Illinois Space Society Space Jam

University of Illinois at Urbana-Champaign

NASA Space Grant Midwest High-Power Rocket Competition 2014-2015

Post-Flight Performance Report

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Illinois Space Society
104 S. Wright Street
Room 321D
Urbana, Illinois 61801

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1.) Rocket Operation Assessment

1.1 Flight Anomalies Assessment

The flight of the rocket itself had no major anomalies. The rocket ascended and was recovered safely and successfully.

One of the things that did not work during the launch were the competition Altimeter Twos in both the dart and the booster. This was because it had not been properly prepared for logging data during the flight. This was the first time using the Altimeter Two for all the members of the team and the members assumed that the altimeter would acquire data by just turning it on similar to the Stratologger. The team foolishly did not read the instruction manual for the Altimeter Twos and did not prepare the it correctly. As a result, the Altimeter Twos were not active when the rocket was flown.

Besides the problem with the Altimeter Twos, the rocket flew normally as planned and was recovered safely and successfully. The competition judges used the data from the stratologgers instead to judge. The only other point to notice was the delayed deployment of the parachutes which is discussed in the recovery assessment section.

1.2 Propulsion System Assessment

The propulsion system of the boosted dart rocket worked successfully with no major problems. The motor burned properly and the rocket ascended normally with a smooth boost phase. The motor with the delay charge was properly inserted in the motor case and the cap was securely tightened to ensure that the motor would provide thrust to the rocket.

The team did, however, have minor problems launching the rocket. The team members went out to the launch pads, set the rocket on the launch rail, and inserted the igniter in the motor. After returning to a safe area, the launch pad officer pushed the button to launch the rocket but the motor did not ignite and nothing happened. The team members thought the problem was that the igniter was not properly touching the clips so the team went out to the launch pad again and made sure that the igniter ends were wrapped around and touching the clips. The launch pad officer attempted to launch the rocket but again, nothing happened. The launch pad officer then put fresh batteries in the launch box that the button was on. After switching the batteries the launch pad officer tried again and finally the motor ignited and the rocket launched successfully.

1.3 Flight Path Assessment

Because our rocket did not go to that high of an altitude, both the dart and booster section remained in sight during the whole flight. This made it easy to observe the flight path and the separation of the dart from the booster.

The rocket flew off of the launch rail smoothly and had a normal boost and coast phase. Even though the whole rocket with the booster and dart combined had a high static margin of 9.0 calibers, the rocket flew regularly during the short time the two sections were together. Even though at the test launch the rocket swayed and ascended at an angle, the rocket flew straight up at the competition launch.

During the ascent, the dart smoothly separated from the booster section as expected. As the dart continued upwards, the booster reached apogee and began to descend. The dart also reached apogee soon after and deployed its streamer. During the launch the team observed the flight trajectory to be as expected. Also, the altitude data from the altimeter shows a smooth parabolic flight and constant descent. The data was generally what was expected and similar to the data retrieved from the test launch.

The only point that did not go exactly as planned occurred when the parachutes deployed a little later than expected. As opposed to the programmed 500 ft. delay altitude for the booster, the recovery system was activated at approximately 200 ft. However, this was not a major problem as the parachutes still opened in time and brought the components down at a steady descent rate. This will be explained in more detail in the recovery analysis section.

1.4 Recovery System Analysis

Both the dart and booster components of the rocket were recovered successfully in reusable condition. The only damage that was done was a small tear in the cardboard body tube of the booster section. It was later found that this trim was caused by the single deployment recovery mechanism providing a large amount of force to eject the parachute. The amount of tape used to friction-fit the sections together can be targeted as the primary culprit. If the tape created provided too much friction between the top and bottom sections of the booster, the resulting separation of those sections would have been awkward and ultimately unstable. The tear was very small and could be fixed with a little bit of tape. The instability in the separation could be considered negligible in terms of the impact it had on the process.

The recovery system for the dart worked as expected. The streamer deployed at approximately apogee and the main parachute deployed at approximately 500 feet just as the Stratologger was programmed to do. This ensured that the dart would not drift too much during descent.

The booster parachute was deployed with a black powder charge with a motor delay. The team mentor drilled the delay to be approximately 11 seconds which was the expected apogee. However, during the launch the parachute actually deployed a couple of seconds after apogee during the descent. This could have been caused by error in drilling the delay or estimating the time to apogee.

1.5 Rocket Location and Recovery Analysis

After the rocket was launched and had descended to the ground, a couple of team members went to recover both the dart and booster section. As recommended from the experienced rocketry members, the team divided tasks to successfully and easily recover the components. Half of the team followed the dart and the other half followed the booster. This was important because both parts needed to be recovered and it is common for someone to lose sight of the rocket due to the distance or the sun. After both parts had landed, two people stayed at the initial position looking towards it. The remaining members then headed towards the landed parts with guidance from the members that stayed at the initial spot. Also, the team put a radio tracker in the dart section and could search for the dart by using a radio transmitter. However, because the dart and booster did not drift too far at the launch, it was fairly easy to successfully recover both parts without the tracker. These procedures written in the checklist were also practiced during the test launch. After recovery, the team members brought all the components to the competition judging table to be judged on a safe recovery, camera footage, and the altitude.

Both the dart and booster section of the rocket landed very close to the launch area. By using the streamer and deploying the main parachute of the dart at a relatively low 500 feet, the dart did not drift a lot and landed close to the launch site. The team was able to identify where the components landed without the use of the tracker and did not have to walk too far.

Figure 1. The booster and dart section descending

1.6 Pre- and Post-Launch Procedure Assessment

Before leaving campus for the competition, the team made sure to pack anything that was needed or could be useful. The team compiled a list of things that were needed at the competition. All of the members helped pack the tools and rocket components safely in the vehicles to make sure that nothing got damaged and that nothing important would be forgotten.

Prior to the launch, the team created a pre and post launch checklist to which the team adhered to on launch day. The checklists were similar to the one used for the test launch but with some changes and additions. The checklist was written in chronological order to make sure that the rocket was assembled correctly and safely. As the team members completed each task, the tasks were checked off and the members moved on to the next step. For each step, one member would do the task and another would supervise in order to confirm that each task was done correctly.

After confirmation was received that the rocket had been fully prepared for launch and recovery, the team members and supervisors exited the premises and the rocket was launched. Ultimately, the launch occurred without mishap. Both sections of the rocket rose together as expected, until burnout occurred. It was at this point in the flight, that the two sections separated, again, as expected. Although neither section of the rocket ascended to the altitudes achieved in the test flight, the systems of the rocket worked perfectly; the recovery systems deployed without mishap and the only damage done to either section was a trimmed fuselage on the booster. This was a result of a slightly awry separation during recovery.

Figure 2. Team members following the checklist and preparing for launch

2.) Actual vs Predicted Performance

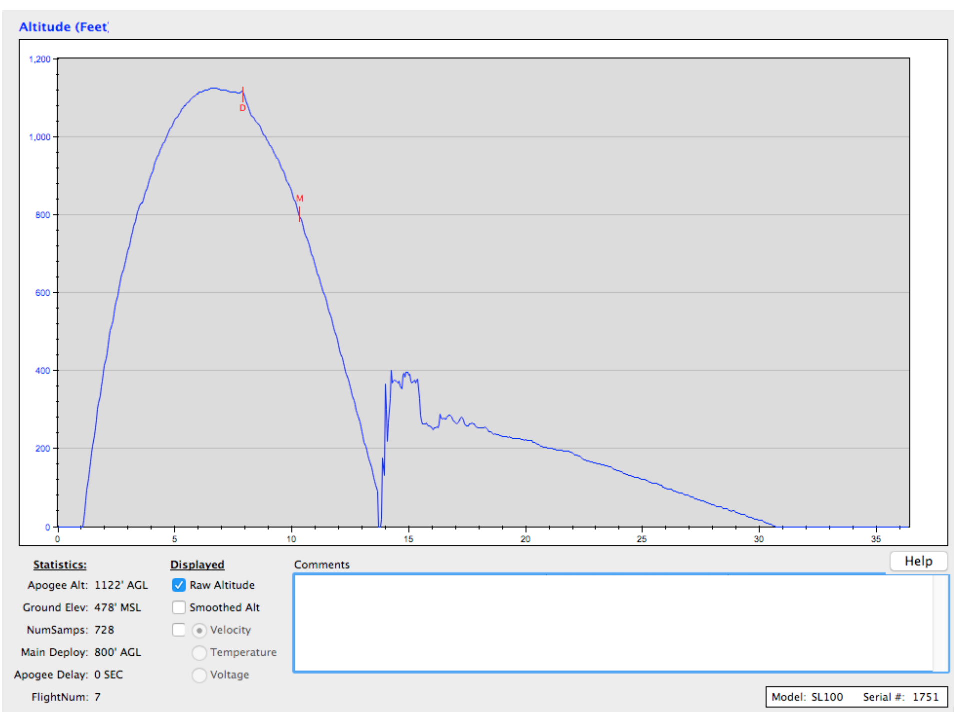

Figure 3. Altitude graph for the booster

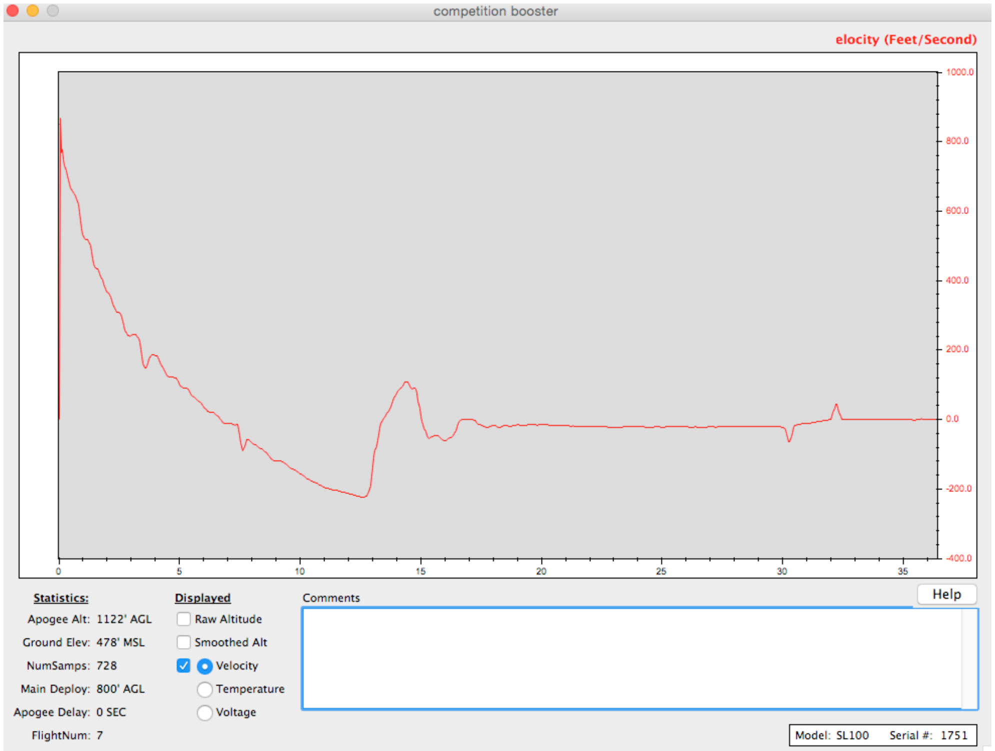

Figure 4. Velocity graph of the booster

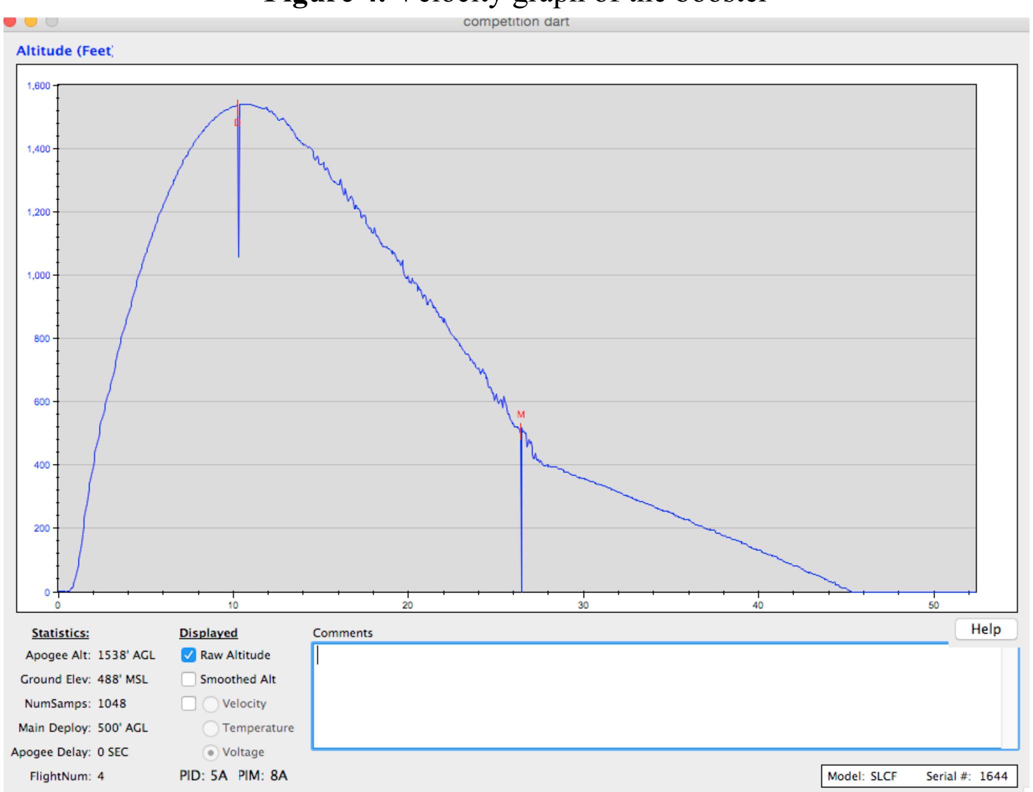

Figure 5. Altitude graph of the dart

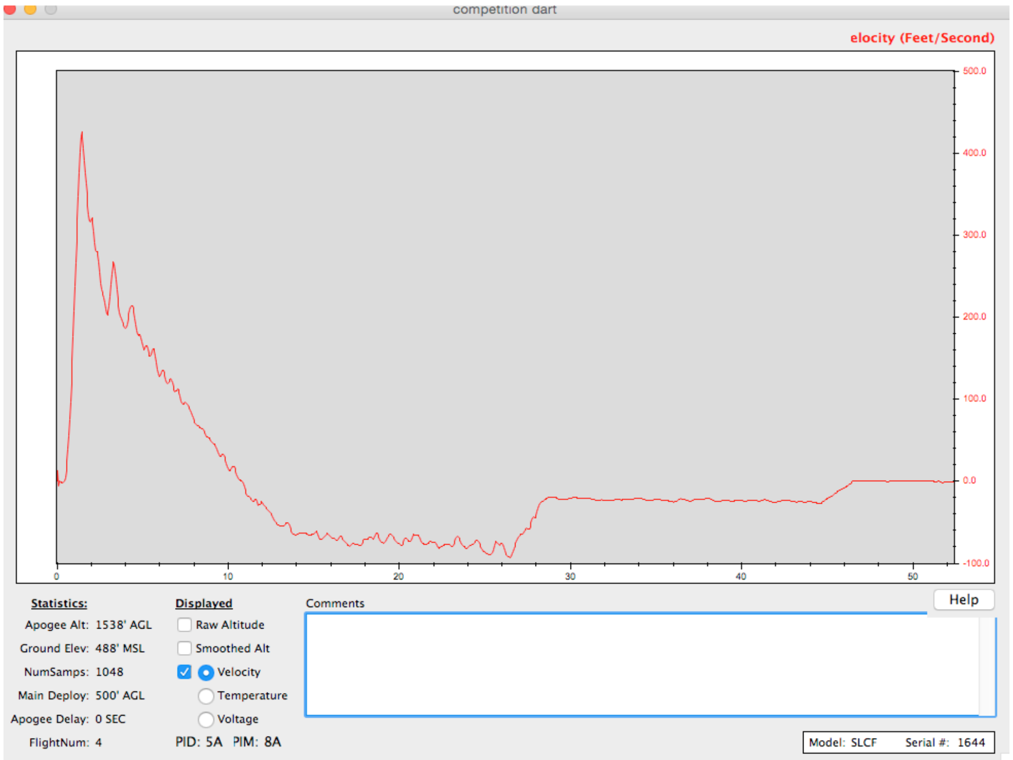

Figure 6. Velocity graph of the dart

2.1 Peak Altitude Comparison

The actual altitude data collected by the Stratologger CF altimeter states that the peak altitude of the dart section of the rocket was 1538 ft and the peak altitude of the booster section was 1122 ft. This corresponds to a separation of 416 feet.

The peak altitude of the dart at the launch was less than the one it achieved during the test launch. It was deduced that there could have been several reasons for this lack of altitude were all related to additions of mass to both sections of the rocket. Primarily, it is believed that the paint on the booster and the addition of the mass of the Jolly Logic Altimeter resulted in a maximum height that was lower than what was expected. In addition, the dart also flew lower than expected because of the addition of the camera, a stability platform made of tape and gauze for that camera, a Jolly Logic Altimeter, and paint contributed to its diminished height. The rocket also became more unstable due to these additions that were made to the rocket but were not actually accounted for in the RockSim simulations due to time constraints.

As it can be seen from the altitude graphs of both the dart and the booster, they both had a smooth boost and cost phase to apogee. However, the descent phase of the booster is illogical and show erroneous data. The data near the deployment of the parachute is jagged and erroneous possible due to leaks holes which messed up the pressure inside the body tube. However, after deployment, the booster descents smoothly as expected.

The dart also shows a smooth trajectory but has spikes near the deployment times due to air leaking out of holes. The coupler the stratologger was in was not completely separated from the black powder charges. This caused the spikes in altitude but expect the spikes, the descent was smooth as expected for both the streamer and parachute.

2.2 Peak Acceleration Comparison

One can analyze the varying acceleration profiles of the two sections of the boosted-dart when examining the sections' velocity profiles/graphs. Though the velocities of the sections are slightly flawed, though the velocity for the dart is the most reasonable and probable, the booster would have had a greater acceleration than that of the dart because of the separation. This acceleration, which allowed the booster to fall away from the dart, was a result of the aerodynamic profile of the section and the fact that it was less drag-efficient than that of the dart.

The acceleration comparison between the dart and the booster is not as dramatic as that of the test flight as the separation distance of the former was two-thirds of latter. Again, the variation in the two distances, and accelerations ultimately, was primarily a result of the paint and other added weight on the booster and the dart in the competition flight.

2.3 Peak Velocity Comparison

Similar to the behavior of the sections in the test flight, the booster and the dart had very different velocities and it appears that the same error occurred in both flights. The booster, according to the data gained from the Stratologger CF had a velocity of approximately 900 ft/s and the dart, according to data gained from another Stratologger CF, had a maximum velocity of about 450 ft/s. In actuality, the maximum velocities of both sections should have been the exact same.

The fact that this discrepancy in data-collection has resurfaced in the competition flight yields the question: were the methods by which the data collected inherently flawed? It is possible that points for the pressure to leak from the avionics bay where the Stratologger CFs resided in both sections were accidentally untouched or sealed for flight. However, the team conducted calculations prior to the launch, which allowed for the drilling/sealing of an appropriate number of holes. It is likely that pressure leakage was not an issue in this occurrence. It has been hypothesized that the booster's avionics bay may experienced far greater vibrations or jostling than that of the dart since the avionics bay of the former was not situated in a coupler.

3.) Data Collection

3.1 Rotation Sensor Data Report

Unfortunately, the team was not able to retrieve data from the rotation sensor system because the data could not be logged onto the memory card.

The team was able to get all the wirings and coding between the arduino micro and gyroscope to retrieve the data. The 3-axis gyroscope would measure the angular velocity that it experienced and would display the data onto the Arduino display menu on a laptop successfully. However, during the actual launch, the arduino micro will not be attached to a laptop so the data acquired needed to be transferred onto some sort of memory device. The team was planning on using a breakout board and a microSD card to record the data to be retrieved and analyzed after the flight.

However, the team had a difficult time figuring out how to incorporate the memory system with the gyroscope and arduino micro. The team attempted to overcome this challenge by researching for previous projects online and asking people familiar with electronics and coding. However, not that many people had previous experience using the arduino micro and the team was not able to have the rotational sensor working by the competition.

3.2 Quality of On-Board Video

Even though the team was able to successfully retrieve on-board video with the keychain camera, the quality was not that great. The turbulence and rotation the rocket encountered made the video very shaky and difficult to watch.

The camera was attached to the avionics sled in the coupler section of the dart. It looked horizontally outwards through a hole at a mirror angled 45 degrees downwards so the footage looks at the ground. The periscope system worked successfully and the footage initially looked directly downwards at the ground. During the boost and coast phase, the camera footage continued to look downwards but rattled a lot and was very shaky. It was visible how the rocket also rotated a lot and this made it difficult to identify what was being shown.

Also, the camera became dislodged during the descent. The team inferred that the camera was dislodged due to the black powder charge used to deploy the main parachute. The footage blacked out during the descent and there was a large popping sound that resembles a deployment. The shock from the explosive charge possibly put stress on the coupler section and moved the camera because it was not attached securely enough. Because the camera looked through a very small peephole, a small shift in the camera caused the camera view to be blocked by the body tube.

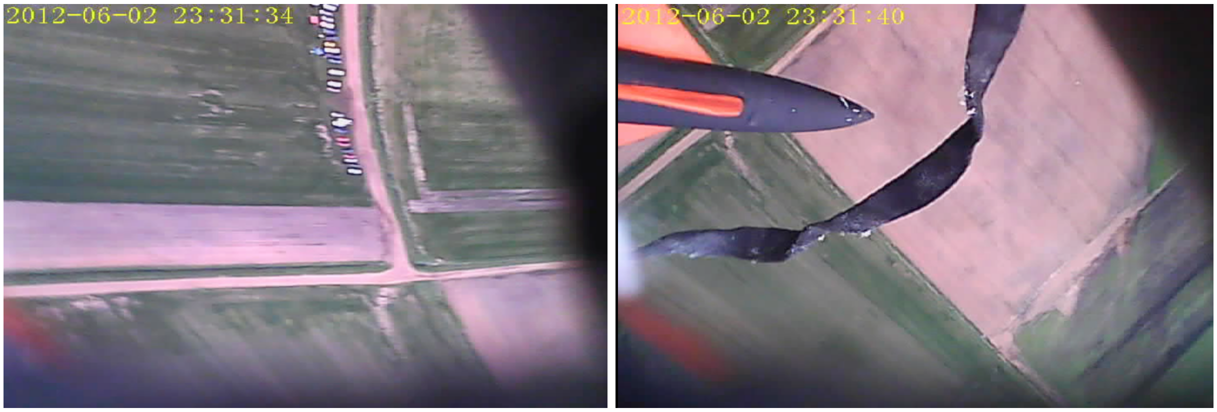

Figure 7. Snapshots from the on-board camera during ascent and at deployment of streamer

3.3 Data Interpretation

Because the rotational data from the gyroscope was not retrieved, it could not be compared to the footage from the camera. However, the camera footage itself provides a lot of information.

As it can be seen from the video taken, the rocket rotates a lot along the vertical axis during ascent. This shows that the fins were either not manufactured identically with respect to each other or were attached unevenly along the body tube. Even though the rotation did affect the quality of the video taken, it has low to no effect on the flight of the rocket.

Also, the video taken by the on-board camera captures the deployment of the streamer and the bottom part of the dart is shown dangling while connected to the shock cord. The streamer was successfully deployed near apogee and it slowed the descent rate of the dart. The video also shows that the main parachute charge successfully deployed. Even though it could not be seen whether the parachute itself deployed or not, it is evident that the charge went off.

Lastly, the video also shows that the camera was not attached securely enough on the avionics bay. The charge for the main parachute dislodged the camera and blocked the view during the last part of the descent.