Space Grant 2014 Post-Flight Report

UNIVERSITY OF ILLINOIS

STUDENT SPACEGRANT SYSTEMS

DAVID DEGENHARDT – FLORIN GHINET
LEIGH HONZATKO – COURTNEY REID
MATHEW HALM

Propulsion System Analysis

Our rocket, the Hail Mary, utilized a 54 millimeter engine tube, thus we chose the K400S engine for our launch. The engine has an estimated burn time of 4.0 seconds and a 14 second ejection charge delay. It contains 4 propellant grains with a max impulse of 1596.7 N-s and a max thrust of 484.5 N. Our engine was already pre-assembled for us. The rocket weighed just over 14 pound with the engine loaded, and launch predictions placed the rocket apogee at just around 3000ft, give or take 100ft due to wind conditions. A level-1 certified member of the group handled the engine, inserting it into the rocket and inserting the igniters. During the launch, the engine burned without incident. Although the drogue shoot had already been deployed, the 14-second delay on the engine ejection charge worked perfectly. There were no major anomalies during the flight.

Flight path analysis

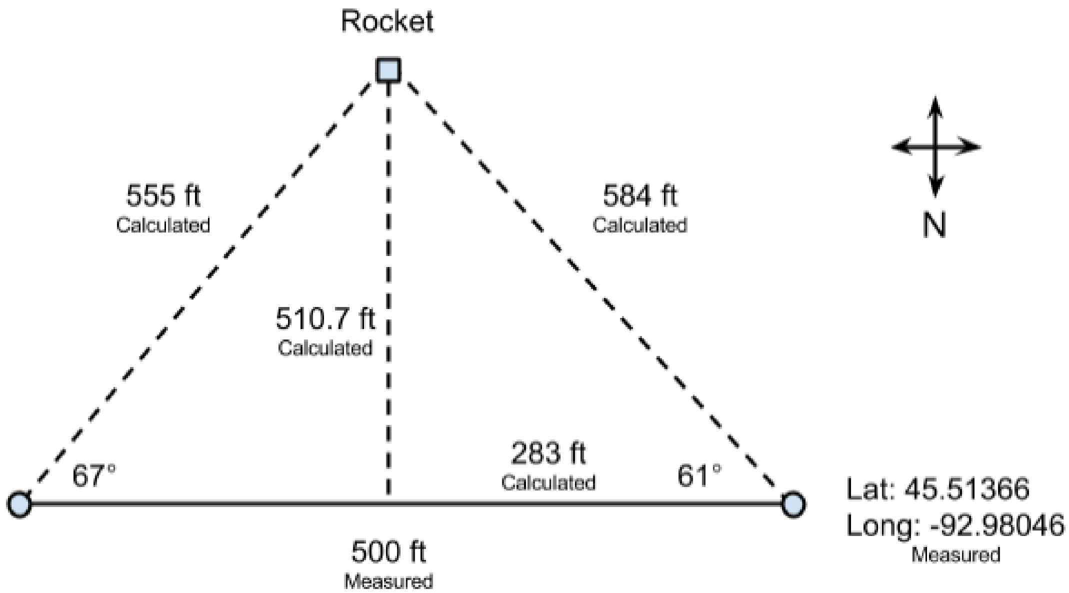
The rocket began its flight on a vertical flight path. Once it cleared the launch rail, which about 6 feet in length, the continued vertically for approximately 20-30 feet. The rocket had a stability of 3.16, which is considered over-stable as optimal stability is between 1.5 and 2. Because of its over-stability, it then began to tilt and fly against the direction of the wind. The angle of tilt increased until the rocket reached an altitude of approximately 50-60 feet, at which point its flight path stabilized at about 10 degrees from the vertical and remained at that angle for the duration of its upward flight.

Recovery System Analysis

The dual deployment system of the rocket was successful during the launch. The drogue parachute deployed at apogee at 3107 ft. The event occurred as predicted, and the deployment was triggered by the StratoLogger altimeter on board. The velocity and acceleration were 22.7ft/s and 592ft/s^2 at the deployment of the drogue parachute. Main parachute deployment occurred at 600ft, approximately 60 seconds after launch, as predicted. During this event, the velocity and acceleration were -75.7ft/s and -14.0ft/s^2, respectively. Our predicted descent rate after the main parachute deployed was 35ft/s. When the rocket hit the ground it was moving with a downwards velocity of 25ft/s.

Rocket Location and Recovery Analysis

To determine the location of our rocket we used trigonometry. After the rocket landed, two members of our group stood 500 feet apart used a compass to measure the angle between each other and the rocket. We also measured the coordinate location of the person standing at the west point to be (45.51366, 92.98046). Once the angles were measured, we used the law of sine’s to calculate the distance from each person to the rocket. These calculated differences as shown on the diagram were 555ft and 584ft. We then used trigonometric identities with the calculated and measured distances to find the horizontal and vertical distances from the east point of the triangle to the rocket. Our calculated distances were 283ft east and 510.7ft south.



Rocket location diagram

Once we found the horizontal and vertical distances, we needed to convert from feet to latitude and longitude. For the longitude we used the conversion 1° latitude= 365,228 ft to get 0.0013983° east. For the latitude we used the conversion 1° Longitude= 255,963 ft to get 0.00110563° south. To calculate the latitudinal coordinate of our rocket, we subtracted 0.0013983° from 45.52366° to get 45.5122617. To calculate the longitudinal coordinate we subtracted 0.001156 from 92.98046 to get 92.979307. Thus, the coordinate location of our rocket was calculated to be (45.5122617, 92.979307).

Pre & Post Launch Procedure Assessment

Pre-Flight Checklist

- Check electronics mounting fasteners
- Check electrical connections
- Insert launch keys in off position
- Connect all quick-connects
- Seal the payload bay
- Connect shock cords
- Check shock cord knots
- Fill and pack e-matches. 3.5 grams main, 2 grams drogue
- Connect e-matches to payload leads
- Pack the drogue shute
- Pack the main shute
- Connect rocket halves
- Get K400 motor
- Ensure adequate delay charge
- Pack motor and seal retainer
- Insert shear pins
- Carry rocket out to launch pad
- Turn on laptop receiving station
- Activate electronics
- Remove launch keys
- Attach motor leads

Post Flight Checklist

- Record angles between distance measures
- Calculate rocket location in longitude and latitude
- Turn in the prediction to the data people
- Locate rocket
- Insert launch keys and turn off all electronics
- Check for any damage, record latitude and longitude and recover the rocket.

The checklist was used at launch and ensured that the rocket would function properly. While activating the electronics, the Raven did not beep when it was first activated, and had to be reset. After activating the StratoLogger, team member verified the beep sequence in order to double check the parachute deployment altitude and ejection charge continuity.

On recovery of the rocket, all sections of the rocket were recovered and the Raven altimeter was returned.

Altitude Comparison

The predicted altitude of the rocket in simulations was 2900 to 3100ft. We ran 20 simulations in different types of weather and compiled the results into an average. The rocket attained an altitude of 3107ft at the launch. This altitude, while very close to 3000ft, was outside of our predicted range. Calm wind conditions during launch or a shorted launch rail than anticipated could be the cause of this discrepancy. Our own system of collecting data, the Arduino system, gave us an altitude of 3876.72 above sea level, with our starting sea level altitude of 774.28, so our final altitude was 3,102.54 feet. This showed that our own measurements were within 5 feet of the altitude the altimeter produced, giving the Arduino system a high accuracy.

Velocity Comparison

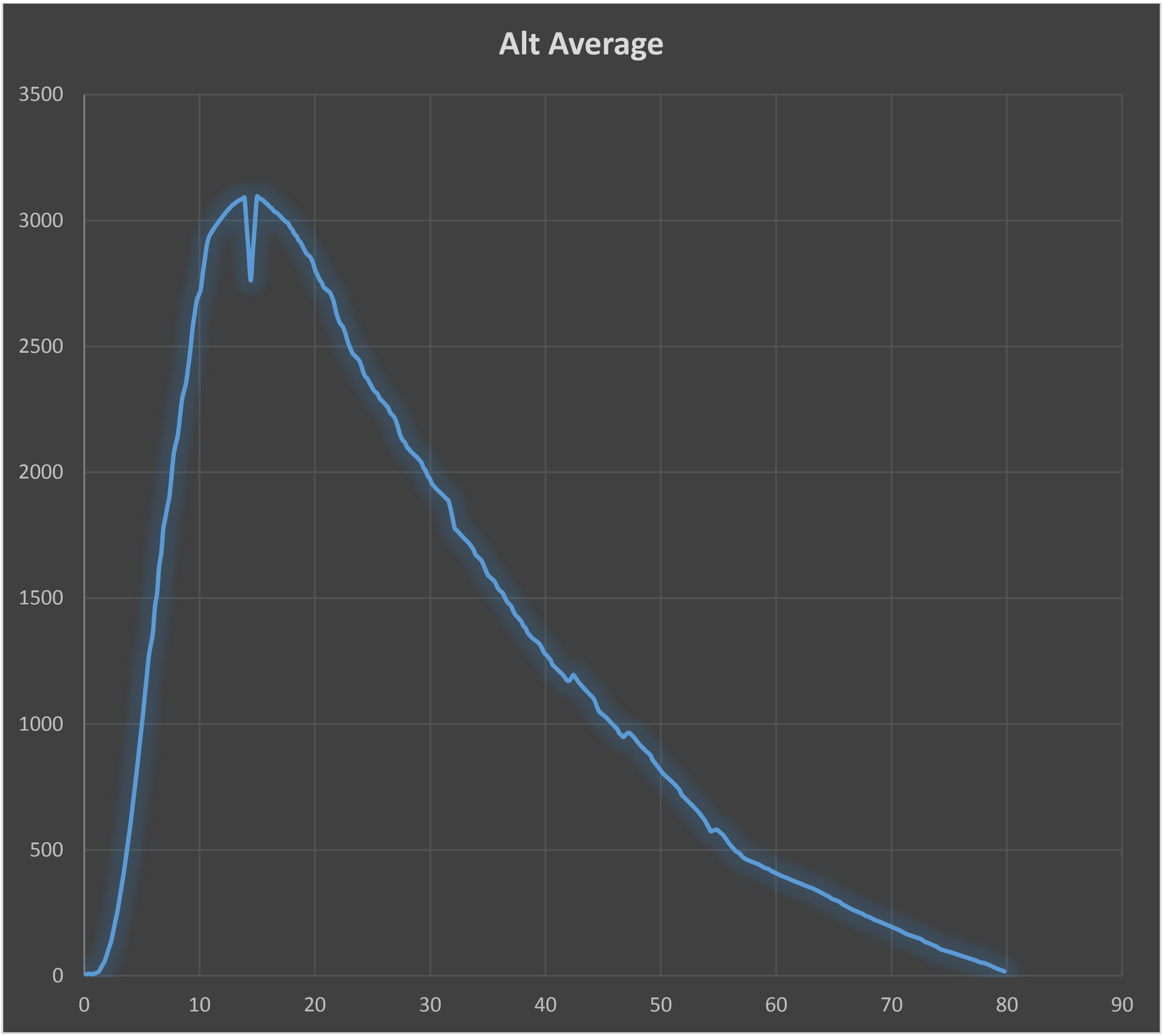
Our estimations on the velocity on Rocksim gave us a max velocity of 437.46 feet/second. This would occur near the end of the burn stage. We also got a variety of velocity values on deployment of parachute and landing. The rocket velocity around the departure of the launch rod was estimated at 68ft/s. Our drogue was deployed at around 35ft/s, and the main at 600ft, was traveling 100ft/s on deployment. A little high for our liking, but these were just estimations. On landing, our rocket was traveling around 35ft/s according to simulations. We connected our altimeter to a laptop and using the software provided, we were able to get the real life velocity data. Our max velocity was actually 550ft/s This again is due to our rocket going above the predicted altitude, and thus at a higher rate of speed. The main chute deployed at

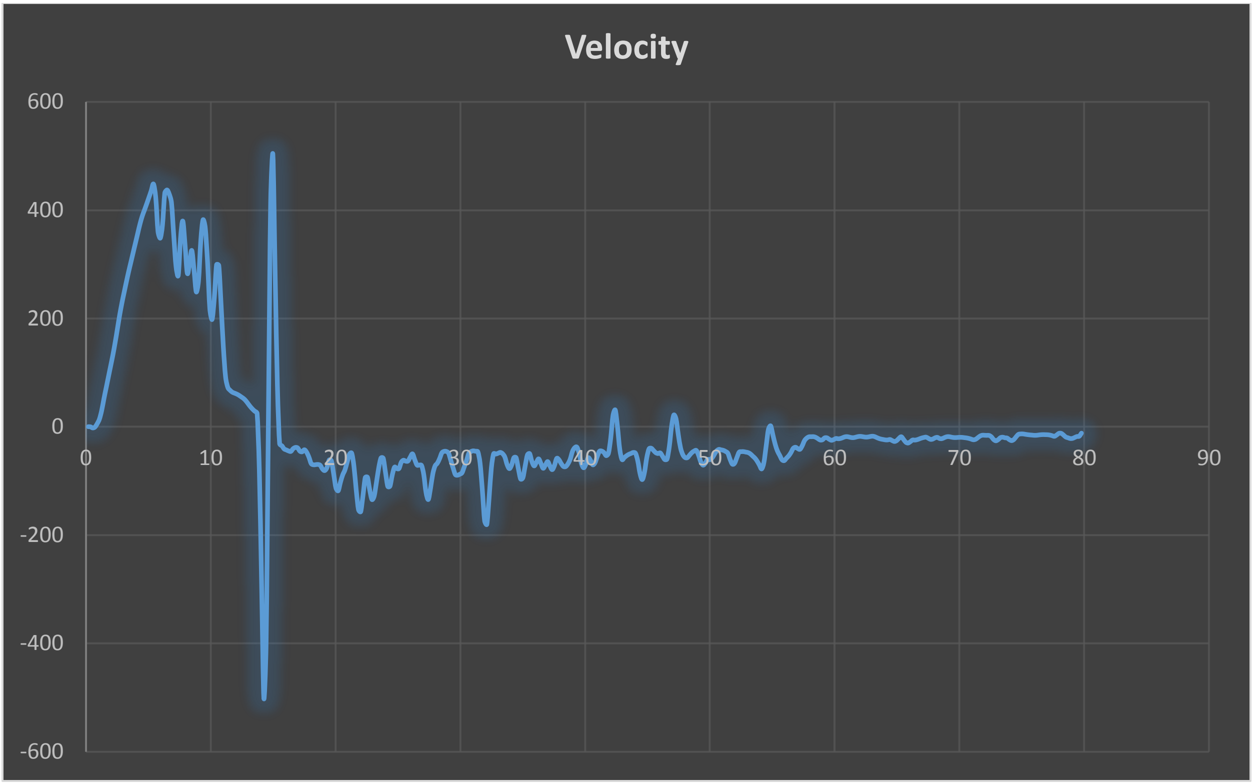
75ft/s, a much safer velocity as well as landing at 25ft/s. While our estimates were a bit off, we were happy to see that the rocket descended at a more controlled velocity.

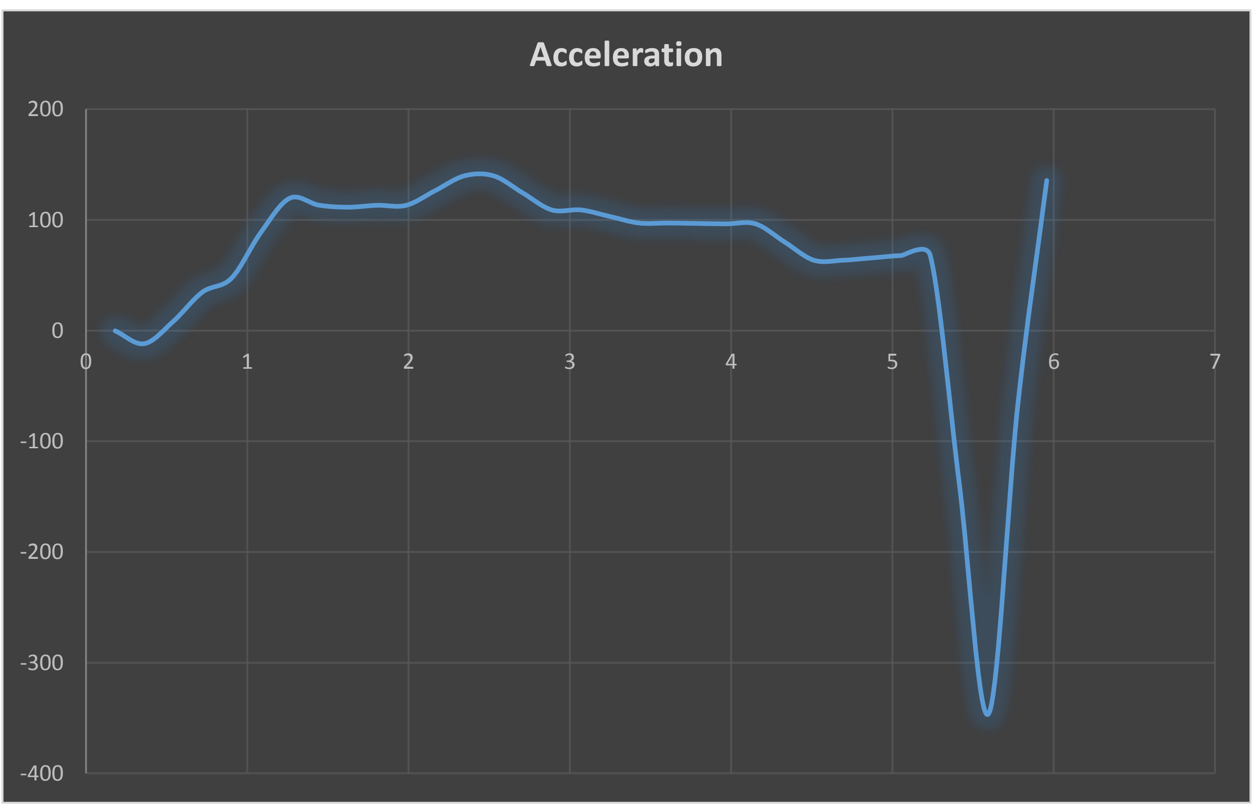
Acceleration Comparison

Our estimations on Rocksim gave us a lot of important information, including the acceleration data. This data was taken at liftoff, throughout the flight, and at both parachute deployments. During the launch phase, the max acceleration was predicted to peak around 170-180ft/s^2. In order to obtain acceleration data from our measuring system, we extracted the altitude data from the Arduino using a Java program that we coded prior to flight, and then graphed the data versus time. The Arduino was set to collected data every 1/5th of a second and transmit it to the ground. Due to an unexpected latency in the altimeter, the Arduino could only read a new altitude about every ½ second, and much of the altitude data send back to the ground was the same as had been sent the transmission before. This altitude data was difficult to clean up for use in calculating acceleration, although we managed to create a graph using the data for the first 7 seconds of flight which matched the acceleration curve created in Rocksim.

Arduino data




Velocity
600
400
200
0
-200
-400
-600
0
10
20
30
40
50
60
70
80
90


Acceleration
200
100
0
-100
-200
-300
-400
0
1
2
3
4
5
6
7

Measurement System Performance Analysis

The Arduino-based radio communication system worked throughout the entire flight of the rocket, and provided real-time altitude data to a ground station. Using this data, we were able to see that the rocket reached apogee at 3107ft just as it was happening. This system provided a reliable method of communication with the rocket. Our goal from here is to work this system into an entirely home-built rocket avionics package. We are developing our own communication protocol to take care of several issues we encountered. First, there was a latency in the altimeter connected to the Arduino. We believe that this latency was caused by a slow refresh time, and in the future plan to augment the altimeter with a GPS board. In addition, we will be pursuing the ability to activated ejection charges remotely from the ground. We are also expanding to use more powerful radios in order to use our avionics package on larger rockets. In addition, upgrades are being made on the ground station. At the launch, we were only able to receive altitude data in a text file. Using our own communication protocol, we will be able to use the data we transmit back to create a live graph of the altitude.