UniSat 2.0 Mission: Empowering Girls in STEM through Nanosatellite Launch

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UNICEF
Agency of Innovative Development of the Republic of Uzbekistan
Tech4Impact NGO

August 11, 2023

Abstract

The UNICEF Satellite (UniSat) is a collaborative project involving UNICEF, Tech4Impact, and the Agency of Innovative Development of the Republic of Uzbekistan. Its purpose is to promote STEM and space-related disciplines among girls and women, aiming to increase their participation in these fields. In 2023, the UniSat project was held for the second time in Uzbekistan. A group of 20 girls assembled and launched two nanosatellites named Aurora and Franky. Besides numerous sensors, both nanosatellites carried biomaterials, including seeds of various plants, as well as mold and yeast. The purpose of launching the biomaterials was to observe whether they would be affected by the rapid changes in temperature and stratospheric radiation.

Keywords - nanosatellite, biomaterials, stratospheric radiation, UniSat.

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1 Introduction

CubeSats are a new generation of satellites that offer accessibility to various institutions and individuals due to their low cost, shorter development time, and mission flexibility. They contribute to the democratization of space access, stimulating space exploration and technological innovation [**1**]. Furthermore, nanosatellites are suitable for launch into the stratosphere, the layer of Earth located above the troposphere, which is approximately 10-50 km above sea level.

Our team assembled two CubeSats at Inno Technopark in Tashkent, Uzbekistan, during a week-long workshop. We received assistance from mentors and coordinators of the UniSat program. The 20 finalists were divided into two groups. One group consisted of 10 girls, with each girl assigned responsibility for a specific part of the CubeSat.

The approximate task division was as follows:

- 2 members for payload
- 2 members for construction
- 1 member for 3D modeling
- 1 member for launch preparation
- 1 member for regulating camera
- 1 member for ground control
- 1 member for data analysis
- 1 member for final presentation.

This type of division proved to be highly productive as team members could focus on their respective tasks without causing any distractions to one another.

The members responsible for the additional payload built CubeSat prototypes from scratch using Arduino boards and Arduino sensors. The participants in charge of 3D printing developed and printed side panels.

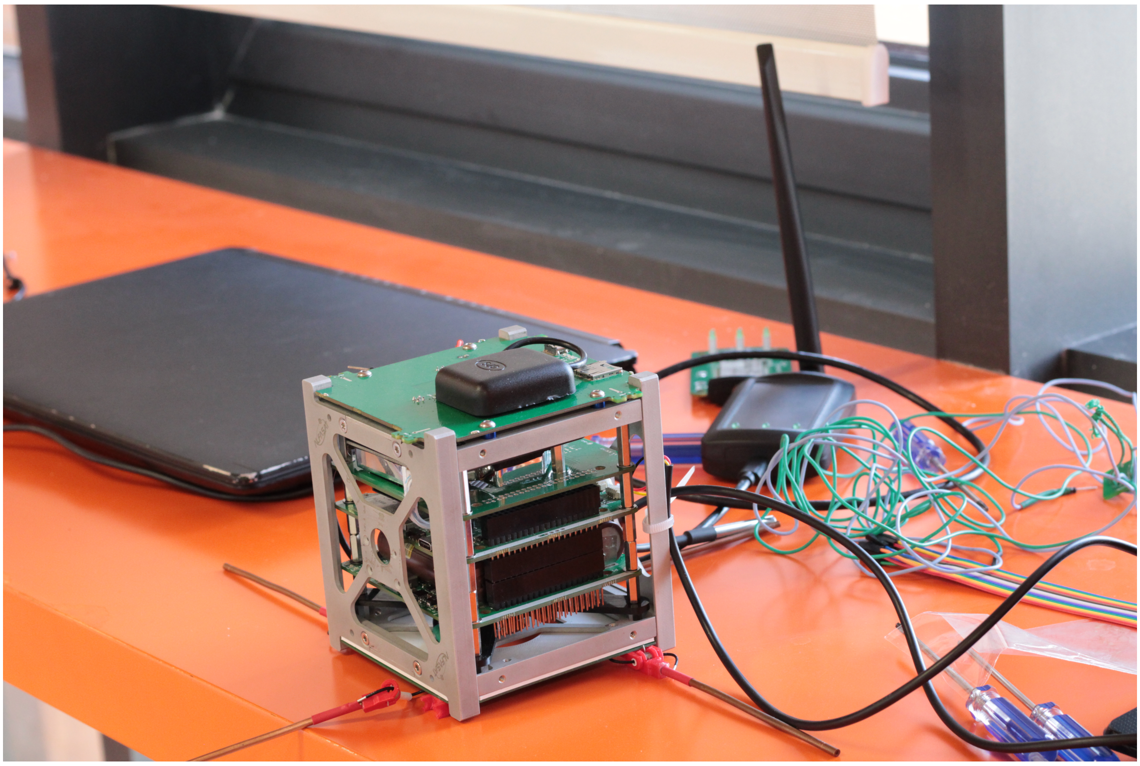
Overall, there were three goals for this mission:

1. To provide participants with the opportunity to construct a nanosatellite from scratch
2. To collect data from multiple sensors and compare the results with the previous year's launch
3. To launch biomaterials and observe any changes in them.

2 Mission Design

The overall structure of construction is quite common and straightforward. It consists of the high-altitude balloon, parachute, CubeSat, resistor with nano-thread, additional CubeSat prototype and camera.

The success of the experiment depends in large part on the use of a high-altitude balloon. In most cases, it is filled with an appropriate volume of helium to provide a stable and safe construction lift. If there is inadequate helium, construction will cease shortly after launch. Such a balloon can go up to 40 km into the stratosphere, where it expands to a certain maximum size before bursting due to the extreme pressure and temperature conditions. In our scenario, we wanted to regulate altitude. As a result, we put a resistor made of nano-thread between the balloon and parachute. The resistor gets heated and melts the nano-thread when a signal of undocking is sent from the ground station at an altitude of around 8 km, which causes the balloon to deflate and lose its payload. It begins falling freely for a time. When it comes to the role of a parachute, it helps to lower the speed of our payload with respect to its size. To make it work, we used a specific circular piece of red tissue and a plastic circle.

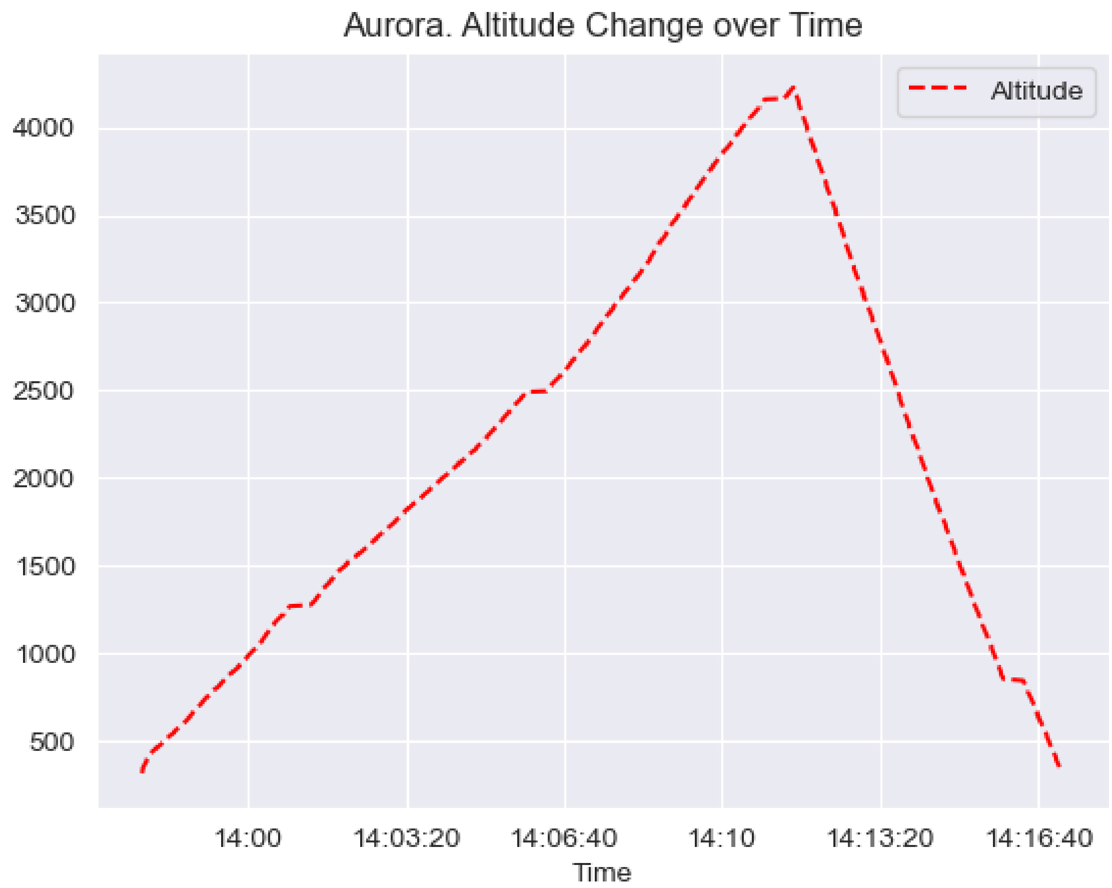


The UniSat Antenna board is mounted at the bottom of the satellite and has four antennas for communication with the Earth. Next comes the UniSat EPS system consisting of four batteries; it provides the power supply for our satellite. The UniSat Main Board contains an onboard computer from the ATmega Microcontroller family and other chips and sensors. Next, a separate board for its large dimensions is used for Nova PM sensor SDS011. The last closing board is the UniSat Top Board with minor required elements.

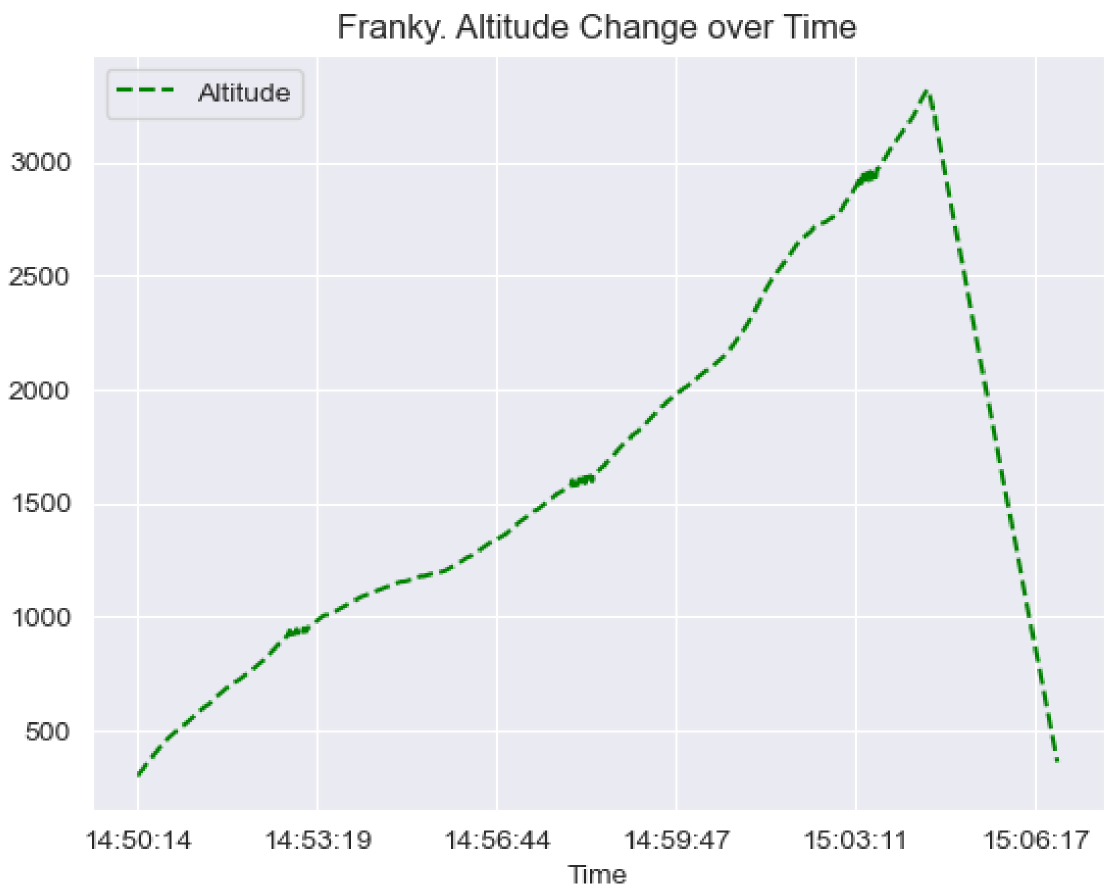
3 Mission Process

On May 13, we reached our destination in the Karmanin region of Navoiy province. The location was selected due to its favorable landscape. Prior to our arrival, a scientific camp had been established by EMERCOM of Uzbekistan. As a result, the first team of girls immediately began their work. The CubeSat named "Aurora" was intended to be launched first. While the initial team prepared and tested their CubeSat and the biomaterials, other girls assisted in inflating a helium balloon. Subsequently, "Aurora" was attached to the balloon, and after a countdown, we released the balloon at 13:26:46. Unfortunately, after reaching its peak altitude of 4230.6 meters at 13:40:30, it started descending.

There have been several suggestions as to why this may have occurred. One suggestion is that there was insufficient helium in the balloon. Another suggestion is that the monofilament fishing line used to secure the balloon became tangled and eventually severed.



While the first team was tracking "Aurora," the second team wasted no time and commenced their work. The second launch took place at 14:50:14. Unfortunately, unlike "Aurora," "Franky" did not have a communication module as it was accidentally damaged during testing at the workshop. Consequently, we were unable to track "Franky" or obtain geodata for our ground control system. Additionally, we were unable to send a signal for undocking after reaching a certain altitude, as we did with "Aurora." To overcome this limitation, mentors and participants devised a plan for the CubeSat to initiate the undocking process after a predetermined time, approximately when it reached 8 km. These calculations were based on the previous year's launch. Nevertheless, "Franky" only reached a maximum altitude of 3320.4 meters at 15:04:14. Subsequently, it began descending and touched the ground at 15:06:42.



Subsequently, two search teams were organized. One of the teams was tasked with locating the approximate position of "Franky." Prior to the search, we analyzed the estimated flight path of the balloon using a web-based tool that utilized atmospheric models and wind data to predict the trajectory. Fortunately, this team was successful in locating "Franky" first. They then used the last GPS signal received from "Aurora" to guide their search for it. Soon after finding "Franky," the team also located "Aurora." The biomaterials were retrieved, and the nanosatellites were carefully packed and transported back to Tashkent.

4 Data Analysis and Experiment with Biomaterial

4.1 Data Analysis

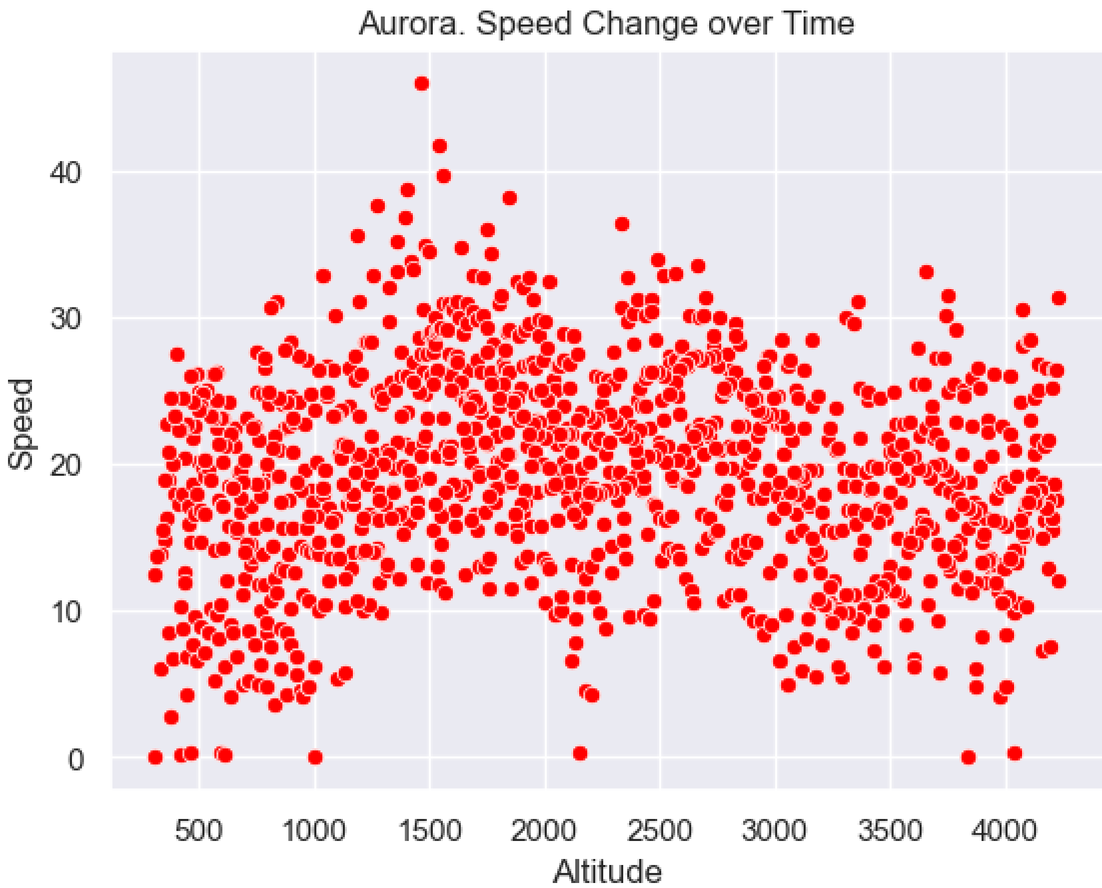
We retrieved the files from the hard drives of the CubeSats, which contained two separate sets of data: geodata and sensor values. Using the Python programming language's Pandas library, we merged these two files into one, matching the common time values. Following this process, we obtained two final CSV files for "Aurora" and "Franky" respectively. Additionally, the data was found to be intact as the CubeSats remained operational throughout the mission, and no emergency situations occurred. As a result, the merged data was consistent and easily accessible for further analysis. In addition to Pandas library we used NumPy, MatPlotLib, Seaborn and Pytz libraries to analyze and plot our data.

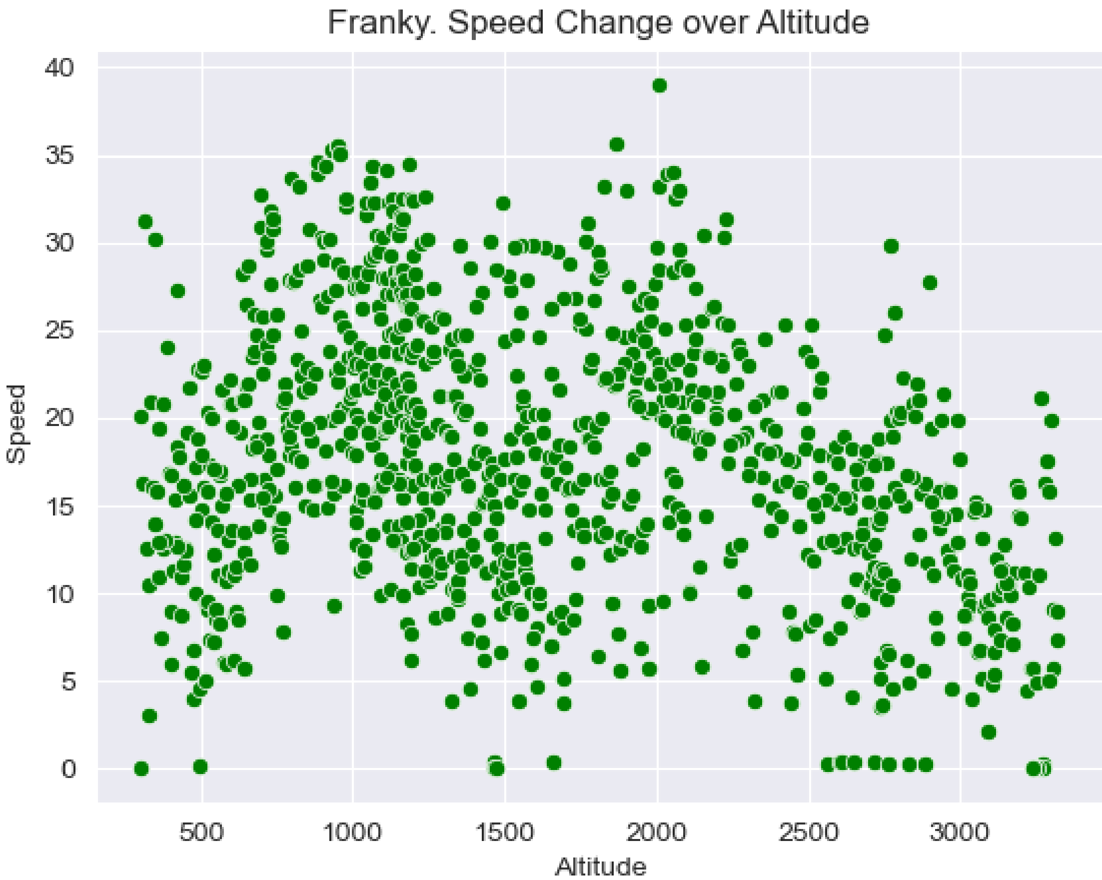
Furthermore, we collected data from the additional payload. Although Aurora's payload did not include a real-time sensor, we were able to track time accurately with milliseconds. Additionally, we obtained data on temperature, humidity, and air quality from Aurora's payload, and data on temperature, humidity, and gas levels from Franky's payload.

4.1.1 Speed Change over Altitude

From the speed data, we generated a scatter plot that illustrates the speed ranges and corresponding heights. The density of points in a particular area indicates the certainty of the recorded speeds. After analyzing the data, we reached the following conclusions:

1) During the first launch, the maximum speed reached was approximately 45 km/h, which occurred approximately 6 minutes after the launch; 2) During the second launch, the maximum speed reached was around 38 km/h, observed at an altitude of approximately 2000 meters.


Aurora. Speed Change over Time
Speed
Altitude
0
10
20
30
40
500
1000
1500
2000
2500
3000
3500
4000


Franky. Speed Change over Altitude
Speed
Altitude
0
5
10
15
20
25
30
35
40
500
1000
1500
2000
2500
3000

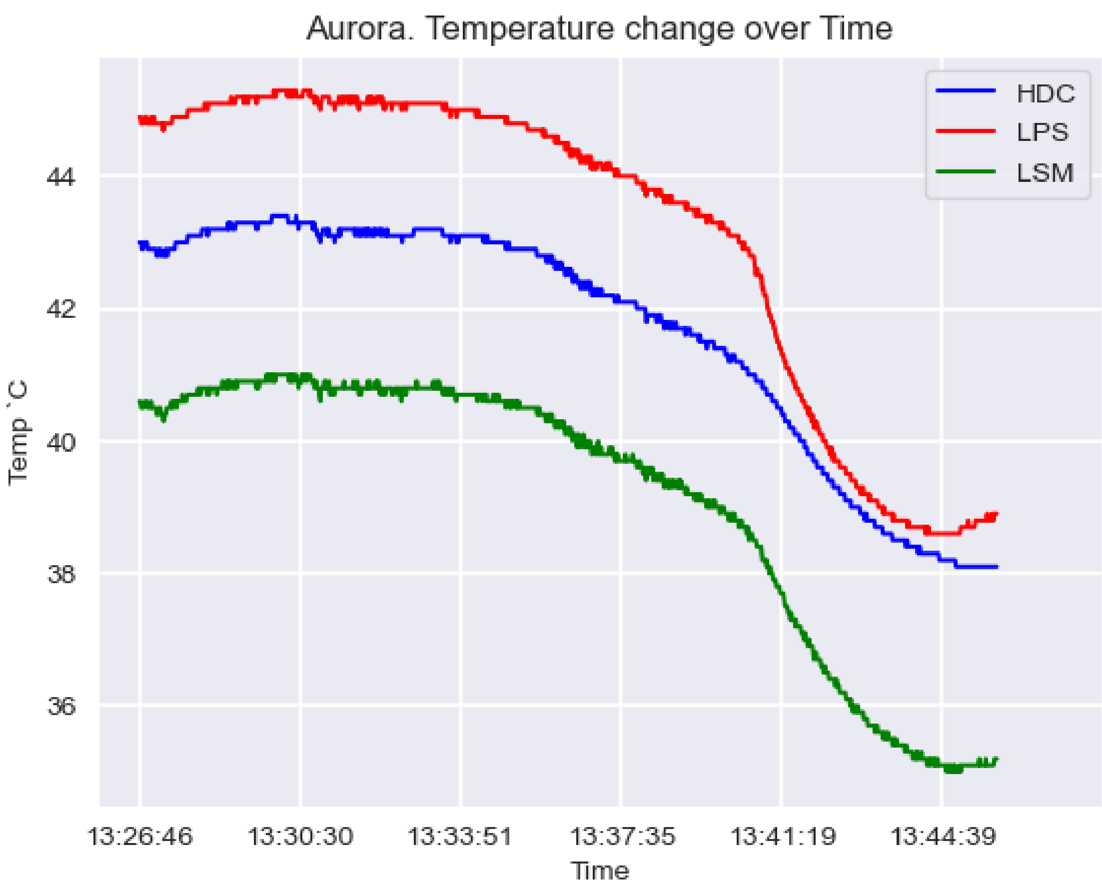
4.1.2 Temperature change over Time

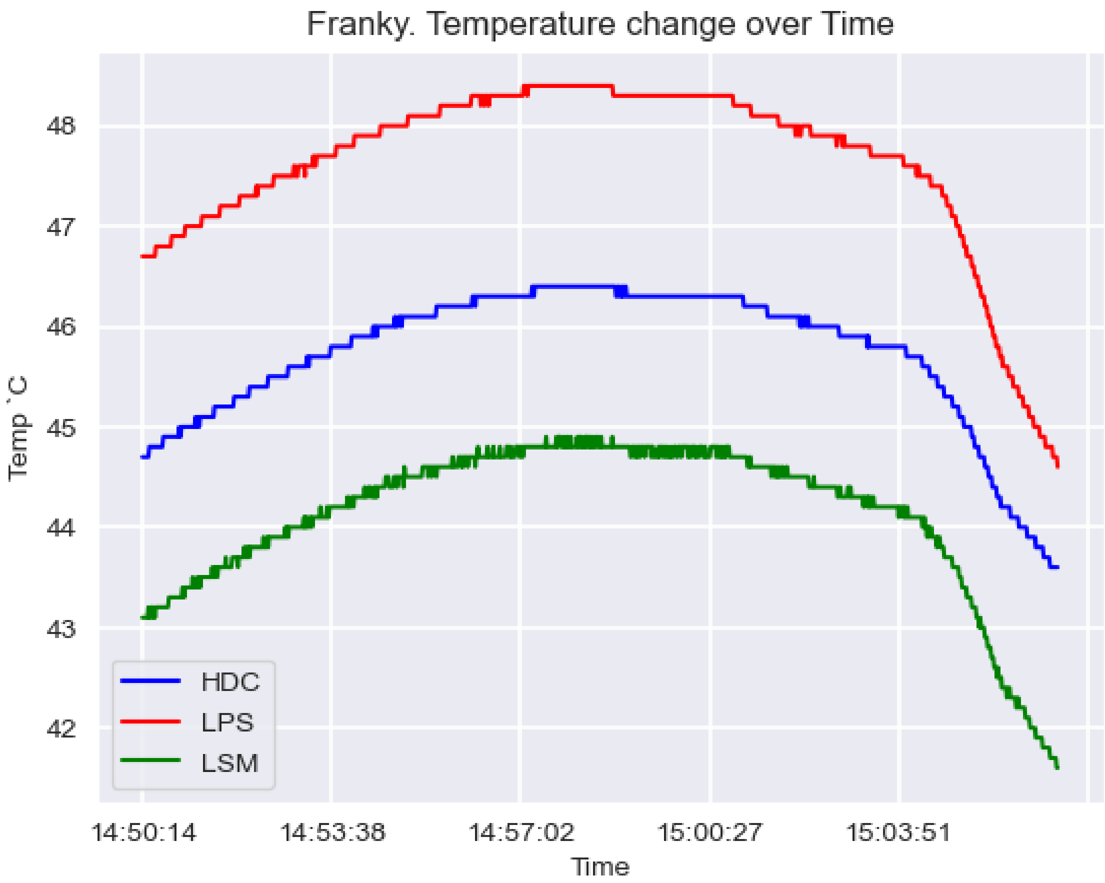
The list of temperature sensors used, along with their corresponding temperature ranges, is as follows:

- HDC (Humidity and Temperature): -40°C to +125°C
- LPS (Low Power Pressure): -40°C to +85°C
- LSM (accelerometer and gyroscope): -40°C to +85°C.

Based on the data, we observe that both CubeSats recorded the highest temperature values using the LPS sensor, while the lowest temperature values were obtained from the LSM sensor. Additionally, it is evident that all the sensors remained consistent throughout the flight.

To protect the sensors from potential damage caused by low temperatures at high altitudes, both CubeSats were insulated. This insulation contributed to the relatively higher temperature readings. Furthermore, the naturally hot climate of Navoiy province in May may have influenced the temperature measurements as well.

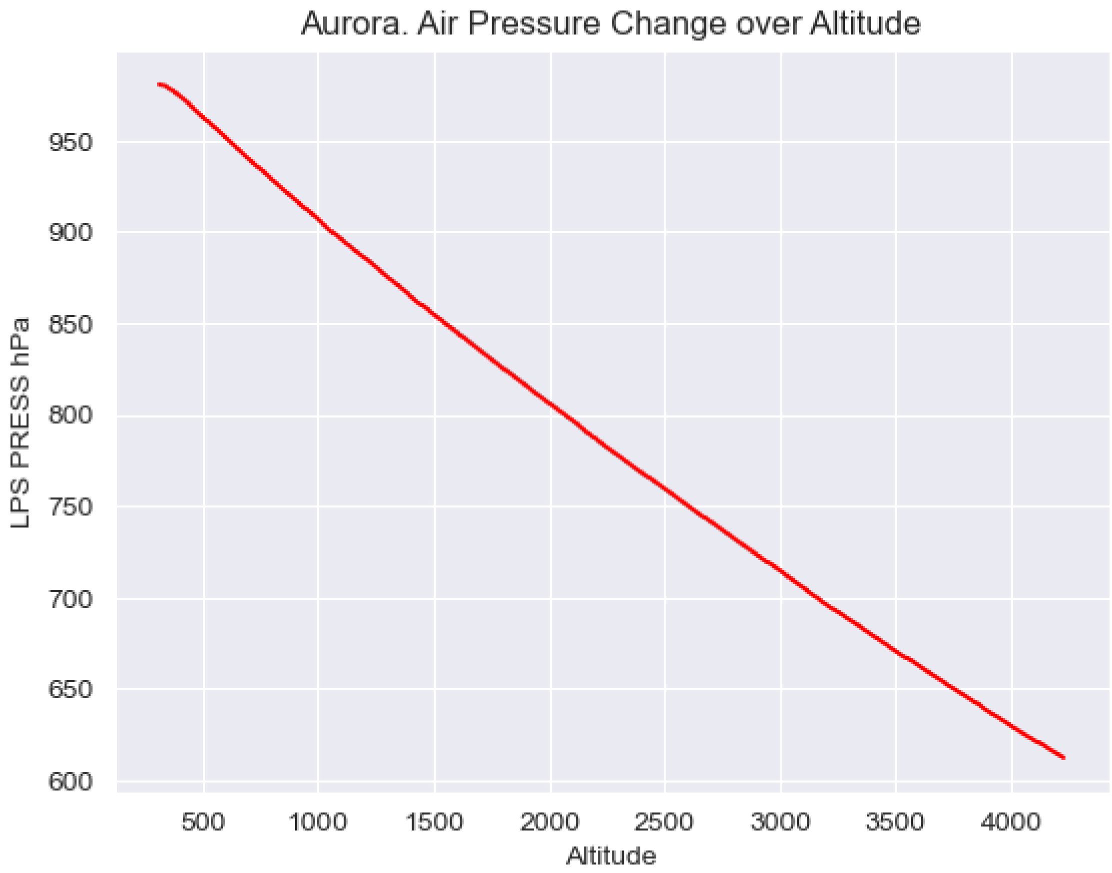




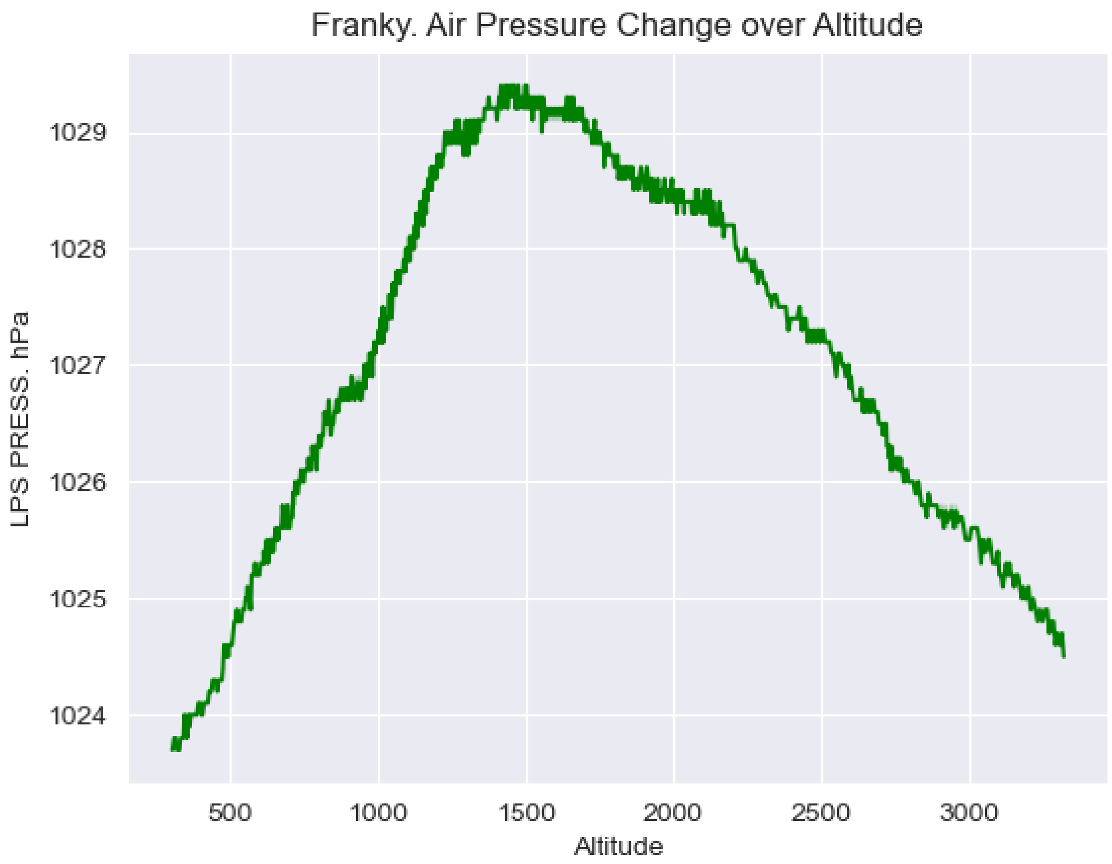
4.1.3 Atmospheric Pressure Change over Altitude

For the Aurora CubeSat, we observed a gradual decrease in pressure with increasing altitude, which aligns with expectations. The lowest pressure value was recorded at the peak of the flight, while the maximum value was observed at the beginning of the flight.

In the case of the Franky CubeSat, we assume that there were sensor malfunctions. This assumption is based on the significant and abnormal increase in air pressure observed during the middle of the flight. The hPa values deviated from normal standards, indicating a potential issue with the sensor readings.



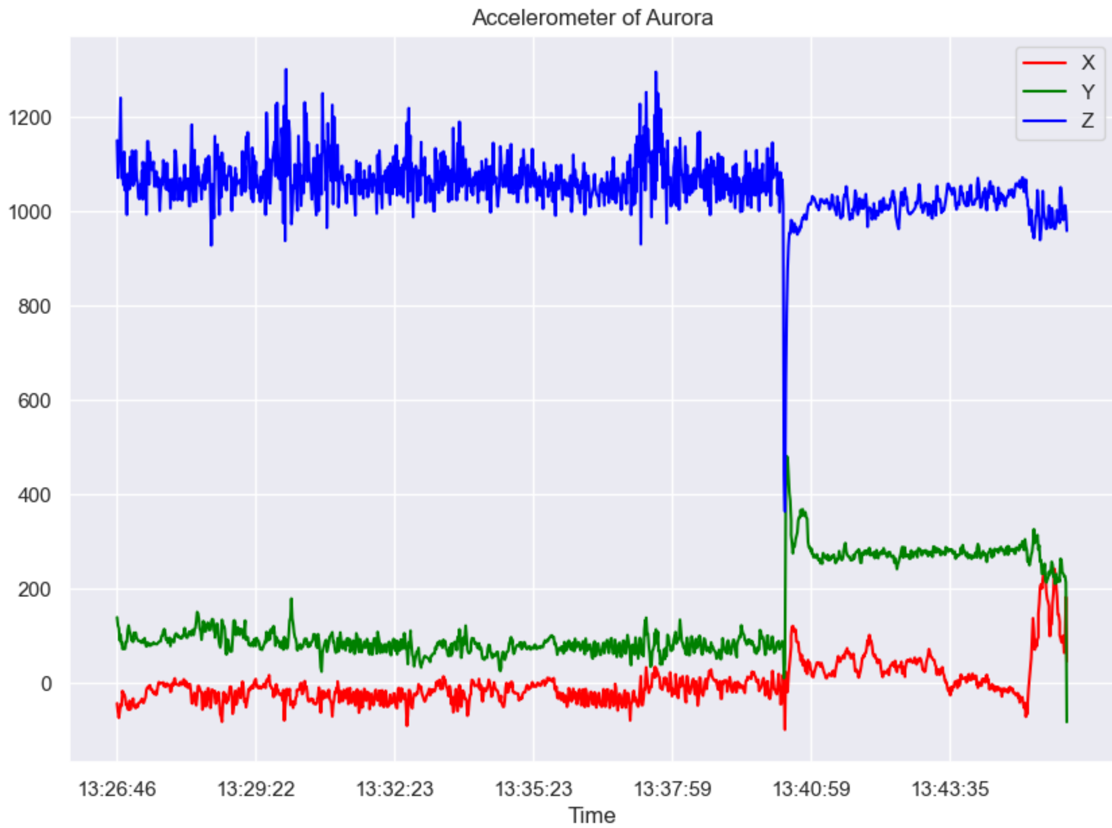
Aurora. Air Pressure Change over Altitude
LPS PRESS hPa
950
900
850
800
750
700
650
600
500
1000
1500
2000
2500
3000
3500
4000
Altitude



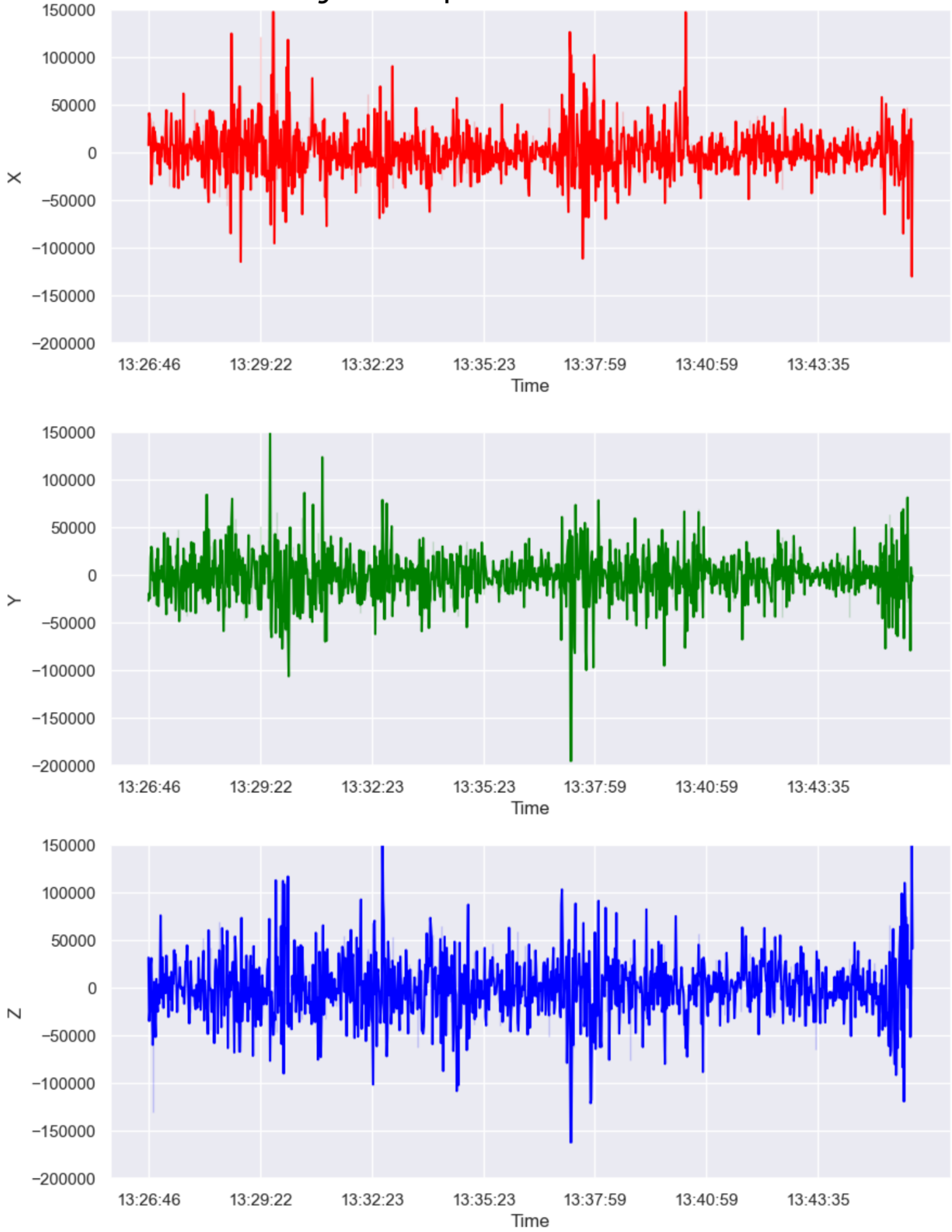
Franky. Air Pressure Change over Altitude
LPS PRESS. hPa
1029
1028
1027
1026
1025
1024
500
1000
1500
2000
2500
3000
Altitude

4.1.4 Accelerometer and Gyroscope

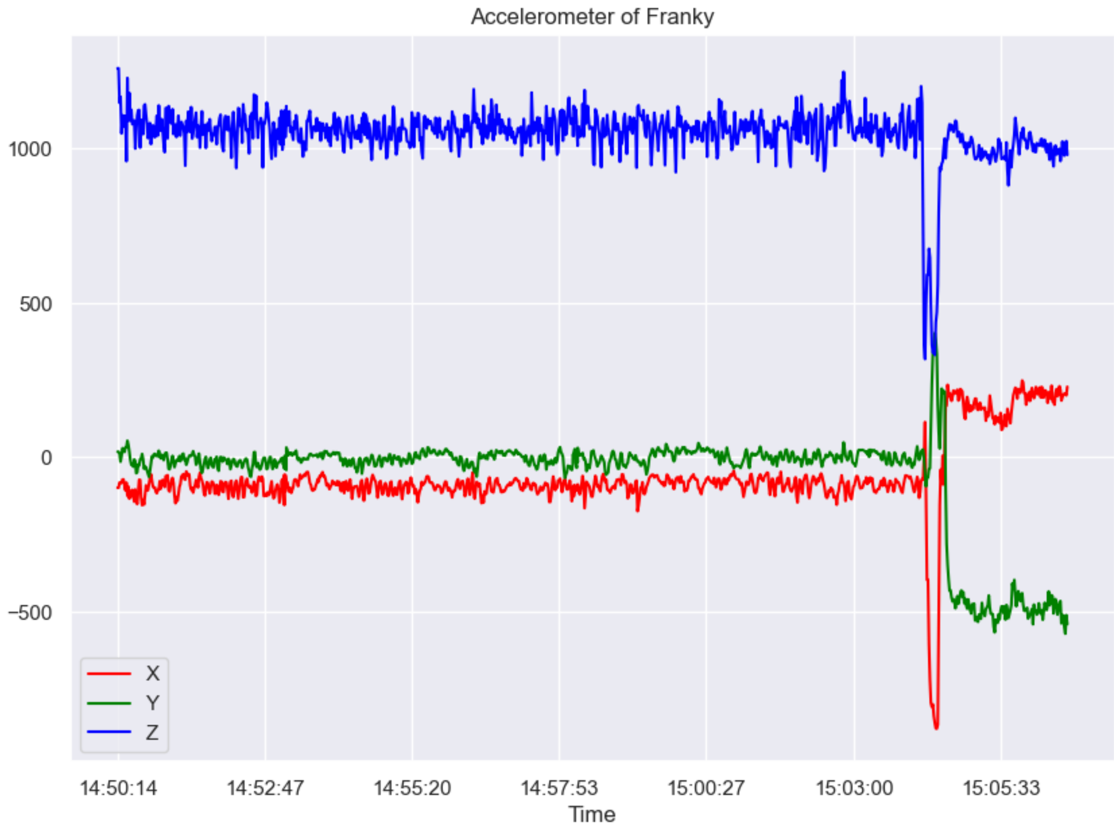
An accelerometer and a gyroscope are sensor devices commonly used in electronic systems for motion sensing and orientation detection. An accelerometer measures linear acceleration forces along multiple axes, providing information about changes in velocity and orientation. It detects movements such as tilting or linear motion and converts them into electrical signals. On the other hand, a gyroscope measures the rate of angular rotation or rotational velocity around multiple axes. It helps determine the exact position and orientation of an object by sensing changes in angular velocity. By combining the data from both sensors, precise motion tracking and orientation determination can be achieved in applications such as navigation systems, virtual reality devices, robotics, and mobile devices. The accelerometer and gyroscope work together to provide comprehensive motion-related data, enabling more accurate and responsive control and interaction with electronic devices.



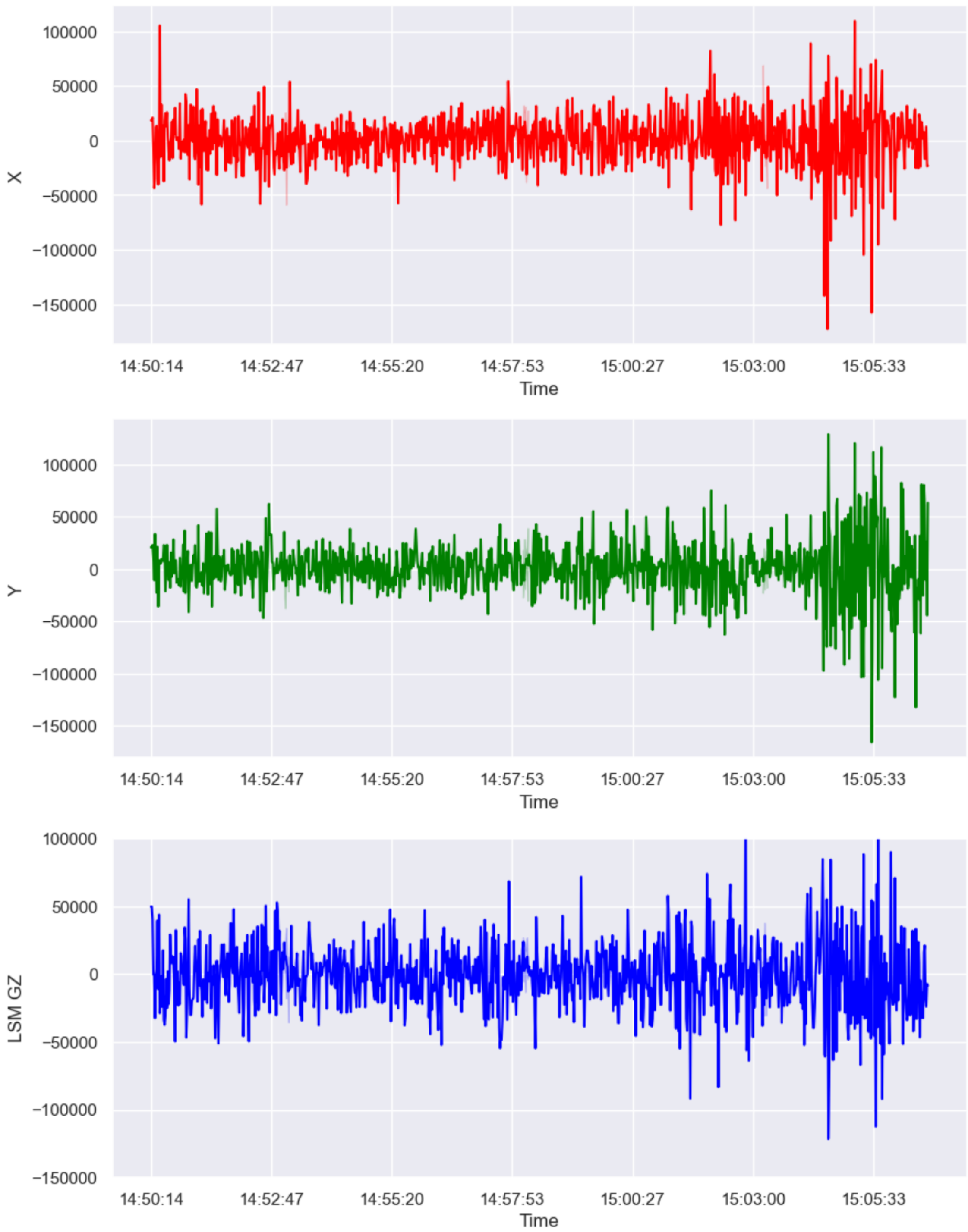
Gyroscope of Aurora



From the provided graphs, it is evident that both Aurora and Franky exhibited continuous motion in all three dimensions. This observation supports our hypothesis that the CubeSats experienced excessive rotation, leading to the tangling and subsequent cutting of the monofilament fishing line. Additionally, in the accelerometer data, we can observe a sudden change, indicating the moment when the nanosatellites ceased ascending and began their descent.



Gyroscope of Franky



4.1.5 Additional Payload

As it was stated above, we made two CubeSats from the scratch using Arduino boards. Each CubeSat carried 3 sensors: Aurora: temperature, humidity and air quality sensors Franky: temperature, humidity and gas level sensors

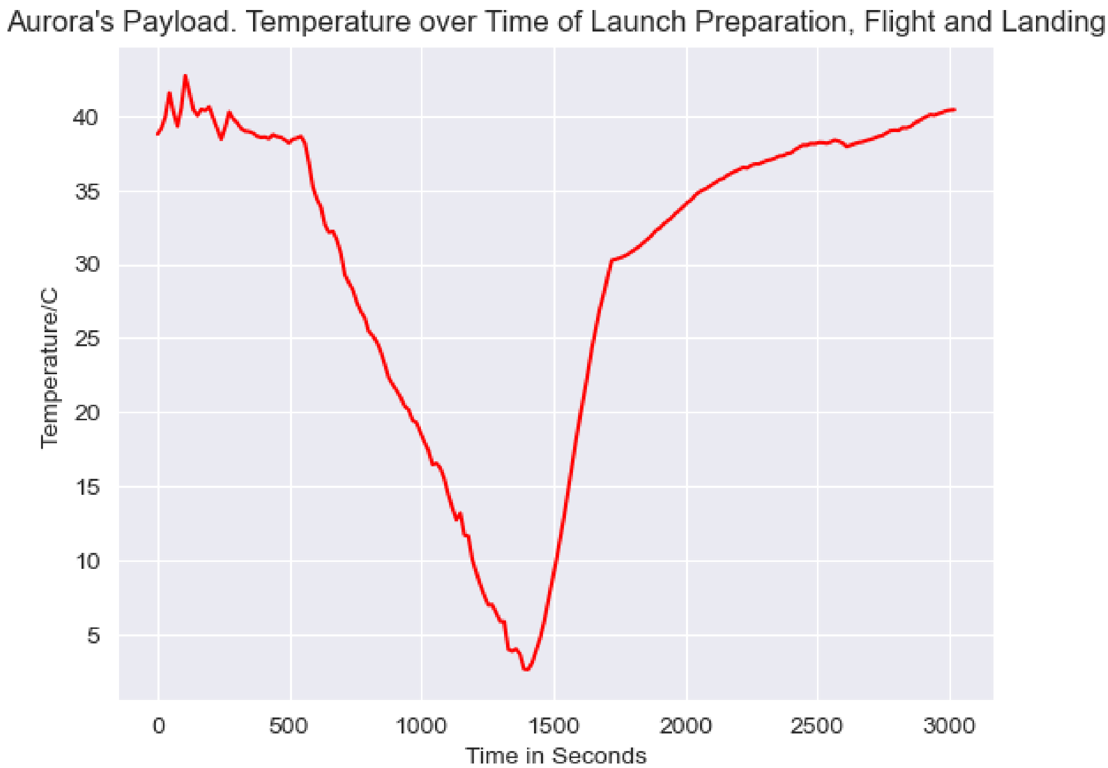
Aurora

Since Aurora's board did not include a real-time sensor, we tracked time in milliseconds and later converted it into seconds during the data analysis process. The temperature data captured spans from the activation of the Arduino board until the landing of the CubeSat. Consequently, we can observe a consistent decrease in temperature after approximately 500 seconds, which corresponds to the ascent phase of our CubeSat. It's worth noting that the temperature sensor on Aurora measured the outer air temperature, in contrast to the LPS, LSM, and HDC temperature sensors within the main CubeSat that measured the temperature internally.

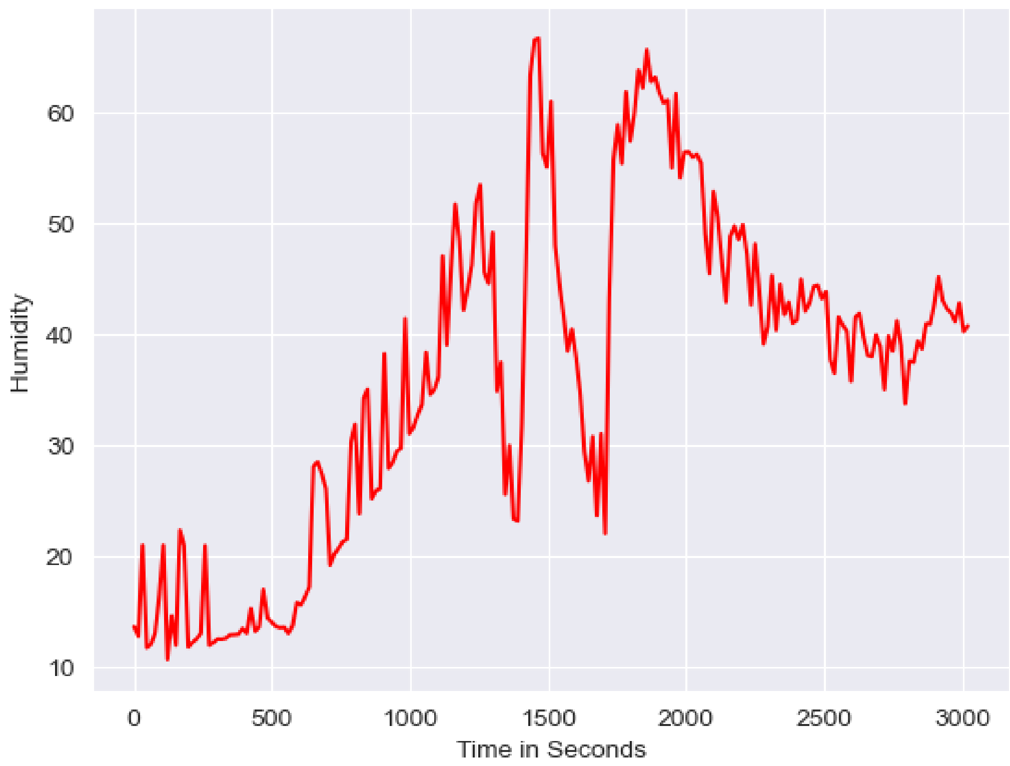
After reaching its lowest point at the peak of the flight, the temperature began to increase once again and subsequently stabilized.

From humidity data, it is evident that the highest point was reached at the peak of flight.

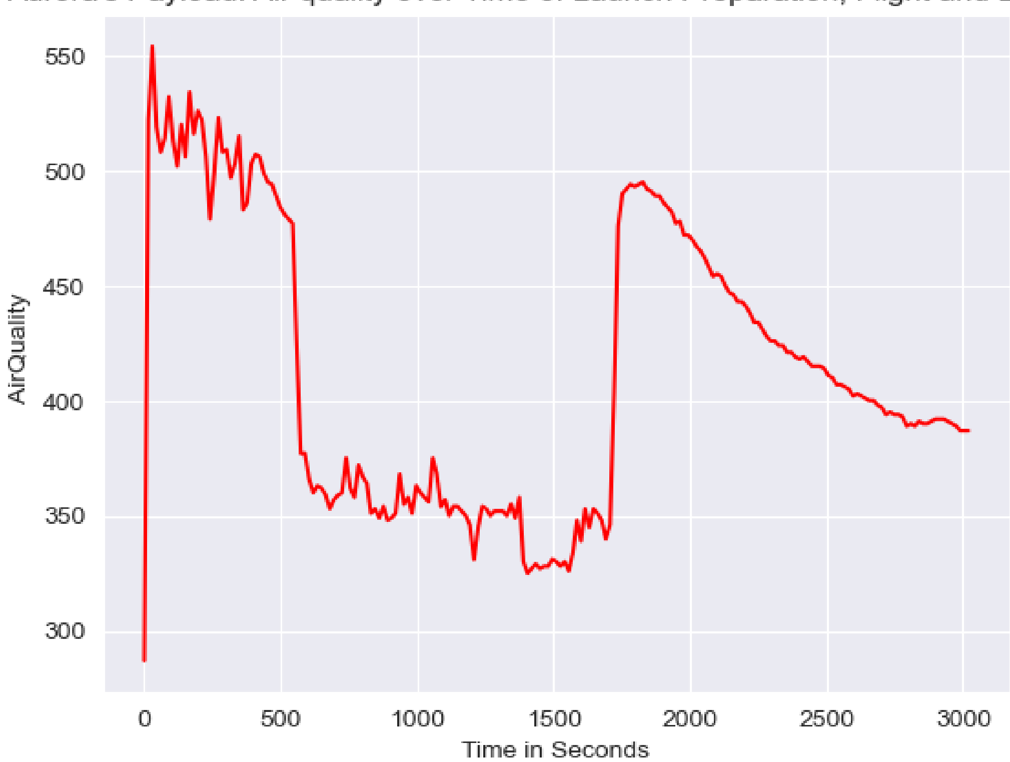
Based on the readings from the air quality sensor, it is our belief that there might have been some malfunctions or coding issues with its operation.



Aurora's Payload. Humidity over Time of Launch Preparation, Flight and Landing



Aurora's Payload. Air quality over Time of Launch Preparation, Flight and Landing

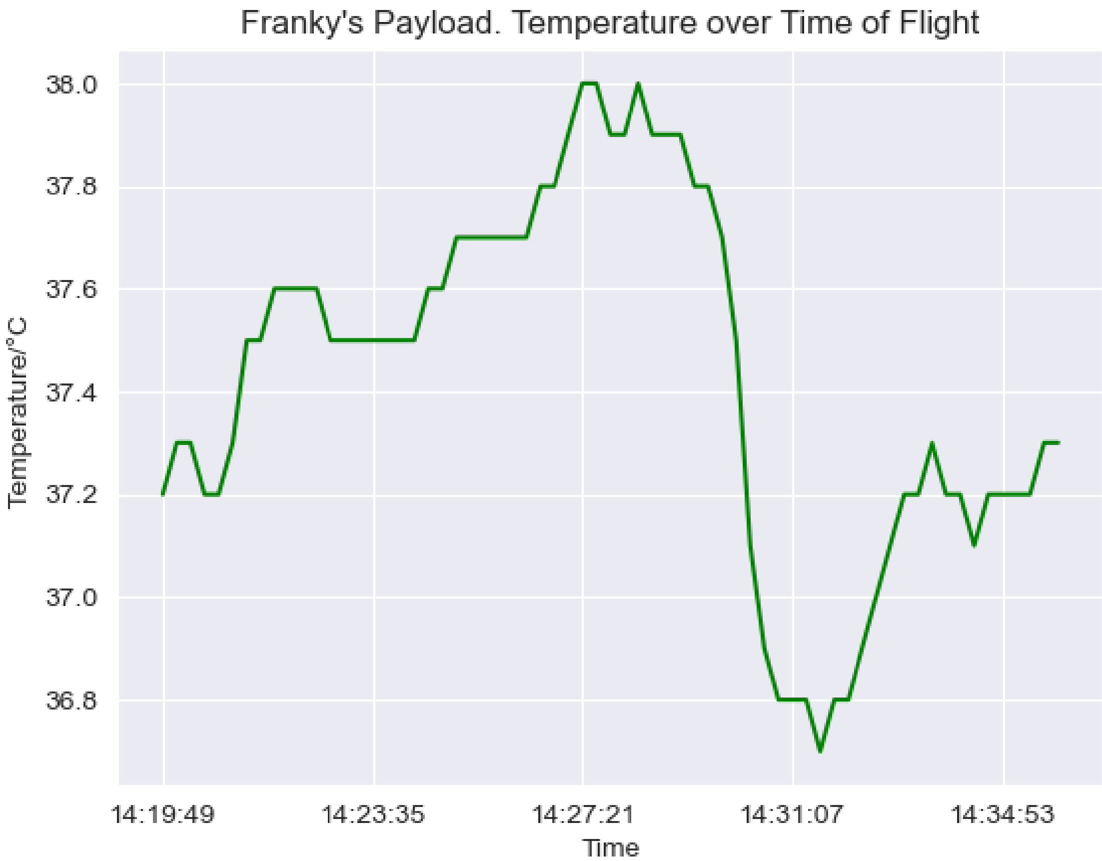


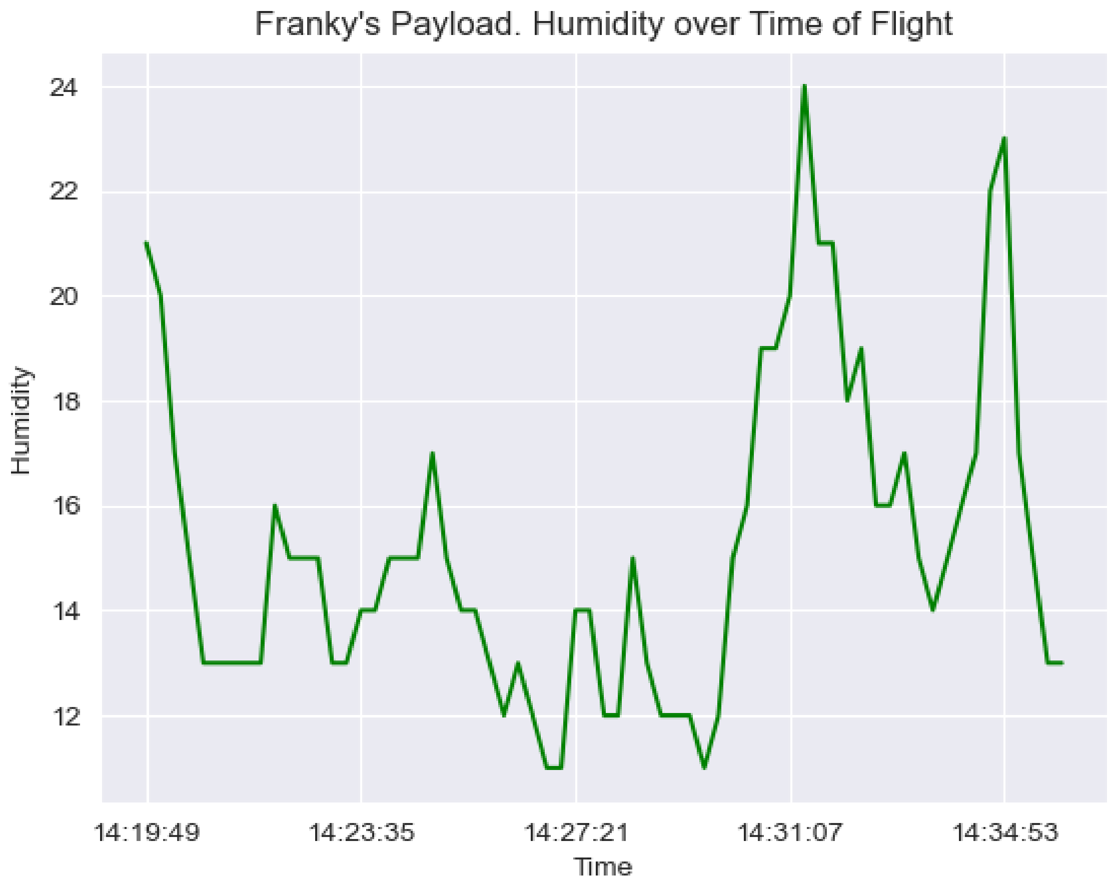
Franky

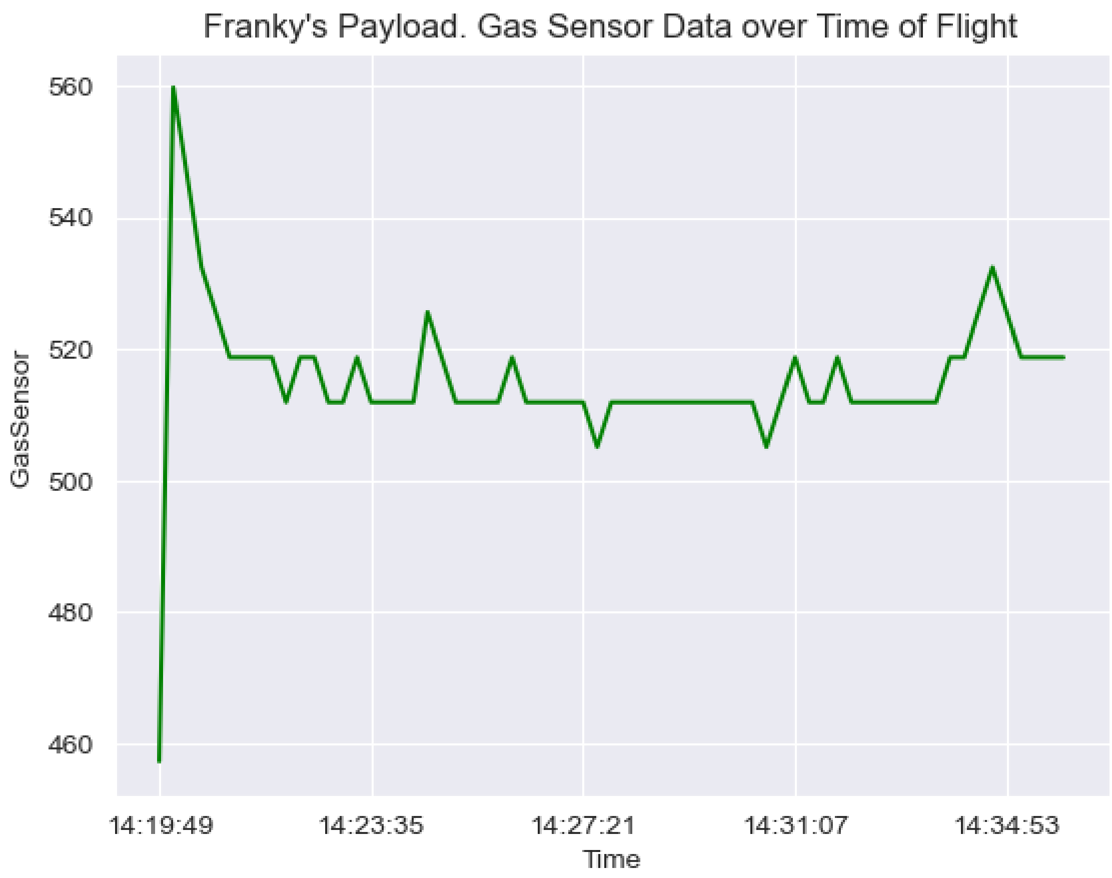
The inclusion of a real-time sensor in Franky's payload enabled us to obtain more precise and accurate data. It is important to note that the graph presented depicts information solely captured during the flight duration unlike the graphs of Aurora. Moreover, the temperature sensor within Franky's payload measured internal conditions, aligning its data with that of the LSM, LPS, and HDC sensors.

It is interesting to observe a stark contrast in humidity data between Franky and Aurora in terms of the range recorded.

Once more, upon analyzing the data obtained from the air quality sensor, we have come to the conclusion that there could have been potential malfunctions or coding errors affecting its proper functioning.




Franky's Payload. Humidity over Time of Flight
24
22
20
18
16
14
12
Humidity
14:19:49
14:23:35
14:27:21
14:31:07
14:34:53
Time


Franky's Payload. Gas Sensor Data over Time of Flight
560
540
520
500
480
460
GasSensor
14:19:49
14:23:35
14:27:21
14:31:07
14:34:53
Time

4.1.6 Pollution sensors

Pollution sensors PM2.5

PM2.5 sensors are designed to measure and monitor tiny particles in the air that are 2.5 micrometers or smaller. These sensors provide real-time data on air quality, aiding in the identification of pollution sources and the protection of human health. The data collected by these sensors can be used to make informed decisions, guide interventions, and promote environmental awareness.

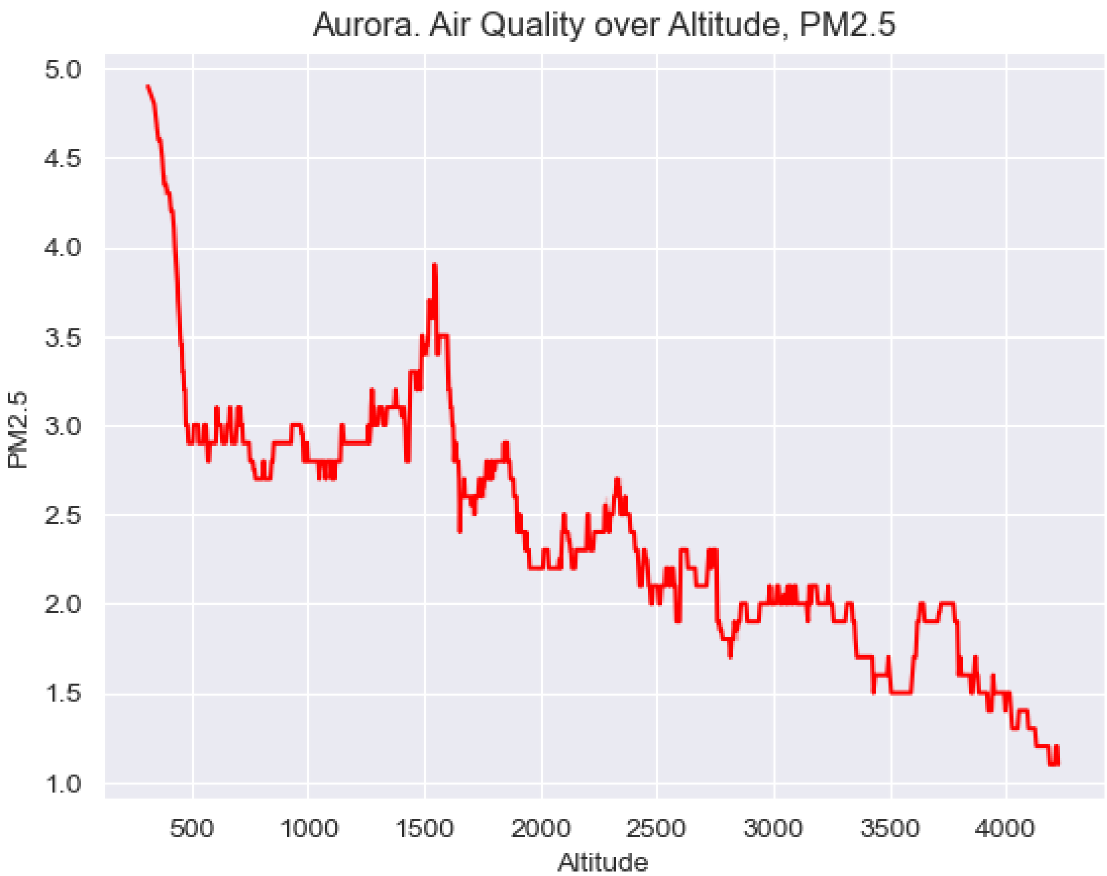
The line graph depicted in the figure illustrates the correlation between PM2.5 levels and altitude as measured by the pollution sensor. The vertical y-axis represents the concentration of PM2.5 in micrograms per cubic meter (µg/m^3), while the horizontal x-axis corresponds to the altitude measured in meters above sea level.

Aurora

Upon examining the data, a clear correlation between PM2.5 levels and altitude emerges. The data showcases a range of PM2.5 concentrations, with the highest recorded level being approximately 4.9 µg/m^3 at the beginning, and the lowest recorded level around 1.1 µg/m^3 at an altitude of 4,000 meters. This indicates an inverse relationship, where higher altitudes correspond to lower PM2.5 values.

Based on the provided PM2.5 concentrations, we can classify the air quality as follows:

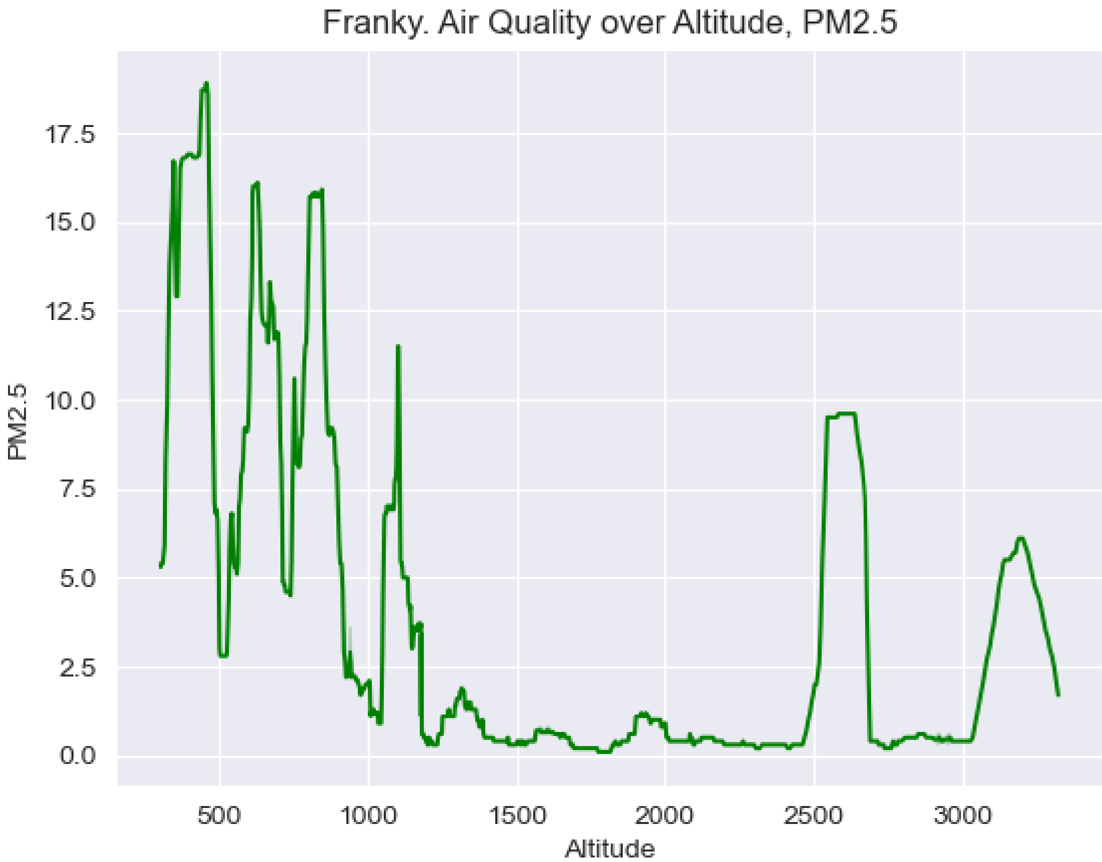
Fortunately, both values fall within the "Good" category, indicating a low amount of particulate matter in the air of the Karmanian region.



Franky

From the figure, it is evident that there are distinct differences in the PM2.5 sensor values between Franky and Aurora. We believe that Franky's PM2.5 sensor was more accurate, as its values align more closely with the results from the previous year. Additionally, the PM2.5 values in the graph exhibit greater fluctuations compared to Aurora's readings. Up until an altitude of 1200 meters, there was a constant and rapid change in values, while at higher altitudes, the values became more consistent.

The maximum value was in the initial stage and was equal to about 18 $\mu g/m^3$, which falls within "Good" category according to standards. At the peak of flight it was approximately 1.5 $\mu g/m^3$, which also falls within "Good" category. Despite the fact that the values of Franky were higher, they still stayed within "Good", which is in range between 0 to 50 $\mu g/m^3$ [**2**].



Pollution sensors PM10

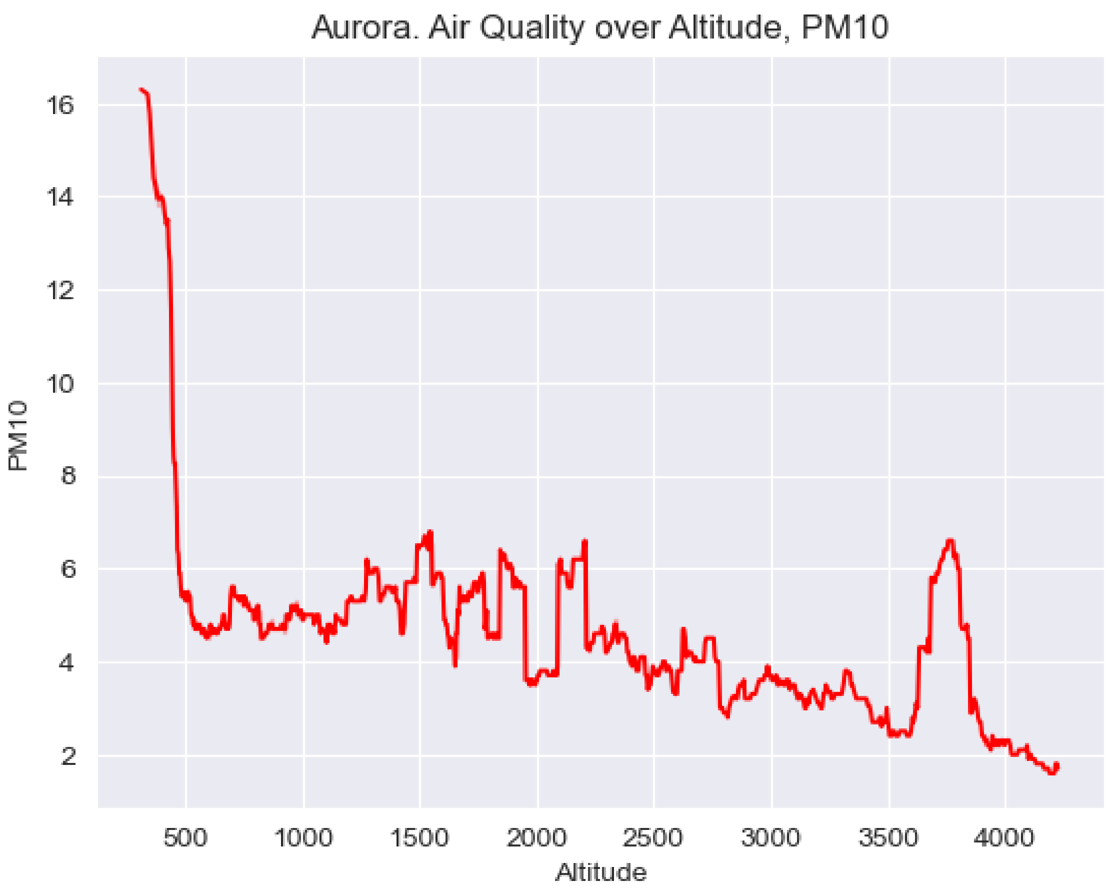
The figures depict the correlation between altitude and PM10 levels as measured by the pollution sensor 10. PM10 sensors are specifically designed to monitor and analyze particulate matter with a diameter of 10 micrometers or smaller. These particles can originate from various sources such as vehicle emissions, industrial processes, dust, and pollen.

PM10 sensors utilize advanced technologies, including optical methods or particle counting techniques, to detect and measure the concentration of these fine particles in the air. By continuously monitoring PM10 levels, these sensors provide valuable data that helps in assessing air pollution levels, identifying high-risk areas, and evaluating the effectiveness of pollution control measures.

The data collected by PM10 sensors plays a crucial role in understanding the potential health impacts of exposure to particulate matter. Fine particles, including PM10, can deeply penetrate the respiratory system, potentially causing respiratory issues, cardiovascular problems, and other adverse health effects.

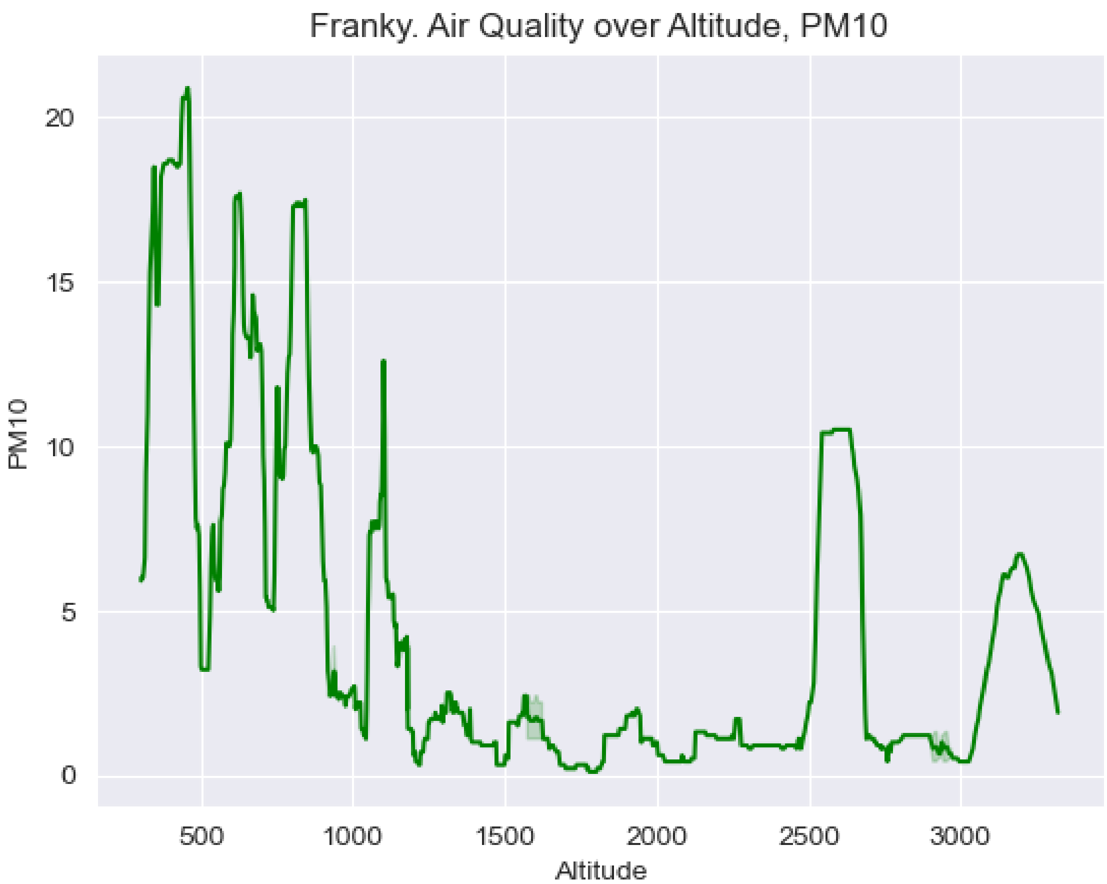
Aurora

The line graph illustrates the change in air quality with respect to altitude within a designated timeframe. It is evident that initially, the concentration value reached a peak and then sharply declined to approximately 4.3 µg/m^3. Subsequently, the concentration remained relatively stable with minor fluctuations, as well as one major fluctuation. The PM10 concentration data reveals that the highest recorded level is approximately 16.3 µg/m^3, whereas the lowest recorded concentration is around 1.7 µg/m^3. Both the values fall within "Good" category according to international standards [**3**]. This means the atmosphere in Karmanian region poses little or no risk to public health.



Franky

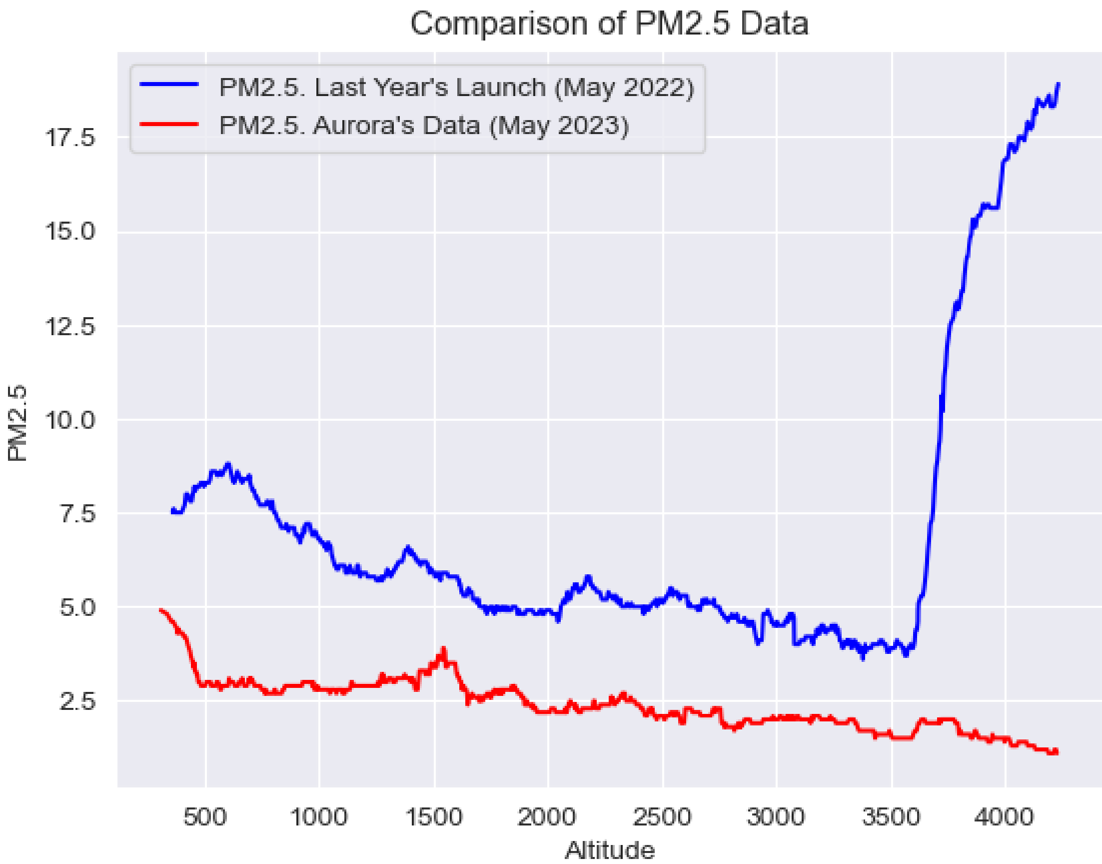
The values recorded by Franky's PM10 sensor are also higher in this instance. The initial values were high, and the maximum value reached approximately 22 µg/m^3 at an altitude of around 490 meters. The lowest points were observed within the range of 1600-1800 meters in altitude. Despite these higher values, they still fall within the "Good" category according to international standards.



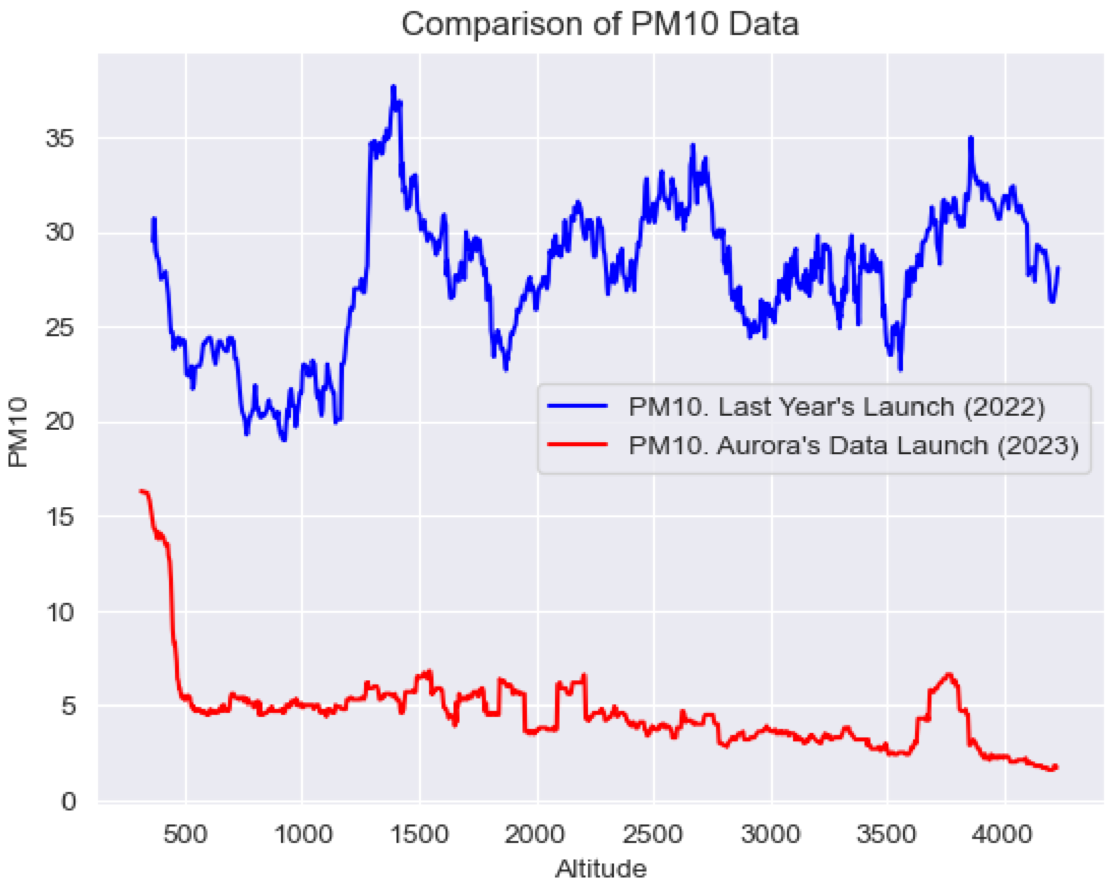
PM2.5 and PM10. Comparing to last year's results

Because last year only one CubeSat was launched in Karmanin region during UniSat 1.0 program, we have a single source of data for comparison.

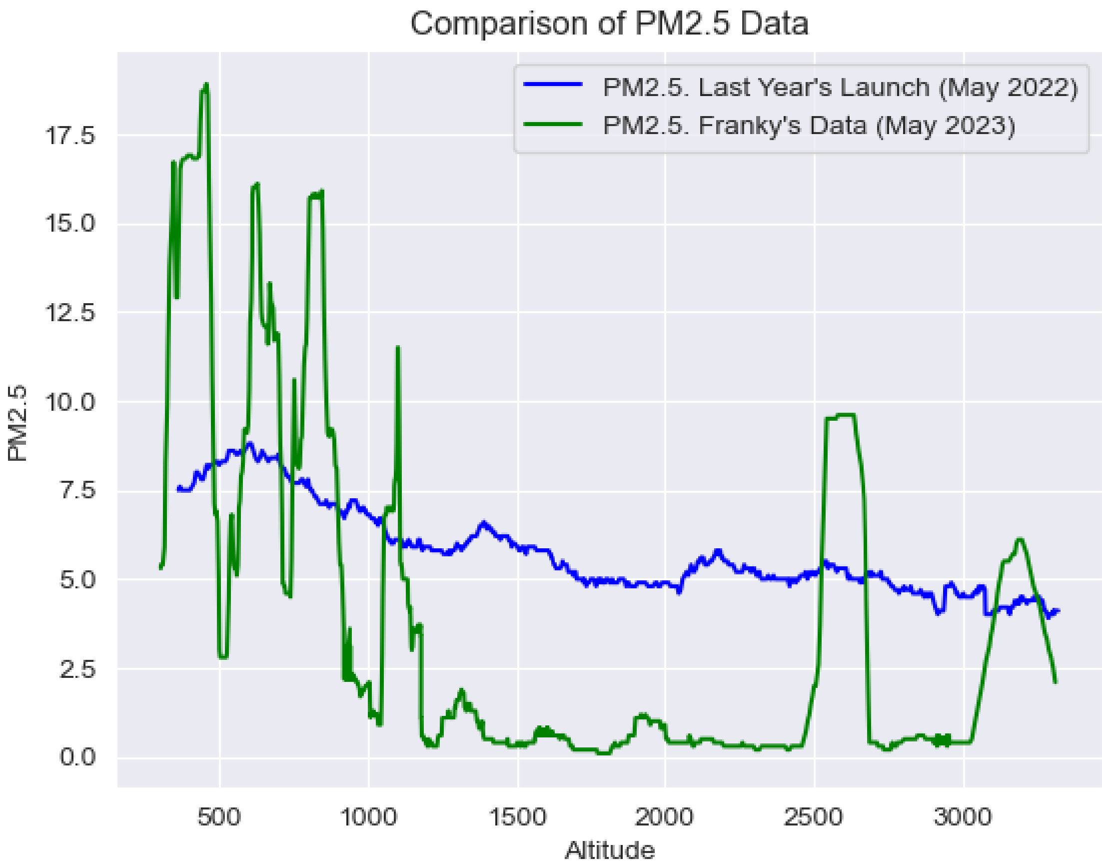
Overall, we can observe a significant decrease in the values from 2023 compared to the results from the previous year. It is worth noting that only the PM2.5 data of Franky initially exhibited higher values. In comparison, last year's data was closer to the Moderate air quality category, although it still fell within the Good category. We were delighted to witness considerably lower measurements this year, which we attribute to the commendable efforts of eco-activists in our country who have contributed to improving air quality.

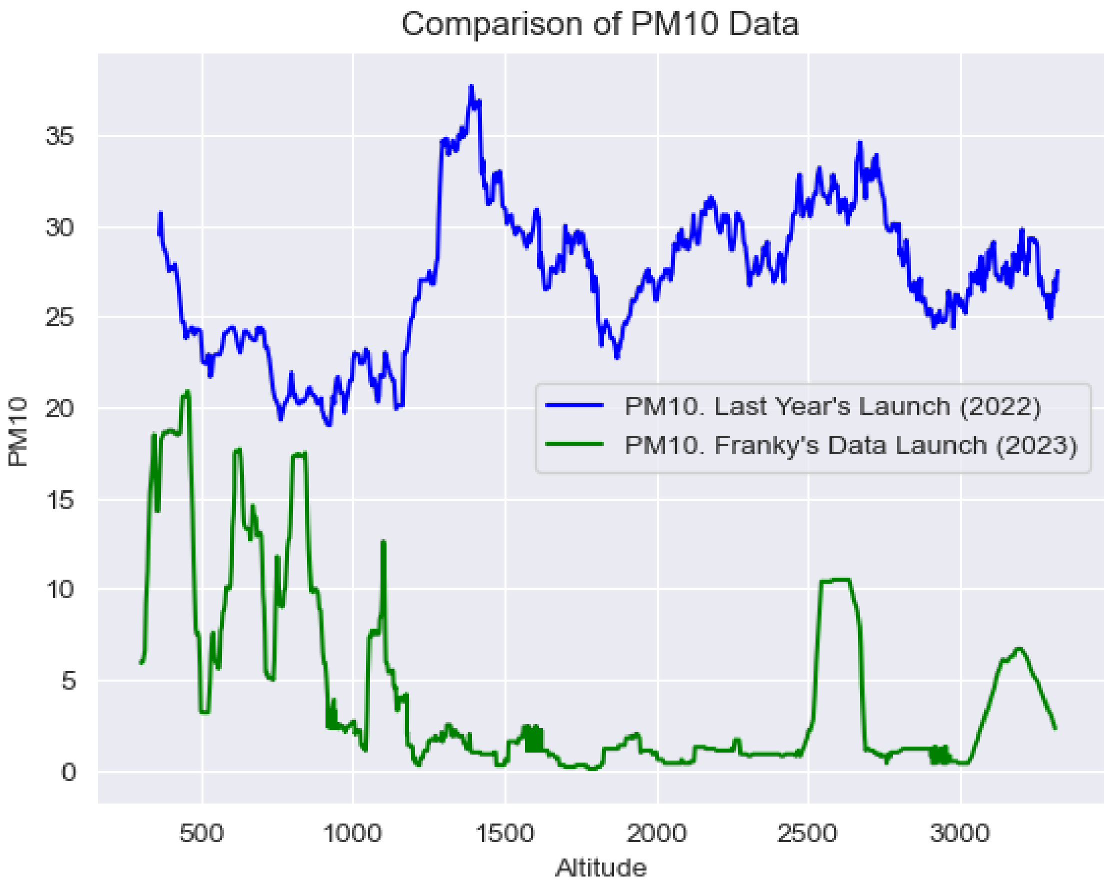


Comparison of PM2.5 Data
PM2.5. Last Year's Launch (May 2022)
PM2.5. Aurora's Data (May 2023)
PM2.5
17.5
15.0
12.5
10.0
7.5
5.0
2.5
500
1000
1500
2000
2500
3000
3500
4000
Altitude



Comparison of PM10 Data
PM10. Last Year's Launch (2022)
PM10. Aurora's Data Launch (2023)
PM10
35
30
25
20
15
10
5
0
500
1000
1500
2000
2500
3000
3500
4000
Altitude


Comparison of PM2.5 Data
PM2.5. Last Year's Launch (May 2022)
PM2.5. Franky's Data (May 2023)
PM2.5
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
500
1000
1500
2000
2500
3000
Altitude


Comparison of PM10 Data
PM10. Last Year's Launch (2022)
PM10. Franky's Data Launch (2023)
PM10
0
5
10
15
20
25
30
35
500
1000
1500
2000
2500
3000
Altitude

4.2 Experiment with Biomaterial

As mentioned above, we also launched biomaterials, including seeds of some plants, yeast and mold. One of our goals is to contribute to the future of stratospheric agroplantations. We are concerned about food security, and the concept of high-altitude farming appears to be one potential solution to address malnutrition and hunger. Despite the numerous challenges, stratospheric agroplantations offer several benefits, including exposure to higher levels of unfiltered sunlight and reduced competition for water and soil. Moreover, this concept could help mitigate issues related to soil degradation, such as erosion, salinization, soil compaction, and pollution.

Furthermore, extensive research has highlighted the similarities between the stratospheric environment and the conditions found on Mars [**4**]. This resemblance has served as a significant motivation for conducting experiments with biomaterials.

In our project, we specifically selected seeds of plants known for their fast growth, allowing us to observe changes more quickly. Among the chosen seeds were carrot, tomato, parsley, coriander, dill, and mung beans. To enhance the chances of successful growth, we soaked these seeds in water two days prior to the experiment. This practice, supported by relevant research papers, aimed to optimize the outcomes of our experiments. Inspired by the findings of previous studies [**5**], [**6**], [**7**], we decided to independently replicate and expand upon their methodologies, ensuring the robustness and reliability of our own results.

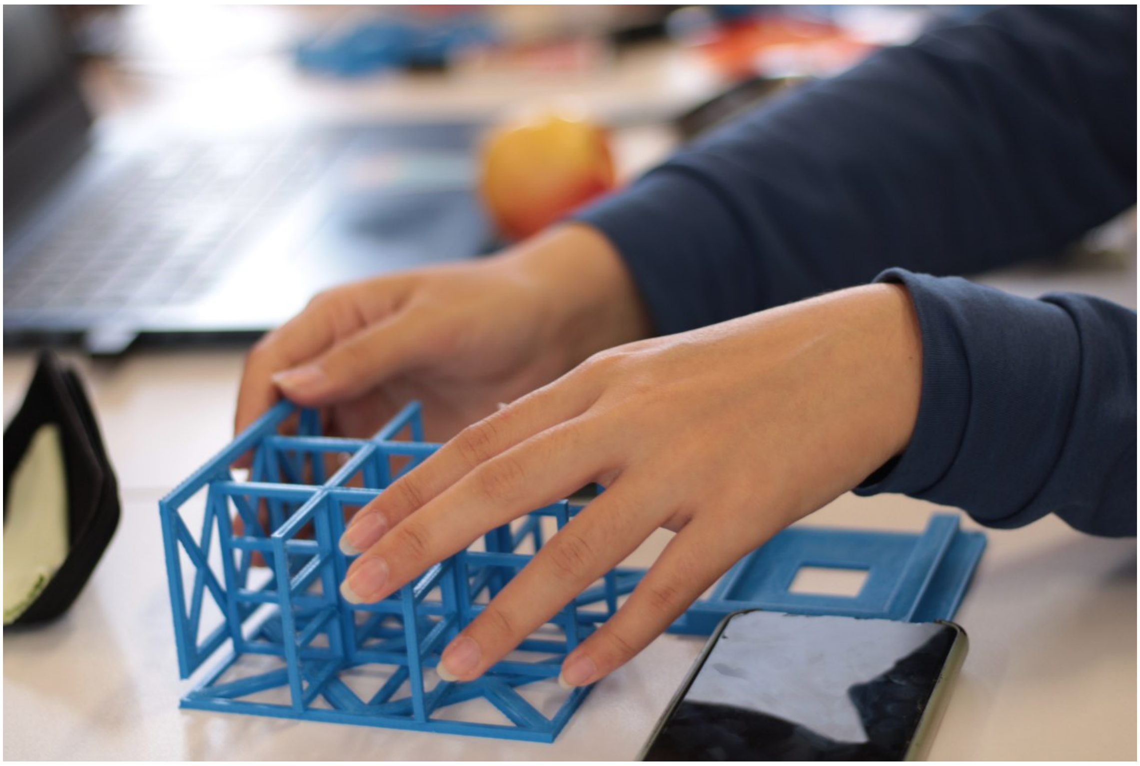


Figure 1: Assembling a box for containers

In preparation for our experiments, we conducted a search for Botrytis cinerea, a common mold. We successfully isolated it from a spoiled strawberry and carefully transferred it into a small, transparent container. Additionally, we obtained yeast for our experiments and placed it in a separate container. Each type of seed was also placed in its own transparent container. To organize and secure all the containers, our talented team members from the 3D printing team designed and created a specially designed box. This box not only held the containers in place but also provided a convenient and efficient setup for our experiments.

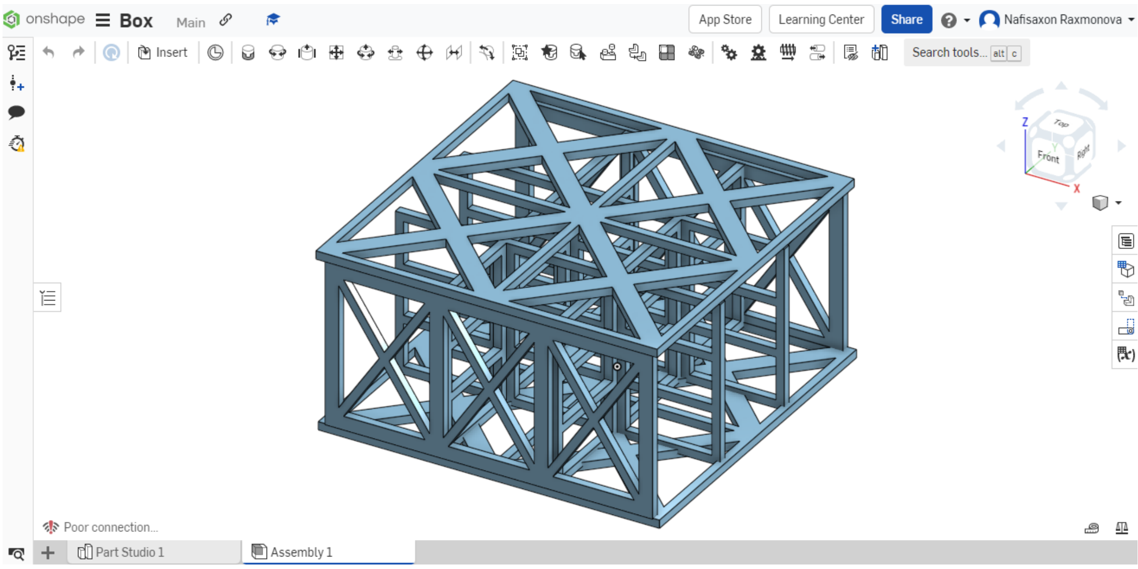


Figure 2: The process of 3D modeling of a box for containers

Upon comparing the control and experimental groups, it became evident that the control group exhibited significantly faster growth. Tomato, parsley, and carrot seeds in the experimental group did not show any signs of growth. However, the experimental group did yield sprouts from coriander, dill, and mung beans. In the control group, mung beans showcased the most robust growth, producing numerous plantlets. Coriander and dill also exhibited successful cultivation, while carrot seeds displayed small sprouts.

We hypothesize that the slower growth of plants in the experimental group can be attributed to the prolonged exposure to sultry heat before the search team located the CubeSats. This extended exposure might have had a detrimental effect on seed viability and overall plant development.

Figure 3: Control group of seeds after one and a half week of planting

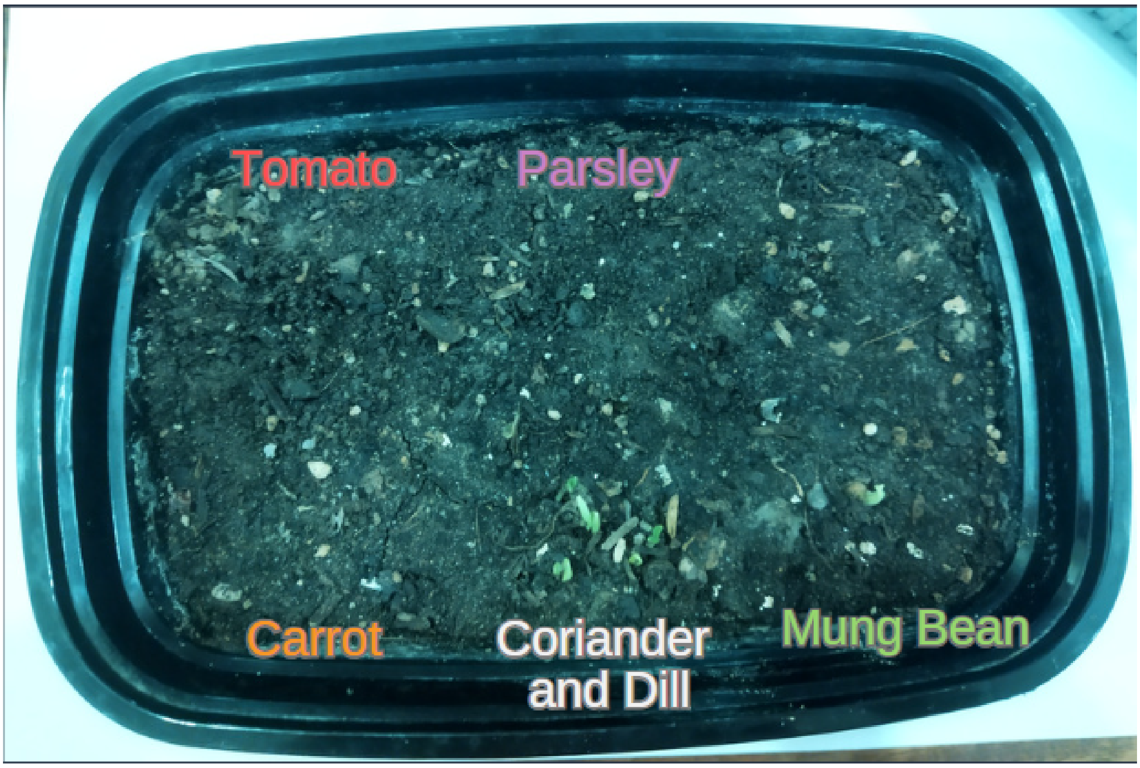


Figure 4: Experimental group of seeds after one and a half week of planting

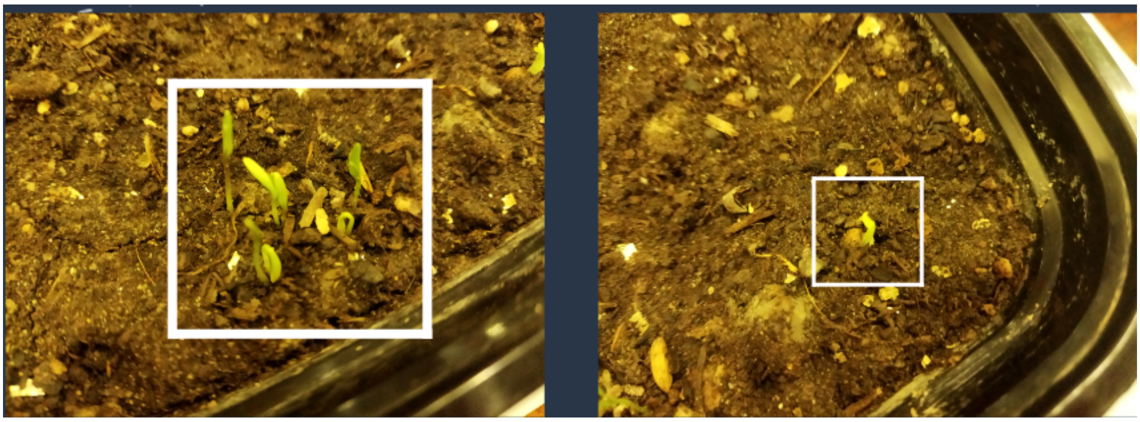


Figure 5: Closer look at experimental group of seeds after one and a half week. From left to right: coriander and dill, mung beans

5 Conclusion

This paper presents an overview of the UniSat 2.0 program, detailing the process and results of the project. The program involved the assembly of two CubeSats and two nanosatellites from scratch, which were then utilized to measure pollution levels and temperature. Additionally, experiments with biomaterials were conducted as part of the project.

By leveraging the data from the previous year's launch, a comparative analysis was conducted, leading to the conclusion that air quality in the Karmanin region, home to numerous manufacturing enterprises, had actually improved rather than deteriorated. This finding underscores the positive impact of environmental initiatives in the area.

One of the most noteworthy aspects of the project was the acquisition of practical knowledge and skills by the participants throughout its duration. The project not only provided a platform for conducting experiments but also facilitated the development of important soft skills, including leadership and team-building abilities among the participants.

The culmination of the project was marked by a final presentation delivered in the presence of esteemed representatives from UNICEF, as well as ambassadors from the United States, Latvia, and Israel in Uzbekistan. In recognition of their participation and achievements, all participants were awarded certificates and received small gifts.

Overall, the UniSat 2.0 program proved to be a valuable learning experience, combining scientific exploration, environmental monitoring, and the fostering of important interpersonal skills among its participants.

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