Pioneer Rocketry 2019 WSGC Intercollegiate Rocket Engineering Competition

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Abstract

The Intercollegiate Rocket Engineering Competition is held by the Experimental Sounding Rocket Association every year at Spaceport America, New Mexico. The competition has many categories, and Pioneer Rocketry chose to compete in the 10k COTS category, flying Something Cheesy to an altitude of 10,000 feet on a commercial motor, with a 4 kg payload. The payload studied the breakdown voltage of air with respect to altitude. Pioneer Rocketry is proud to report that Something Cheesy had a safe and successful flight and recovery. Unfortunately, due to a motor anomaly, Something Cheesy flew short of its 10,000-foot goal. The team is proud to have represented the state of Wisconsin at this international event, winning the "Cheesiest Rocket" award, as well as being runner up for the spirit award.

1. Rocket Operation Assessment

1.1 Propulsion system specifications Initially the Aerotech disposable motor system M1350 motor was chosen as it did not require the purchase of a new casing, the rocket was designed using this motor. After talking with our local motor vendor, the motor that we planned on using was unavailable. In the end, the vendor gave a good price on two motors and a casing, which led to the choice of the Aerotech M1845. This motor has the highest impulse available in that casing size, which gives flexibility in the rocket design that the initial motor choice did not.

1.2 Flight trajectory assessment Something Cheesy had a safe flight both times that it flew, but each flight had a few anomalies. The first flight the main parachute tangled with the drogue which caused the rocket to descend faster than expected. The rocket ended up landing in a tree and was fully recovered with no damage. The second flight (the competition flight) a motor

anomaly occurred approximately halfway through motor burn which caused a loud report and a decrease in performance by 20%. After analysis of the flight data and the spent motor reload, it was determined that the anomaly was caused by a casting tube being ejected during motor burn. After talking with the Vice President of Aerotech Rocketry, he clarified that ejecting a casting tube is not uncommon and is more likely to happen with higher thrust motors like the one that was used. Although there were no errors made in the assembly of the motor, more care will be taken when following the motor assembly procedure. After boost, Something Cheesy had its second anomaly by deploying the main parachute at apogee. This was quite unexpected as there were no issues with this in the first flight. It was pointed out that the launch rail was angled more at the competition than the test flight. This leads to more horizontal velocity which caused the main parachute to eject when the drogue ejection charge went off. Lastly the rocket sustained a cracked fin fillet upon landing. It is uncertain what had caused this damage as the descent velocity was nominal, but a few things that could have caused this were: damage from the first flight, damage in transportation, and or landing on a rock.

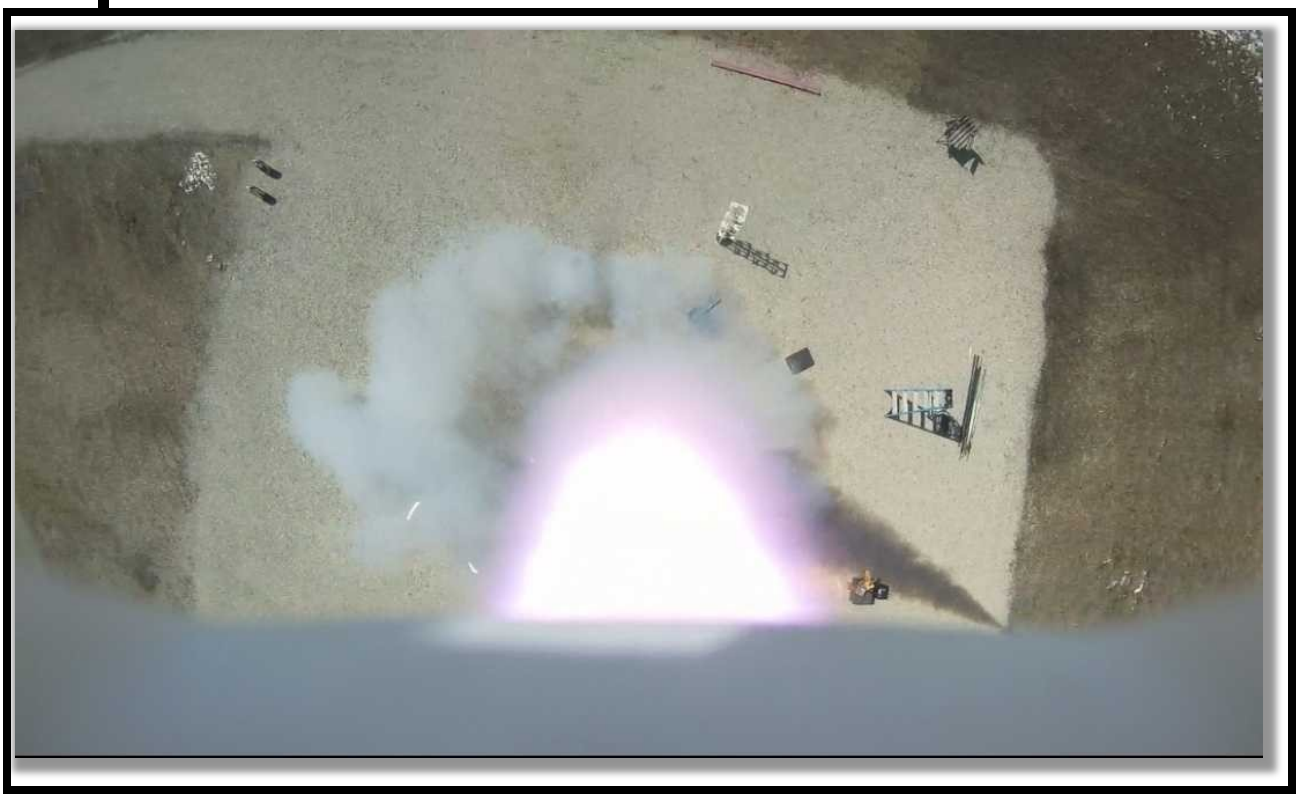

Figure 1: On board camera view during boost on the first flight of Something Cheesy

Figure 2: Something Cheesy during boost on its first flight

1.3 Recovery System Assessment Something Cheesy used a head end dual deployment recovery scheme. This consists of the drogue parachute in the main body of the rocket with the main parachute in the nose cone. This style of dual deployment allowed the rocket to have less airframe tube which shortens the rocket and makes it lighter. The drogue parachute was a 48" Fruity Chute parachute which deployed at apogee. The main parachute is a Skyangle Cert 3XL parachute which was set to deploy at 1100ft for the primary ejection charge and 900ft for the backup charge. After the first flight with the tangled main parachute a more detailed packing procedure was

implemented which resolved the tangled parachute issue. The drogue parachute allows the rocket to descend at a reasonably fast speed of 70ft/s to reduce recovery distance and the main parachute had a decent rate of 20ft/s. For the first flight the recovery distance was close: approximately 1000ft away from the launch site. Since the second flight deployed the main parachute at apogee, the recovery was around 3000ft away from the launch site. Luckily there were access roads that could be used, and most of the recovery distance was able to be done in a vehicle.

1.4 Pre and Post Launch Procedure Assessment Spaceport America Cup requires very detailed checklists and procedures which helped tremendously. From experience in previous years along with extensive planning and detailed checklists, Something Cheesy was the second rocket launched of the competition. Launching early allows for a more expedited recovery and post flight check in with the judges as there was no line. Although the checklists were extensive, there are a few places that it can be improved. Inspection of the launch rail was added to the checklist as the launch pad that was initially assigned was not fully assembled and required the rocket be moved to a different launch pad. The post launch procedure will have an added section on how to deal with live ejection charges if they did not go off as we had this happened and did not have a procedure for that. Lastly there will be a secure SD card section to prevent data loss in the future.

1.5 Payload The theory behind the payload stems from Paschen's Law. This law is an equation that defines the voltage necessary to discharge or arc, between two electrodes in a gas. This is known as the breakdown voltage of the gas. The distance between the electrodes and the pressure of the gas can determine the breakdown voltage of the gas. For this payload, the effects of pressure on the breakdown voltage were examined. The test will occur on the descent of the rocket so the pressure will increase as the altitude decreases. According to Paschen's Law, as the pressure increases, the breakdown voltage will increase. The equation for Paschen's law is:

$$V_B = \frac{Bpd}{ln\,(Apd) - ln\,[ln\,(1+\frac{1}{\gamma_{se}})\,]}$$

The constants A and B are experimentally determined and are based off the E/p (electric field divided by pressure) of the gas. The constant γse is the secondary electron emission coefficient, which is also experimentally determined. The constant A is the saturation ionization of a gas and B is related to the excitation and ionization energies. The secondary electron emission coefficient is the number of secondary electrons produced. The one limitation with this equation is that it is meant for micro sized gaps. When the gap is around centimeter and meter sized, the equation is harder to determine due to the difficulty in determining the constants. Luckily, there is an easy approximation. The breakdown voltage can be calculated as the product of the gap size and the pressure in terms of Pascal. Using this approximation, a spark gap of 1 mm at STP would need about 1 kV to spark. This results in a linear relationship between pressure and breakdown voltage, as shown in Figure 3.

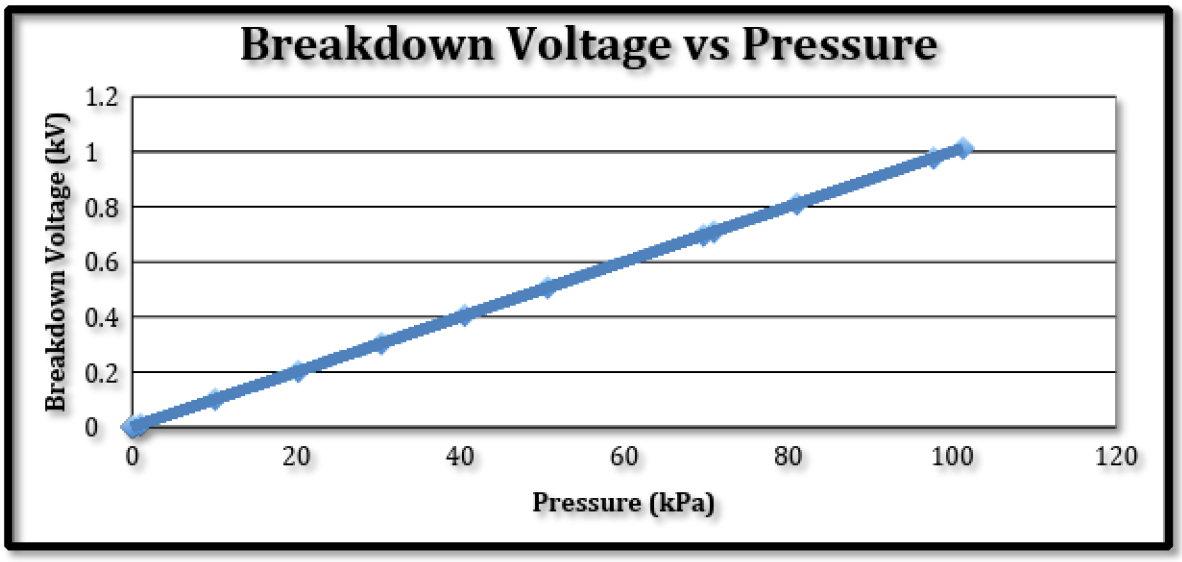

Figure 3

Once pressure is determined, altitude can be calculated assuming constant temperature and density. The results from the breakdown voltage in relation to altitude can be seen in Figure 4

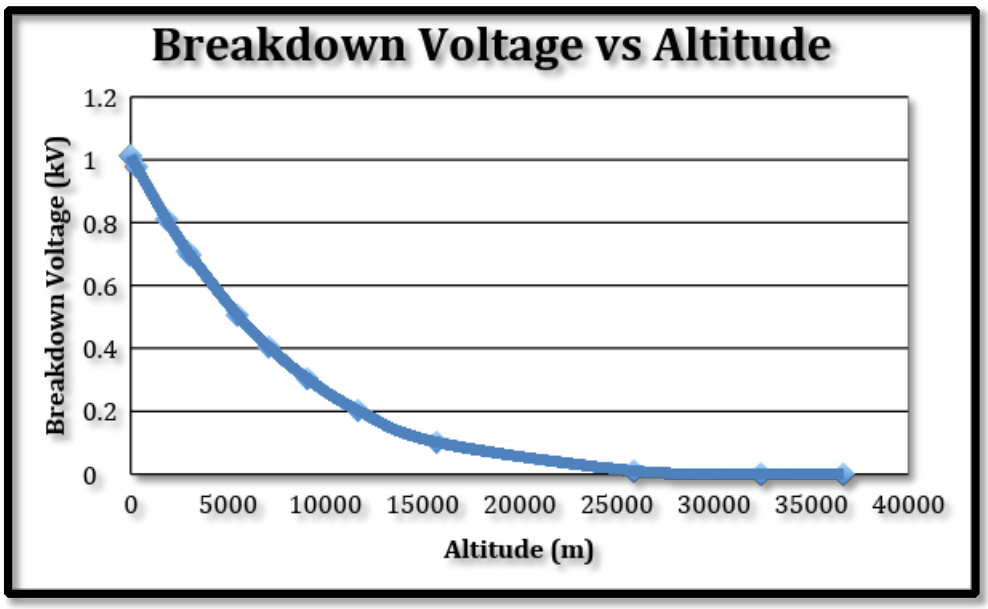

Figure 4

Unfortunately, due to the SD card being ejected during flight, Pioneer Rocketry was unable to recover data from the payload.

2. Conclusion

While Something Cheesy flew short of its target altitude, Pioneer Rocketry is very pleased with the team's overall performance. We are thankful to have the opportunity to participate in this competition year after year. The new members that have participated this year are eager to see what next year has in store for us. Every year, our team gains new knowledge about rockets and we have a blast working together. We are thrilled to have this opportunity to share our enthusiasm for aerospace with the world.

Figure 5. Something Cheesy on the launchpad ready for flight at the Spaceport America Cup.

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