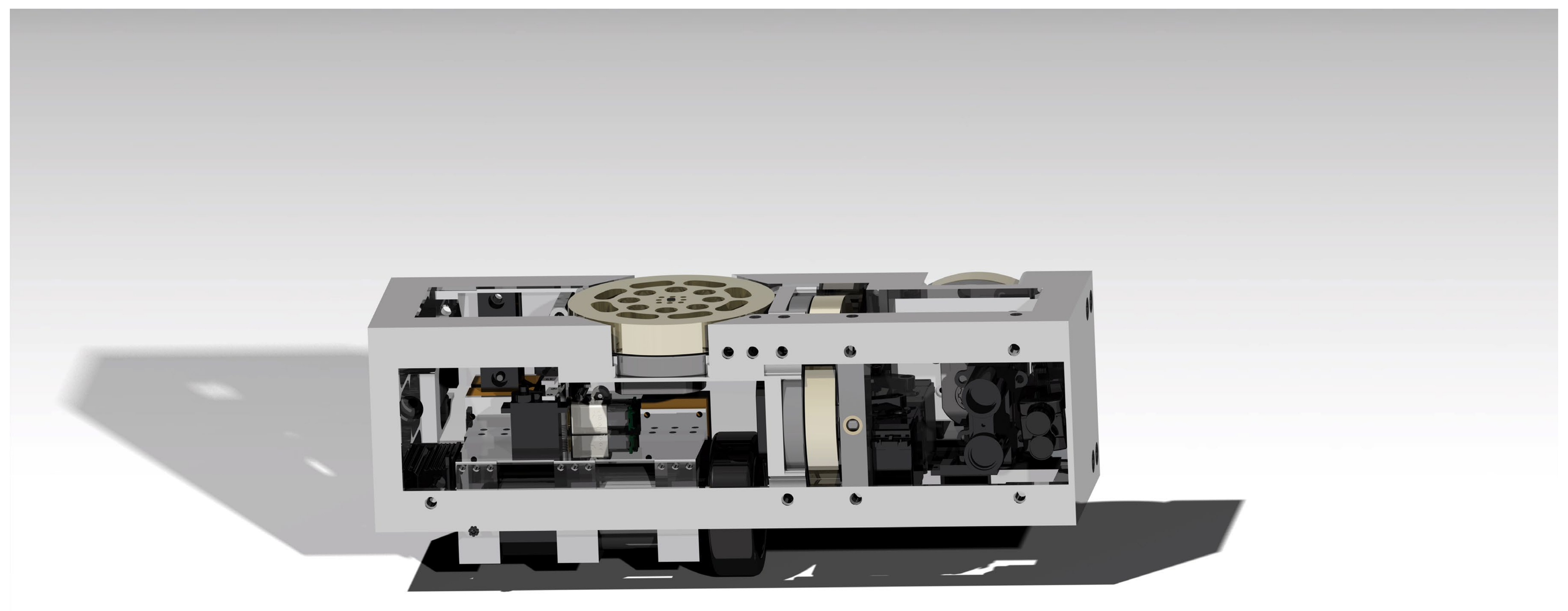
BYU 2021 High Power Rocketry Team

Project Objective
Design, build and test a high-power rocket that is capable of carrying a 4 kg payload to 10,000 feet AGL with a commercial motor with less than 40,960 N-s of impulse.

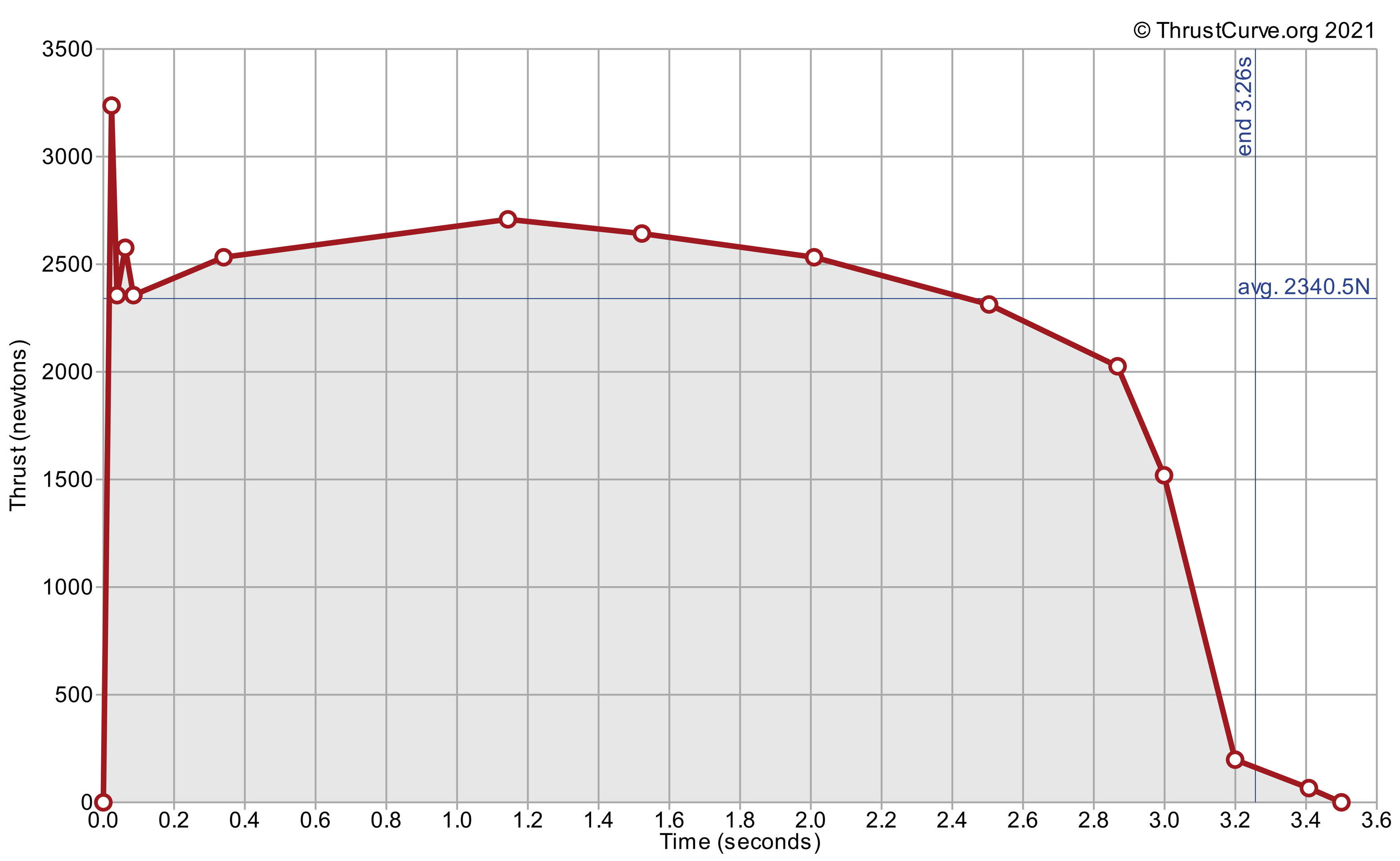
Project Background
The BYU Rocketry Association competes annually in the Spaceport America Cup's International Rocket Engineering Competition. Previous rockets have flown to within 500 feet of the target with a variety of payloads.

How It Works
The rocket is propelled to 10,000 feet by an Aerotech M2400T commercial off the shelf motor. The altitude is carefully adjusted by a modular airbrake system which was designed by a BYU Capstone team. At apogee a drogue parachute is deployed by a black powder charge which also deploys the payload, to be recovered separately. The main parachute is then deployed at 900 feet AGL to slow the rocket for landing.

Payload
The rocket carries a payload that is ejected separately from the rocket at apogee by the same black powder charge that deploys the drogue parachute. The payload consists of an aluminum frame with brass reaction control wheels that control the orientation of the rocket during descent under parachute. This enables the payload to record video of the recovery of the rocket. Upon landing, the payload then deploys a single wheel and uses the reaction control wheels to balance and drive around the recovery site and take data.

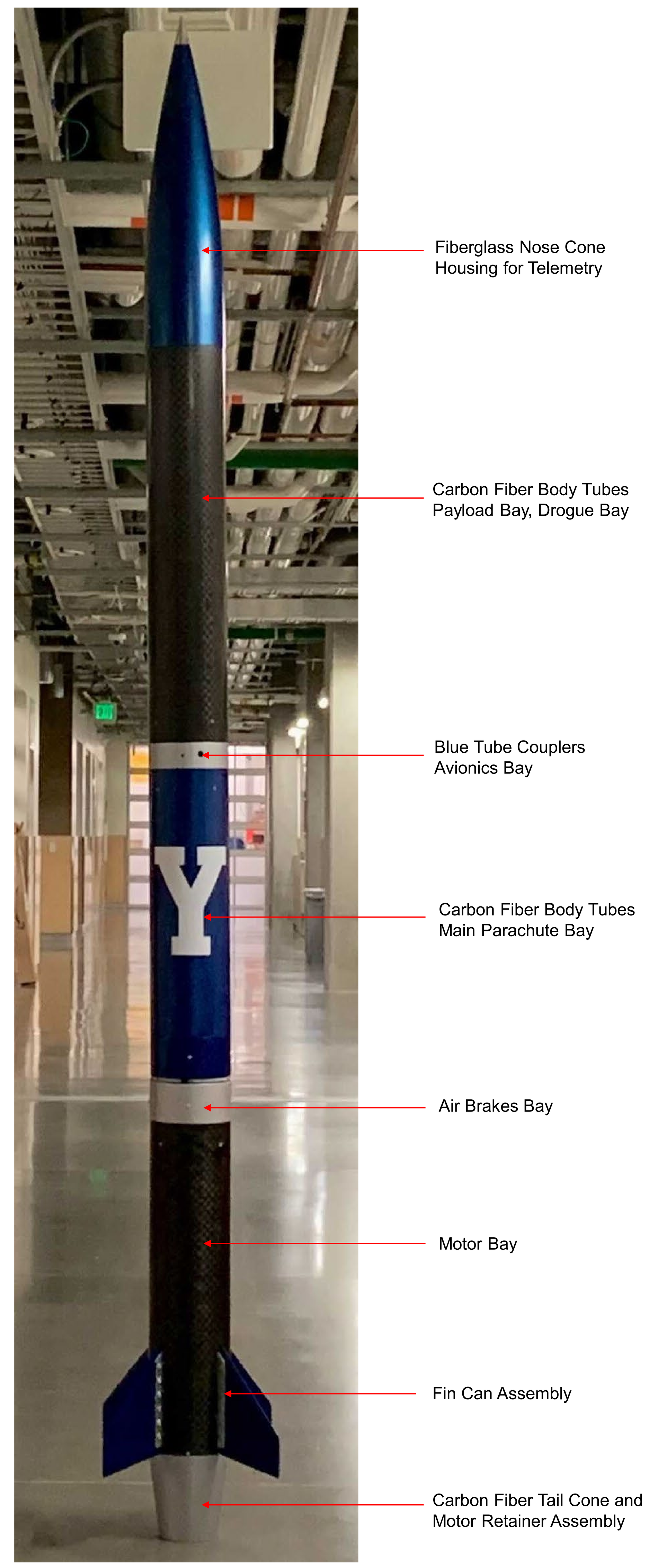


A render of the completed payload system



Thrust curve for the M2400T COTS motor used for the rocket

Structure
The rocket is composed of a fiberglass nosecone and carbon fiber body tubes. The body tubes are rolled in-house at BYU to the dimensions required. The coupler segments are made of Blue Tube and our fiberglass fins are attached to the frame using an aluminum fin can. The motor is then held in place using a custom carbon fiber tail cone.

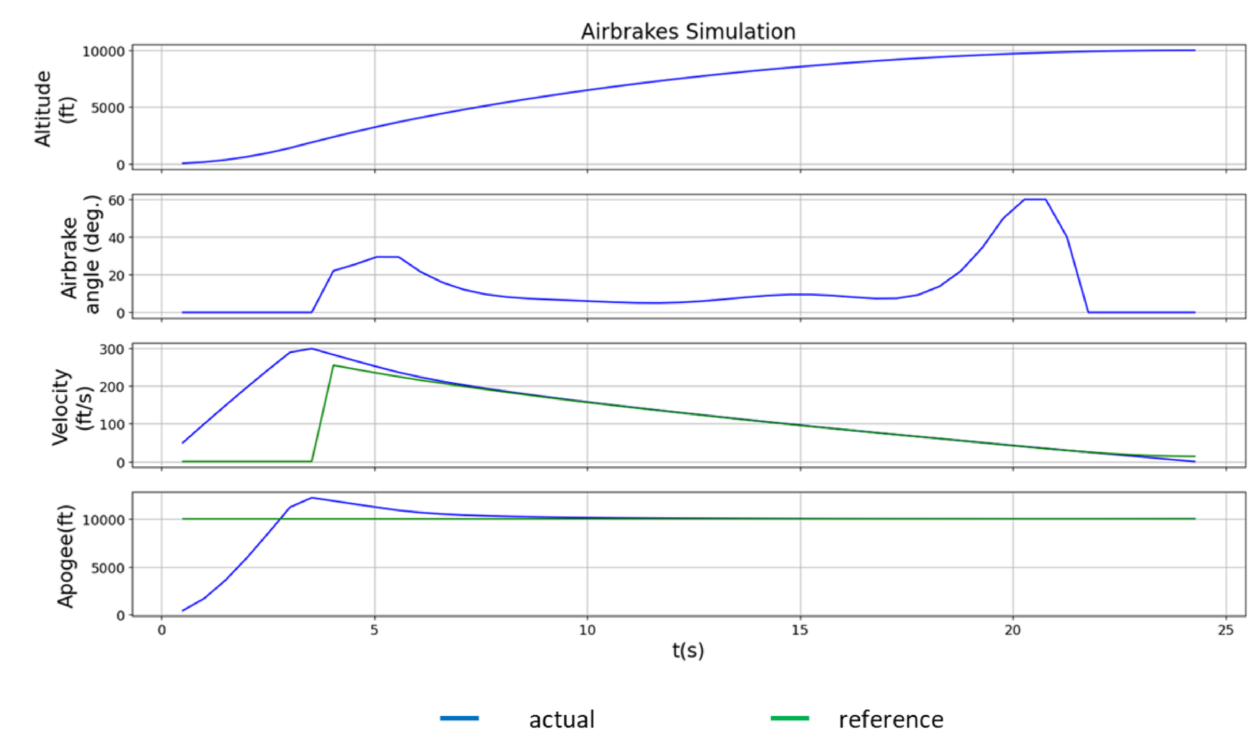


Completed rocket design with all components integrated.

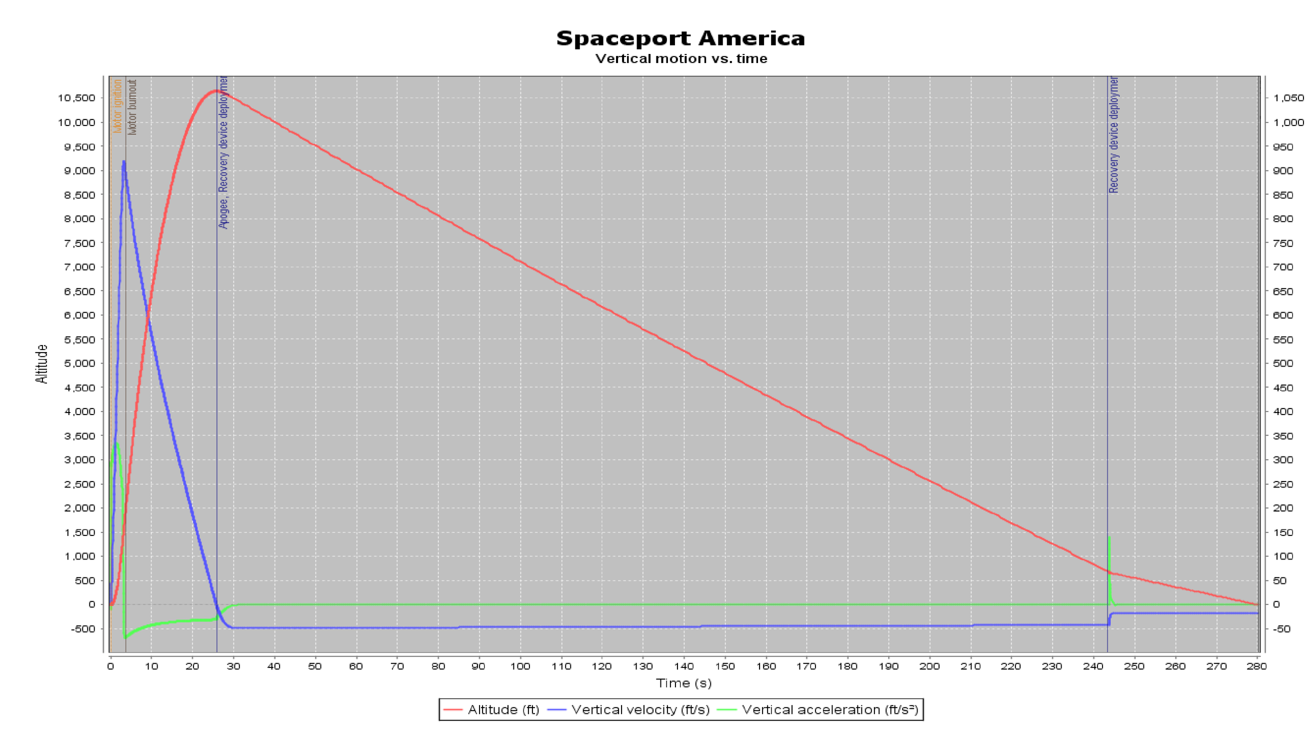
Air Brakes Control System
This rocket features an air brake control system to tailor the altitude to 10,000' exactly. This system utilizes four planar paddles that rotate out perpendicular to the flight trajectory to increase drag during flight, all mechanically coupled through a planetary gear system.

A proportional controller is used to deploy the air brake paddles based on current velocity and a reference velocity. The reference velocity is a precalculated trajectory that will send the sponsor rocket to exactly 10,000 feet. This simple, yet effective control method allows the system to trim excess altitude to within 5 feet of the desired value, or 0.05%. A robust state-machine architecture prevents the air brakes from deploying too early or too late. This preserves the stability of the launch vehicle as well as the integrity of the control unit.

The rocket state (altitude and velocity) cannot be directly measured. Instead, these values are estimated by combining barometer and accelerometer readings into an Extended Kalman Filter. The Kalman Filter propagates the rocket state forward by integrating the accelerometer twice, yielding velocity and altitude. Measured barometer values are used to correct the estimates made with the accelerometer.



An example of the control system's performance in flight simulation. This example reached within 5 feet of the target apogee.



A graph of expected altitude, velocity, and acceleration throughout the flight as exported from OpenRocket modeling software. The altitude will further be decreased to match 10,000 feet by the airbrake system.

Results
Due to unforeseen circumstances, we were not able to launch the rocket for a test flight before submitting this poster. It is planned to be launch in the near future to provide validation of the systems. We anticipate the system's success in that test flight and in its eventual competition flight.

2020-2021 Sponsors
BYU Dept. of Mechanical Engineering

BYU Rocketry High Power Rocketry Team
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