INCIDENT REPORT

ROCKET-MEN AE628 Senior Design

Planned Mission

The Rocket-Men attempted to launch the rocket for the first time on May 4, 2016 around 5:45 PM CST near Argonia, KS (37°10'04.2"N 97°44'23.1"W). The intended mission for the rocket was as follows:

- Record flight data, including barometric pressure, temperature, and altitude,
- Record drag system response to the mission, and ensure no accidental activation occurred,
- Climb to an estimated altitude of 4900 feet should the rocket motor provide 100% of the thrust and impulse output,
- Deploy the drogue parachute 17 seconds after engine burnout,
- Deploy the main parachute at 600 feet above launch site elevation during descent.

Rocket Performance during Mission

The detailed information from the flight can be found in table 1. The key points of the rocket performance are as follows:

- The rocket lifted off as expected. The burnout time recorded was 1.3 seconds which we assume to imply a 1.6 second burnout time as suggested by the manufacturer in figure 1.
- The rocket achieved an apogee of 5913 feet (figure 2). While significantly higher than 4900 feet, the python code the team used predicted that the rocket could achieve 5980 feet if the rocket motor provided 10% extra thrust. Cesaroni, the rocket motor manufacturer, labels the J580 motor used with an accuracy of ±10%.
- The ejection charge in the rocket motor went off at 24.8 seconds after lift-off, i.e. 23.2 seconds after engine burnout. While not a contributor to mission failure, the reason for the discrepancy from the 17 second delay the manufacturer rates the ejection charge for can be attributed to improper placing of the ignitor in the engine at the launch site. The ejection delays are known to be greater than the rated time if the ignitor is not placed high enough in the rocket motor. This is something that the team expects and planned for.
- When the motor ejection charge went off, the shock cord connecting the aft section (figure 3) of the rocket to the flap section of the rocket disconnected. The failure occurred at the bonding site on the aft section. When the rocket was recovered, the adhesive was found to have peeled off cleanly. The adhesive was also found to be soft to the touch. The team concludes with certainty that the adhesive did not cure properly and did not have enough hardener in it to result in a strong bond.
- The team therefore looked at the acceleration data and found peaks in the acceleration curve at the time of ejection of -86.3 and 50.9 m/s^2. The team will keep these values in mind while designing a failsafe method to ensure that shock-cord detachment shall not be a cause for mission failure in the future.

- The Main parachute deployed, and the payload section landed safely, enabling the team to recover the payload, the data, and the fore section of the rocket.
- One of the flaps was found attached to the rocket body merely by aluminum tape; the aluminum tape was used to provide a smooth transition from the rocket body to the flap surface and was not intended to be a structural member. The flap was adhered to a carbon fiber stiffener using an epoxy-based adhesive prior to launch. The flap was found to have peeled-off the adhesive bond on the stiffener. This could only have occurred due to a direct impact. The team rules out an impact on landing as the flap section's approach to the ground was controlled. The only other instance when the flap section may have suffered an impact would have been when the aft section was detached. The aft section must, therefore, have struck the flap section during its free fall. (Figure 4)

Proposed Solution to Key Issues

At the outset, the team would like to establish that the fore, flap, and aft sections of the rocket are structurally sound as individual components. The key failure in the mission was due to an improperly bonded shock-cord to the aft section.

Proposed shock-cord connection improvements

The aft-section will be reconstructed as per the original design, but with the following improvements:

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- The shock-cord will be attached to the foremost centering ring on the aft section via 2 eye bolts. The original bonding technique did not account for peeling forces, which led to a failure in the mission. The use of eye bolts will handle the applied loads better.
- In the removable bulkhead that attaches onto the flap section, the team plans on using two eye bolts as well.
- In order to be certain that the bulkhead will not rupture during deployment we calculated the force applied by the ejection charge and the resulting force on the eye bolt when the shock cord eventually tugs. Research suggested that we could not exceed 2700 psi of applied pressure during the tug. In order to prevent this, we will attach the main shock cord to the bulkhead and centering ring via two separate sections of cord, fastened to two separate eye bolts. This will insure that neither eye bolt will take the full load, and will insure that shock cord failure is prevented.

Proposed flap-stiffener bonding improvements

The flaps are currently bonded to the stiffener via an epoxy-based adhesive. While this holds up excellently in shearing and compressive loading situations, it holds up poorly if a peeling force is applied to it.

- Holes will be drilled through the flaps and stiffener as pictured in figure 5.

- A steel safety wire will be passed through the holes in order to strengthen the bond, and address a situation such as the one encountered in the failed mission.
- The ultimate tensile strength of safety wire is 31200 psi. Using the equation P=F/A we calculate a pressure of 326 psi that the safety wire will experience. The force was derived from the two sections of the rocket colliding in free fall like we assumed happened.

Figures and Tables

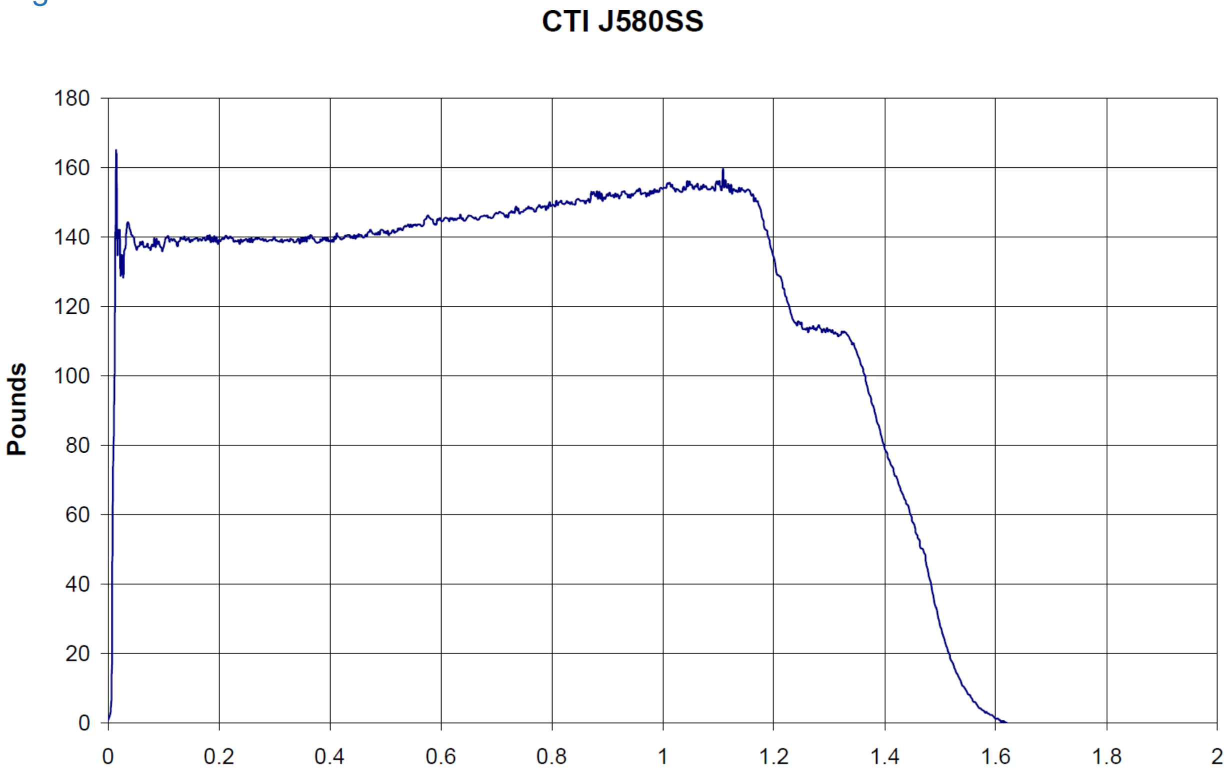

Figure 1: Cesaroni J580 Thrust vs. Time graph. Note the drop in thrust around 1.3 seconds that is often read as the burnout time by the altimeter.

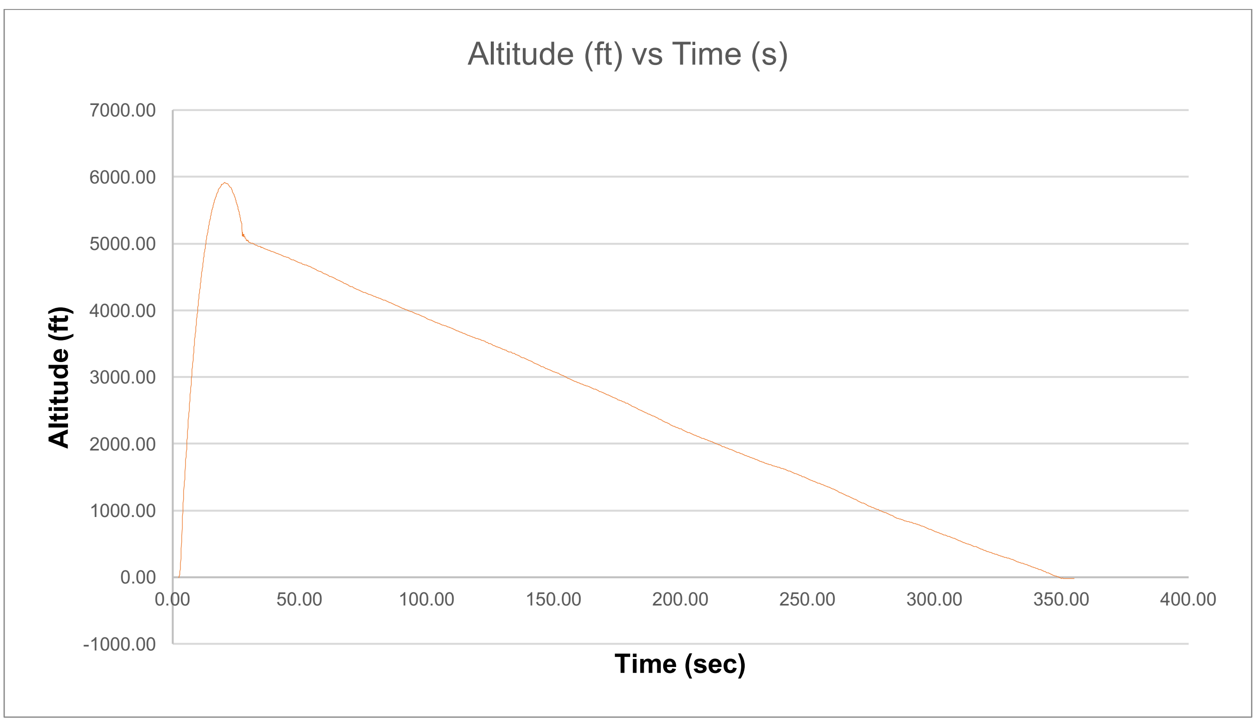

Figure 2: The rocket achieved an altitude of 5913 feet above the launch site. The data was measured using an Adafruit Altimeter, and was confirmed by the Entacore altimeter and the Altimeter 2 on board that reported very similar values.

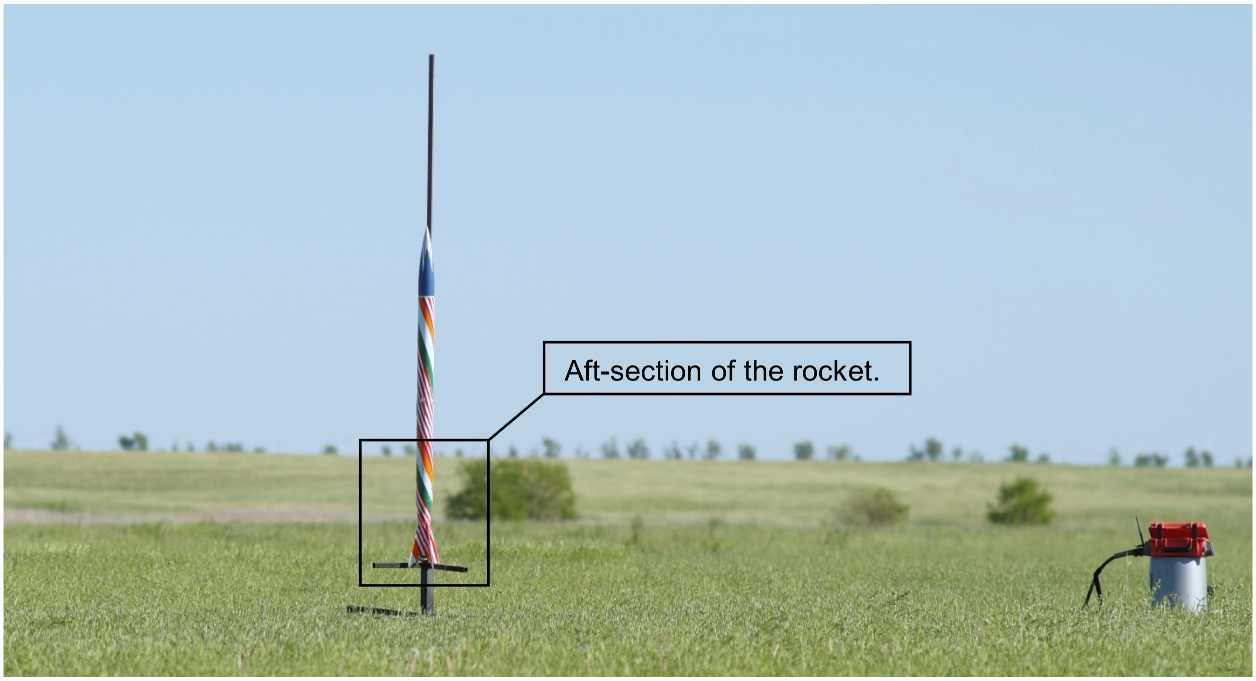

Figure 3: Rocket-Men's rocket on the launch site near Argonia, KS on May 4, 2016 moments before the unsuccessful mission. The aft-section that went unrecovered is highlighted.

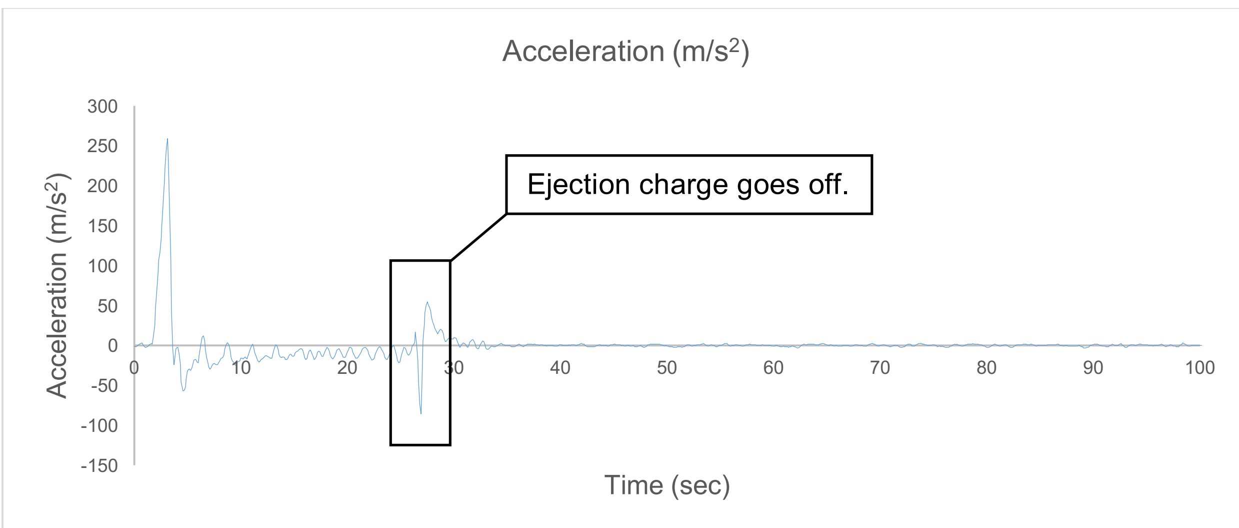

Figure 4: After achieving apogee, the rocket was inverted with the nose pointed towards the ground. The highlighted section's negative spike implies a downward movement in the payload section caused by the ejection charge going off. As a result, the aft section would have moved upwards initially; it would have then proceeded to hurtle to the ground ballistically.

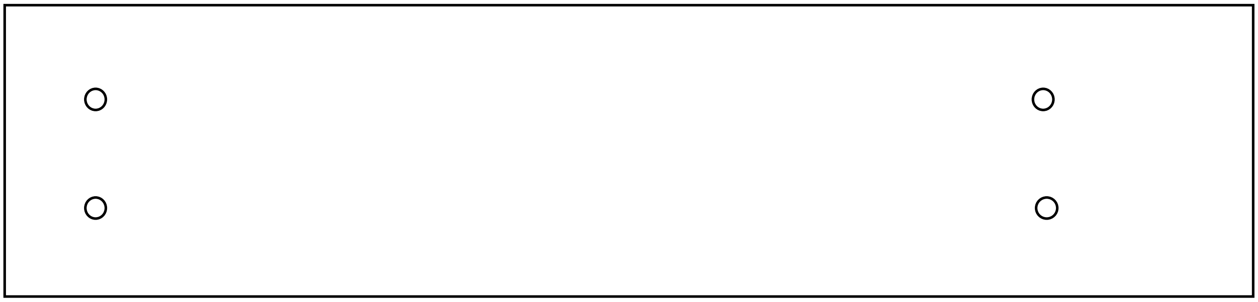

Figure 5: Holes to be drilled in the flaps. Steel safety wires will be used to strengthen the attachment of the flaps to the stiffeners.

Table 1: Flight statistics from the launch at Argonia, KS on May 4, 2016

Length	66.17”
Diameter	3.125”
Initial weight	8.3 lbf
Final weight	6.0 lbf
Apogee	5913’
Time to burnout	1.6 s
Time to apogee	17.9 s
Time to ejection	24.8 s
Maximum velocity	242.6 m/s
Maximum acceleration	26.4 g