Development of a Small Satellite for Deep Space

Destination SPACE Inc.

Western Carolina University

PROBLEM STATEMENT

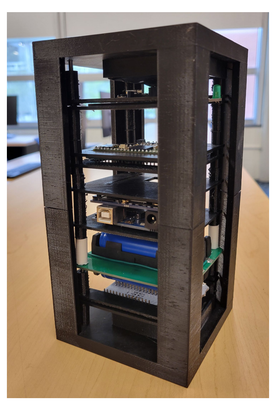
- Design and construct a prototype of a satellite to submit to NASA's CubeSat initiative and receive funding to continue the CubeSat program at Western.
- Scintillators will collect coincidence data from muons, which are high energy particles produced by supernovas. Coincidence occurs when a particle passes through both detectors which allows us to find the direction the particle has come from.
- Telemetry will provide the positioning and orientation of the CubeSat using a GPS and magnetometer and accelerometer.
- Refining the current design and adding communications to the CubeSat are the next steps for the prototype.

REQUIREMENTS

#	Description
1	The CubeSat will have to fit in a U variation of dimension as 2U (20cm x 10cm x 10cm) and a 1U for balloon launch testing.
2	The CubeSat prototype must be able to detect coincidence of particles using two scintillators within the range of 10^9 to 10^12 Electron Volts.
3	The CubeSat must maintain constant telemetry (communication).
4	The CubeSat must record data collected from scintillators by sending data back to team or record onto secondary storage.
5	The CubeSat must not only meet NASA CubeSat Initiative standards but also FAA guidelines for payloads on high altitude balloon launches.
6	Withstand and operate under mechanical stress during tethered balloon launch.
7	The prototype must be tested in a tethered balloon launch. This is separate from the coincidence testing. The parts in the balloon to be functional are one scintillator, communications (and secondary storage), battery power, and telemetry.

FRAME

The outer frame is printed with PETG in a 2U CubeSat layout. Inside are electrical modules with boards that are 80 x 80 mm help by customized supports. These are held by an inner frame of 10cm long screws. The scintillators are placed at each end.



FINAL DESIGN

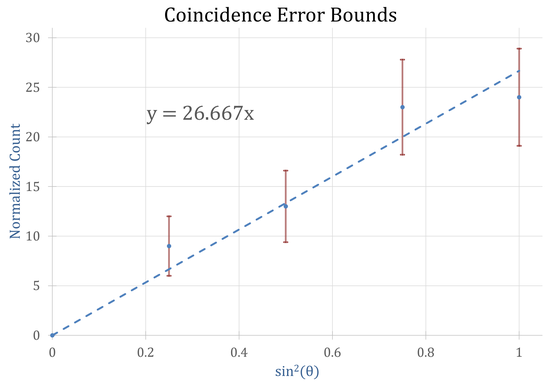
The final design of the CubeSat includes several modules to meet the requirements set forth. We started with the construction of our second scintillator, achieving coincidence mode. A GPS logger detects location and writes to an SD card as secondary storage. The magnetometer and accelerometer record the direction and orientation of the CubeSat using the earth's magnetic field and acceleration due to gravity. Four 3.2v Lithium Ferrite batteries are fitted with 2 pairs in series then parallel for a total of 6.4 volts at 3000mAh.

TOTAL SOLAR ECLIPSE

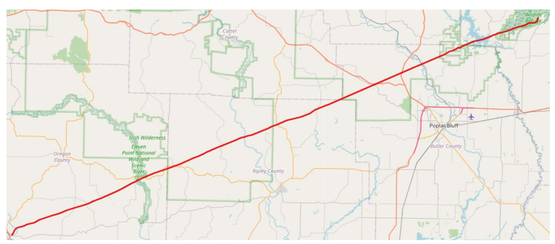
Our launch was an untethered high-altitude balloon launch coordinated by Virginia Tech as part of the Nationwide Eclipse Ballooning Project during the April 8th Total Solar Eclipse. The team traveled to Missouri to assist in launching two high-altitude balloon with a payload that was a simplified version of our CubeSat prototype. We were able to receive around 15,000 GPS data points. During the launch and flight, one of the wires connecting the scintillator to the SD reader module detached and few coincidences were detected. While finalizing the design, the team ensured that all connections were strong to not detach during future launches.

RESULTS

The detectors to receive more data when the satellite is vertical, at 90 degrees. As the satellite becomes more horizontal, less data is received by the scintillators. Data was collected at 90, 60, 45, 30 and 0 degrees, 90 being straight up and down and 0 degrees laying horizontally left to right.



The team had to adapt quickly to changing how the GPS data collection worked. The prior Teensy 4.1 microcontroller could not properly write data taken from the GPS with the code that was being used. The team installed an Adafruit Ultimate GPS Logging shield to an Arduino Uno. That way the Data could still be written to an SD card even when there isn't a USB power supply connected to the microcontroller.



The magnetometer and accelerometer was implemented into the team's design so that the exact orientation of the CubeSat could be determined during its flight. The accelerometer measures the current acceleration in the X,Y, an Z coordinate directions. The magnetometer measured the orientation of the CubeSat relative to the Earth's magnetic field.

Accelerometer	Magnetometer
X: 6.00 Y: -20.25 Z: -6.60 uT	X: 0.15 Y: -0.23 Z: 9.59 m/s^2
X: 5.40 Y: -19.95 Z: -7.35 uT	X: 0.15 Y: -0.31 Z: 9.59 m/s^2
X: 5.25 Y: -20.55 Z: -6.45 uT	X: 0.08 Y: 0.46 Z: 10.28 m/s^2
X: 17.55 Y: 14.70 Z: 3.30 uT	X: -1.53 Y: -7.59 Z: 4.75 m/s^2

SUMMARY AND CONCLUSIONS

Many of the requirements for this project were achieved during the Fall '23 and Spring '24 semesters. Namely, we have obtained GPS data and coincidence data. The team also created modules for measuring telemetry data. Further work will need to be completed so that all of the requirements can be met.

FUTURE WORK

This capstone project will continue to be worked on as our team did not fully meet the requirements that our sponsor provided us. The team has made impressive progress towards the requirements, given our allotted time and knowledge of the previous team's satellite. Future plans to improve the CubeSat include communications so that a ground station can receive data packets, power management system, and refine the frame design.

TEAM & ACKNOWLEDGEMENTS

- Team 04 Members
  - Anna Batman (Mechanical Engineering)
  - Wesley Jolly (Electrical Engineering)
  - Shannon Miller (Mechanical Engineering)
  - Brandon Spann (Electrical Engineering)
- Academic Mentor
  Dr. Yanjun Yan
- WCU Project Contact
  Dr. Enrique Gomez
- Sponsor
  Dr. DeWayne Cecil

References

[1] "CubeSat Launch Initiative - NASA." 01/2024 NASA. https://www.nasa.gov/kennedy/launch-services-program/cubesat-launch-initiative/.

[2] "CosmicWatch::Catch Yourself a Muon." 07/2017 http://www.cosmicwatch.lns.mit.edu/about.