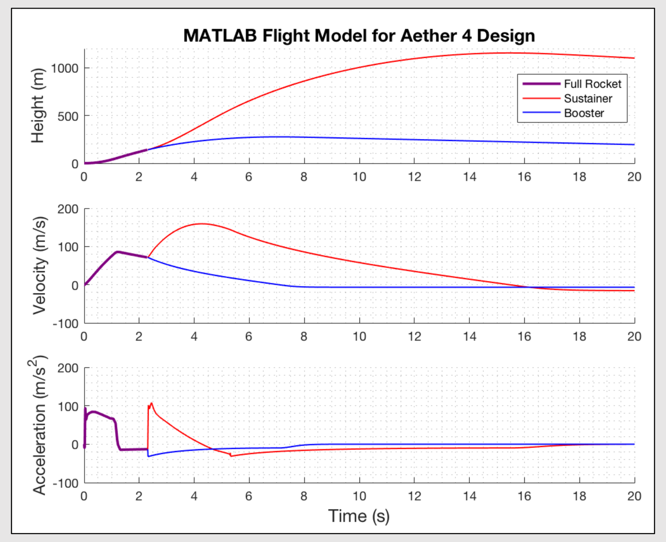
- Rocket trajectory was simulated using MATLAB. This required accurate **stability, thrust, drag,** and **atmospheric** models to produce ordinary differential equations that are then numerically solved for given rocket dimensions
- Caliber is a measure of passive stability, and should remain between 1-3 for stable flight (right)



	Flight Data	OpenRocket Model	MATLAB Model
Sustainer Apogee	1071.1 m	1020.6 m	1154.1 m
Booster Apogee	290.0 m	238.6 m	276.3 m

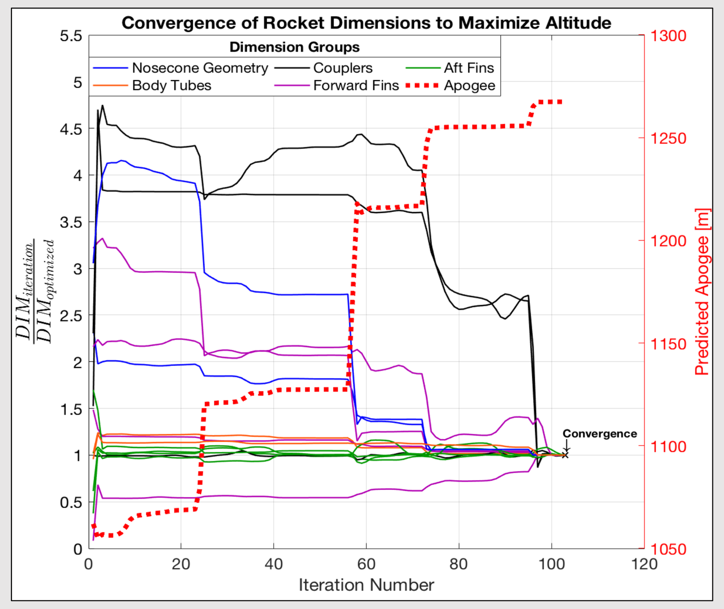
- The MATLAB flight model is verified by comparing results to flight data from launches and to OpenRocket predictions (a pre-existing rocket simulation program)

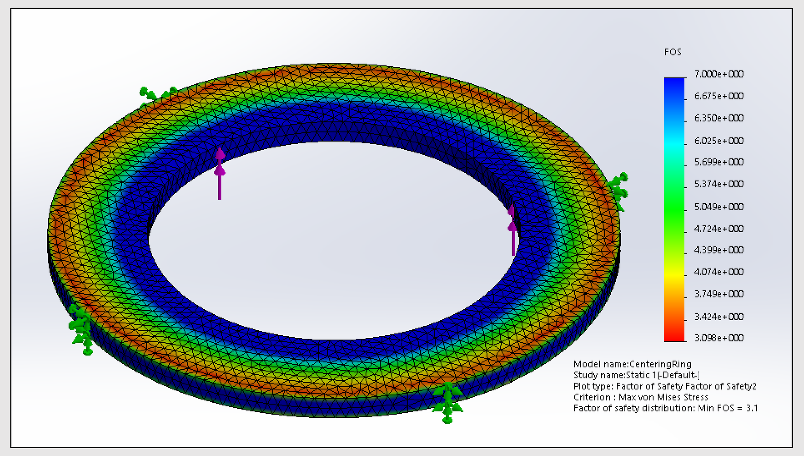




Design & Analysis

- An **optimization** program was created to determine the nominal dimensions for each component that will result in the highest simulated altitude
- This was achieved by maximizing the height output from the combined aerodynamic models through nonlinear programming using the interior-point algorithm
- Optimization Constraints:
  - Maintain in-flight stability
  - Structural integrity factor of safety of at least 3.0
  - Manufacturing limitations





- **Stress analyses** are performed on the optimized components that are prone to failure, such as the engine centering ring (left)
- Optimization must be reconfigured if resulting FOS is less than 3.0

Acknowledgments

A huge thanks to all the members of UNH SEDS, Prof. Martin Wosnik, Alireza Ebadi, Thomas Collins, the Parents Association, and our advisor Todd Gross for all the support