Monitoring Solar Effect with CubeSats on Cosmic Ray Flux Variation at Sea Level

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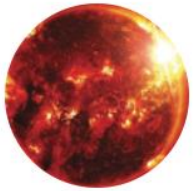
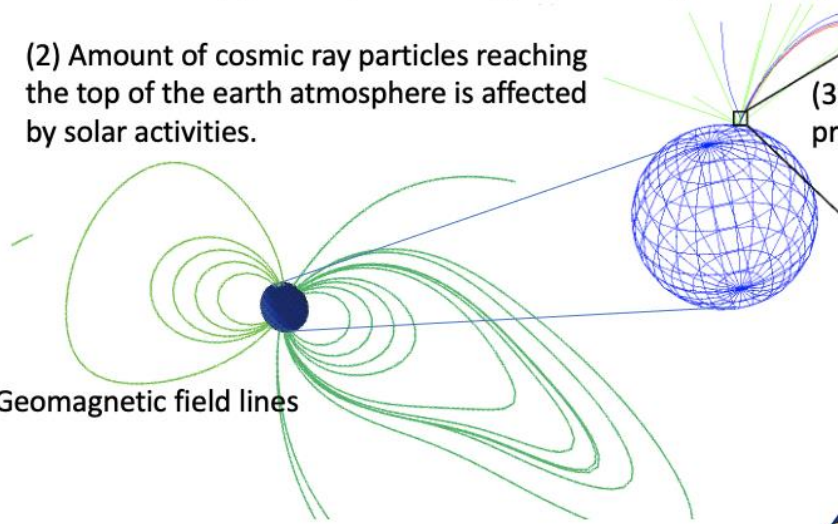
Background and Motivations

(1) Primary cosmic ray particle has galactic origin



(2) Amount of cosmic ray particles reaching the top of the earth atmosphere is affected by solar activities.



These ionizing particles are regarded as health hazards for flight crew

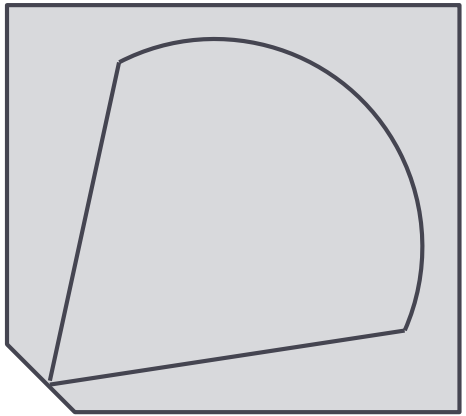
(4) Most particles reaching to the surface of earth are muon particles together with a few percent of neutrons. By measuring muon flux variation around the world allows us to derive the state of space weather and atmospheric profile in real-time.

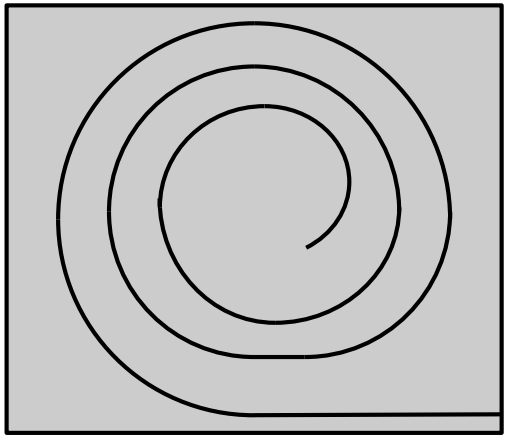
Existing Research

- Portable low-cost detectors have been built by Georgia State University for muon detection.
- It is expected that we would see one muon count per cm within the detector.
- It’s expected to see higher counts when the pressure within a region is lower, and lower counts when pressure is higher.

Xiaochun He, Carola Butler, Montgomery Steele, Sawaiz Syed, James Shirk, Nadia Qutob, Emily Knutson, Yung-Chi Jao, and Ting-Can Wei. Hybrid Portable Low-cost and Modular Cosmic Ray Muon and Neutron Detector. PoS, ICRC2019:078, 2019.

Design of CubeSat: Sensors



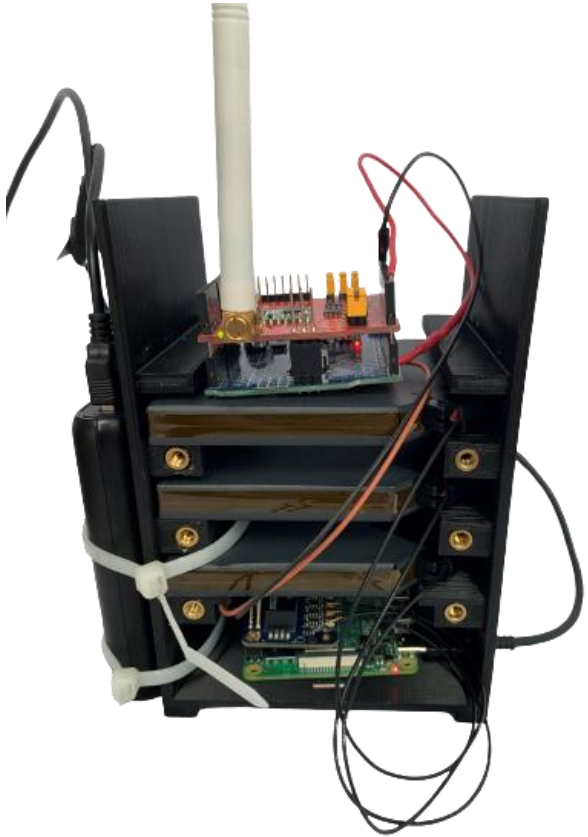


- There are currently two sets of sensors being developed by the team.
- Both are comprised of a thick plastic and optical wires in which the muons are captured and the light is passed through the wires to a SPIM.

Design of CubeSat: Current Hardware

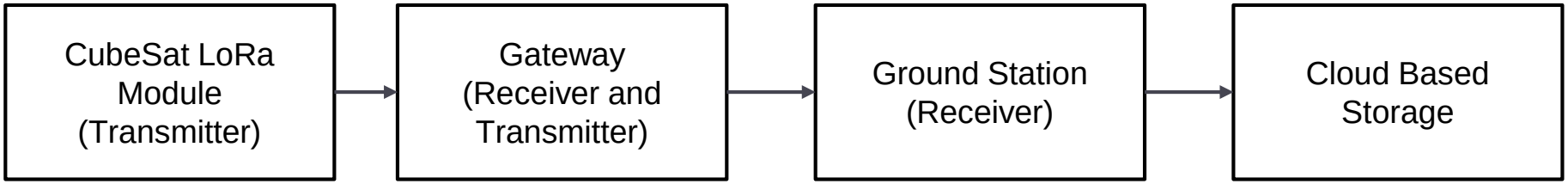
- Current hardware for a prototype to test the sensors is comprised of:
  - Raspberry Pi
  - LoRa Communication Module
  - Scintillator Tiles (Sensors)
  - Battery
- A FPGA is used in conjunction with the Raspberry Pi to collect muon counts.
- Serial communication is used between devices.

Design of CubeSat: Future Consideration



- Noise happens on occasion, which is believed to be caused by long cable connections.
- Currently we are working to implement shorter cables.
- Raspberry Pies have a power consumption, thus we are looking at switching CPUs.

Design of CubeSat: LoRa Communication



Data Format

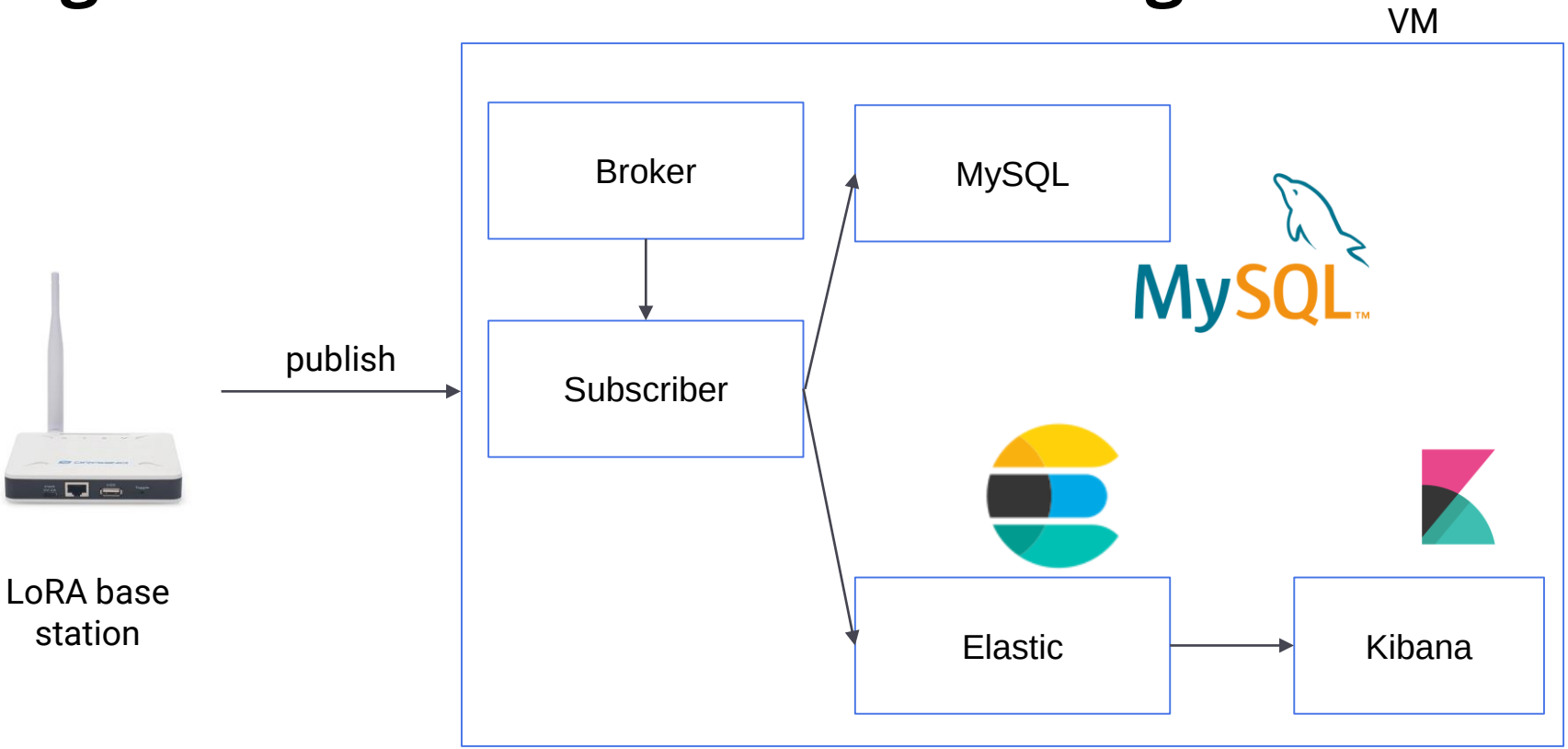
```
Chan_0_1,Chan_0_2,Chan_1_2,timestamp
1, 2, 13, Thu Mar 30 17:18:33 2023
8, 5, 9, Thu Mar 30 17:19:33 2023
5, 3, 9, Thu Mar 30 17:20:33 2023
```

Bottom and Middle Plate Coincidences (Channels 0 and 1)

Middle and Top Plate Coincidences (Channels 0 and 2)

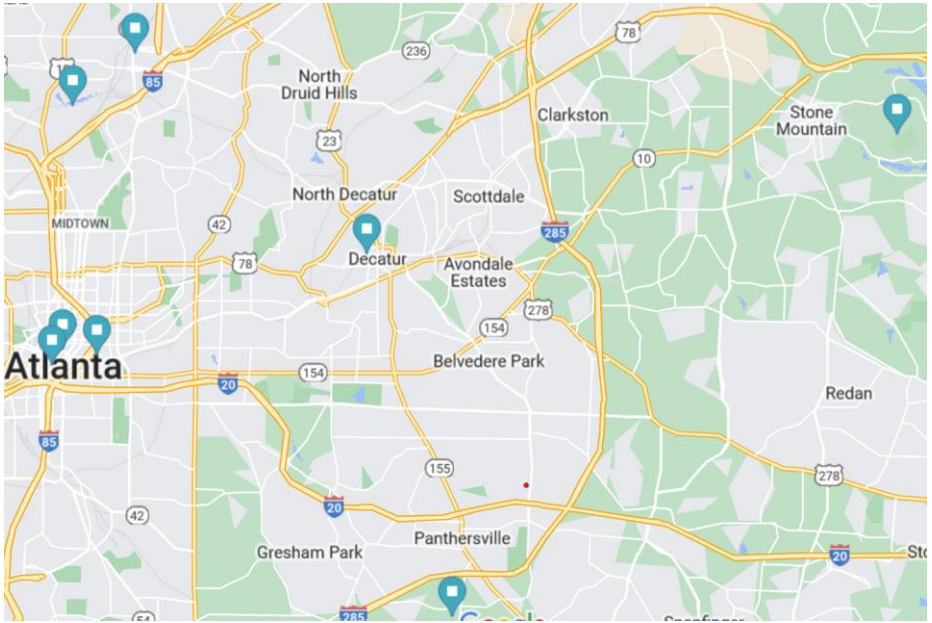
Bottom and Top Plate Coincidences (Channels 1 and 2)

Design of CubeSat: Cloud Data Storage

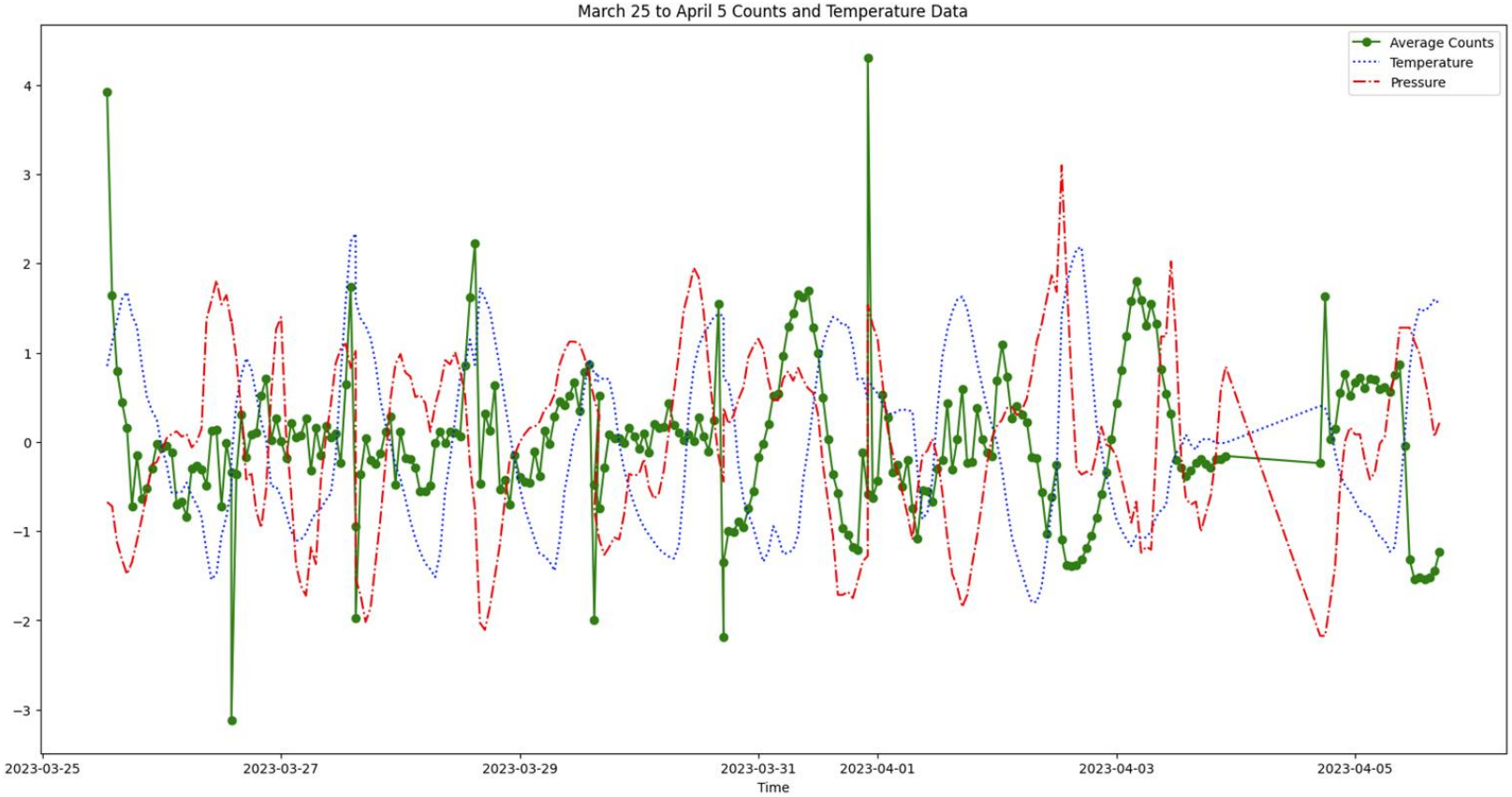


Geographical Testing

- Portability testing is being conducted by moving the CubeSat for 24 hour periods across Atlanta.
- The data showcases that over an area of 13 miles, with the expectation of noise, we can expect similar muon counts.



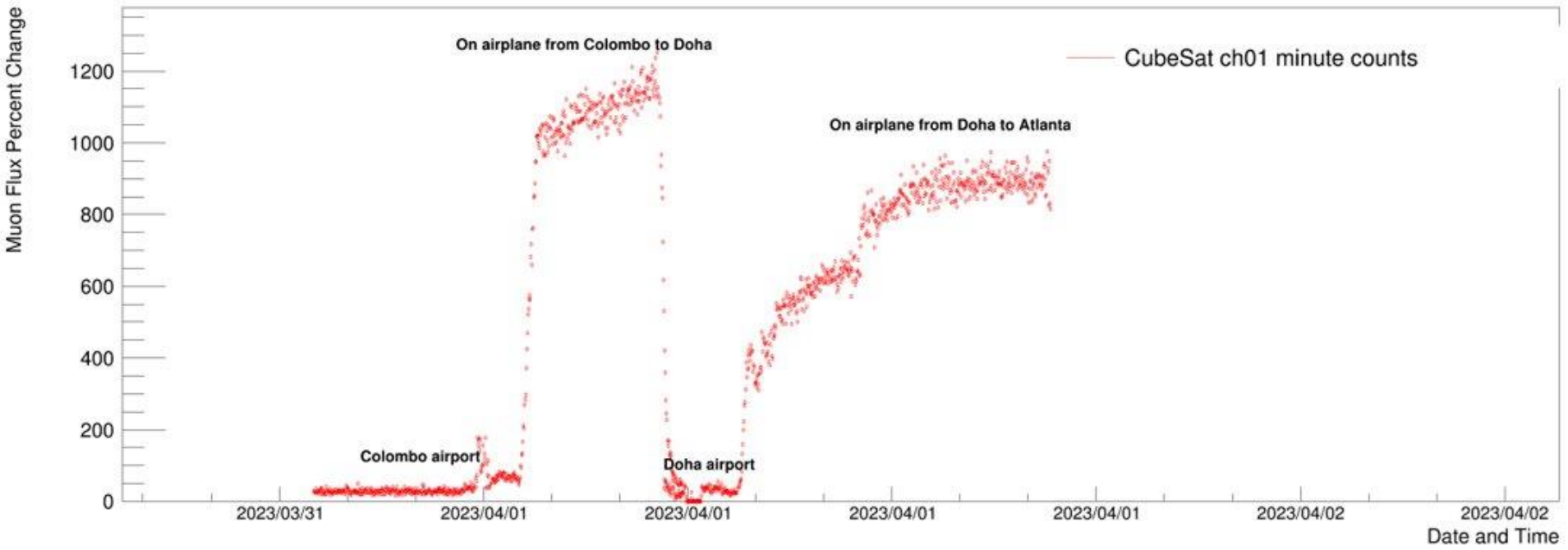
Geographical Testing Results



In-Flight Testing

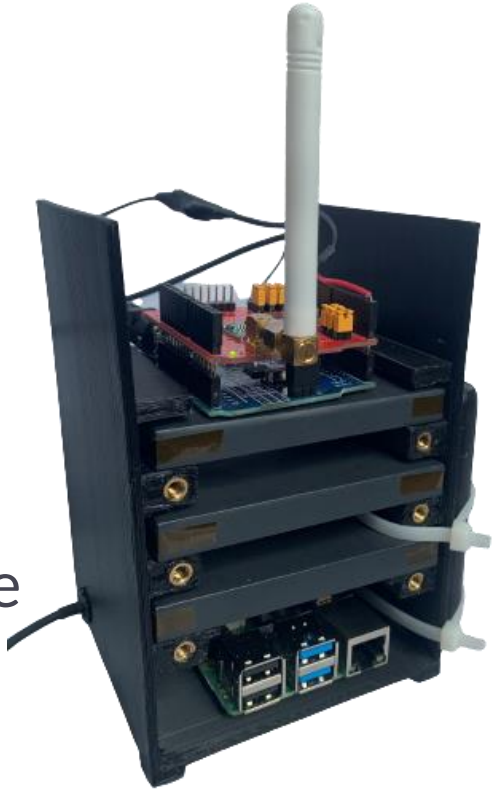
- Flight testing was completed during a return trip from Sri Lanka to Atlanta.
- We expect higher counts than one muon per cm to be collected in the atmosphere.
- During flight testing, we notated up to 30 times more muon particles.

In-Flight Testing and Results



Conclusion

- We currently have designed a mobile prototype to collect muon counts on ground-level and within the upper atmosphere.
- Ground level testing showcases that over a similar region, we will receive similar muon counts.
- In flight, the average number of muons can be expected to increase due to proximity to the sun within the atmosphere.



Future Work

- Currently, we are **completing extensive testing with both types of scintillator tiles** to determine the better design choice.
- Calculating how many Cubesats to be deployed in orbit in order to monitor the atmospheric muon counts for the globe.
- We’re currently looking at **switching to a low-power microcontroller version** of the current setup for a more robust control and update the LoRA modules.
- Determine potential launch opportunities.

Thank you!

Questions?

[1] Xiaochun He, Carola Butler, Montgomery Steele, Sawaiz Syed, James Shirk, Nadia Qutob, Emily Knutson, Yung-Chi Jao, and Ting-Can Wei. Hybrid Portable Low-cost and Modular Cosmic Ray Muon and Neutron Detector. PoS, ICRC2019:078, 2019.
[2]Hank Heidt, Jordi Puig-Suari, Augustus S. Moore, Shinichi Nakasuka, and Robert J. Twiggs. Cubesat: A new generation of picosatellite for education and industry low-cost space experimentation. 2000.
[3] NASA CubeSat Launch Initiative. Cubesat 101: Basic concepts and processes for first-time cubesat developers, Dec 2017.
[4] Alexander A. Doroshkin, Alexander M. Zadorozhny, Oleg N. Kus, Vitaliy Yu. Prokopyev, and Yuri M. Prokopyev. Experimental study of lora modulation immunity to doppler effect in cubesat radio communications. IEEE Access, 7:75721–75731, 2019.
[5] Lara Fernandez, Joan Adria Ruiz-De-Azua, Anna Calveras, and Adriano Camps. Assessing lora for satellite-to-earth communications considering the impact of ionospheric scintillation. IEEE Access, 8:165570–165582, 2020.
[6] L. Fernandez, M. Sobrino, A. Rodriguez, A. Gonga, C. Molina, L. Ray´on, M. Badia, P. Fabregat, A. Perez-Portero, J. Ramos-Castro, J. A. Ruiz-de Azua, A. Calveras, A. H. Jallad, and Z. Abdul Aziz. Sdr-based lora enabled on-demand remote acquisition experiment on-board the alainsat-1. In 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS, pages 8111–8114, 2021.
[7] Alexander M. Zadorozhny, Alexander A. Doroshkin, Vasily N. Gorev, Alexander V. Melkov, Anton A. Mitrokhin, Vitaliy Yu. Prokopyev, and Yuri M. Prokopyev. First flight-testing of lora modulation in satellite radio communications in low-earth orbit. IEEE Access, 10:100006–100023, 2022.