NASA STUDENT LAUNCH

2022-2023

Flight Readiness Review Addendum

University of South Florida

Society of Aeronautics and Rocketry

4202 East Fowler Avenue, MSC Box #197

April 3rd, 2023

UNIVERSITY of SOUTH FLORIDA
College of Engineering

Table of Contents

1. Summary of FRR Addendum

a. Team Summary

i. Team name and mailing address

Society of Aeronautics and Rocketry (SOAR) at the University of South Florida. Mailing address: 4202 East Fowler Avenue MSC Box 197 Tampa, Florida 33620

ii. Mentor name, TRA#, certification level, and contact information

Jonathan Fitzer. Member, Previous SOAR President (TRA# 17393, Certification Level III) (813) 389-3876, fitzer@mail.usf.edu

iii. Documented hours spent working on the FRR addendum milestone

Table 1: Documented hours

Name	Hours
Frank Alvarez	3
Enrique Hernandez	3
John Turner	3
Alvaro Lazaro	3

b. Purpose of Flights

The flights were conducted to fulfill the requirements of both the Payload Demonstration Flight and Vehicle Demonstration flight.

c. Flight Summary Information

i. Flight 1

Table 2: Flight 1 information matrix

Date	Location	Launch Conditions	Motor	Ballast
3/25/24	Varn Ranch, Plant City FL	Sunny, 5MPH SSW	Cesaroni K780	14oz
Final Payload Flown?	**Air Brake Info**	**Target Altitude**	**Predicted**	**Measured**
Y	N/A	4,500 ft	4125 ft	4,007 ft

- Off-nominal event:

  -Switch in avionics bay failed when turning on altimeters on the launch rod. Had to replace it on site after removing the rocket from rail.

  -Launch rod was not able to be canted 5 degrees towards the wind.

ii. Flight 2

Table 3: Flight 2 information matrix

Date	Location	Launch Conditions	Motor	Ballast
3/25/24	Varn Ranch, Plant City FL	Sunny, 5MPH SSW	Cesaroni K780	0oz
Final Payload Flown?	**Air Brake Info**	**Target Altitude**	**Predicted**	**Measured**
Y	N/A	4,500 ft	4,179	4,076 ft

- Off-nominal event:

  -Launch rod was not able to be angled 5 degrees towards the wind.

  -New 80" main was used due to burn damage in 60" main

d. Changes Made Since FRR

The first flight was conducted with no changes since the FRR. However, during flight the 60" main parachute sustained some burn damage and a shroud line was snapped. A new 96" main parachute was purchased from an on-site vendor and used in the second flight without incident. This is further detailed in Section 3, Vehicle Demonstration Re-Flight.

2. Payload Demonstration Flight Results

i. Altimeter Flight Profile Data

Flight Summary

Max Altitude	4007	Power Up Temp	96.8	Pad Time (min)	5.85	Descent Time	49.85
Max Velocity	499	Launch Temp	101.5	Power Up Volts	10.04	Drogue Rate	71
Ascent Time	18.05	Low Temp	101.7	Launch Volts	10.29	Main Rate	N/A
Flight File	Flight Filename TBD					Add Flight Notes	

Fig. 1: Launch 1 flight data from **backup** Missileworks RRC3

Flight Summary

Max Altitude	3986	Power Up Temp	96.8	Pad Time (min)	5.78	Descent Time	72.45
Max Velocity	484	Launch Temp	104.2	Power Up Volts	9.70	Drogue Rate	71
Ascent Time	17.85	Low Temp	104.2	Launch Volts	9.65	Main Rate	24
Flight File	Flight Filename TBD					Add Flight Notes	

Fig. 2: Launch 2 flight data from **backup** Missileworks RRC3

Flight Summary

Max Altitude	4076	Power Up Temp	98.6	Pad Time (min)	6.85	Descent Time	74.75
Max Velocity	477	Launch Temp	102.4	Power Up Volts	9.67	Drogue Rate	55
Ascent Time	17.2	Low Temp	101.5	Launch Volts	9.59	Main Rate	26
Flight File	Flight Filename TBD					Add Flight Notes	

Fig. 3: Launch 2 flight data from **main** Missileworks RRC3

The main altimeter did not record data from the first flight for some reason. The main altimeter did deploy the black powder charges for the first flight. This has led SOAR to believe that the hard landing of the avionics bay may have led the main altimeter to lose that data due to a faulty connection.

ii. Kinetic Energy Calculations

The mass of the flight vehicle has stayed the same since the FRR report. Therefore, the kinetic energy calculations are roughly the same as before. The main difference in the calculations is the addition of the ballast weights in the avionics bay. The max additional weight that the ballast can hold is 14 oz.

Upper Body Tube:

Total Mass: 10.49 lbs

Total Kinetic Energy: 65.850 ft-lb

Avionics Bay (14oz Ballast):

Total Mass: 3.75 lbs

Total Kinetic Energy: 23.29 ft -lb

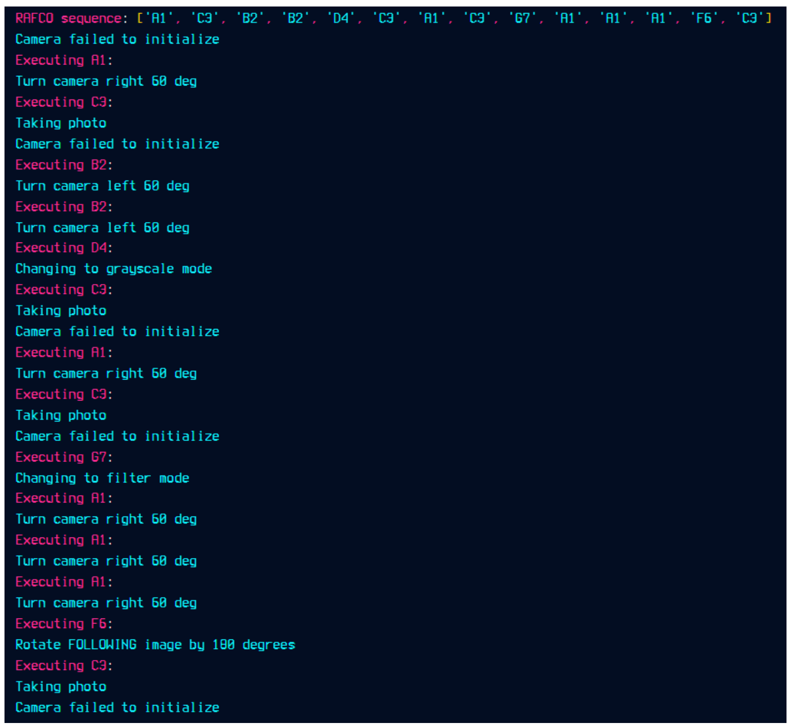
Booster Tube:

Total Mass: 7.13 lbs

Total Kinetic Energy: 44.758 ft-lb

iii. Payload System Function

During our two flights, many systems functioned as intended, but there were some functions that did not perform as inspected. During the first flight, the piston cover did not fully open. From a software side, the rest of the system was verified to be correct and in the proper sequence. Even though the camera failed to initialize due to a hardware issue (discussed in the next section) main computer transmitted the a sample of RAFCO commands (A1, C3, B2, B2, D4, C3, A1, C3, A1, A1, A1, F6, C3) successfully to the microcontroller, and executed the picture commands at correct timing, without any communication error:



```
RAFCO sequence: ['A1', 'C3', 'B2', 'B2', 'D4', 'C3', 'A1', 'C3', 'G7', 'A1', 'A1', 'A1', 'F6', 'C3']
Camera failed to initialize
Executing A1:
Turn camera right 60 deg
Executing C3:
Taking photo
Camera failed to initialize
Executing B2:
Turn camera left 60 deg
Executing B2:
Turn camera left 60 deg
Executing D4:
Changing to grayscale mode
Executing C3:
Taking photo
Camera failed to initialize
Executing A1:
Turn camera right 60 deg
Executing C3:
Taking photo
Camera failed to initialize
Executing G7:
Changing to filter mode
Executing A1:
Turn camera right 60 deg
Executing A1:
Turn camera right 60 deg
Executing A1:
Turn camera right 60 deg
Executing F6:
Rotate FOLLOWING image by 180 degrees
Executing C3:
Taking photo
Camera failed to initialize
```

Fig. 4: Log of the computer completing RAFCO sequence in spite of hardware issues

Though the piston did not open fully, preventing the camera from extending out of the tube, we were able to verify that nearly all of the motors on the gimbal system moved to the proper final position (within our determined tolerance). This included the stepper motor choosing the proper opening, the first servo attempting to extend the rack, the second servo did attempt to align the camera upright but was blocked by the piston. Due to this, we were unable to verify if the microstepper had completed a 360 degree rotation about the Z-axis.

For the second flight, the piston cover did in fact fully open, and the camera did align to the Z-axis. However, as the gear that extends the camera rack went missing, we were unable to verify if the camera would have properly extended out of the airframe. Similar to the first flight, we were able to verify that all of the software ran at the proper time and moved the motors to the correct position.

iv. Hardware Failures

There were some minor failures and one major failure on the hardware side of the payload system. A first minor failure that will be easily fixed was the wear down of our camera ribbon cable, which we should've replaced before the main launch but didn't take into account, which therefore didn't allow our system to successfully take pictures even though the commands did run in the correct sequence. During our first (of two) flights, as mentioned above, the piston cover was unable to fully open as it did during ground testing. Though the system did initialize and the cover began to move part of the way, it only revealed about half of the target area (the openings in the body tube). We are assuming this is because the servo motor was improperly mounted to its 3D printed base. This made the mesh between the gear and the rack looser than intended and did not provide the proper force to pull the rack (and thus the piston).

Another area of concern is the wiring of the gimbal system. During ground testing, we calculated that the gimbal could only rotate twice before the wires would tangle. In theory, after a launch, the system would only need to move 180 degrees in either direction, meaning we would be within a feasible range of rotation. However, during the first flight, the gimbal system did in fact tangle, and prevented the last ~20 degrees of needed rotation. To prevent this, we have redone where wires are taped together, and drilled additional openings in the bulkhead to allow wires to remain separated before passing through.

Additionally, once the rocket was recovered after the first flight, we noticed that the gear of the rack and pinion that moved the camera system out of the airframe was simply missing. We assume the cause of this is due to the piston cover system preventing the camera system from extending outward, and the force of the motor against a stuck rack causing the gear to push out and off of the servo motor. Though this gear went missing post recovery, there was no damage to any other 3D printed components, even with the pressure against the closed piston.

During the second flight, in which we ran the system without this gear, we did not find additional failures on the hardware side. During this second flight, as mentioned, the piston was able to fully open. Since the gear was not placed on the motor, we could only detect the alignment of the camera from within the tube, which we indicated to be properly vertical due to the selected opening (via main stepper motor) and the final adjustment of the camera base.

v. Lessons Learned

There are a variety of lessons the demonstration flight taught us. First, though we bought extra copies of many of the 3D printed components in the case they failed (as we noticed in ground testing) we did not bring extra individual gears. This prevented us from testing key features on the second launch, as the camera extending gear was simply missing. In the final launch, we will thus bring additional gears to ensure that for the launch, the gear is still properly fitted onto the motor.

We also learned the need to bring extra ribbon cables to replace the current ribbon cables attached to the main camera in the circumstance that they get too much degraded from the continuous testing.

Next, to assist with the piston opening, we will reprint the mount for the rack and pinion attached to the piston. This will give us a chance to reevaluate how the motor is mounted, and ensure that the mesh between the gear and the rack is enough to overcome the resistance of the piston on the body tube. We will also use synthetic grease on the outside of the piston coupler tube component to reduce the friction between this piece and the inside of the body tube.

3. Vehicle Demonstration Re-Flight

a. System Function

i. Aerostructures

The aerostructures components withstood the sequence of both flights. There was no zippering that occurred on the rim of the body tubes. No cracking was observed on the epoxy. Tip of the nose cone was not damaged.

ii. Recovery

The recovery system functioned as intended. Both the main and backup altimeters detonated their black powder charges for each launch. The main and drogue parachutes had no issue deploying without tangling. The GPS module also functioned throughout the duration of both flights. The landing location of the rocket was almost identical for both the first launch and second launch.

b. System Failures

i. Altimeter

On the first launch, one of the altimeters did not record the data onto its memory. The altimeter was still on when the flight vehicle was collected after the launch. We are unsure as to why this occurred. The same altimeter collected data for the second launch without any issues.

ii. Main Parachutes

The main 60” parachute with a Cd of 2.2 for the first launch obtained holes near the center of the parachute and a shroud line was sheared off after flight.

SOAR had to purchase another main parachute at the launch which was a 96” main parachute with a Cd of 0.97. This led to similar performance in terms of descent times.

The 60” main had a descent time of 67.9 seconds. The 96” main parachute had a descent time of 70.7 seconds.

To the surprise of the team, the new parachute had holes as well near the center. SOAR determined that the black powder charges lead to the holes in the parachutes as it was getting inside the nomex fire protectant.

c. Altimeter Flight Profile Data

The flight data collected from the altimeters can be seen below.

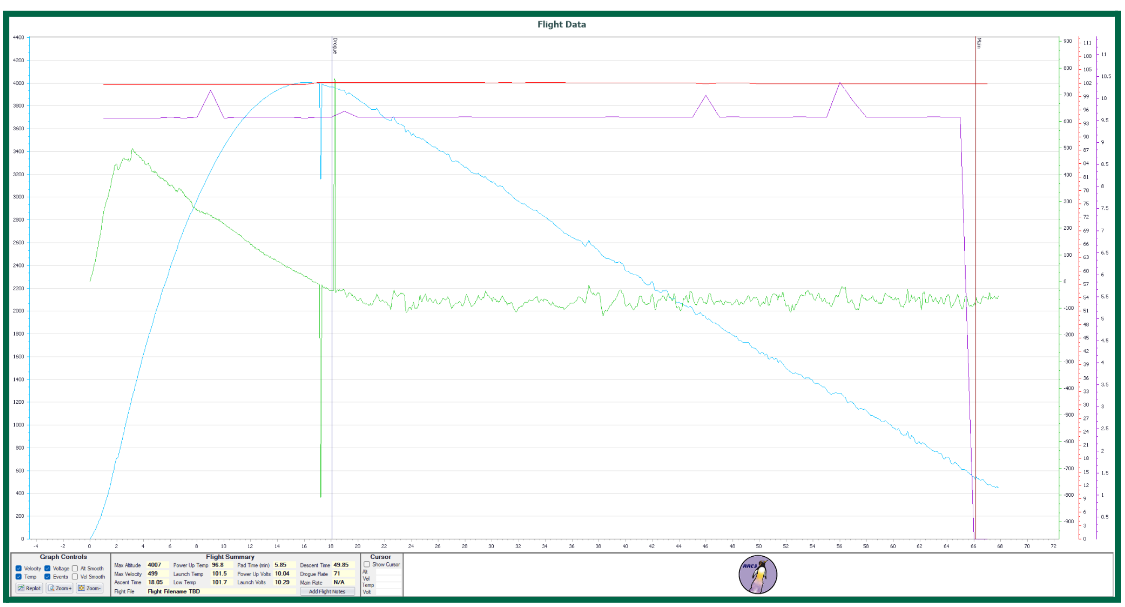


Fig. 5: Launch 1 flight graph from **backup** Missileworks RRC3

Flight Summary							
Max Altitude	4007	Power Up Temp	96.8	Pad Time (min)	5.85	Descent Time	49.85
Max Velocity	499	Launch Temp	101.5	Power Up Volts	10.04	Drogue Rate	71
Ascent Time	18.05	Low Temp	101.7	Launch Volts	10.29	Main Rate	N/A
Flight File	Flight Filename TBD					Add Flight Notes	

Fig. 6: Launch 1 flight data from **backup** Missileworks RRC3

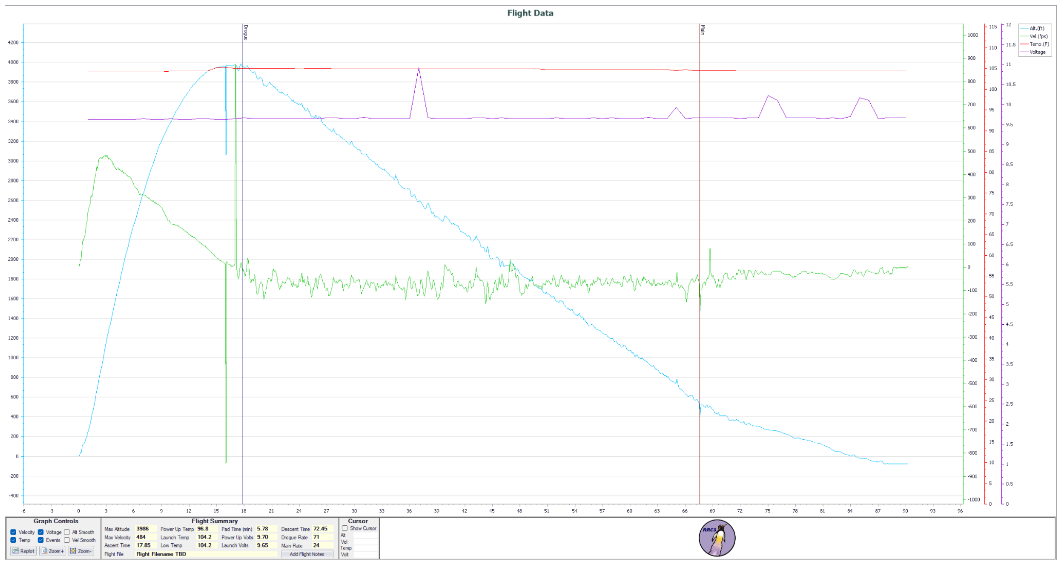


Fig. 7: Launch 2 flight graph from **backup** Missileworks RRC3

Flight Summary							
Max Altitude	3986	Power Up Temp	96.8	Pad Time (min)	5.78	Descent Time	72.45
Max Velocity	484	Launch Temp	104.2	Power Up Volts	9.70	Drogue Rate	71
Ascent Time	17.85	Low Temp	104.2	Launch Volts	9.65	Main Rate	24
Flight File	Flight Filename TBD					Add Flight Notes	

Fig. 8: Launch 2 flight data from **backup** Missileworks RRC3

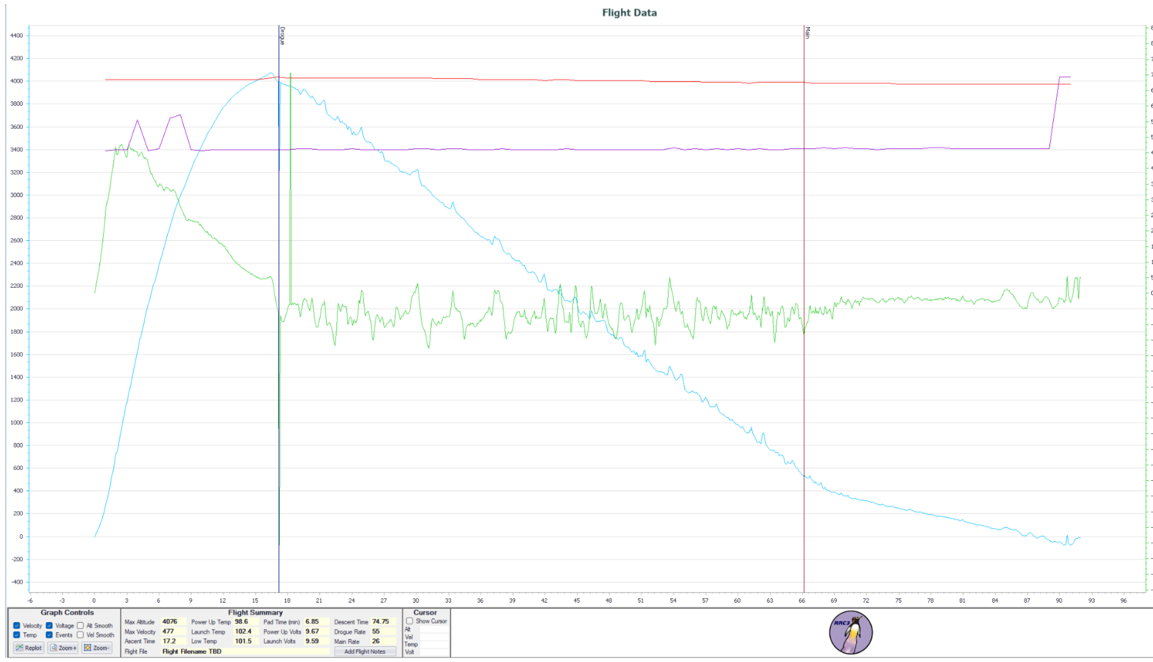


Fig. 9: Launch 2 flight graph from **main** Missileworks RRC3

Flight Summary

Max Altitude	4076	Power Up Temp	98.6	Pad Time (min)	6.85	Descent Time	74.75
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Flight File	Flight Filename TBD					Add Flight Notes	

Fig. 10: Launch 2 flight data from **main** Missileworks RRC3

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d. Photography of Landings

i. First Launch

Fig. 11: Launch 1 landing of rocket

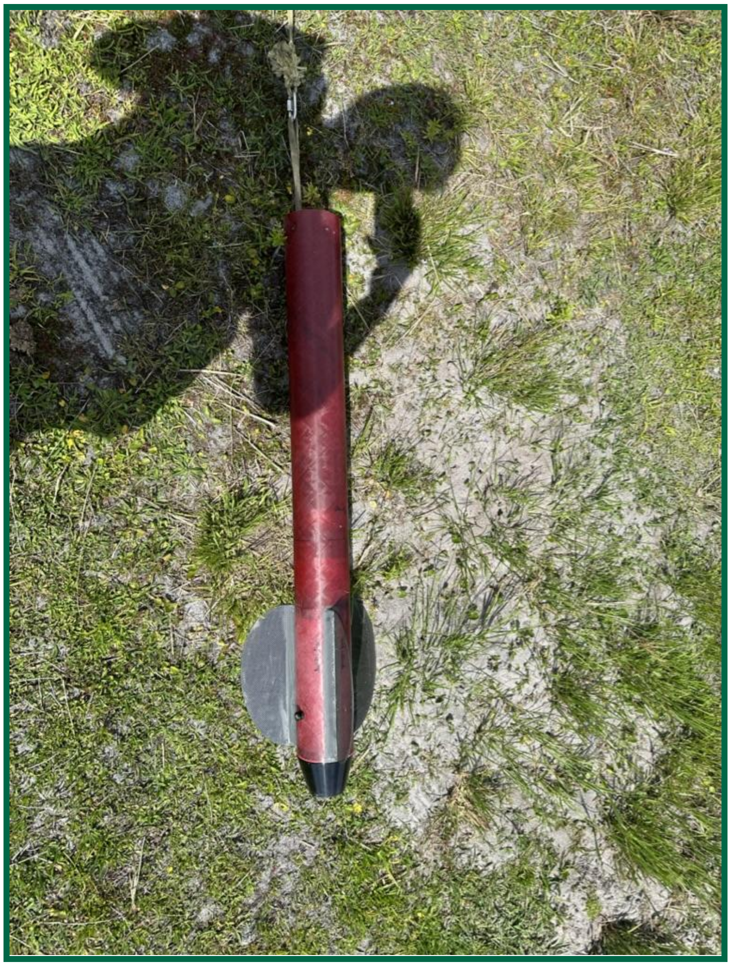

Fig. 12: Launch 1 Booster Tube

Fig. 13: Launch 1 Upper Tube and avionics bay

Fig. 14: Launch 1 Avionics Bay

The second launch landing photos were not taken due to the fact that there was a large snake very close to our rocket. However, we do have the photos of the rocket landing from videos taken of its flight.

Fig. 15: Launch 2 Recovery Descent.

Fig. 16: Launch 1 Recovery Descent

e. Kinetic Energy Calculations

The mass of the flight vehicle has stayed the same since the FRR report. Therefore, the kinetic energy calculations are roughly the same as before. The main difference in the calculations is the addition of the ballast weights in the avionics bay. The max additional weight that the ballast can hold is 14 oz.

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Total Kinetic Energy: 65.850 ft-lb

Avionics Bay (14oz Ballast):

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Total Kinetic Energy: 23.29 ft -lb

Booster Tube:

Total Mass: 7.13 lbs

Total Kinetic Energy: 44.758 ft-lb

f. Vehicle Demonstration Flight Analysis:

The results of the analysis is that the simulated flight model is similar to the flight performance at the launch day. The fine tuning of the wind values in the plotting section can always be improved by collecting more wind data with the anemometer during the launch day. All though the average wind speed was at 5 mph during the day, there was gusts of wind that reached up to 12 mph. This could have led to the changes in the apogee that we saw with the flight data.

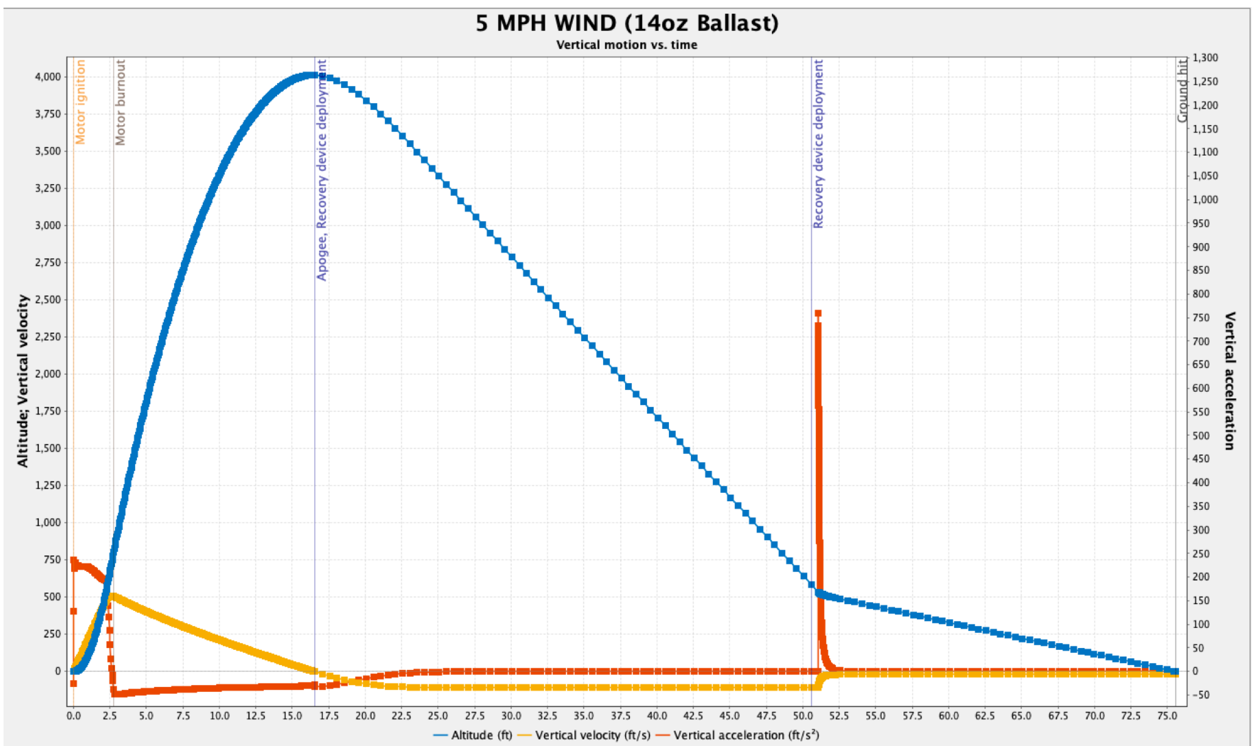

Fig. 15: Simulated flight model with launch day conditions.

g. Damaged Hardware

As previously stated, one of the switches on the avionics bay stopped functioning during the arming of the altimeters on the launch rail. This led to our team removing the flight vehicle from the rail and replacing the faulty switch with a functional one.

The damage of the main parachutes exposed how SOAR should bring backup parachutes of the same time if multiple launches are wanted in one day. Also, there is never enough insulation that can be used to make sure that the main parachutes are not going to obtain a burn from the black powder charges.

h. Lessoned Learned

-The flight vehicle shall have a final mass check and a final updated OpenRocket file. Slight changes in the location of mass objects can affect the accuracy of the simulation software. SOAR will be re-massing all of the items inside the air frame.

-The main parachutes must have more insulation to preserve the recovery system.

-Test and verify that the avionics electronics are functional before mounting them to the launch rod.

-If possible, try to cant the launch rod 5 degrees towards the wind to make your test launch as close to the actual launch in Huntsville, Alabama.

-Collect more wind data during the launch to refine simulated apogees and landing locations.