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# UMD Flying Bulldogs: Post Flight Report


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## Summary

On April 26, 2014 the Flying Bulldogs competed in the Regional Rocket Competition held by the Minnesota and Wisconsin Space Grant Consortiums. The rocket had to include two electronically deployed parachutes, a competition altimeter, use two independent methods of flight performance verification, and be recovered in flyable condition. The goal of the competition was to achieve an apogee of 3,000 ft as precisely as possible.

The Flying Bulldogs team designed a rocket utilizing the rocket's mass and drag force as the key components in achieving the desired apogee. Both of the electronically deployed parachutes were controlled by the team's Stratologger altimeter: the drogue chute was to be deployed at apogee, with the motor ejection as a backup; and the main was to be deployed at an altitude of 500 ft to ensure a safe landing while minimizing the drifting distance from the launch location. Two altimeters, not including the altimeter provided by the competition, were used in order to have more sources of data for accuracy. Additionally a Pitot-static tube was used in order to measure the airspeed.

## Discussion of Results

**Table 1:** Flight Performance Comparison

| | | |
|---|---|---|
| Operation (determined by RSO or designee) | ✓ | |
| Launch | ✓ | |
| Parachute deployment | ✓ | |
| Recovered | ✓ | |
| Determined to be in flyable condition | | |
| | Predicted | Actual |
| Maximum Altitude (ft.) | 3,000 | 1,100 |

On launch day, the written prelaunch procedure proved to be very useful in preparing the rocket for flight, from assembly to arming the altimeters.

Once the Flying Bulldog was launched, it had a brief flight which ended in catastrophic failure. Almost instantly after ignition of the motor, a gray PVC "spacer" was detached from the side of the launch rail and hurled into a fin. The detachment of the spacer initiated the sequence of events resulting in catastrophic failure.

As the rocket ascended up the launch rail another whole fin was detached completely from the lower section. Once off the rail and in the air, a combination of wind, instability from losing fins, and loss of upward acceleration caused the flight path to abruptly change directions in the air. Figure 1 shows the acceleration as measured by the Raven III and the eLogger accelerometer. A spike in acceleration can be seen at the time of the abrupt change in direction from the Raven III, eLogger, and Stratologger altimeters. The change in direction caused the shear pins to shear, and allowed the bottom section of the rocket to detach, which was the catastrophic failure. Upon separation, the drogue chute caught the air at a high speed and was torn from the parachute cords. The separation caused the instrumentation to misread the altitude,

which resulted in a spike in the data. This spike can be seen in Figure 2, which shows the altitude data from the Raven III, eLogger, and Stratologger altimeters. It can also be seen that all three instruments were in agreement with the overall flight path. Note that the predicted altitude was removed from Figure 2 so that the measured data could be seen more clearly. Due to the failures throughout the flight, the predicted and measured altitudes were not in agreement.

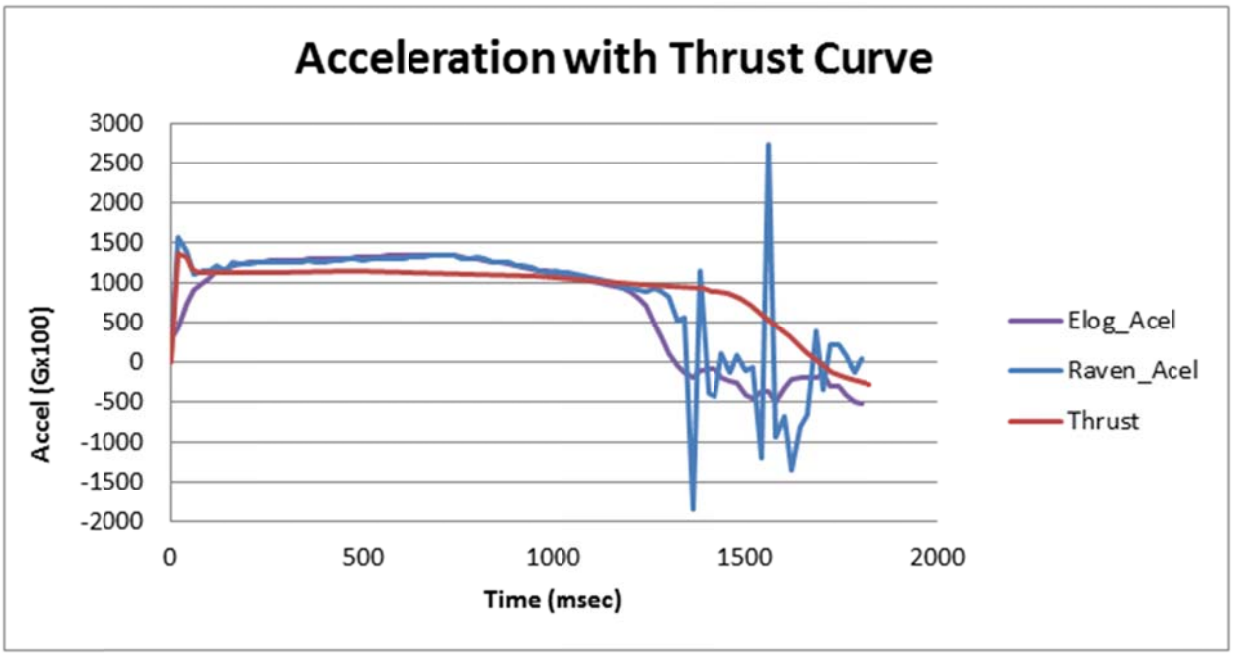


**Figure 1:** Predicted vs. Measured Acceleration

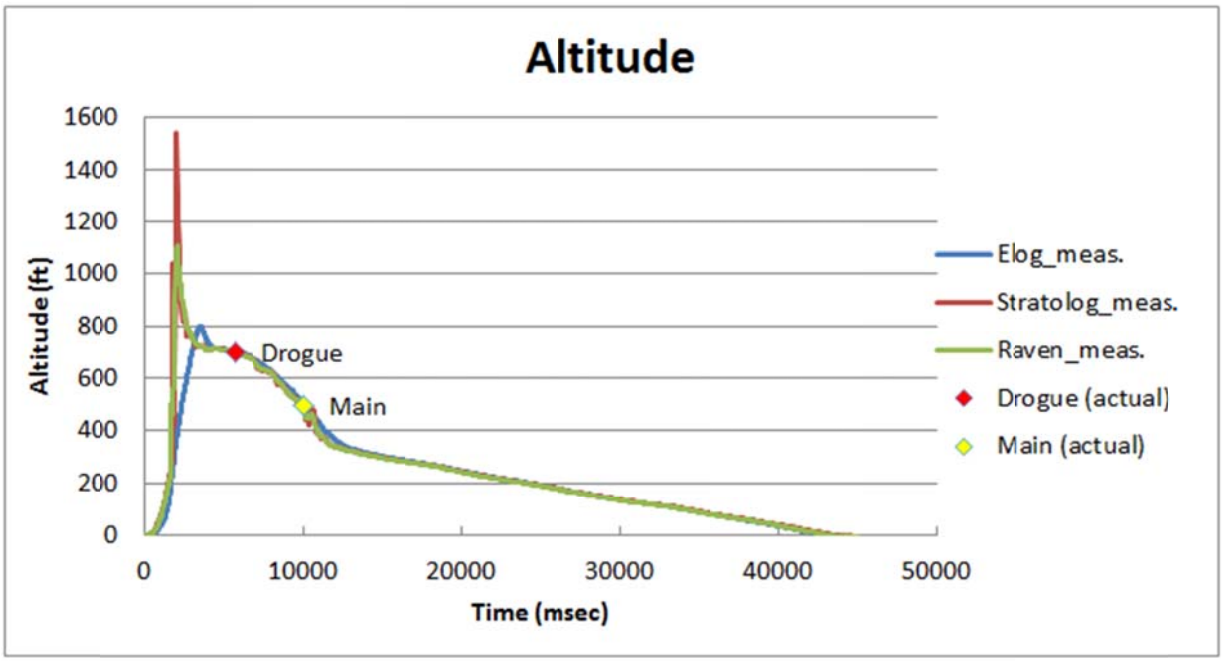


**Figure 2:** Measured Altitude

The official apogee altitude for the Flying Bulldog was recorded as 1,100 ft, however, it is believed that the actual altitude was approximately 800 ft based upon the data collected from the teams' instrumentation. It is believed that even with the instability, the rocket should have reached a higher altitude. When comparing the predicted thrust to the measured acceleration, it can be seen that the motor burned out earlier than expected (see Figure 1). As soon as the acceleration decreased, the flight saw the large abrupt change in direction as mentioned above. The predicted maximum velocity was 500 ft/s, and the Raven III measured a maximum of 470 ft/s. The Pitot - static tube connected to the eLogger only read a maximum velocity of 100 ft/s, which was believed to be an error resulting from dampening integrated into the eLogger data system.

Once at apogee, with the drogue chute detached, the rocket began a short free fall descent in two connected pieces. At an altitude of 500 ft, the Stratologger deployed the main chute as expected, and the rocket descended to a soft landing as planned. However, due to high winds, the rocket drifted slightly from the launch pad. Once on the ground, the wind caused the large 72 inch parachute to continue to drag the rocket along the ground until it was recovered. This made the rocket location calculation more difficult, because the actual landing site where the GPS measurement was taken had to be approximated. The calculation was approximately 100 ft from the measured location.

Upon recovery, the post flight procedure was followed, and all rocket parts were found, with the exception of one fin that detached during the catastrophic failure. Due to the failure in flight, the rocket was not recovered in flyable condition.

Although the flight was not successful, the instrumentation worked properly, and provided important data for analyzing the flight. Once the eLogger data was compared with the Raven III, it was observed that the general profiles of data would match, but the eLogger did not read the large spikes in data at key points. It is believed that this is due to over dampening within the data measurement system of the eLogger. If the eLogger is used again, action must be taken to lower the dampening characteristic of the component prior to use.

## Conclusion

Overall, it was unfortunate that the Flying Bulldogs did not have a successful flight; however, the competition was a very useful experience. We learned many lessons throughout participation in the regional rocket competition. As a team, we learned the importance of teamwork and communication. As engineers, we were able to gain useful project experience, data analysis skills, and knowledge of high powered rocketry. The project proved to be fun, yet challenging. Additionally, we learned many important lessons and gained useful advice from the volunteers and advisors. As for the PVC spacer that started the failures, we are still uncertain if that was a necessary part of the launch rail, or something left behind from an earlier launch. It was observed that the spacer was first used for the smaller "Scotch Rocket", but never removed, as that rocket was launched prior to the Flying Bulldogs launch, which were both launched from Launch Pad 1.

**Attachments:** Appendix A Failure Analysis

# Failure Analysis

**Failure 1**

High speed video footage from a GoPro Hero 3, positioned just off the launch pad, revealed that an entire fin plus a piece of another fin was lost as the rocket traveled up the launch rail. Shown in Figure 1 is a side-by-side launch pad configuration between the test launch and the competition launch. A gray PVC "spacer" can be seen in the competition launch configuration, which is not present in the test launch configuration.

**Figure 1:** Launch Pad Configurations of Test Launch (Left) and Competition Launch (Right)

Figure 2 shows the spacer being thrown from the launch rail, next to a sheared off piece of a fin, along with another full fin that detached farther up the rail. This can also be observed in the slowed down high speed footage captured by the GoPro [1].

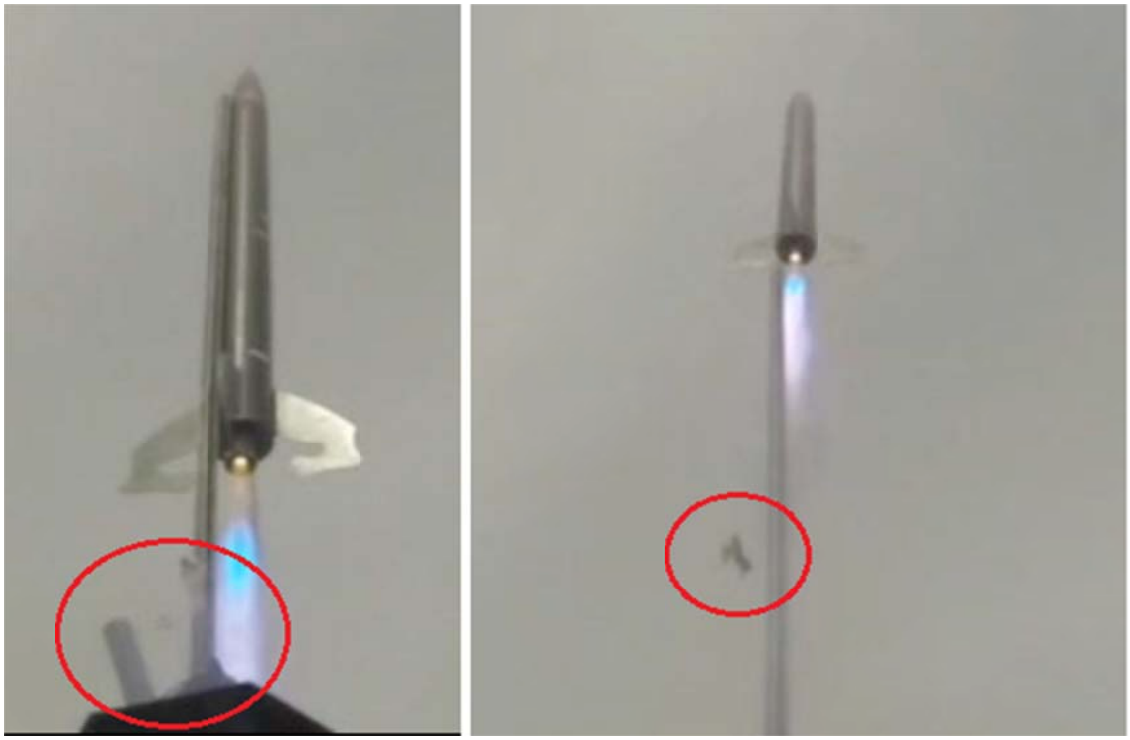

**Figure 2:** Separation of PVC Spacer & Part of Fin (Left) and an Entire Fin (Right)

**Failure 2**

Shortly after the rocket left the launch rail, the instability was clearly noticed. The rocket first did an abrupt side-to-side motion, followed by premature separation. Upon separation of the body sections, the drogue was deployed, which caused an extremely large jerk on the body sections. As a result, two more full fins separated from the body tube, leaving only one partial fin attached to the lower body section.

The lower section of the body tube was rebuilt between the test launch and competition. Upon further investigation, it was found that an old revision of the fin design with a smaller tang was used to water jet cut the new fins. Because of this, the contact area for the epoxy attachment was reduced by nearly 45% as shown in Figure 3. The lack of contact between the fins, motor mount tube, and the centering rings allowed for easier separation of the fins during flight.

**Figure 3:** Cutaway of Lower Airframe Showing Wrong Size Tang

## Conclusion

Based upon the analysis, there was multiple failure modes found. Although the failures were initiated by something out of our control, we could have taken better steps to prevent further failures, as the fin size should have been inspected more thoroughly prior to reconstruction.

## Reference

1. https://www.youtube.com/watch?v=KLBMC0mS3Fk