NASA's Space Grant Midwest High Power Rocket Competition

2014-2015

Post- Flight Report

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Freshman Team

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Rocket Operation Assessment

Flight Anomalies Analysis

Upon takeoff, the booster and rocket began a continuously curving trajectory. The dart separated from the booster almost immediately, but both components followed the same shallow parabolic path. The booster booster ejected its parachute upon reaching the apogee of its curved trajectory, as was planned. The dart however continued beyond its apogee and continued its shallow parabolic fall all the way to the ground. There were two distinct anomalies that occurred:

The Curved Trajectory

This problem had occurred in an earlier test flight, but the problem had since been addressed. Tests were run upon the booster in a wind tunnel between the semi-successful practice launch and the final launch to find its true static margin, and lead weight was added to the nose cone to correct for inaccuracies from the computer model and to stabilize the entire rocket. This adjustment was expected to keep the rocket from trailing off as had been observed in the previous flight, but clearly this did not occur, as a nearly identical trajectory was followed by the rocket in the competition flight.

The only explanation that our team has been able to produce for this unexpected failure is that the dart and booster combination was somehow greatly affected by the hole in the front of the booster; even more so than the booster alone. This does not seem like a logical situation, but the incessant curving trajectory of the rocket is not logical in and of itself. The exact cause is still unknown to us.

Dart Ejection Failure

The failure of the darts parachute ejection system was unfortunately another problem that had been encountered earlier, but was not able to be remedied. In another earlier practice flight, the dart had lawn-darted, but was found. Upon inspection, it was discovered that the cause of the failure was the fact that the Raven Altimeter that's purpose was to eject the parachute had been improperly wired. In future flights, this problem had been remedied, and this was confirmed by the distinctive beep pattern from the Raven. This beep pattern was heard on the day of the competition flight, which would indicate that the wiring was not the cause of the failure. However, the dart proceed to fall all the way to the ground during the competition flight without any indication of an ejection event.

The misfortune continued as it became clear that the dart would be nearly impossible to locate. It contained a radio beeper (the same kind which was successfully used to locate the booster), but upon impact with the ground the radio beeper most likely shattered along with the other avionics, and assuming the dart embedded itself deep in the ground, the signal would not be likely to be interceptable by the receiver. These two factors eliminated the the radio beeper, our main tool for locating the dart. In addition, the likelihood of the fact that the booster lawn darted made the dart very difficult to locate visually. This, coupled with fact that the dart was headed directly toward a patch of thick forest and brush, eliminated the possibility of finding the dart without some technological aid, the hopes of which had been crushed along with the radio beeper.

As stated earlier, the beep pattern was confirmed on the launch pad, so the wiring of the dart avionics can not be blamed for the ejection failure. Instead, our best hypothesis as to what went wrong is that the wiring of the Raven actually could have fallen out of the connection to the battery and/or the ejection charge during the jolt of the acceleration from the motor. This prediction is based on the observation that, prior to the flight, the Raven wiring had a tendency to come loose if not tightened perfectly in the terminals. We thought that we had achieved as perfect as possible a housing of the wires in the terminals as to avoid this situation, but it seems as though this being a false assumption in the most likely cause of the failure. The idea that perhaps the Raven did not register apogee because of the shallow flight was also suggested, but soon dismissed because of the high quality of the Ravens and the fact that a Raven with the same setup succeeded in ejecting the booster parachute even with a similar trajectory. This problem could have been avoided if we had had the foresight to permanently attach wires to the Raven, then attach more reliable terminals to that wire to connect to the battery and ejection charges for a more resilient connection.

Propulsion System Assessment

By all accounts, the propulsion system seemed to be successful. The booster and dart took off smoothly, although not in the correct path. It is probable that a more powerful motor with a larger impulse would have helped keep the rocket from veering off as it did, that failure is due to the rocket design rather than the motor choice. The motor was successful retained in the booster and had no signs of an unsuccessful flight.

Flight Path Assessment

The flight path was one of the two major failures in the competition flight. It was the more minor of the two failures, but is still worth noting. The booster and dart combination began a shallow parabolic path immediately off the rail. The booster and dart continued this trajectory separately even after separation. This path began with an angle of about 60 degrees with the ground, but quickly turned over to horizontal. The booster ended this trajectory upon the ejection of the parachute at apogee, but the dart continued to follow a parabolic path all the way into the ground.

Recovery System Analysis

The booster recovery system went off perfectly. The parachute ejected at apogee and the rocket drifted slowly to the ground. Once on the ground, the rocket was located using the radio beeper and radio tracker that had been implemented. An alarm was also set off by the extension of the shock cord that audibly aided in the rocket search. Upon finding the rocket, it was inspected and it was determined that the avionics ejection charge had ejection the parachute rather than the motor eject. This was also indicated by the fact that a poof of smoke was seen as the booster was descending already on the parachute, indicative of the motor eject going off. The inspection of the booster also resulted in the conclusion that the descent rate had been safe and the booster was not damaged by hitting the ground.

The dart on the other hand had a very unsuccessful recovery. The parachute never ejected and the dart presumably embedded itself into the ground, leading to an unsuccessful three hour search for the dart. The recovery process was a complete failure. As stated before, this could have been do to the questionable tightness of the wiring between the Raven and its components.

Rocket Location and Recovery Analysis

The booster was located using the radio beeper and the siren about two-thousand feet away from the launch site. Upon recovery, a list of tasks were completed, including checking the status of the ejection charges, recording the Altimeter 2 data, and checking for damages or other indications of irregularities within the flight. All of these checks resulted in the expected results, so the booster was reassembled and left to continue the search for the dart.

The dart was never found even after a thorough three hour search of the landing area, so it is impossible to state exactly where it may have landed, but it seems most likely that in landed in a thick patch of forest in the tall brush beyond or to the left of the trees. These areas were about the same distance from the launch pad as the landing site of the booster half of the rocket. The search for the dart employed first the radio beeper, then a thorough grid-based search of the area it was thought to have been seen that the dart went down. When these two methods failed to provide any visual sign of the dart, it was concluded that the dart must have landed in the forest or the brush, in order to explain the fact that the dart was not visible. A haphazard search of these areas was all that was possible do to their thicknesses, and this did not result in the finding of the dart.

Pre- and Post- Launch Procedure Assessment

Our preflight checklist successfully resulted in the booster and dart taking off and the booster being recovered successfully. The failure of the dart was expected to have been caused by the fragile nature of the wiring situation. Though we thought that we had wired the Raven as sturdily as possible, having further checks related to the wiring on the checklist could have helped avoid this situation. Other than this however, our pre-flight checklist served our purposes adequately.

The post flight checklist was used first to recover the booster. We located the booster using the radio beeper and the audio siren as per the checklist and then we proceeded to confirm the ignition of both charges. We then disabled the electronics onboard and recorded the data from the Altimeter 2. This was all in accordance with the post-flight checklist that we had devised.

The checklist was not usable for the dart however, as the dart was not findable. The radio beeper was used in an attempt to locate the dart, as per the checklist, but this proved futile. Because the first step in the dart checklist, finding the dart was unsuccessful, there was no way to follow the remainder of the dart checklist. It would not have been possible to write a post-flight checklist for the dart that would have made it easier to find the dart, because the one that we used exhausted all of the recourses we had available, primarily the radio beeper. Because of this, it was necessary that we abandoned the specifics of checklist and instead searched for the dart as best as we could.

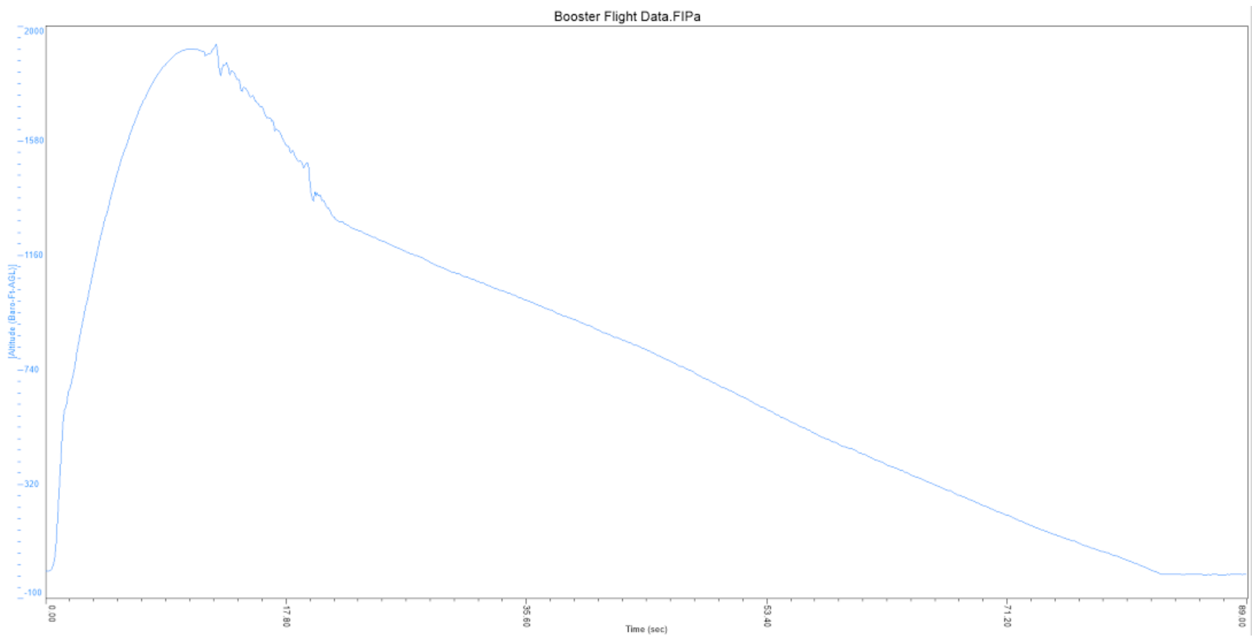
Actual vs. Predicted Performance

Because the dart was unable to be found, only the performance data for the booster was collected and compared to the pre-flight predictions. This booster peak altitude, acceleration and velocities are shown below:

Peak Altitude Comparison

actual: 1935 feet above ground (as reported by the barometer)

predicted: 2378.61 feet above ground



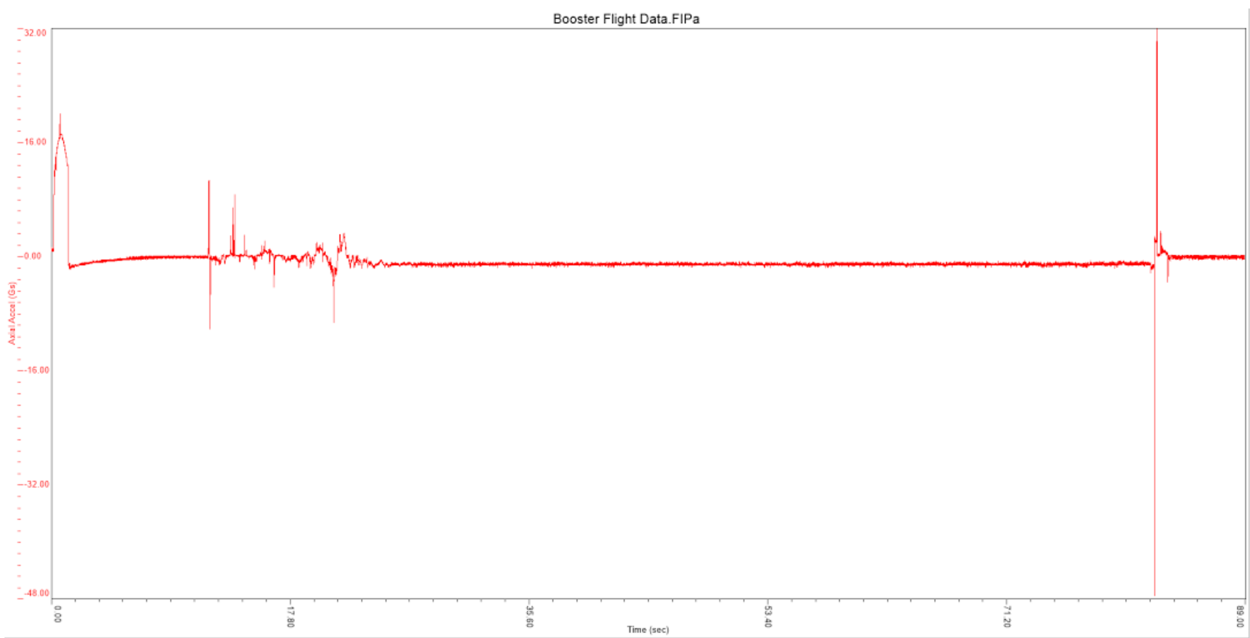
The actual peak altitude value of the booster for the competition flight was 1935 feet above ground-level (as reported by the barometer), compared to the computer simulation-based predicted value for this altitude of 2378.61 feet. The difference between these values is 444 feet, for a margin of error for the booster's altitude of -22.9%. This value is fairly small compared to the other abnormalities that occurred within this competition flight. This error between the actual and expected values can likely be explained by the rather non-vertical nature of the flight.

The computer simulation used predicted a vertical flight, and the Raven used to measure actual altitude measured the vertical altitude, rather than the distance travelled by the booster until apogee. Had this flight been perfectly vertical, as the simulation that resulted in the predicted value was, it seems probable that the predicted and actual values would be extremely close to one another.

Peak Acceleration Comparison

actual: 20.10 Gs

predicted: 20.24 Gs

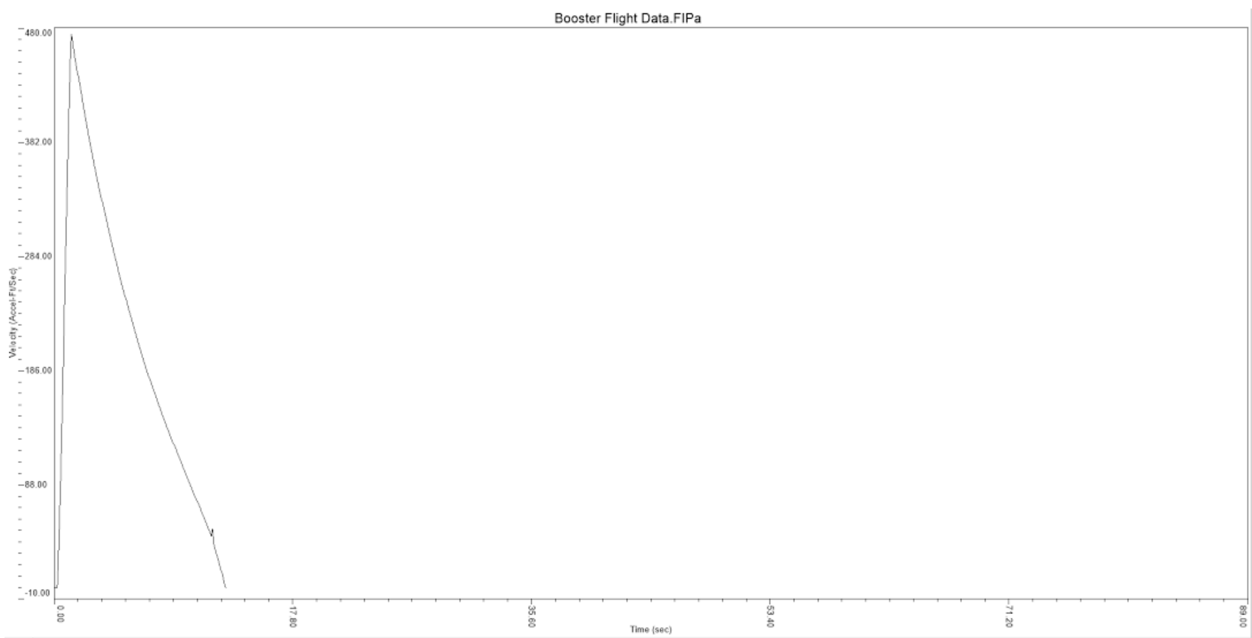


The peak acceleration value of the booster for the competition flight was 20.10 Gs, compared to 20.24 Gs predicted acceleration value for the booster acquired by the computer simulation. The difference between these values is .14 Gs, with a margin of error for the acceleration of -0.7%. This is very small and indicates that in regards to the propulsion section of the competition flight, all went as planned and simulated. Because of the fact that this acceleration was acquired during the boost phase, while the booster and dart were still together, this competition value of 20.10 Gs is also the peak acceleration value acquired by the dart. Similarly, the predicted value of peak acceleration for the dart is also consistent with the booster, meaning that all that was discovered about the peak acceleration for the booster also holds true for the dart.

Peak Velocity Comparison

actual: 475 feet per second, as determined by the accelerometer

predicted: 568.6 feet per second



The peak velocity value of the booster for the competition flight was 475 feet per second, compared to the 568.6 feet per second predicted velocity value for the booster acquired by the computer simulation. The difference between these values is 94 feet per second, with a margin of error for the peak velocity of -19.8%. This value is fairly small in comparison to the other problems that this flight faced. It is interesting to note that the margin of error for peak velocity of -19.8% is very close to the peak altitude margin of error value of 22.9%. These values are likely closely linked and are therefore very similar. The reason that the peak altitude margin of error mimics the peak velocity margin of error is that neither of these measurements take the curved trajectory of the booster and dart into account. Similarly to the peak acceleration, the peak velocity of the dart is also equal to that of the booster for both the actual and predicted flights. This means that all that was discovered about the peak velocity for the booster also holds true for the dart.

Data Collection

Dart Sensors

The sensors that were utilized for this flight, the 9-axis IMU that was meant to measure the rotation of the dart and the camera to capture video of the separation and post-separation flight of the dart were unfortunately both housed in the dart. Because of this, neither sensor was recovered. For this reason, there is no data to display here, and there is no data to interpret from the competition flight that was not covered in the analysis of the flight of the booster based on the Raven data.