

MIT ROCKET TEAM

FLIGHT READINESS REVIEW

Overview

- Mission Updates
- Rocket and Subsystems Updates
- Payload and Subsystems updates
- Full Scale Test Results
- Management Updates

Purpose and Mission Statement

Our Mission:

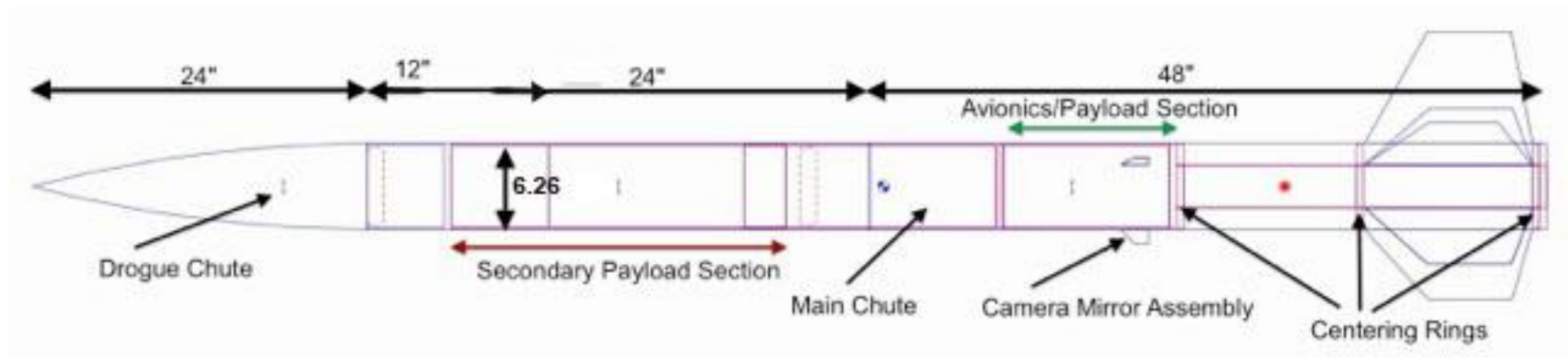
The MIT Rocket Team aims to develop and test methods of analyzing the causes and effects of fin flutter as it pertains to the flight of high powered rockets.

Mission Requirements

- Launch rocket with 6 fins of different thicknesses, geometry, and materials
 - Analytically demonstrate rocket stability with 6 fins and additionally only the 3 non-fluttering fins.
 - Attach strain gauges to fins to measure predicted versus actual strain
 - Purposely induce flutter or failure in 3 of 6 fins
- Successfully deliver high school outreach payload
- Visually identify flutter effects with high speed camera and custom mirror system
 - Use image post-processing software to accurately track fin movement

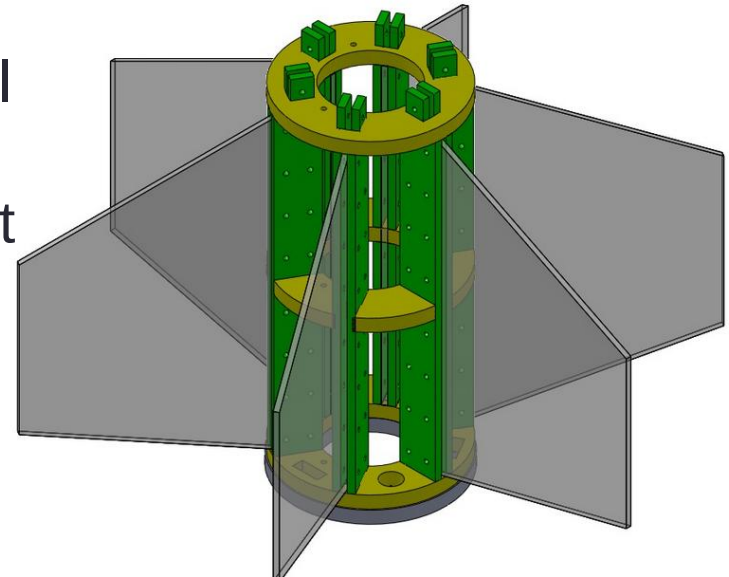
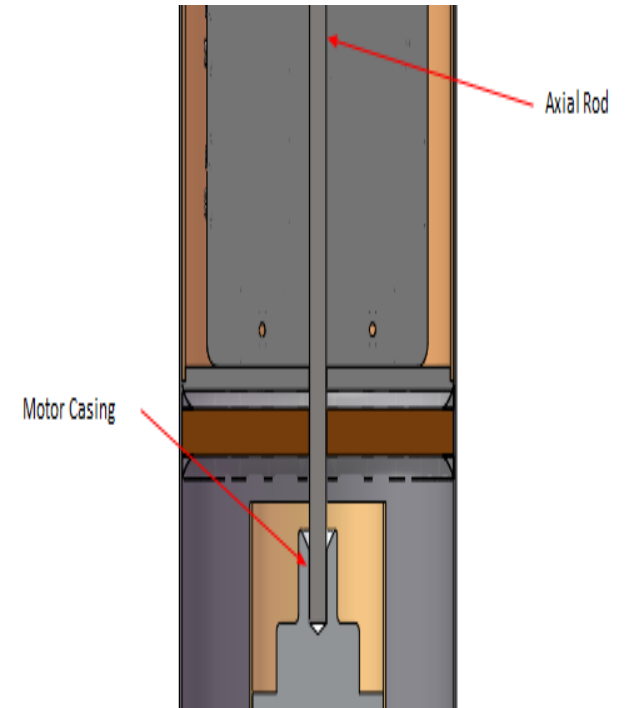
Rocket Overview (1)

- Requirements:
 - Launch rocket to 5280 ft
 - Induce flutter in 3 test fins
 - Deploy High School Science Payload
- Final Launch Vehicle Dimensions
 - 9'0" Tall
 - 6" Diameter
 - 42.5 Pound liftoff weight



Rocket Overview (2)

- Key Design Features
 - Motor retention via threaded rod to recovery eye bolt
 - Fin Retention via custom waterjetted frame
 - Avionics package inside coupler tube above motor
 - Recovery package consisting of dual deployment via Tender Descender with high school payload deployment



Rocket Airframe and Materials

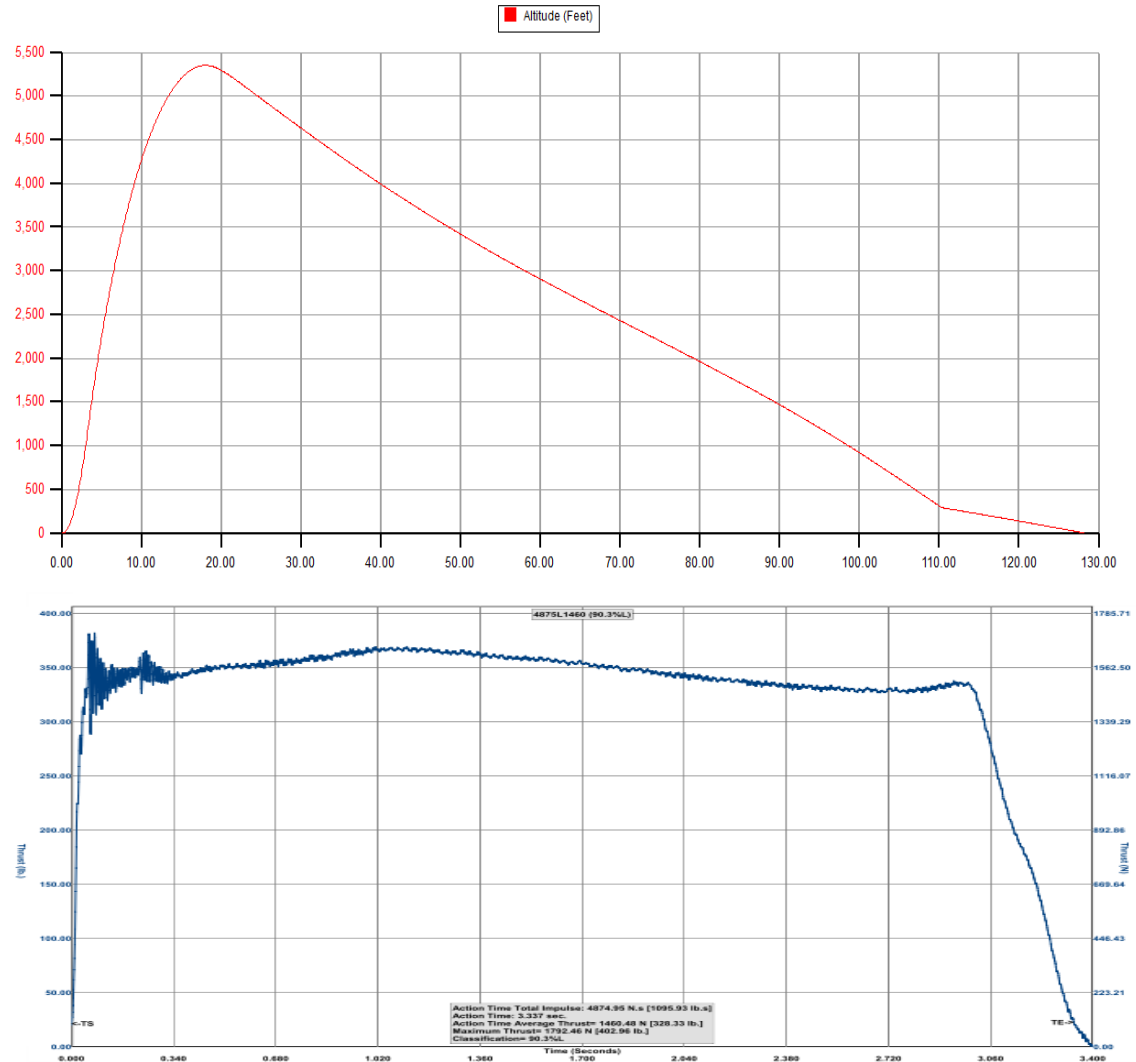
- Airframe
 - PML 6" Phenolic
 - Carbon fiber: Soller Composites Sleeve
 - Aeropoxy 2032/3660
- Bulkheads & Centering Rings
 - ½" Plywood
 - Wood glued to motor mount tube
- Fins
 - G10/FR4
 - Mechanically attached and removable/ replaceable
- Various
 - Phenolic tubing: motor mount, avionics package
 - Nylon: avionics assembly components
 - Stainless steel: quick links, eye bolts
 - Nomex: chute protectors, deployment bags

Final Motor Choice

- Rocket Motor – Cesaroni L1395
 - 4895N-s impulse - more than enough to reach target altitude given mass estimates
 - Proven track record and simple assembly
 - Cheaper and more reliable than Aerotech alternative
- Full-scale Test Motor – Cesaroni L1395
 - Will provide nearly identical flight profile to test flutter experiment
- Thrust to Weight Ratio: 8.1:1
- Rail exit velocity: 60ft/sec (assuming 96" of guidance)

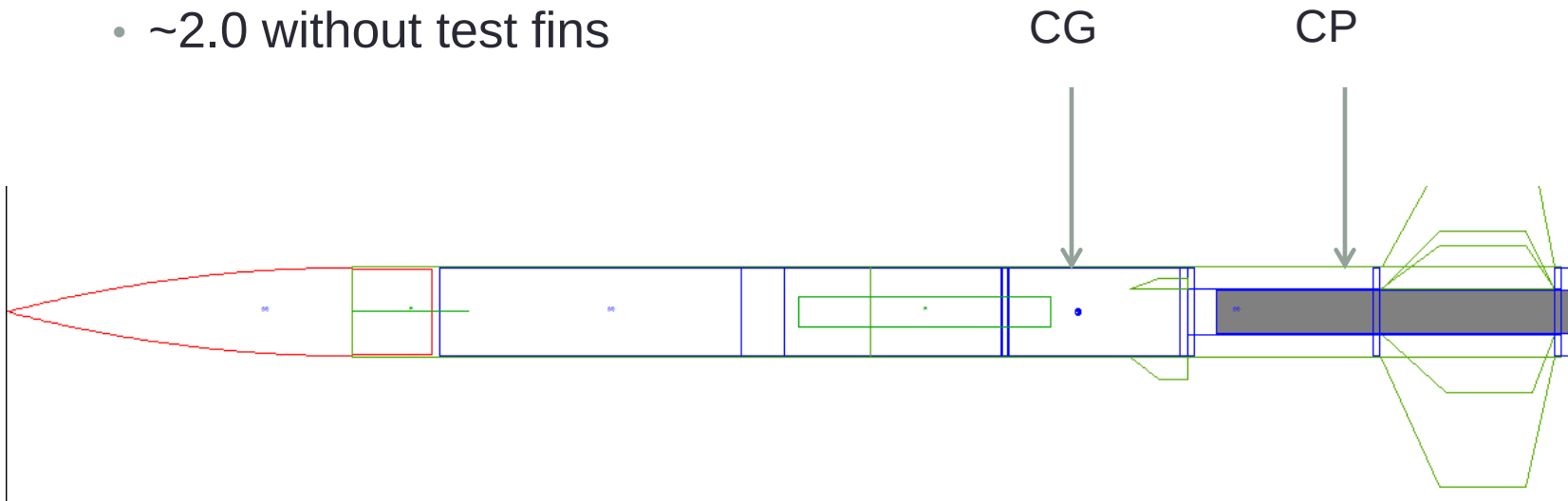
Motor and Flight Profile

- Motor: Cesaroni L1395
- Ballast Selection:
 - Minimize sensitivity
 - Adjust for local conditions
 - Remain below designated altitude
- Target: 5350 feet



Static stability margin

- Center of Pressure
 - 92" from nose tip
- Center of Gravity
 - 74" from nose tip at launch
- Stability Margin
 - ~3.0 Calibers
 - ~2.0 without test fins

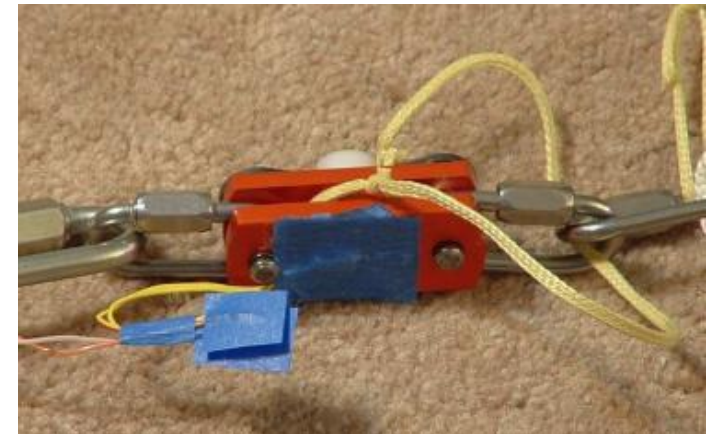


Vehicle Mass

- Launch Mass: 42.5 Pounds
- Mass margin: $\sim .5$ pounds or 1%
- Rocket has already been built and flown, so mass is very well known

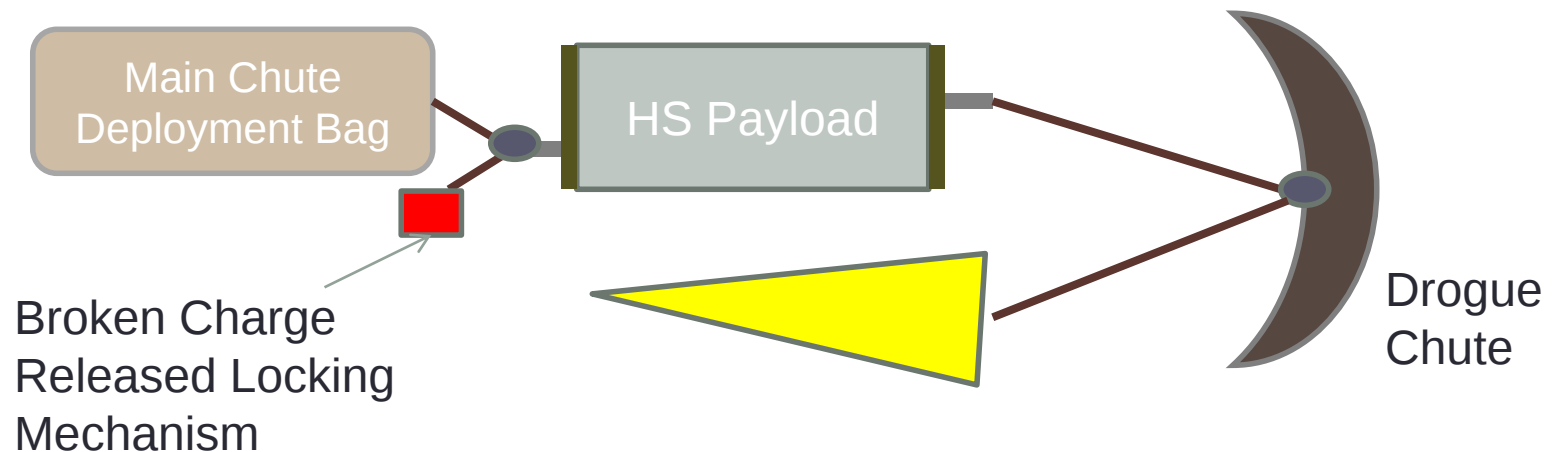
Rocket Recovery System

- 5 ft drogue parachute
 - Deployment at apogee
 - Shear 2x 2-56 screws
 - 6g black power charge
 - 16' x 1" tubular nylon webbing harness
- 16 ft main parachute
 - Deployment at 300 feet
 - Pulled out by high school payload
 - High school payload released by Tender Descender
 - Deployment Bag used
 - 3.25' x 1" tubular nylon webbing harness



High School Payload Deployment

- Tube-Stores payload during flight
- Charge released locking mechanism - releases sabot at 300 ft
- Chute Bag – ensures clean main parachute opening
- Separation of rocket and nose cone prevents parachute entanglement



Descent Rates and Drift Calculations

Final Descent Rate & Energy		
System Under Drogue	55 ft/s	1670ft-lbf
Nose/Payload Final Descent Rate	19.1 ft/s	72ft-lbf
Rocket Body Under Main	13 ft/s	65ft-lbf
Liberated Fin	<40 ft/s	<9 ft-lbf

Drift Calculations				
Section Drift	Main Body	Nose cone and payload	Fin 1 (light)	Fin 2 (heavy)
Descent Time	113 seconds	106 seconds	16 seconds	33 seconds
Drift at 0mph	0	0	0	0
5mph	828'	777'	117'	242'
10mph	1656'	1554'	235'	484'
15mph	2484'	2331'	352'	726'
20mph	3312'	3108'	470'	968'

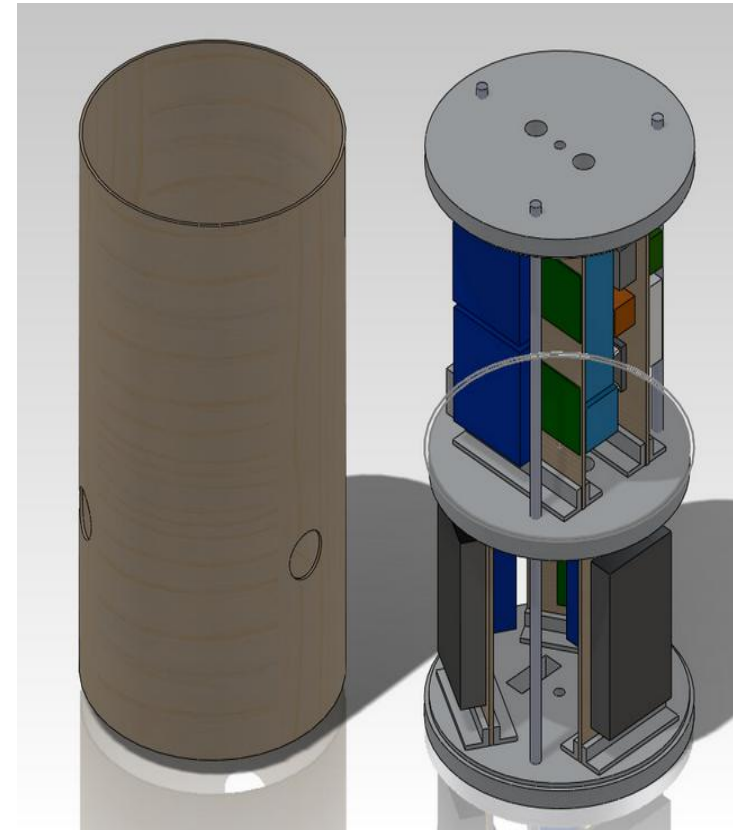
Vehicle Safety Verification and Testing

- Body tube structural tests
 - Passed on January 15.
- Ejection Charge Tests
 - Passed on January 15-6 grams gently separates nose cone
- Fin drop tests
 - Performed January 20, descent rates of 39 and 28 fps for each fin thickness without streamers
- Avionics Tests
 - Vacuum Chamber
 - Electric match actuation
 - Passed January 14th & 15th.

Payload Design Overview

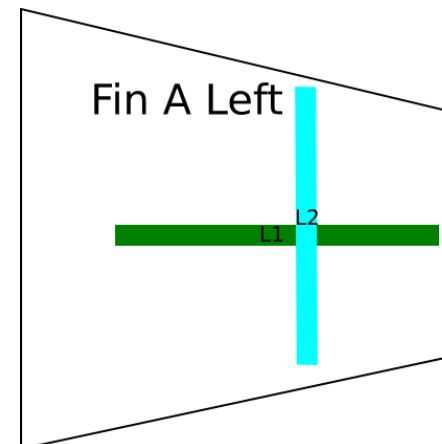
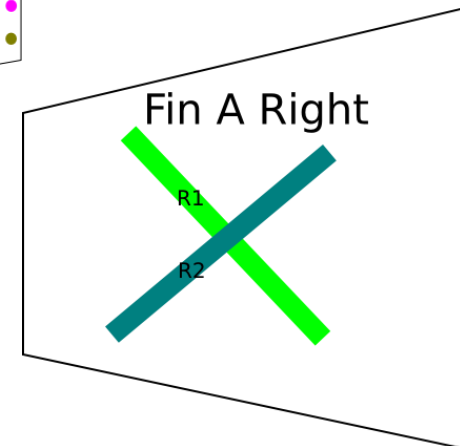
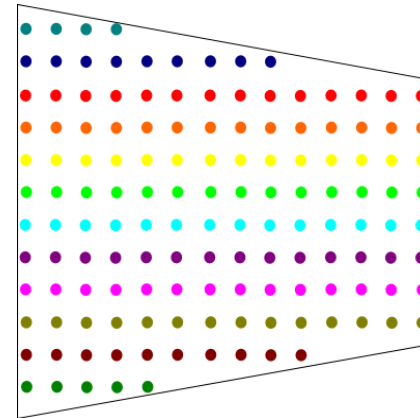
Fin flutter measurement system to quantitatively analyze the fin flutter induced modes in the three test fins

- High-speed Cameras
 - A Cassio Exilim camera for each fin
 - Recording at 480 frames per second
 - Securely mounted in avionics bay
- Software and Simulations
 - Models
 - Rockety Online
 - AeroFimSim 4.0
 - Reinfuth and Smith
 - Rocket Team
 - OpenCV image processing
 - Matlab image processing
 - Matlab strains to deflections converter
- Data (Predicted vs Experimental)
 - Time, velocity, and altitude at which fins experience flutter
 - Fin deflections versus time and velocity



Payload Design Overview

- Fin Design
 - Colored dot grid pattern
 - Pattern printed on sticker which is attached to the fin
 - Expected maximum flutter frequency $< 100\text{Hz}$
- Strain Gauges
 - 4 on each fin
 - 6 inches long
 - Data logged at over 1400Hz
 - Saved to SD card via Arduino
- Mirrors
 - Mounted on the outside of rocket
 - Enables head-on view of each fin



Payload Integration

- Strain gauges mounted to fins
- Internal electrical connections to avionics bay without tube on
- Tube slid onto avionics bay and fin unit stack and secured with screws

Interfaces

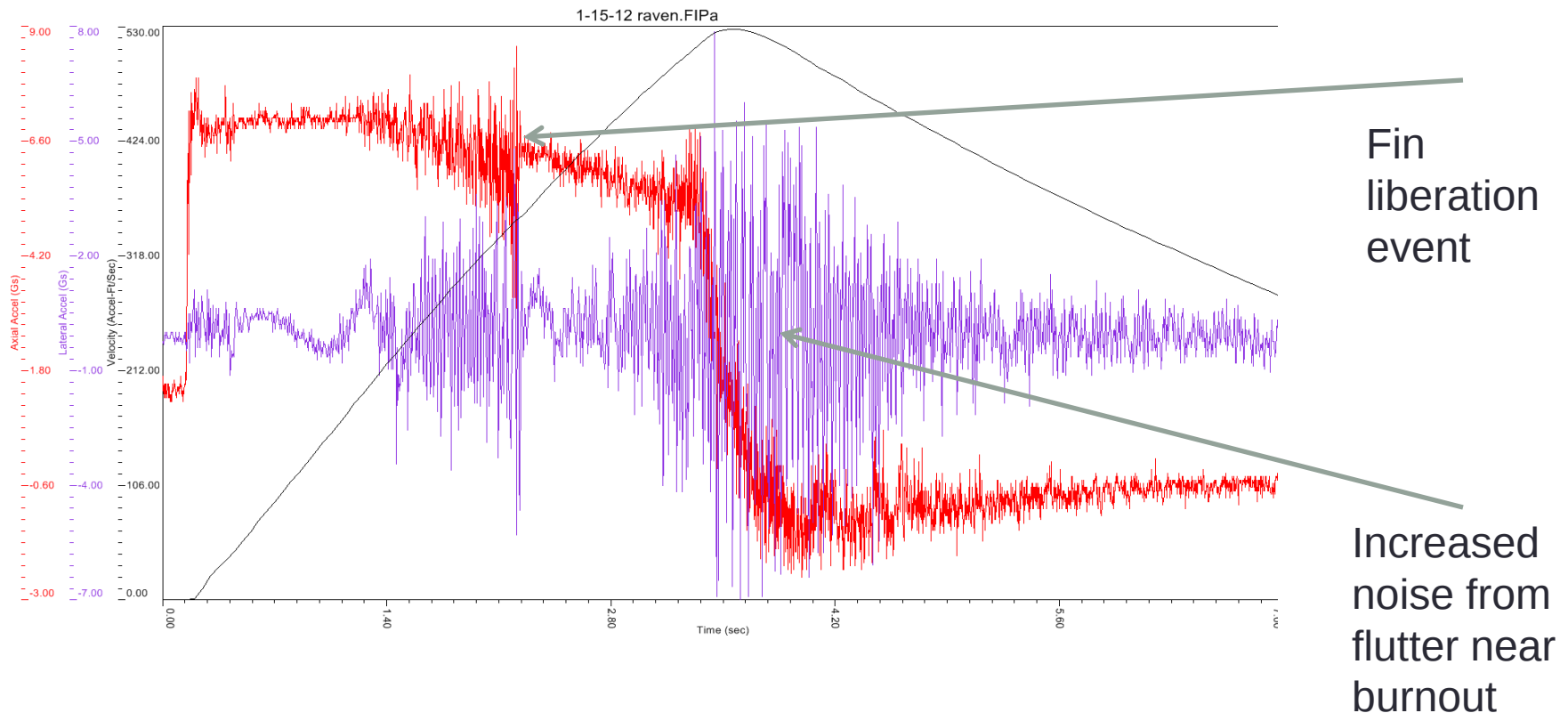
- Launch Rail
- Motor Clips
- Internal connection of avionics to ejection charges and strain gauges with headers
- Solenoid interface to activate cameras prior to launch

Full Scale Launch

- January 15 with MDRA outside Price, MD
- L1395
- 44.8 pound liftoff weight
- 15-20mph winds
- 4,890' apogee
- Test fins of same design as main fins, thicknesses of 1/32", 1/16" and 1/8" flown
- 1/32" fin failed at 2.3 seconds. 1/16" fin clearly fluttering.
- Streamer recovery not viable-free fin recovery slow enough

Full Scale Accelerometer Data

- Fin liberation event seen at 2.3 seconds.
- Noise from fin flutter clearly increases near burnout
- Integrated velocity and acceleration data not valid



Full Scale Launch

- March 24 with MMMS near Berwick, MN
- K1440
- 42.5 pound liftoff weight



Staged Recovery System Tests

- Altimeters and charges checked out prior to flight
- Full scale flight 1 recovery 100% successful



Launch vehicle verification and test plan overview and status

- Subsystem Tests
 - ~~Ejection Charges~~
 - ~~Avionics~~
 - ~~Recovery~~
 - ~~Fin~~
 - ~~Vehicle~~
- 3 Full Scale Test Launches
 - ~~1/15 at MDRA~~
 - ~~2/18 at CRMRC~~
 - ~~3/25 at MMMS~~
- Final Flight
 - 4/7 at MMMS
- Competition Launch
 - 4/21 Huntsville, AL

QUESTIONS?
