Post-Flight Performance Report

University of Iowa

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Executive Summary

This report contains information about the University of Iowa's post-flight comparison and analysis for this competitions rocket. Detailed descriptions of all the components of the rocket, such as fins, airframe, propulsion system, and payload, are included. An analysis of the rocket design is included with appropriate figures and plots used to show the rocket simulation data and includes comparison to the actual flights that took place. Finally, a discussion of the final results is given including reasons why there were discrepancies between the simulated and actual launch.

Rocket Airframe

Rocket Body Specifications

The main body tube of the rocket is approximately 51 in (129.5 cm) long and is constructed out of G12 fiberglass tubing with a diameter of 4 in (10.2 cm). G12 fiberglass was the chosen material because it has been proven as a very strong material, highly suitable for high power rocketry. In order to accomplish the assigned task of capturing visual data of successful parachute deployment, a camera will be mounted on the side of the airframe, coincident with the electronics bay. The camera will be mounted at an upward angle so that it can be mounted without causing any extra drag force, however minimal, while also still being able to record the parachutes successfully deploy. Simulations also estimate the total mass of the launch vehicle to be 10.258 lbs (4.653 kg).

Nose Cone Specifications

The nose cone, which is also made of fiberglass with an ogive shape, adds an additional 15.75 in (40 cm) with a shoulder length of 4.7 in (11 cm). This brings the total length of the rocket to 66.75 in (169.5 cm). The length was extended a small amount to account for the payload bay, which is where a mass will be placed during launch with the larger motor. This concept will be further explained in the payload section.

Fin Specifications

Four fins will be manufactured in-house, comprising of 1/16 in (1.59 mm) thick carbon fiber. This material has been proven to be a strong material to use for fins, and has performed excellently in the past. The fins will be tabbed such that they can be attached to the motor mount via internal filleting for extra strength. This internal filleting will be complemented by external filleting with epoxy resin composite. This will not only provide extra strength on the external airframe, but will also serve to reduce the drag from surface imperfections. Each fin is trapezoidal, with an 8 in base, 4 in free side, and a 5 in height. This shape was chosen to take advantage of the stability of wider wings, and fins will be placed 90 degrees apart from each other in order to achieve symmetry.

Rocket Recovery System

The recovery subsystem is not only comprised of the parachutes that will ensure safe descent, but also the electronics that control the blasting charges. The electronics that control the subsystem are laid out in greater detail in the electronics section. Other than electronics, the recovery subsystem is made up of the drogue parachute, main parachute and blasting caps that will deploy the aforementioned parachutes. The drogue parachute will be 15 in (38.1 cm) in diameter. It will be deployed just after apogee is reached at the start of the descent. Further into the descent stage (roughly 800 - 1000 ft above ground), the main parachute will be deployed. This parachute will be approximately 36 in (91.45 cm) in diameter. Although the mass of the launch vehicle is currently an estimation, the estimate was given a comfortable amount of cushion in order to size the drogue and main parachute.

Rocket Propulsion System

For the propulsion subsystem, the two motors chosen are the J449 for the smaller motor, and the K360 for the larger motor. These motors have a very similar specific impulse, so they will be able to launch the rocket to similar heights. Each motor will be enclosed in an appropriate motor casing, which will then be slotted into 2 in (54 mm) fiberglass tubing. Each motor casing is made out of thin-walled 6061-T6 aluminum tubing with an anodized coating for corrosion protection and also includes a rear enclosure. On the end of the tubing towards the tail end of the rocket, the casing will be secured with a retaining ring. The predicted performance of these two motors will be further detailed in the Analysis of Anticipated Performance Section.

Electronics

Dual Deployment Altimeter and Velocity Data Collection

Overview

The device selected for the dual deployment has a built in altimeter to measure the altitude of flight. The device, known as the stratologger, is capable of deploying two parachutes, a main and drogue. After the flight has concluded, the stratologger communicates to the user the flights apogee. The velocity of the flight is then transferred to the computer for further data evaluation. The velocity data is collected via a DT4U Transfer Kit. This device is able to connect directly to the Stratologger and records data such as velocity and acceleration for the flight.

Setup

The materials needed to assemble the dual deployment altimeter and velocity collection system are listed below in table 1:

Table 1: Electronics Materials List

Description	Altimeter Quantity	DT4U Quantity
9V Battery	1	1
StratologgerCF Altimeter	1	0
Switch	1	1
DT4U Transfer Kit	0	1
Electrical Wire	Arranged	Arranged

The connections for Stratologger and battery can be seen in the wiring diagram below:

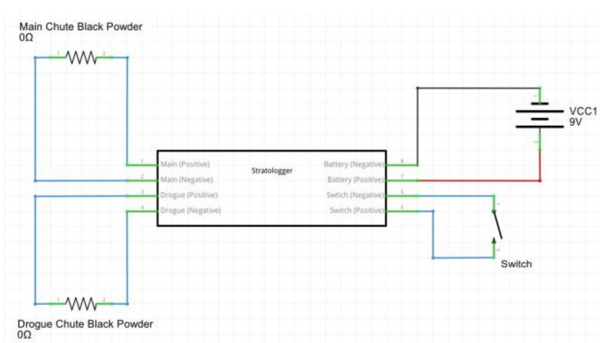

Figure 1: Recovery System Wiring Diagram

Design Features

The Stratologger various features produces a lot of adaptivity in the design of the recovery system. The Stratologger has a set of terminals designated for an external switch. The external switch allows the user to turn on the Stratologger right before launch in order to reduce any possible misfires of the black powder charges. The external switch will be in the off position during mounting on the launch rail. The switch will be activated when the rocket is ready for launch.

Once the launch vehicles reaches apogee, a current is sent through the drogue terminals on the Stratologger to ignite the black powder that will deploy the drogue parachute. The second charge, the main terminals, will send a current when the predetermined height is reached. The main parachute ignition can be chosen from a pre determined values on the Stratologger or programmed manually.

After the flight, the Stratologger will repeat the max altitude and max velocity using audible beeps until powered down. Using, the DT4U transfer kit, PNUT and Stratologger software, the altitude and velocity of the flight can be displayed graphically for the user.

Payload Design Features

The payload bay subsystem will be entirely mechanical, so no electronics will be required to operate it. The payload bay is mounted internally inside the body of the launch vehicle. It is constructed out of the same fiberglass material as the rest of the rocket. This round component is comprised of internal coupling tubes that will slide into the body. The tube is capped on both ends with fiberglass bulkheads on either side. Figure 5 on the next page shows a CAD model of the payload bay.

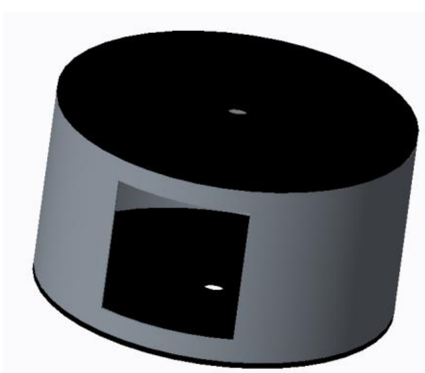

Figure 2: CAD Model of Payload Bay

In order to access the payload bay, a hole was cut into the side, and the payload bay is allowed to freely rotate in order to expose the internal bay to the outside. To achieve this, the coupling tube is restricted from translational movement by the bulkheads. The bulkheads are secured and prevented from moving in any way using epoxy and also 4 elbow brackets.

These brackets are fastened to the exterior body with the head of the fastener on the outside of the body in order to limit the amount of drag on the exterior. Each fastener is also be further secured with epoxy in order to prevent the fasteners from loosening during flight. Once closed, the door will be locked using a simple system that consists of two I-bolts and a quicklink, or other self locking carabiner. Both I-bolts will be secured to the airframe in the same fashion as the fasteners for the brackets.

Because the specific impulse of both motors is very similar, a very small amount of mass is required to bring the larger apogee down to the lower apogee. The projected mass required will be approximately 0.33 lbs (150 g). This brings the cylinder height to be about 0.47 in (1.56 cm).

Results

Table 2 below shows a comparison between the simulated and actual launches between each motor.

Table 2: Comparison Between Simulation and Launch

	J800		K456	
Parameter	Simulated	Actual	Simulated	Actual
Apogee	1346 m	1405 m	1366 m	1215 m
Max Velocity	243 m/s	243.8 m/s	217 m/s	170.7 m/s
Max Accel.	246 m/s2	-	74.3 m/s2	-
Mass	4825 g	5898 g	6075 g	5962 g

As demonstrated by the table above, the apogee of each motor was predicted incorrectly, however the velocity was much more closely accurate. Unfortunately, the DT4U kit does not measure acceleration so it is not known what the maximum acceleration of either flight actually was.

The following figures show both velocity and altitude plotted against time for both flights.

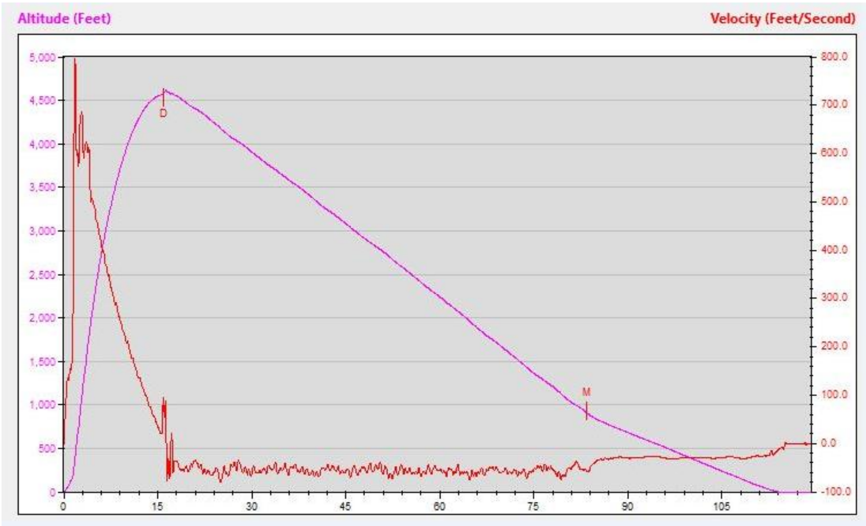

Figure 3: Altitude and Velocity for Flight 1 (J-Motor)

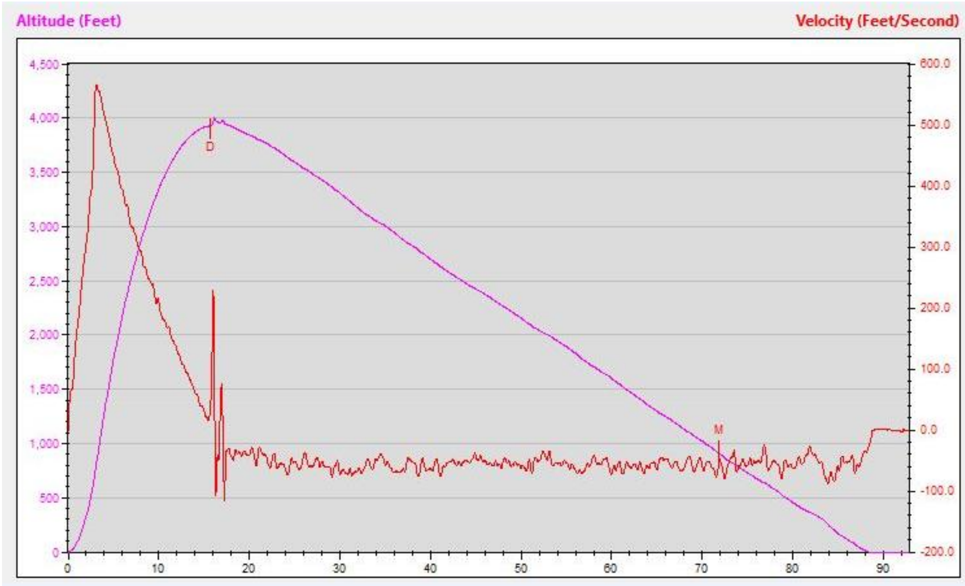

Figure 4: Altitude and Velocity for Flight 2 (K-Motor)

On the above figures, it is also marked when the ejection charges were fired. In Figure 4, it is interesting to note that the main parachute is still marked for the K-motor flight even though the charge was not successfully deployed. Unfortunately, the team realised that more parts were needed to successfully record and save video footage of the parachutes deploying so that system was not included in the rocket. Therefore, there are no screenshots to show of said footage.

In order to make an attempt at a deployment verification system, a circuit was put together which was controlled by an Arduino Nano. This circuit comprised of two photoresistors that would be directed towards either bulkhead within the electronics bay. When the parachutes deployed, the resistors would sense the incoming light and then turn on an LED light to signify that both parachutes deployed. However, before the final code for the Arduino could be uploaded, the computer stopped communicating with the host laptop. Therefore the system would not function properly and was not included in the rocket during either launch.

Discussion

As seen in the previous section, the two flights did not have a similar apogee to the simulation. This could be due to a number of different reasons. Firstly, the mass of the rocket (with motor) could have been different from the simulation. A different mass results in either a higher or lower apogee depending on if the rocket is lighter or heavier than simulated. Another possibility is that the stability of the rocket was different than simulated. If the stability is higher, then that means the rocket has a better trajectory and encounters less wind resistance on ascent which results in a higher altitude. Vice versa, if the stability is lower, then the rocket will have a much more wobbled flight path which leads to more resistance.

As seen in the previous section, the J-motor flight achieved a similar max velocity to the simulation. However, the K-motor max velocity was a bit lower than predicted. This could again be due to the extra wind resistance encountered with a less stable flight than what was predicted. The simulations were run using the assumption that there was no wind. However, this was obviously not the case and the extra wind could also influence the rocket's flight path depending on what direction it was blowing. Again, the DT4U kit does not record acceleration data, so there can be no comparison between simulated and actual flight data.

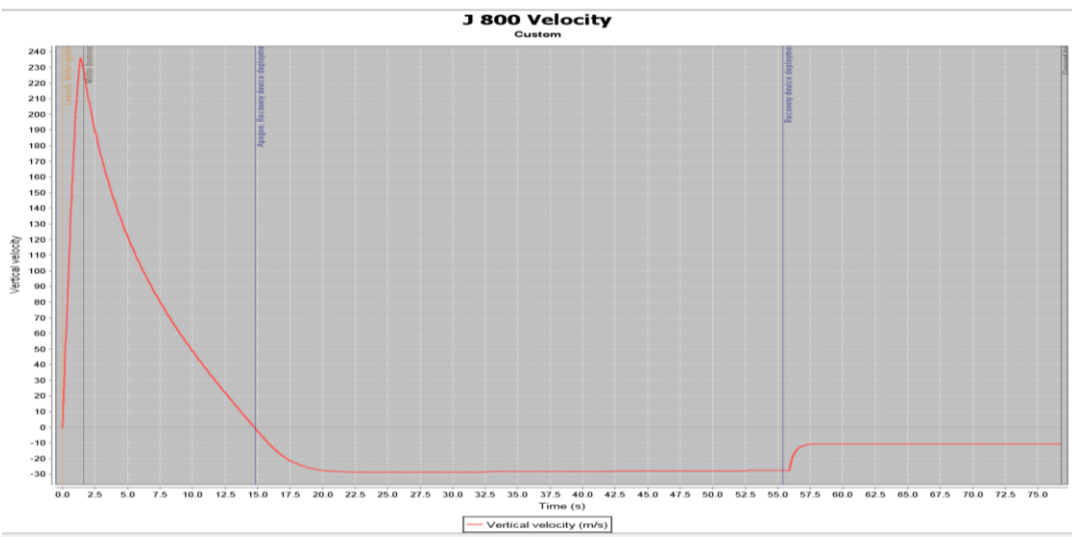

Figure 5: Simulated Velocity vs. Time for J800

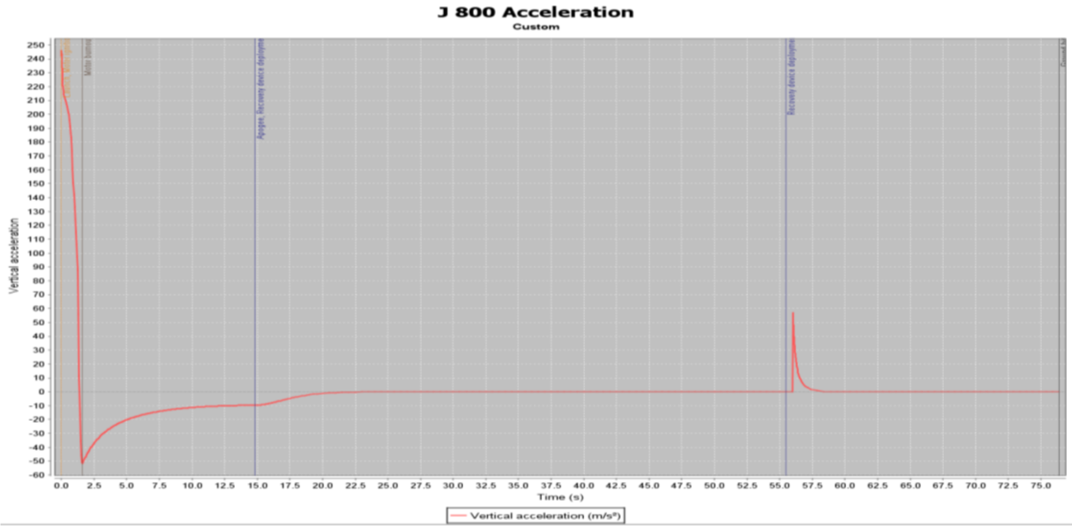

Figure 6: Simulated Acceleration vs. Time for J800

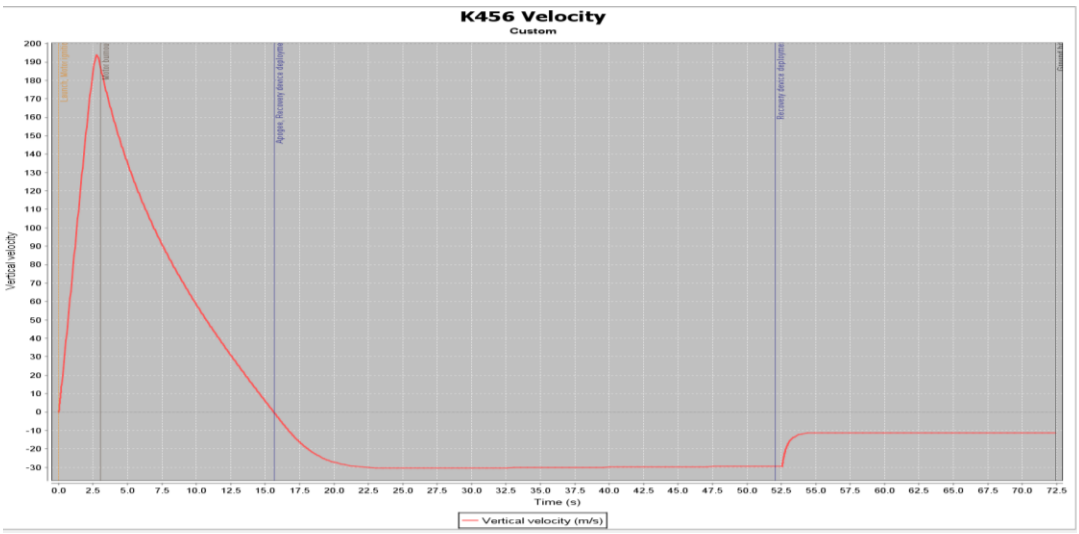

Figure 7 Simulated Velocity vs. Time for K456

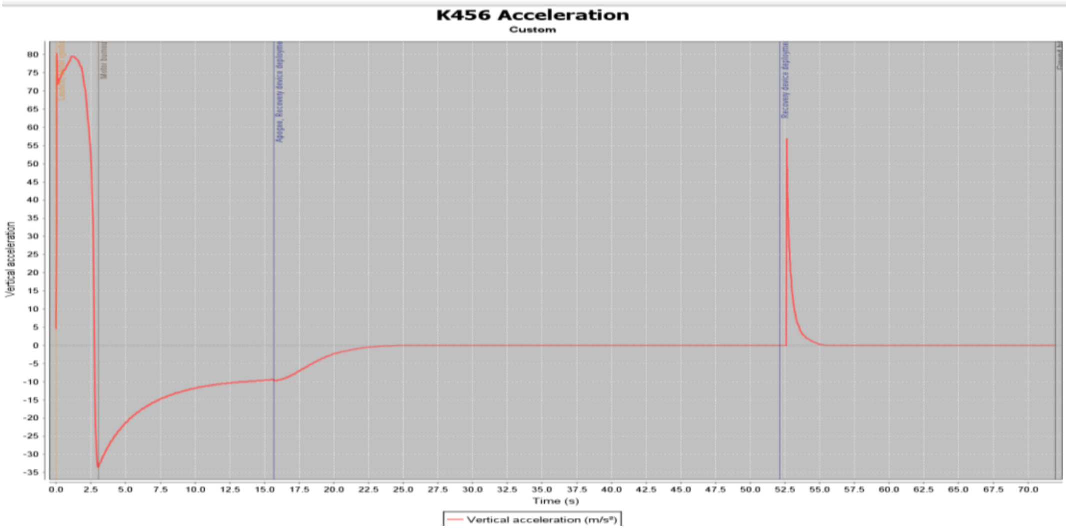

Figure 8: Simulated Acceleration vs. Time for K456