Pioneer Rocketry
2021 WSGC Collegiate Rocketry Competition

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Abstract:
The Wisconsin Space Grant Consortium hosts the annual Collegiate Rocket Launch Competition every year. The goal of the competition this year was to design and build a rocket to fly to between 2500 and 3500 ft and record flight data along with additional internal readings. The rocket, "Error :(", used a CTI I435 motor to lift it to an apogee of 2300 ft.. An onboard electronics bay would take measurements before and during flight and a breakaway USB cable from the launch pad to a ground station allowed communication with the rocket until the point of liftoff. The rocket flew successfully but there were problems with the electronics.

1. Introduction

The challenge for this year's Collegiate Rocket Launch Competition was to build a rocket that could record flight data. The rocket would be connected to a PC via a break away USB cable on the launch pad. The flight computer would send data to the PC where it would be displayed. Upon liftoff, the USB cable would detach and the flight computer would switch to a record data only mode. The data would be recovered when the rocket is landed and the data would be analyzed. The team managed to successfully launch and recover the rocket however, the rocket was short of the targeted altitude. This paper will go into the details on the issues that the team faced as well as potential design improvements.

2. Materials and Methods

Payload Materials: The payload system is centered on the Raspberry Pi Zero, which controls all other sensors on the payload. The payload includes a MPL3115A2 pressure sensor to record the altitude. To record the temperature, there is a k-type thermocouple and a MAX31855 thermocouple amplifier breakout board. To record location data, a GPS module is also included.

1 Special thanks to the Wisconsin Space Grant Consortium

A 9 V battery connected to a 5 V converter provides power to the circuit. A Strattologer is used to provide additional altitude measurement as well as to serve as the primary chute release.

Rocket Construction: The body of the rocket is primarily constructed using phenolic materials. The fins are constructed using plywood that has been laser cut to the specified dimensions. The nose cone is 3D printed from plastic. These materials were chosen due to their low cost and ease of use. The motor used was a CTI I435. This motor was chosen since it would provide enough thrust to launch the rocket to the targeted altitude.

Software Design: The software is written in the Python programming language. This allows it to easily interface the sensors with the Raspberry Pi. The flight performance is estimated by setting the pressure sensor to altimeter mode. The barometric data is recorded as 20-bit unsigned integers in Pascals. This is then converted into the altitude measurement and recorded as 20-bit 2's complement in meters [1]. This data is transmitted to a PC on the launch pad which it would be viewed with the PuTTY terminal. The data is stored on the Raspberry Pi in a CSV format. This will allow the data to be easily read and analyzed.

3. Key Results

Rocket Operation Assessment:

Flight Anomalies Analysis: The rocket, "Error :(", had one flight where it was recovered without any damage. There was an issue with the electronics on the launchpad where the electronics would not properly power on. This was likely due to a short in the electronics circuit. The rocket reached an apogee of 2300 feet recorded by the provided Altimeter2, which was short of our targeted goal of 3500 feet. The reason behind the loss in altitude is suspected to have been caused by either the USB cable getting caught on the body of the rocket during liftoff or an underperforming rocket motor. The team was very surprised by the altitude anomaly.

Propulsion system and flight path assessment: The rocket safely and successfully performed one launch on the competition day. There were no discrepancies with the flight path, other than the aforementioned unexpected apogee. The rocket drifted slightly and was recovered within 300 feet of the launch pad. Due to a loss of power to the avionics bay, precise GPS and StratoLogger data was not recorded.

Recovery System Analysis: The rocket included a StratoLoggerCF as well as the motor backup for parachute deployment. Due to faulty wiring, the StratoLoggerCF became disconnected during flight and so the motor backup was used. The ejection was able to successfully deploy the drogue and main parachute. More precise descent data was not recorded.

Rocket Location & Recovery Analysis: Locating the rocket posed no difficulty, as the team had visual line of sight throughout the flight. "Error :(" suffered no structural damage upon landing and was in good condition. Due to space and time constraints, some of the wiring had to be secured to the exterior of the rocket and became disconnected during flight. The flight setup of “Error :(“ had wiring running along the shock cord from the motor mount to the avionics bay for recording motor casing temperature. Efforts to load the shock cord in a manner that would avoid tangling were unsuccessful and the increased diameter and stiffness resulted in significant tangling. Enough shock cord was ejected to allow for deployment of both parachutes and a safe landing.

Pre and Post Launch Procedure Assessment: Pioneer Rocketry prepared checklists with tasks to be completed the day before the launch, on launch day, before the rocket was taken to the pad, and after the rocket was recovered. The team was able to work quickly and efficiently to prepare, launch, and recover the rocket safely. Improvements needed for checklists and plans would include checking electronic connections prior to bringing the rocket to the launch pad. This would be helpful to avoid possible electronic malfunctions during flight, as this was the main problem of this year’s competition rocket.

4. Discussion

Payload System Performance:

Payload Tests: The avionics system used a Raspberry Pi as the primary controller. The payload was successfully tested before the launch day and all systems were able to function within the payload section. The GPS was tested by wiring the GPS module to the Raspberry Pi and then inserted into the rocket and taken outside. The correct signal from the satellite was picked up after a few minutes. The pressure sensor and temperature sensor were also tested with the Raspberry Pi and were successfully calibrated and picked up the expected measurement of approximately 97000 Pa [2]. During testing, the Raspberry Pi was connected to a computer which displayed nominal data from the Pi.

Payload in Flight: The payload was unable to function during the flight. Due to time constraints, the team had to devise a fast solution in order to power on the avionics system while the system was fully inside of the rocket. The team decided to use the twist and tuck method and connected several wires together by wrapping the exposed ends of the wires and taping them together to power on all of the electronics. However, the wires would not fit into the avionics bay and had to be taped to the side of the rocket. It is likely that one of these wires was not connected correctly which caused a short. The short was detected by the LED on the USB cable being dimmer than usual. It is also likely that the exposed twisted wires were disconnected by the high velocity airflow around the rocket experienced during the flight.

Possible Improvements: An upgrade that could be incorporated into a future design is to implement a better power system for the avionics. The design used in the rocket involved powering the system with two 9-volt batteries and using external wires to power everything on. This can be changed so that the system is powered by rechargeable batteries. The batteries could then be charged from the USB cable while the rocket is plugged in. The external wires could also be changed to a more reliable internal switch that could be pressed to power everything on.

Predicted Flight Performance:

Altitude:

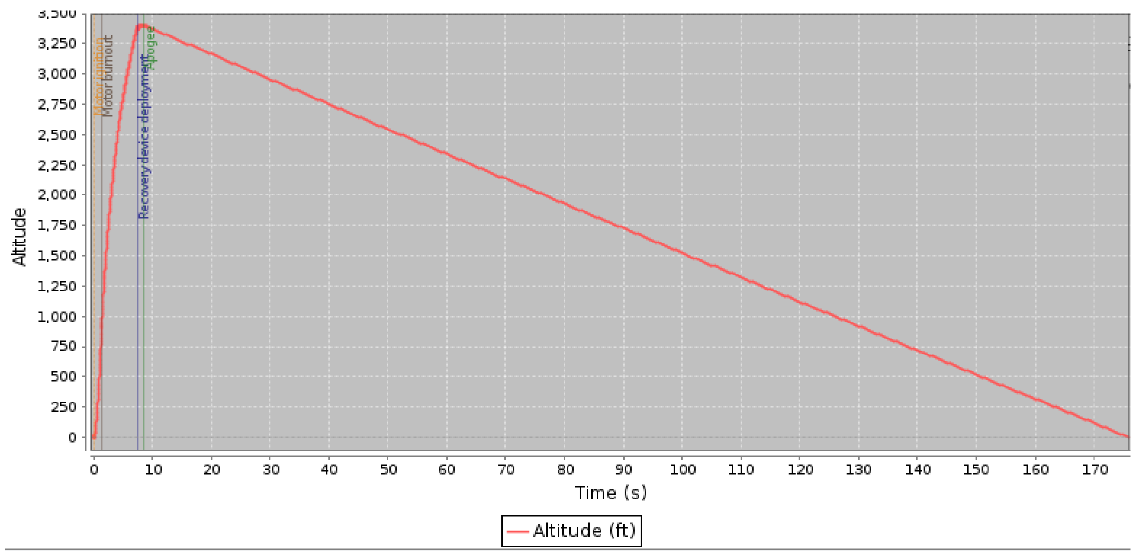

Figure 1: Altitude vs time simulation, showing a predicted altitude of 3400 ft

The altitude was to be calculated using the pressure sensor, Raspberry Pi, and StratoLoggerCF. This would use the pressure sensor to record the barometric pressure. The details of how this was done was mentioned in the software design section. Due to the power failure experienced during the flight, data was not recorded.

Acceleration:

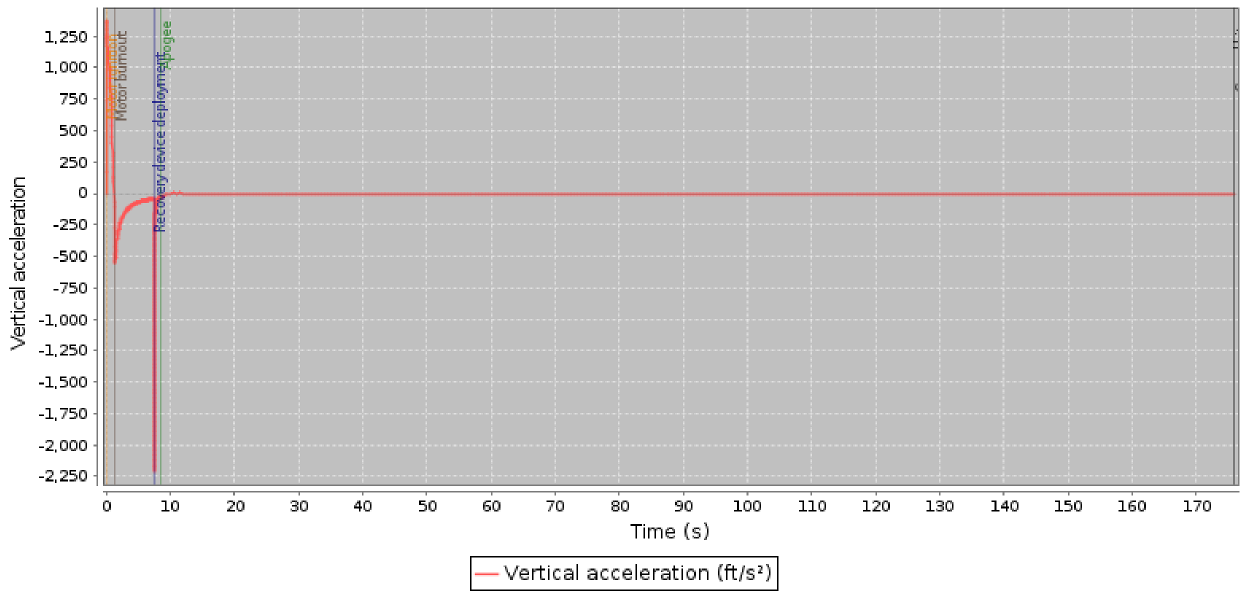

Figure 2: Predicted acceleration, showing a maximum of 1250 ft/s2

The acceleration was to be calculated using the GPS, Raspberry Pi, and StratoLoggerCF. Actual flight acceleration was not recorded due to the loss of power.

Photographic Documentation of Flight:

Figure 3: "Error :(" on the rail (left) and taking off (right) during the competition flight.

Figure 4:”Error :(“ after landing.

Conclusion: This year’s CRL competition provided many unique challenges that need to be solved. The main challenges were to successfully feed the wires for the electronics from the inside of the payload to the exterior of the rocket without ruining any of the wires and to design a payload that could fit within our rocket while also being able to contain all of the electronics needed. The rocket safely achieved an apogee of around 2300 ft and was recovered in good condition. The team has learned a lot from this experience and enjoyed the opportunity to compete in this year’s competition.

5. Acknowledgements

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6. Bibliography

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