Project Photogator

NASA Student Launch 2023 Flight Readiness Review Addendum

University of Florida
Swamp Launch Rocket Team
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Gainesville, FL 32611
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1. Summary of FRR Addendum

1.1 Team Summary

1.1.1 Team Name & Address

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1.1.2 Contact Information

Primary Contact: Erik Dearmin (Team Lead)
Email: dearmin.erik@ufl.edu

1.1.3 Hours Spent on FRR Addendum

The total time spent developing the flight readiness review addendum was 42 hours.

1.2 Purpose of Flight

The flight addressed in this addendum was conducted to satisfy the payload demonstration flight requirement.

1.3 Flight Summary Information

The summary information of the Payload Demonstration Flight was tabulated (Table 1).

Payload Demonstration Flight Summary	
Date of Flight	March 25, 2023
Location of Flight	Tampa Bay Rocketry Association (Prefecture #17)
Launch Conditions	3 mph wind, 86˚F, 5˚ launch angle
Motor Flown	Aerotech L1090-W
Ballast Flown	N/A
Final Payload Flown	Yes
Air Brake System Status	N/A
Official Target Altitude	4600 ft
Predicted Altitude from Simulations	4975 ft
Measured Altitude	4974 ft
Measured Drift from Launch Rail	2454 ft
Descent Time	84.5 s
Off-nominal Events	Vehicle landed in a tree; flight itself was nominal

Table 1: Payload Demonstration Flight Summary

1.4 Changes Made Since FRR

After the flight readiness review, the launch vehicle's surface finish was altered to perform closer to the team's declared target altitude. The surface roughness of the launch vehicle was overestimated prior to Vehicle Demonstration Flight, so the surface of the launch vehicle was roughened before the Payload Demonstration Flight to increase the skin friction drag experienced by the vehicle, and thereby lower its apogee altitude. To apply a rough surface finish, a layer of fine-grain sand was uniformly applied to the forward airframe, the central airframe, and the payload airframe. The sand was then sealed to the airframe with a layer of primer and two layers of paint.

In addition to the surface finish, some modifications were made to the payload. After a test fit of the payload, the payload electronics coupler was repositioned 0.7 in forward of its original position to allow the payload's wires to fit within the payload airframe. This change is still within accordance of NASA's requirement that a separation point have at least one diameter of coupler between the two sections. The coupler now has 4.7 in within the central airframe, which separates from the coupler, and 3.3 in within the payload airframe, which does not separate from the coupler.

2. Payload Demonstration Flight Results

2.1 Payload Execution Sequence

The payload acts as a simple state machine that transitions to the next state only when certain criteria are met. The payload will startup and configure the external IMU and barometer for data collection and perform health checks to make sure the systems are ready.

Once the payload has passed the startup and health check states, it will start a continuous loop of reading the acceleration and pressure data from the IMU and barometer to detect launch. Once either of those components has detected launch conditions, the payload will enter the next state, which is to wait for landing. Landing is detected by waiting for the acceleration of the payload to stabilize after the noise from launch.

When the payload successfully lands, it will then calculate its orientation relative to the ground and begin listening for radio messages. If a message is received with the proper callsign and command format, those events are decoded and sent to the systems for execution.

Finally, the cameras and motors will perform all the operations and the payload will save all data to the Raspberry Pi's SD card to be analyzed afterwards. Then the payload will turn off all external components and enter an idle state until recovered. Figure 1 represents a simplified state flowchart of all the events that the payload will step through.

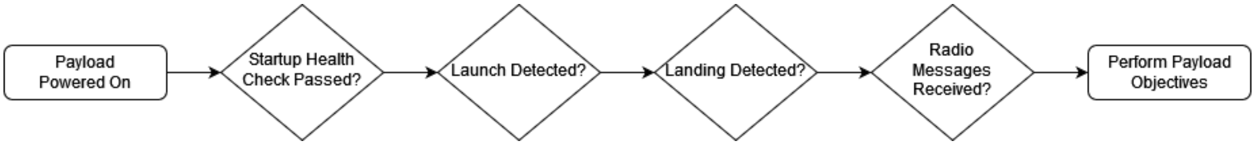

Figure 1: Software State Flowchart

2.2 Payload Retention

2.2.1 Payload System Retention

Each payload system is mounted inside the airframe with threaded inserts and 8-32 fasteners so that the outer surface of the camera mount is flush with the outer diameter of the airframe (Figure 2).

Figure 2: Payload Assembled in Launch Vehicle

Each of the three camera systems is retained in its own housing (Figure 3). Each system has a stepper motor that is fastened inside the housing (Figure 4). Each housing features two rectangular holes in its walls for motor and camera wires to pass through. The housing secures the motors with fasteners and protects the launch vehicle from potential mechanical failure.

Figure 3: Payload Housing Retention

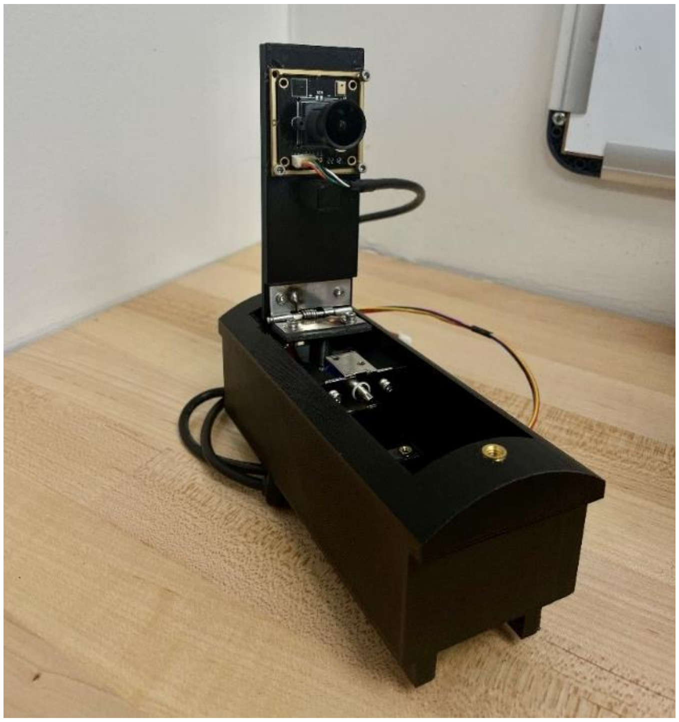

Figure 4: As-built Payload System

The central payload system includes a designated fastening compartment for the radio (Figure 4). The 3D printed bottom surface of the radio compartment will be fastened to the walls of that compartment with M2.5 fasteners (Figure 5). When the solenoid retracts, the camera mount system rotates on the spring-loaded hinge to its naturally released state out the airframe. The spring-loaded hinge is fastened to a spring mount. The mount and hub are 3D printed with PET-G, and the torque is transmitted through two M4 threaded inserts and set screws. The spring mount is secured to a stepper motor that rotates the camera system about the z-axis. The stepper motor aligned with the fin normal to the ground receives commands for the payload challenge.

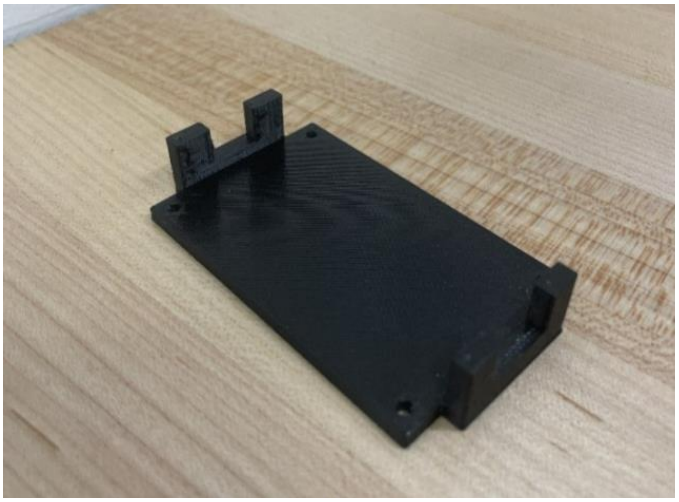

Figure 5: Radio Housing Retention Cover

2.2.2 Payload Electronics Retention

All the electronic components are integrated into the payload electronics housing assembly. The assembly consists of a sled and a two-piece battery housing that is secured to the sled with two threaded rods (Figure 6). A Raspberry Pi 4 and a PCB are retained on top of the sled with M2.5 fasteners. All the other electronic components are connected to the PCB through solder joints. Two power supplies are retained through the battery housing on the bottom of the sled (Figure 6, Figure 7).

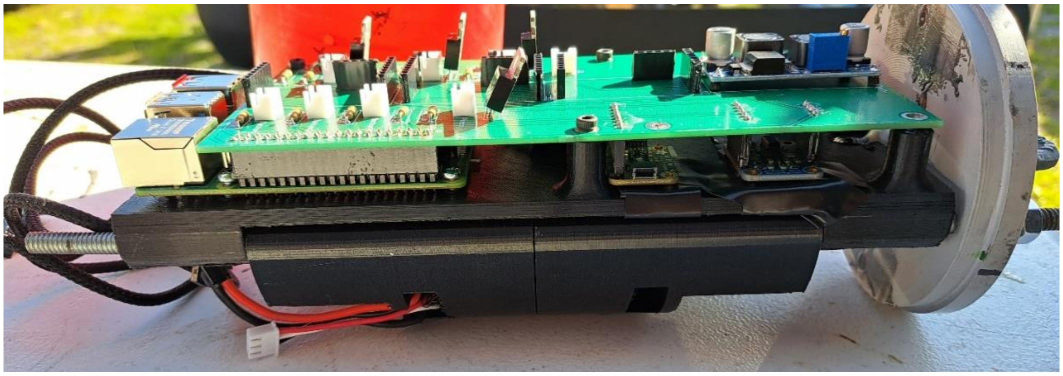

Figure 6: Payload Electronics Housing Assembly with Raspberry Pi 4, PCB, and battery attached

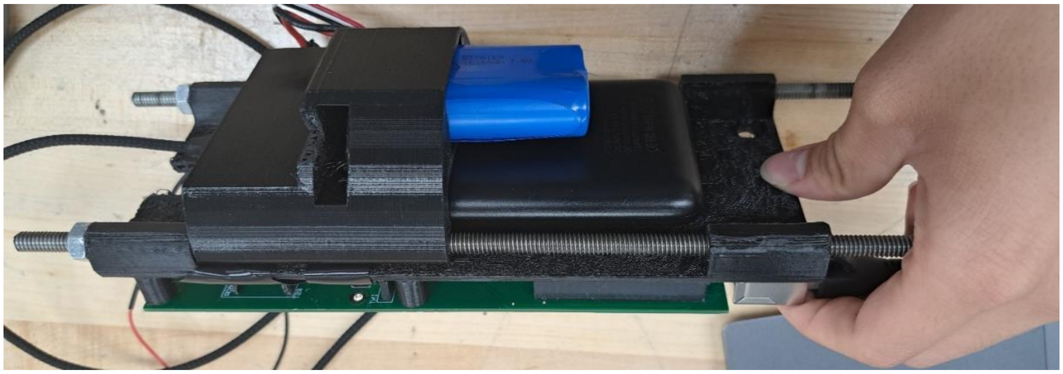

Figure 7: Payload Electronics Housing Assembly with 1 of the two pieces of battery housing (to show the structure)

The payload electronics housing assembly fits into the payload bay (Figure 8).

Figure 8: Payload Bay with all electronics inside with the Payload Electronics Housing

2.3 Payload Functionality

2.3.1 Functional Systems

2.3.1.1 Mechanical Systems

The payload mechanical systems were fully assembled and installed in their final configuration for the payload demonstration flight. All three camera systems were successfully retained within the vehicle during launch and recovery (Figure 9). None of the systems sustained any damage and can be re-used for the final flight. Additionally, all the onboard electronic systems were successfully retained within the payload electronics coupler. This was verified by inspecting them and by analyzing the data from the altimeters, onboard IMU, onboard barometer, and onboard GPS and by verifying data that was collected throughout the entire flight. Therefore, all payload mechanical systems were successful in safely retaining the payload in the vehicle.

Figure 9: Payload Retained in Vehicle Post-Recovery

2.3.1.2 Electrical Systems

All the electronics components function as intended. The Raspberry Pi powered on and automatically began running the flight program. The IMU and barometer were running and provided data to the Raspberry Pi throughout the entire launch window. The radio and actuator systems were functioning but never got activated due to a software issue. The power supply kept the payload system active for the entire four-hour launch and recovery window.

All the electronics were retained during flight and were functioning after the flight. The Raspberry Pi and PCB were retained on top of the sled and the power supplies were not damaged (Figure 10, Figure 11).

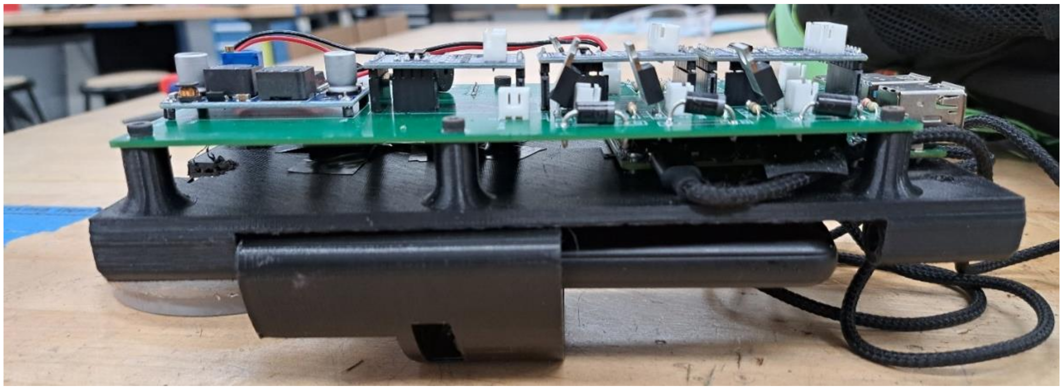

Figure 10: Side view of the Payload Electronics Housing Assembly after the Payload Demonstration Flight

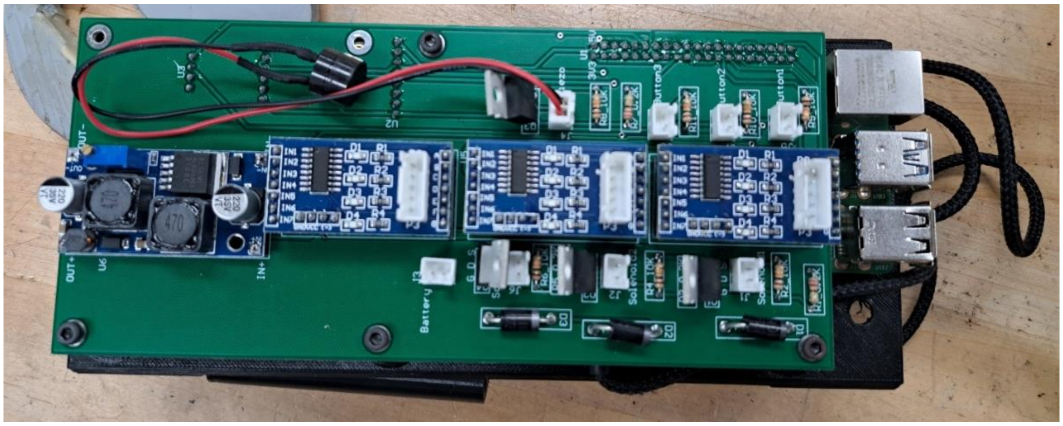

Figure 11: Top view of the Payload Electronics Housing Assembly after the Payload Demonstration Flight

2.3.1.3 Software Systems

The payload was set up in its final flight configuration the night before launch and tests were performed on the launch site to confirm functionality. One important aspect of the payload system that proved useful during launch site preparations was the piezo, which provided routine beeps that conveyed that the payload was still healthy. The payload performed mostly as expected except for an anomaly that occurred in the payload state sequencing that will be discussed in section 2.3.3. Even though that anomaly occurred, the payload continued to operate and collect important data where it was still able. Most importantly, the payload was successfully able to detect and log launch detection at the proper moment. Figure 12 represents the full x, y, and z axis acceleration data starting from launch until the payload landed in the trees.

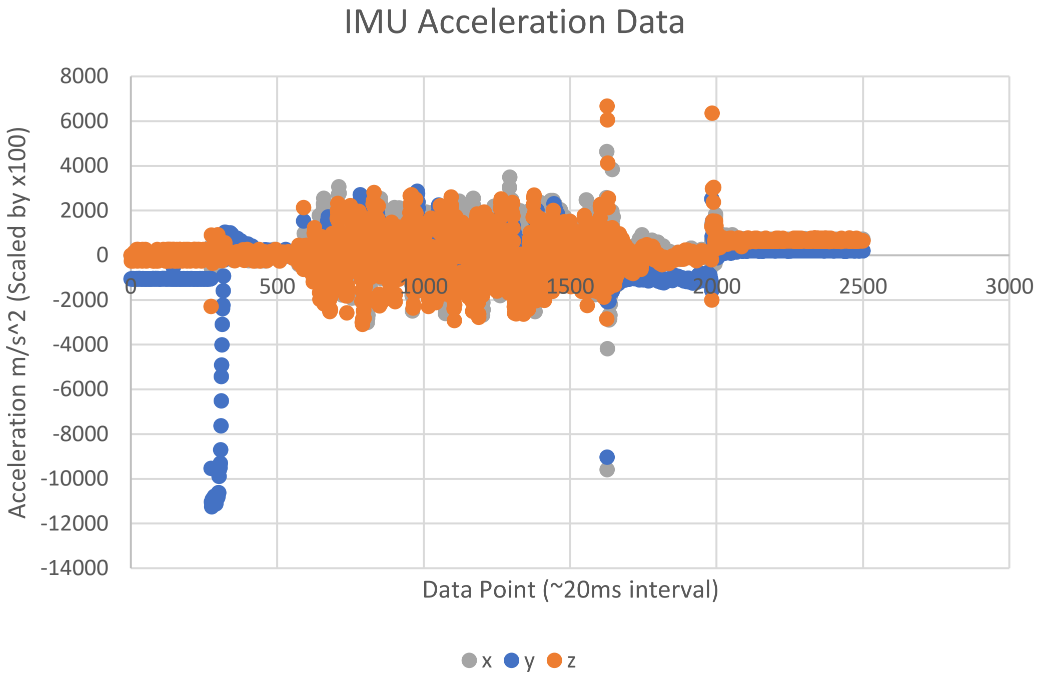

Figure 12: IMU Acceleration Graph

As shown in the graph, the successful launch detection is depicted by the negative spike in blue representing the y-axis acceleration. This once again confirmed that the payload is successful in collecting acceleration data and detecting launch. In addition to the acceleration data that was collected during payload demonstration, the payload was successful in collecting pressure data. This is the first successful collection of pressure data during flight. This data was graphed (Figure 13).

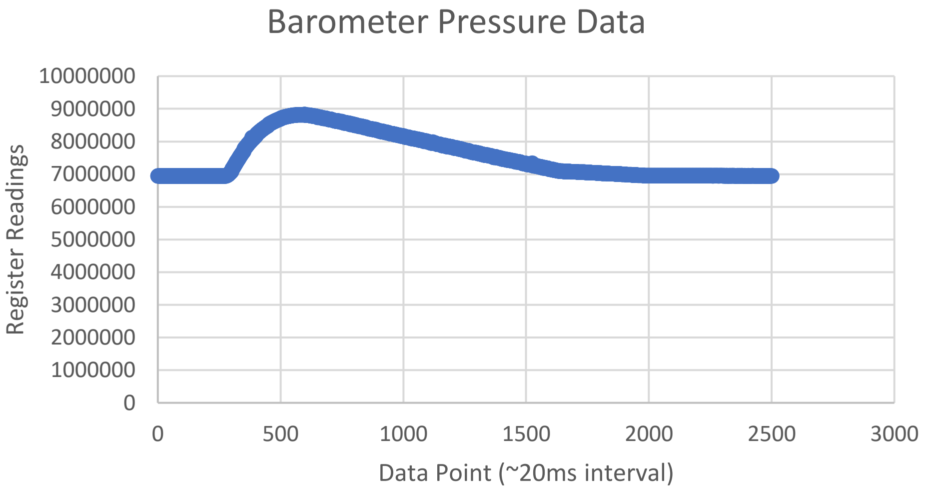

Figure 13: Barometer Pressure Data

Finally, the radio and motors in the camera systems were tested at the launch site and performed nominally. However, due to the state sequencing issue mentioned above and explained more in section 2.3.3, they were unable to perform once the payload had landed.

2.3.2 Hardware Failures

There were no hardware failures. The vehicle and payload were all undamaged and can be re-used for flight and successful payload operation.

2.3.3 Software Failures

There was a constraint error in the software system that prevented the payload from transitioning from the flight state to the landed state. This can be associated with two factors, the first being that the payload and vehicle landed in a tree. This provided an unstable landing surface that caused the payload to continuously move slightly due to the wind. This combined with fluctuations in acceleration data from the IMU meant that the predefined constraints were too narrow to detect landing; therefore, the payload was not able to transition to the landed state. As a result, it was unable to perform any further operations. This will be solved by broadening the landing detection criteria and including a secondary timer as a backup that will be configured for twice the precalculated flight time to make sure the payload does not experience the same failure.

2.4 Flight Data

Altitude data was collected during vehicle demonstration flight by the altimeters (Figure 14).

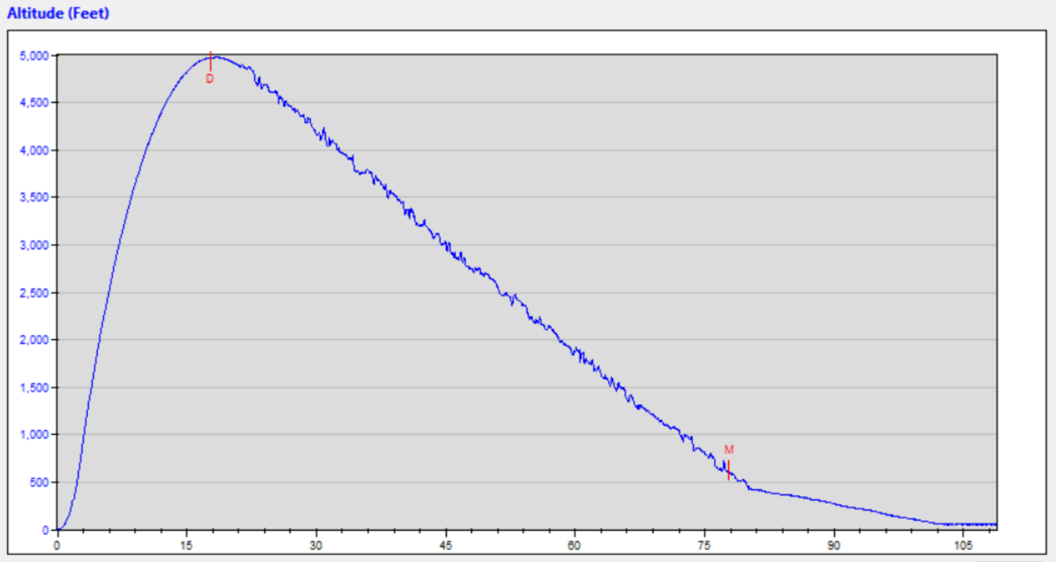

Figure 14: Altitude Data Collected During Payload Demonstration Flight

The launch vehicle landed in a tree (Figure 15).

Figure 15: Vehicle Landed in Tree (Left to Right: Nosecone Section, Central Section, Aft Section)

The launch vehicle was undamaged (Figure 16-Figure 19).

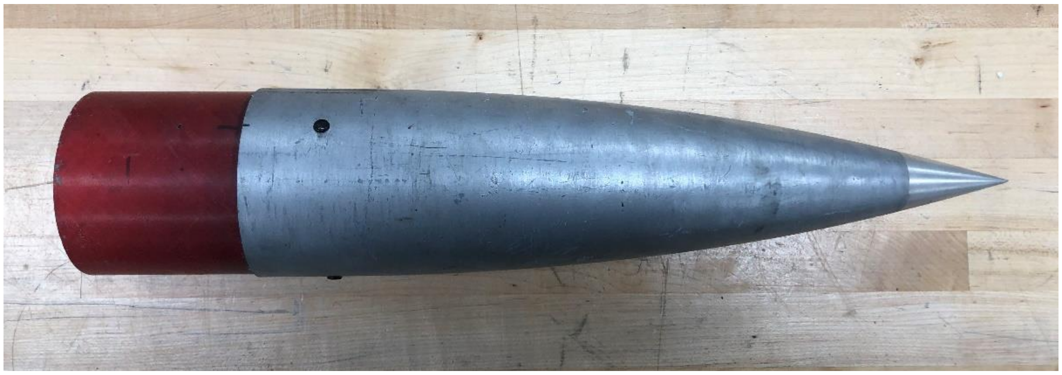

Figure 16: Nosecone Section Post-Recovery

Figure 17: Forward Airframe Post-Recovery

Figure 18: Central Airframe Post-Recovery

Figure 19: Aft Section Post-Recovery

Average descent rates under the drogue and main parachutes were determined from the altimeter flight data (Table 2).

Descent Rates from Payload Demonstration Flight	
Drogue Parachute	76.1 ft/s
Main Parachute	17.1 ft/s

Table 2: Experimental Descent Rates

To ensure that competition requirements were met, kinetic energy at ground hit was calculated using the masses of each section and the experimental descent rate from payload demonstration flight (Table 3).

Kinetic Energy at Ground Hit			
Section	Nosecone	Forward	Aft
Magnitude	7.9 ft-lb	33.0 ft-lb	61.1 ft-lb

Table 3: Kinetic Energy at Ground Hit for Each Section of the Launch Vehicle

Drift from the launch pad to landing was recorded with the GPS (Figure 20). The total drift was 2,454 ft which was under the 2,500 ft requirement.

Figure 20: Measured Drift from the Launch Pad

2.5 Lessons Learned

A lesson learned regarding the payload software is to test edge cases and constraints in the program. The situations that the payload encounters during a launch are much more dynamic and unexpected than when testing in the lab. Therefore, the payload software must be more capable in adapting and handling those situations better to successfully ensure execution. Going forward, the constraints will be widened, and more dynamic tests will be performed in attempt to trick the payload to find other edge cases that might occur.

3. Conclusion

Based on the payload demonstration flight results addressed in this flight readiness review addendum, the University of Florida Swamp Launch Rocket Team is confident in the ability of the payload retention system and payload to meet the requirements set externally by NASA and internally by the team.