SOCIETY OF PHYSICS STUDENTS

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SPS Chapter Research Award Proposal

Project Proposal Title	Characterizing Atmospheric Muon Concentration Using a High Altitude Balloon-Based Detector
Name of School	George Washington University
SPS Chapter Number	2319
Total Amount Requested	$1,995.35

Abstract

Incoming cosmic rays produce showers of high-energy particles called muons when they interact with the upper atmosphere. The George Washington University SPS chapter proposes the development of a muon detector to be launched on a high-altitude weather balloon to investigate the relationship between altitude and atmospheric muon concentration.

Proposal Statement

Overview of Proposed Project

Muons are elementary charged particles with charge and spin identical to that of an electron, but with a rest mass approximately 200 times m_e. We most commonly observe them as the byproduct of collisions between high-energy particles from space—known as cosmic rays—and molecules in the Earth's atmosphere. When this happens, showers of muons are sent towards the surface of the Earth at relativistic speeds

Muon detection has been of recent interest to scientists as their applications to fields such as imaging and tomography expand. However, their properties and conditions before reaching the Earth are not yet fully understood. To do this, a better picture is needed of the muon flux stratification in the atmosphere. Our chapter proposes the development of a muon detecting payload to be launched in a weather balloon to measure the dependency of muon flux with respect to altitude and other atmospheric parameters.

Data from this experiment will be used to investigate the question of muon flux with respect to atmosphere altitude and atmospheric conditions. This serves as an opportunity for members to learn basic data visualization and experimental data analysis.

Our SPS Chapter will use this project to engage new members, with a special focus on underclassmen and potential/undecided physics majors. We are planning to promote the project within the department and include it in our outreach efforts in the DC Public School System this upcoming year.

Background for Proposed Project

In 1912, Victor Hess brought an electroscope with him on a balloon flight to an altitude of >5 km, where he discovered that the amount of ionizing radiation was more than double that at sea level. He correctly interpreted this as the first solid evidence that the source of commonly observed background radiation was not within the Earth itself, but outside our planet's atmosphere. To this day, the extraterrestrial origins of this radiation are still not completely understood, and there are a number of possibilities as to where cosmic rays come from.

Muons are elementary particles created in the upper atmosphere of the Earth. When cosmic rays from astrophysical sources, consisting of high energy protons and nuclei, reach Earth's atmosphere, they produce showers of secondary particles, among them muons. Although many of these particles never make it to the surface due to attenuation as they travel through the atmosphere, muons are energetic enough and travel fast enough that many make it to Earth.

The atmosphere is a vital and complex part of our planet. We can attribute many phenomena we experience on the surface to atmospheric conditions. Muon generation relies on both atmospheric composition and incoming cosmic rays. As climate change and other environmental trends progress, the atmosphere changes. This raises questions about atmospheric conditions and their relationship to elementary particle generation and propagation. Important variables subject to change include atmospheric temperature, gas concentration, and sunlight; these may influence muon fluxes.

Expected Results

This project would be the chapter and department's first high-altitude balloon developed and launched. Our chapter will primarily investigate the relationship between altitude and muon fluxes. Current understanding supports that muon fluxes will increase as altitude increases and detection gets closer to the site of generation. Above a certain point however, muon flux may decrease, as their creation depends on having some non-negligible amount of matter present for cosmic rays to interact with. Observing this relationship and gathering data about muon fluxes could help more accurately parametrize muon generation in the atmosphere. We will also gather data about atmospheric chemistry, measuring gas concentrations, temperature, pressure, and sunlight intensity. This information will contribute to a more complete picture of the factors affecting muon generation, leading to a more comprehensive understanding of the phenomena.

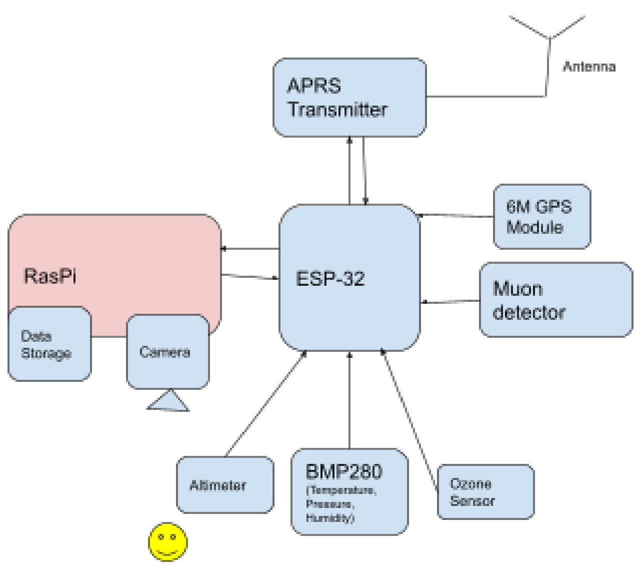
In addition, our chapter will have the opportunity to work on technology that fosters more sophisticated understanding of electronics, radio/GPS tracking, and signal processing. Atmospheric knowledge, basic particle physics, and relativity principles will also be incorporated in a comprehensive understanding of the investigation.

Description of Proposed Research - Methods, Design, and Procedures

Weather balloons have been utilized for over a century to collect atmospheric data and learn about conditions above the surface. More recently, they have been expanded and utilized for new functions in data collection, analysis, and service applications. Our chapter had been interested in ballooning for several years, since Sandeep Giri presented his work at PhysCon 2019.

Our proposed instrument apparatus must be assembled and launched in order to provide the data we hope to collect in carrying out our scientific mission. The scientific goal of this project is to develop an understanding of muon flux throughout varying altitudes at the sub-stratosphere level. To achieve this study, we will develop a high-altitude balloon payload outfitted with stacked muon detectors which will be launched from the ground, with a maximum possible height of 30km, before descending back to ground level. The Federal Aviation Administration has well-established guidelines regarding high-altitude balloon flights, and we expect to be well within the allowable parameters. From the time the balloon is launched, until it touches down (a mission time frame on the order of a few hours) it will be collecting and storing data, most of which will be accessed upon payload retrieval. In order to develop a holistic understanding of the atmosphere and draw meaningful conclusions from our data, we will need to compare muon and ozone concentration, correlating the two factors with the altitude read by the payload's on-board altimeter.

The proposed project structure will consist of two sets of instrumentation: one for mission data collection and storage, and a second for the purposes of collecting and communicating system telemetry. These two structures will be bridged by an MCU capable of addressing each of the datastreams appropriately and orchestrating payload function. The tracking infrastructure will consist of a GPS connected to an APRS transceiver which will relay the payload's position during flight and during recovery. Additionally, this structure will also include the onboard altimeter, barometer, and accelerometers which will gather atmospheric data to be analyzed with muon fluxes.



Plan for Carrying Out Proposed Project

The main personnel at this stage are current GW SPS Executive Board members Marisa Lazarus, Caden Gobat, Adellar Irankunda, and Danny Allen. This team already collectively possesses an extensive body of relevant experience in electronics, software development, project management, and mechanical design from extracurricular activities and physics laboratory courses, and we also plan to recruit additional talent from our membership body as we scale up the operation and the project progresses. Development work for the research project will be incorporated into our already existing weekly meetings. Subteams will be headed by general or Eboard members, and will be encouraged to hold additional meeting times to work on the project.

The GW Physics Department houses a state of the art Innovation Lab in the basement of our building equipped with electronics workstations, tools, 3D printing facilities, and lab benches. This is where the project will be developed and housed.

A few department faculty have expertise in muon and particle detection on the ground, whom we have already been in contact with for guidance in validating our muon detection methods and to help advise project development.

Project Timeline

Task Name	Start Date	End Date
Muon Detector Development		
Detector design	1/10/22	2/14/22
Signal Processing	2/1/22	2/28/22
Detector integration with Computer module	3/1/22	3/31/22
Muon detection testing	4/1/22	4/30/22
Design and Manufacturing of Payload Chassis	2/1/22	5/31/22
Comms/Tracking		
APRS Radio Programming	2/1/22	3/31/22
ESP integration with Transmitter	3/1/22	3/31/22
Tabletop Radio Testing and Decoding	4/1/22	4/30/22
HAM Licensing	2/1/22	9/30/22
Sensors and Main Computer Module		
Altimeter	1/10/22	1/24/22
BME280 Connection	1/25/22	2/8/22
RaspPi Data Management and Hardware Testing	2/9/22	3/2/22
Launch Phase		
Full Payload Integration	8/1/22	9/1/22
Final Testing	9/1/22	9/14/22
Launch Site Selection and FAA Approval	8/1/22	9/1/22
Balloon Release and Promotional Phase	9/20/22	10/1/22
Documentation		
Interim Report	4/24/22	5/15/22
Final Report	11/1/22	12/1/22

This timeline includes about a 2 month buffer in the development for unexpected delays.

Budget Justification

At right is a copy of the items listed in our budget request spreadsheet. Here we detail the need and justification for each item.

The weather balloon (1), parachute recovery kit (2), helium (3), helium gas regulator (4) are needed for the balloon to fly.

The sensor capabilities we plan to fly are an ozone detector (5), BMP280 (6), an altimeter (7), and a camera (8). These are necessary for collection of experimental data.

A Raspberry Pi (9) and an ESP-32 MCU (10) are needed for data handling and control. The system will be powered by a battery and power supply set up (11) and our chapter will 3D print a case for all the components, which will require resin material (12).

The telecommunications system will consist of the HX1 APRS Transmitter (13) and the Neo 6M GPS module (14).

The muon detection system will require a muon controller board (15), a silicon photomultiplier (16), an SiPM controller board (17), and a plastic scintillator (18).

General supplies needed during the prototyping and testing phases include the wiring (19) and breadboard (20).

Item	Item Description
1	Weather Balloon 1.2kg Payload
2	5 ft. Parachute Recovery Kit
3	Helium
4	He gas regulator
5	MQ131 Ozone Detector
6	BMP280
7	High Resolution Altimeter
8	Raspberry Pi 12 MP Camera
9	Raspberry Pi 4
10	ESP-32 Microcontroller (240
11	System Battery & Power Supply
12	UV-Curing Resin
13	HX1 300mW APRS Transmitter
14	Neo 6m GPS
15	Muon Controller Board
16	Silicon Photomultiplier
17	SiPM Controller Board
18	Plastic Scintillator
19	Wiring
20	Prototyping Breadboard (400

Bibliography

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