Gator Locator

NASA Student Launch 2022 Flight Readiness Review Addendum

University of Florida
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939 Center Drive
Gainesville, FL 32611
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1. Summary of FRR Addendum

1.1 Team Summary

1.1.1 Team Name and Address

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1.1.2 Contact Information

Primary contact: Megan Wnek (Team Lead)
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1.1.3 Hours

The total number of hours spent on the design, manufacturing testing, planning, meeting, and writing for the Flight Readiness Review Addendum was 102 hours.

1.2 Purpose of Flights

The flight conducted was done so to fulfill the requirement for the Payload Demonstration Flight.

1.3 Flight Summary Information

Table 1 highlights all important summary information related to the Payload Demonstration Flight.

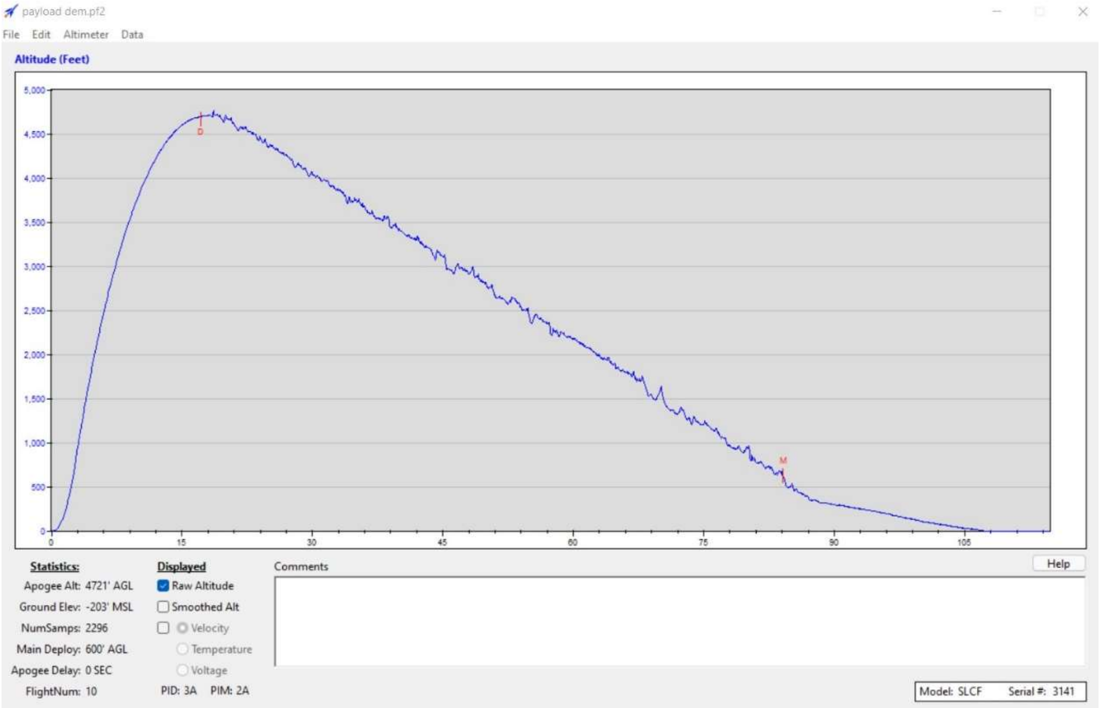
Payload Demonstration Flight Summary	
Date	March 19th, 2022
Location	Tampa Tripoli, Plant City
Launch Conditions	2 mph, 82°F, 1° cant
Motor Flown	Aerotech L1090W
Ballast Flown	1 kg (maximum ballast allowed)
Final Payload Flown?	Yes
Airbrake System Status	N/A
Official Target Altitude	4578 ft
Predicted Altitude from Simulation	4950 ft*
Measured Altitude	4721 ft
Descent Time	89 s
Max Kinetic Energy at Ground Hit	55 ft-lbs
Drift from Launch Rail	180 ft
Off-nominal Events?	N/A

Table 1: Payload Demonstration Flight Results

*This simulation does not include any of the drag effects that may exist due to the addition of paint layers

The flight resulted in all components being recoverable and reusable (Figure 1). The resulting altimeter flight data is shown (Figure 2).

Figure 1: Landing site of launch vehicle after Payload Demonstration Flight



Statistics:
Apogee Alt: 4721' AGL
Ground Elev: -203' MSL
NumSamps: 2296
Main Deploy: 600' AGL
Apogee Delay: 0 SEC
FlightNum: 10

Displayed
☑ Raw Altitude
☐ Smoothed Alt
☐ ○ Velocity
○ Temperature
○ Voltage
PID: 3A PIM: 2A

Model: SLCF Serial #: 3141

Figure 2: Altimeter data from Payload Demonstration Flight

1.4 Changes made since FRR

The only change made to FRR was the additional paint added to the launch vehicle exterior, which did not constitute a re-flight of the Vehicle Demonstration Flight. This change was approved by the NASA Student Launch board prior to the Payload Demonstration Flight. Four layers of primer and two layers of black paint were added to the paint job, thus increasing the mass by 4.6 oz and roughening the surface finish. The result as seen from the Payload Demonstration was a decrease in altitude, by roughly 184 ft, due to an increase in mass and drag.

2. Payload Demonstration Flight Results

2.1 Payload Mission Sequence

Upon startup, the payload enters a low-power idle state. In this state, the payload continuously collects inertial measurement unit (IMU) and altimeter data while the cameras are disabled. The payload remains in this state until launch is detected, which is determined by an acceleration greater than 83 ${}^{\text{ft}}/_{\text{s}^2}$ and an increase in altitude (Figure 3).

In the launch state, the cameras, IMU, and altimeter are active. Both cameras continuously capture images, which are each stored with a time stamp and the altitude at which the image was taken. The inertial measurement unit data, including the vehicle's acceleration and angular rate, is stored along with the time at which it is collected. The payload remains in this state until landing is detected, which is determined by an acceleration below 36 ${}^{\text{ft}}/_{\text{s}^2}$ and a constant altitude below 50 ft.

Upon landing, the payload begins processing the captured images. Images taken near apogee are compared to a pre-uploaded image of the launch field using the Scale Invariant Feature Transform (SIFT) algorithm in OpenCV. The image with the most identified SIFT points is used to determine the vehicle's location relative to the gridded map at the time of image capture. The principal point of the captured image is assumed to be the projection of the vehicle's location onto the launch field, and the vehicle's altitude and orientation at time of image capture are used to adjust for the vehicle's tilt.

Once a reference location is identified, the vehicle's displacement between that reference location and the vehicle's landing location is calculated through integration of the inertial measurement unit data. This displacement is then used to determine the vehicle's final landing grid location, which is transmitted through the payload's XBee radio transmitter and displayed on the ground station's LCD screen.

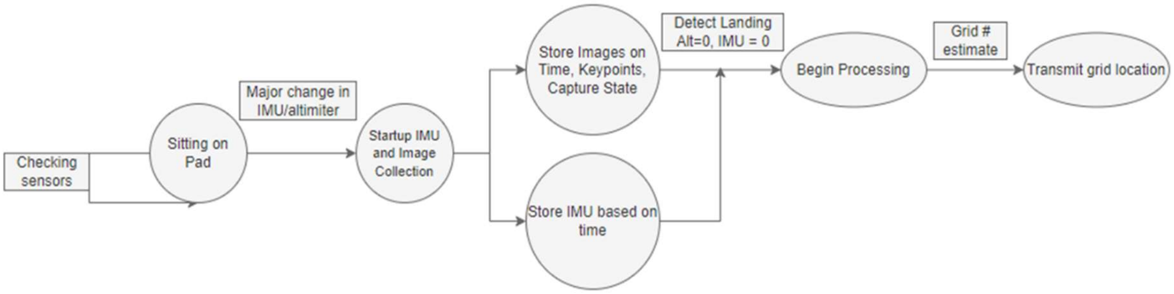


Figure 3: Mission flow chart

2.2 Payload Retention System

The payload retention system is composed of the forward bulkhead, payload sled assembly, 10-24 style fasteners and 10-24 style hex-nuts (Figure 4). The forward bulkhead is epoxied to the payload coupler, which is located in the aft section of the launch vehicle. The payload sled assembly is then mated to the forward bulkhead using the 10-24 style fasteners and 10-24 style hex-nuts (Figure 5).

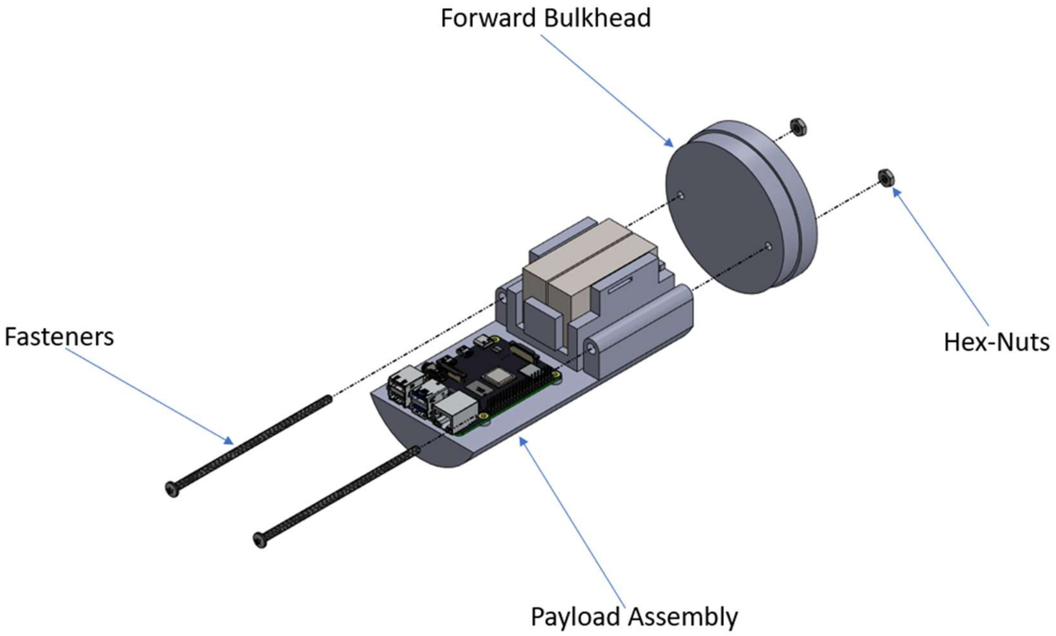


Figure 4: Payload Retention System Design

Figure 5: Payload Retention System Assembled

The payload retention system was flown on the Payload Demonstration Flight in its final configuration with all the electronics mounted to the payload sled assembly. The payload retention system was successful at keeping the payload sled assembly retained throughout flight, as well as all the electronics that were mounted to the payload sled assembly (Figure 6).

Figure 6: Payload Coupler Post-Flight

2.2.1 Camera Mount Retention

The camera mounts consist of the camera housings, camera covers, cameras, and the fasteners utilized to mate the assembly together (Figure 7). The cameras are mated to the camera housing utilizing M3.0 style fasteners and hex-nuts. The camera housing is mated to the aft section of the launch vehicle through the ¼-20 style T-nuts that are embedded in the aft section of the launch vehicle. The camera housing is then sealed by the camera cover which mates to the camera housing using ¼-20 style fasteners and hex nuts (Figure 8). The camera mounts were flown on both the Vehicle Demonstration Flight and the Payload Demonstration Flight. The Payload Demonstration Flight included all the electronics and cameras onboard the launch vehicle. The camera mounts were successful at keeping the cameras retained throughout flight, with images being captured throughout flight.

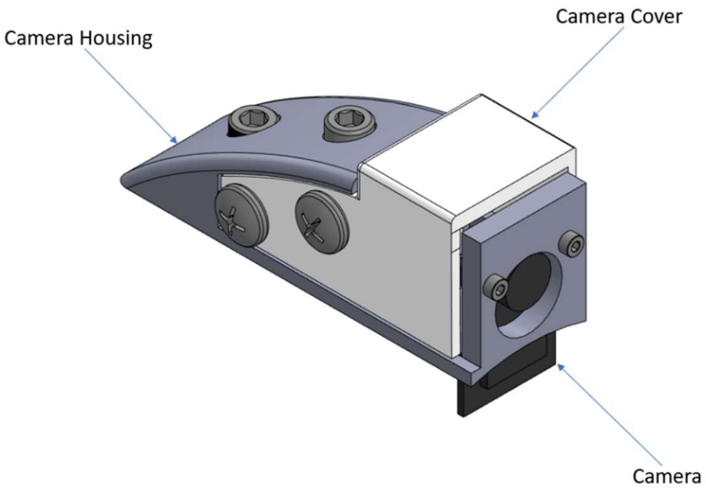


Figure 7: Camera Mount Design

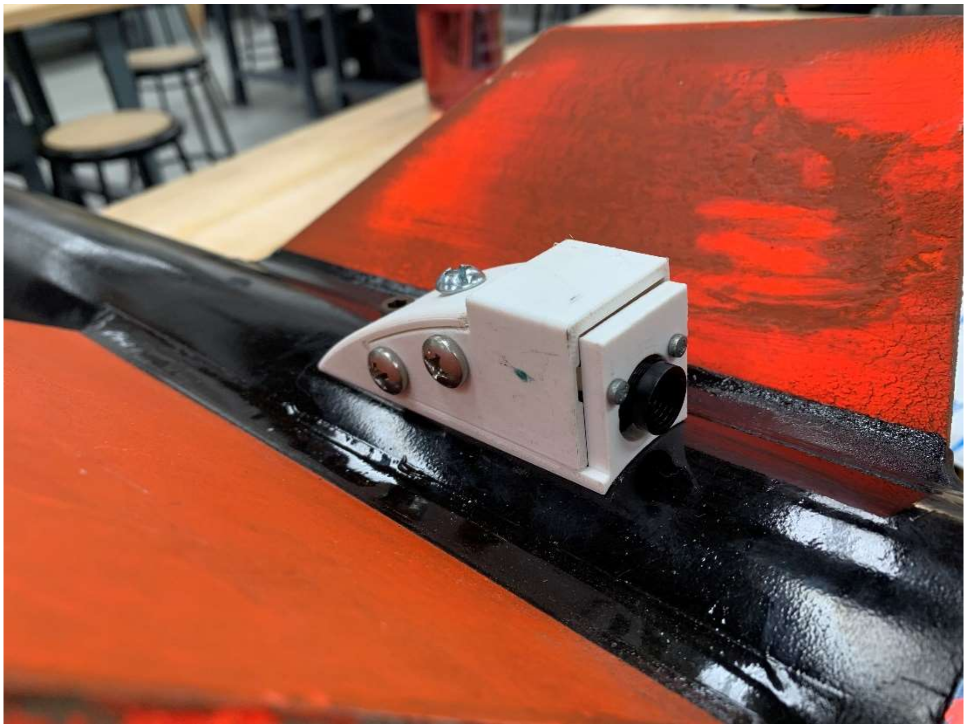


Figure 8: Camera Mount on Airframe

2.3 System Functionality

2.3.1 Functional Systems

2.3.1.1 Electrical Systems

The Raspberry Pi 4, ArduCAM OV5642 cameras, lithium-ion batteries, and power regulation system operated as intended throughout the flight. The Raspberry Pi 4 successfully powered on and began automatically executing the main flight program, as designed. The ArduCAM OV5642 cameras successfully captured images of the launch field during both ascent and descent (Figure 9). The payload batteries remained active and supplied power to the payload throughout the 1.5-hour launch and recovery window.

Figure 9: Image of launch field captured by payload cameras during descent

2.3.1.2 Mechanical Systems

The payload sled functioned as planned, keeping all the electronics on the Raspberry Pi and batteries mounted throughout flight. The structure of the sled was not damaged in any way and is ready for flight again. The battery compartment functioned as intended, keeping the batteries restrained inside the compartment. The Raspberry Pi and cameras all maintained power throughout flight, meaning the batteries connections were not damaged. Similarly, the camera mounts performed as intended, keeping the cameras secured throughout flight. The camera mounts received no physical damage and are ready for another flight (Figure 10). The cameras remained securely mated to the mounts after landing. The electronics tubes were also utilized on the Payload Demonstration Flight. The cameras received power throughout the entire flight, ensuring that the wire tubes functioned well. Their purpose was to provide a secure path from the payload sled to the camera mounts for the wires, allowing the cameras to be powered throughout flight.

Figure 10: Camera mount post launch

2.3.1.3 Software Systems

The cameras' payload software program ran as intended. The program started running after the Raspberry Pi was switched on, controlled the cameras and successfully collected and stored image data.

2.3.2 Hardware and Software Failures

The payload image detection program was developed to compare the images taken by the payload against a satellite image which was pre-uploaded. During development, subsets (cropped parts) of the satellite image were used at different resolutions and zoom aspects to train and check the program. This was done due to unavailability of any other reliable method. During the launch, the images taken contained distortion and tilt which could not be resolved (Figure 11). In addition, the images near apogee which would have been used and would have been at the desired altitude of image comparison were blocked out by cloud cover and tracking smoke (Figure 12). Thus, the image comparison was not able to identify sufficient SIFT points so as to develop a bounding box for determining location.

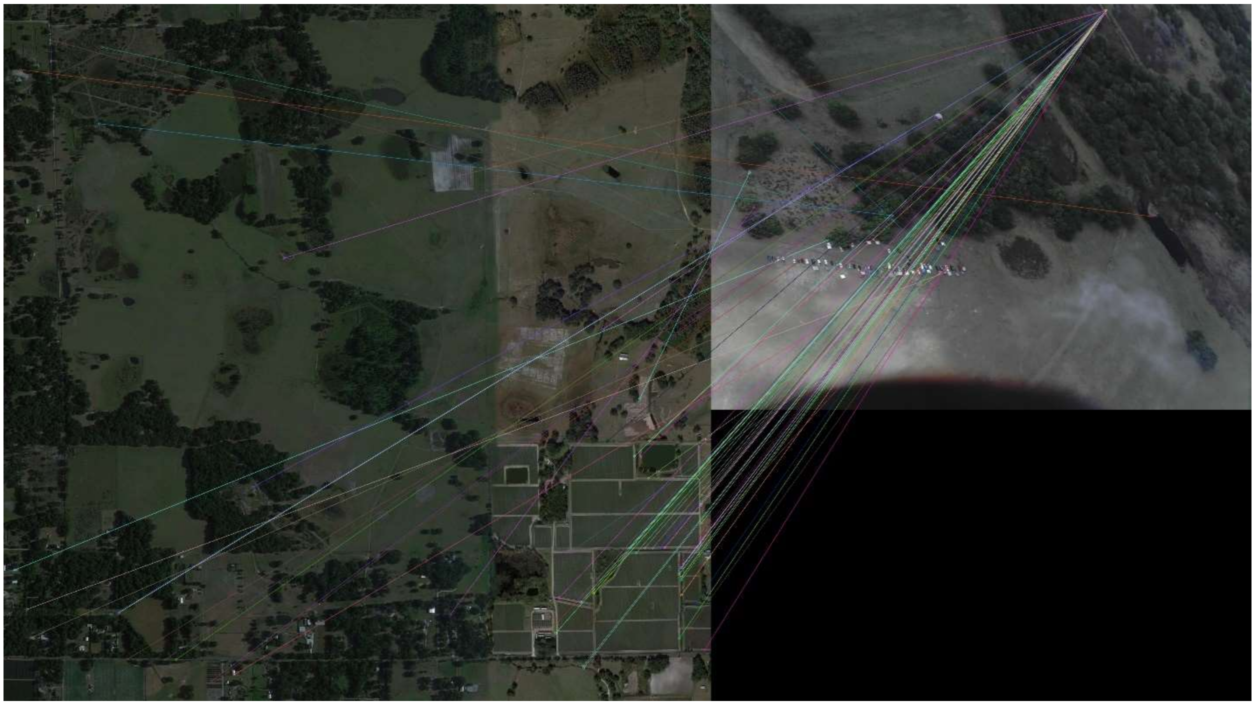


Figure 11: SIFT results with pre-uploaded satellite image (right) and flight image (left)

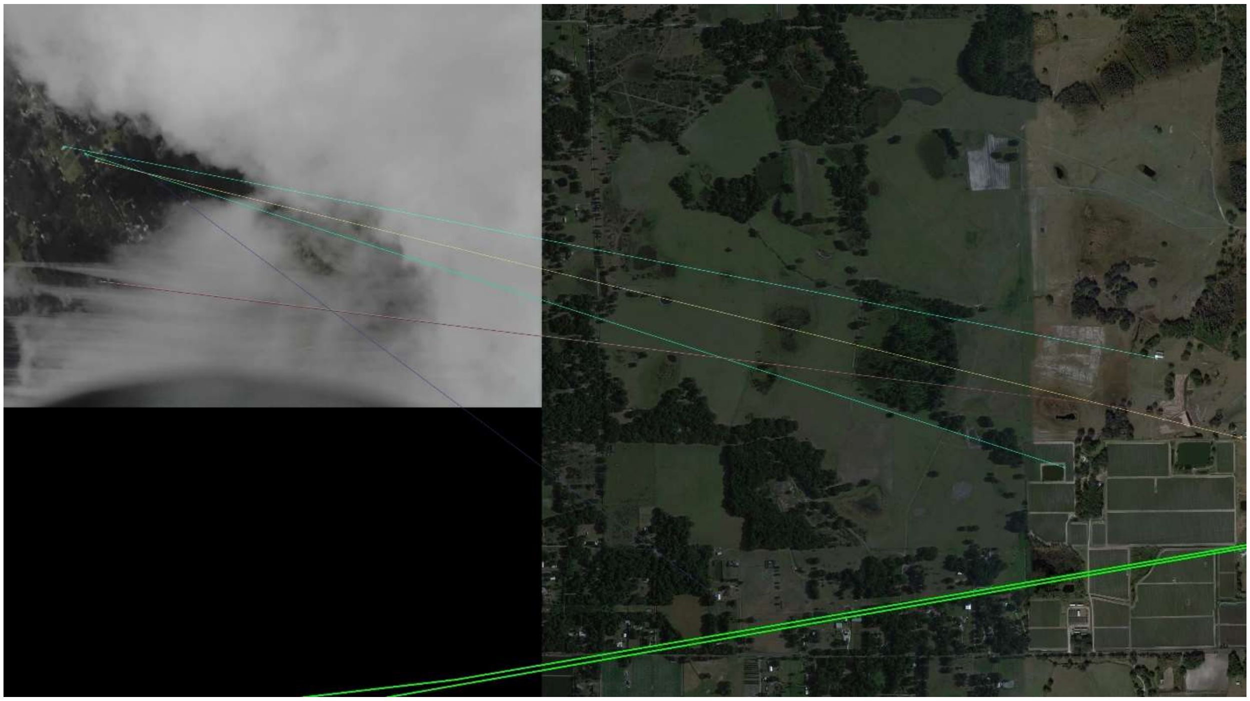


Figure 12: SIFT results with pre-uploaded satellite image (left) and flight image (right)

The ADIS16470 Inertial Measurement Unit (IMU) failed to initialize and thus was unable to collect acceleration and gyroscopic data. The failure was due to an improper configuration of the Serial Peripheral Interface (SPI) software on the Raspberry Pi 4. The payload did not include redundancies to function without data from the inertial measurement unit, and the payload was unable to calculate the vehicle's displacement from the location at apogee and thus no final landing location was transmitted.

2.4 Damaged Hardware

No hardware was damaged during the flight. All components were deemed recoverable and reusable (Figure 13).

Figure 13: Payload post flight

2.5 Payload Lessons

Analysis of the images captured by the payload cameras revealed how vehicle spin can significantly distort captured images. While the vehicle spun, the images were distorted by spatial aliasing and features near the edges of the camera's viewable area became elongated (Figure 14). This effect can be minimized by selecting a camera with a higher shutter speed. For future designs, shutter speed should be considered when selecting cameras.

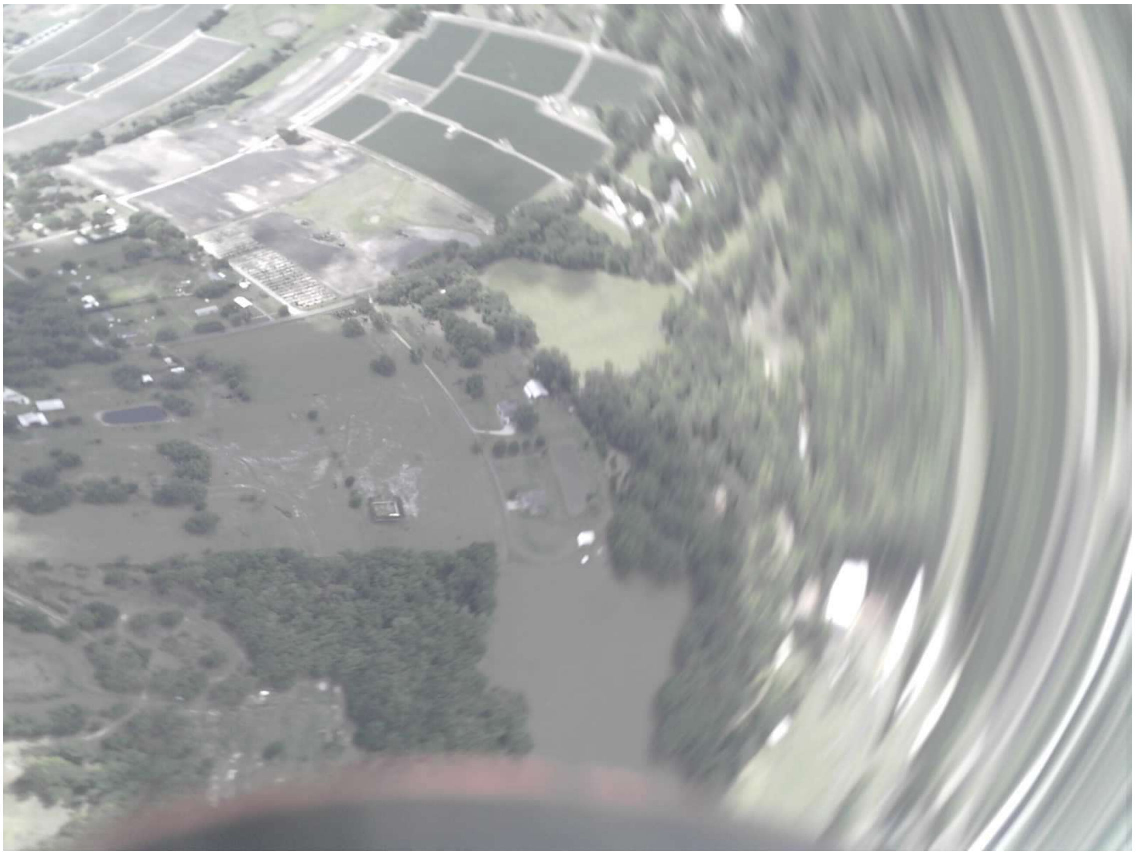


Figure 14: Image with distortion due to vehicle spin

Likewise, tracking smoke from the motor and cloud cover obscured some images taken during ascent (Figure 15). In future designs, the effects of tracking smoke make be reduced through adjustment of the camera's location relative to the vehicle’s airframe or by instead prioritizing the use of images taken during descent. Cloud cover is a condition of the launch field that cannot be controlled but does affect the program’s ability to successfully execute any form of image processing. Using better computer models and image cleaning algorithms stood out as good choices after analysis of the images taken during launch. While the image would always have to be at a high enough altitude to be able to be compared with satellite images, adapting programs and developing code to be able to filter through light cloud cover or other obstacles or the ability to use partially obscured images is important. For future development, the usage of aerial photography using model airplanes or drones with the same mounted cameras would be useful.

Figure 15: Image obscured by motor tracking smoke during ascent

3. Conclusion

In conclusion, the University of Florida Swamp Launch Rocket Team is confident in the payload’s retention system’s ability to safely retain all components throughout flight, as well as the payload’s ability to perform as designed.