



LTS_CanSat - DESIGN DOCUMENT

1. Introduction

Team Name: LTS_CanSat

Team Members:

- Antonio Del Rio - Team Lead
- Eva Hegazy
- Hannah Toussaint
- Félix Gasiaux

Project Goal:

We intend to design and build a CanSat to gather information on air temperature and air pressure, as well as greenhouse gas concentrations and radiation presence during its time in the air. We plan to raise awareness on how certain greenhouse gasses released by human activities, namely Nitrogen and Carbon Oxides, can contribute to climate change and the destruction of the Ozone layer of our atmosphere.

2. Project description

2.1 Mission overview

We aim to raise awareness of the dangers of climate change and of catalytic destruction of Ozone caused by the pollutants Nitrogen and Carbon Oxides as a result of human activity.

Because of climate change, and the cycle of the Earth, annual temperatures rise faster than before. In 2020, the average temperature was 1.07°C higher than the year before. This is an enormous augmentation, and so our team decided to help fight climate change by measuring harmful gases in our atmosphere and later illustrating the impact of human activities on the Ozone layer. Ozone plays a major part in Earth's atmosphere by shielding us from harmful UV radiation. With the help of multiple different sensors which measure for example the temperature, the presence of pollutant gases and Ozone, and the altitude. Using all these different variables and numbers we want to prove that there is a correlation between the presence of different pollutant gases in our atmosphere and the temperature rising.

We use the sensors BMP280 and MPX4115A for temperature and pressure. We hope to get a reliable average for our altitude. We will also use sensors like the MQ-131 and the MQ-135 to measure the different gasses in the atmosphere.



2.2 Mechanical design

We are currently in the process of developing the CanSat parachute (see 2.6 Recovery Systems). The development and 3D-printing of models of the CanSat chassis are also planned for the next stages.

Using the parachute we built (see 2.6 Recovery Systems) we hope to reliably get the CanSat back in one piece after launching it. We are using the case from last year's CanSat team which is 3D printed in red ABS. We plan to attach the parachute directly to the CanSat using a little 3mm Uelsen which clamp the wires together and should be able to withstand a significant amount of force. The rope used for the parachute is PES 2,5 mm thick rope able to sustain 15 kg of load on it. Because we have 8 Ropes coming from the parachute the forces should be spread out to all the wires which should altogether be able to withstand around 120 kg (8 x 15 kg).

2.3 Electronic design

We are using an Arduino Uno board and a variety of sensors to measure the different variables for the primary and secondary missions.

At first, our team developed the electronic design for just the primary mission (Figure 1).

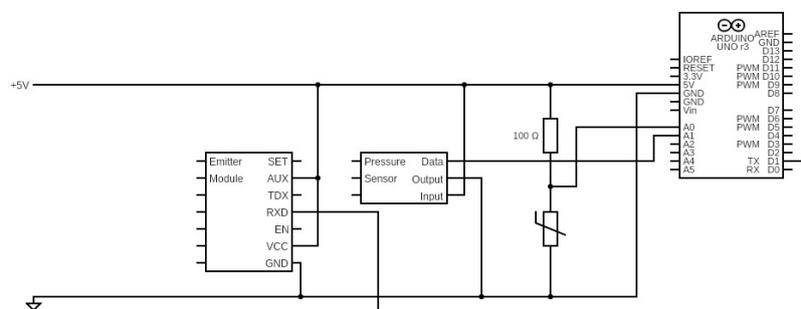


Figure 1 - Initial circuit diagram for primary mission only

In addition to the temperature and pressure sensors and transmitter provided for the primary mission, we are using the following components for our secondary mission (detail of total budget in 4.3 Budget):

- Non-contact IR temperature sensor module
 - Tecnoiot MLX90614ESF (2 mA)
- UV sensor module
 - Waveshare B00NL9XNN8 (1 mA)
- Air quality sensor (for Nitrous Oxide detection)
 - ZHITING MQ135 (160mA)
- Ozone sensor
 - Wzle-Ryp MQ131 (180mA)
- microSD card module
 - KWMobile 40811 (150mA)

After extensive testing and researching (see 2.7 Testing), our team has developed the final circuit diagram (Figure 2).

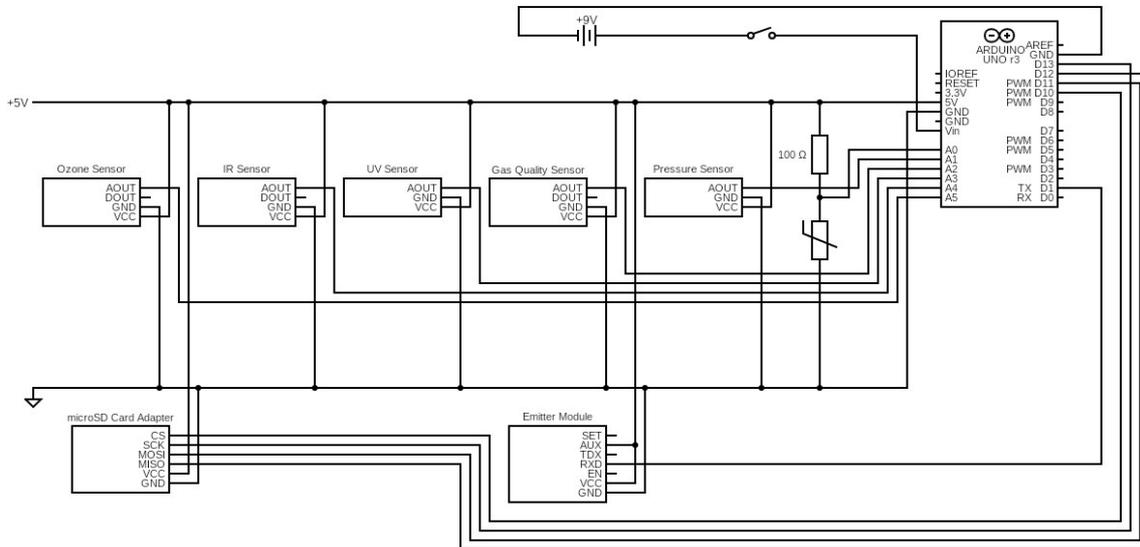


Figure 2 - Final circuit diagram for primary and secondary missions

The whole CanSat is powered by a standard 9V battery. Data will be transmitted via radio antennas and, in case of disruption of signal, a backup copy of the data will be stored on a microSD card attached to the CanSat.

After having finalised the circuit diagram, we have put together the circuitry inside the CanSat chassis (Figure 3).



Figure 3 - Completed circuitry inside CanSat housing

If we add all the different usage from the components, we get a consumption of around 542 mA including the Arduino. Using a standard 9V battery with around 600mA would allow the CanSat to run for a little more than one hour. We would like to be able to achieve the 4 hours of required run time for our CanSat, although the gas sensors use a lot of power and we do not have the sufficient place for a second or a third battery.



2.4 Ground station design

Our team has developed a working ground station using the provided 'APC220 Wireless Communication Modules' (see 2.7 Testing). The ground station (Figure 4) consists of the receiving antenna connected to the computer and a serial port tool to receive and store incoming transmissions.

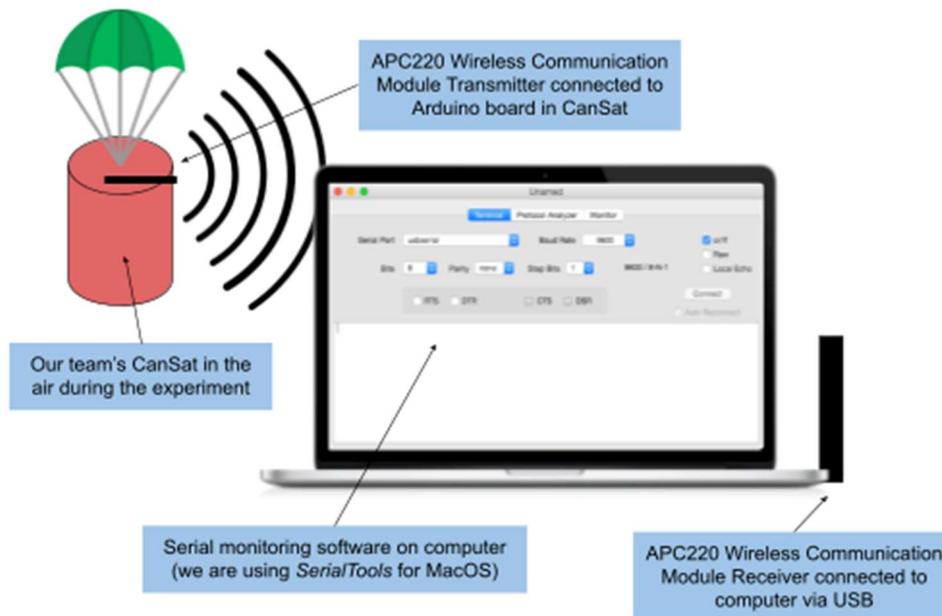


Figure 4 - Ground Station Design

In case the connection is broken between the transmitter part of the CanSat and the receiver of the ground station, we are also using a microSD card module, so that any transmitted data is also stored in the microSD card.

2.5 Software design

To record the values from all six of the sensors present in our CanSat, we used a loop with a delay period of 1000 milliseconds.

As the output values from the Arduino's analogue pins are values between 0 and 1, our team needed to find a function to convert the analogue values to pressure values. We used the 'Transfer Function (MPX4115)' from the sensor documentation for the provided MPX4115 pressure sensor ("Integrated Silicon Pressure Sensor"):

$V_{out} = V_{supply} \times (P(0.009) - 0.095)$, where P is the pressure in Pa, and V_{out} and V_{supply} are the output and supply voltages respectively.

The 'Transfer Function (MPX4115)' equation can be arranged to obtain values of pressure:

$$P = \left(\frac{V_{out}}{V_{supply}} + 0.095 \right) \div 0.009$$



To determine altitude from the pressure values, we used the following equation from *TheEngineeringToolbox.com* ("Atmospheric Pressure vs. Elevation above Sea Level."):

$P = 101325 \times (1 - (2.25577 \times 10^{-5}) \times h)^{5.25588}$, where P is pressure measured in Pa, and h is the height above sea level in meters.

The formula can be rearranged to obtain values of height:

$$h = (10^{\frac{\log(P \div 101325)}{5.25588}} - 1) \div (-2.25577 \times 10^{-5})$$

For the remaining outputs of temperature, gas quality, UV, IR, and Ozone presence, we will be recording the analogue output, and comparing the recorded values from the CanSat launch to control values at ground level.

Below is a flow chart showing the electronic and code cycle of the CanSat (Figure 5):

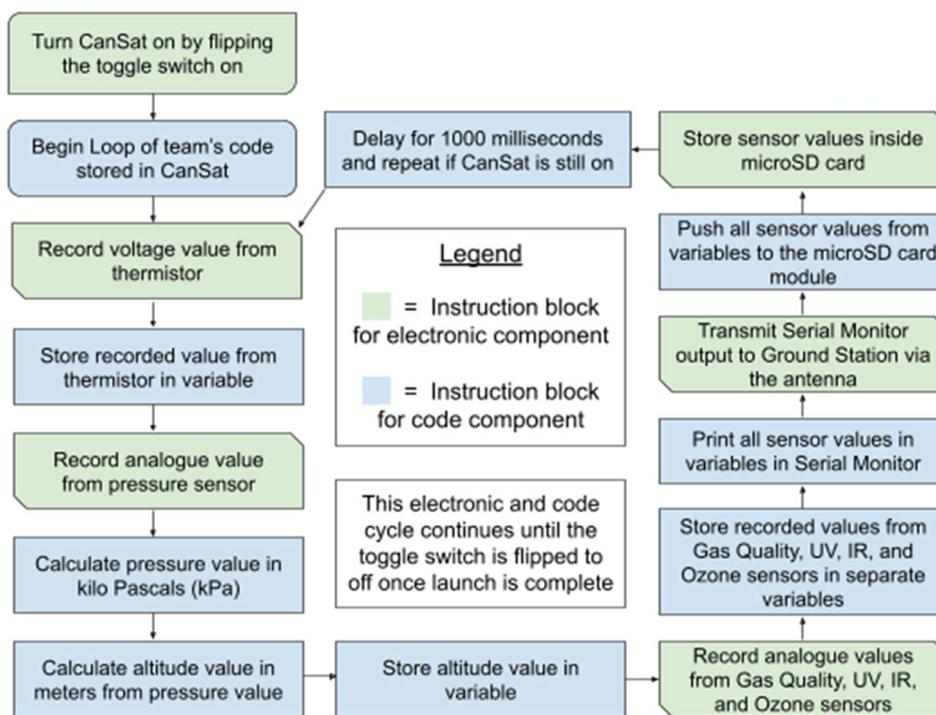


Figure 5 - Flow chart showing the electronic and code cycle of the team's CanSat

2.6 Recovery system

We plan to use a parachute for the recovery of our CanSat. Using the maximum weight allowed we calculate the size of our parachute.

$$D = \sqrt{(8 \times m \times g) / (p \times r \times C_d \times v^2)}$$

$$D = \sqrt{(8 \times 0,35 \times 9,8) / (\pi \times 1,22 \times 0,77 \times 8^2)}$$

$$D \approx 0,38115 \text{ m}$$



Where, D is the parachute diameter in meters.

We used red Ripstop material for the Parachute and braided rope out of PES. We also used little 4mm Eyelets which we put in the tissue hoping the tissue would be less under stress and the force would get distributed more equally.

The Rope is connected through the little Eyelets and attached to itself with the Uelsen (see images below).

Not having the CanSat at hand our team member had to simulate the ring used to attach the parachute to the CanSat using a simple O ring and then attach the weights on it. Using this we were able to test a lot of different designs of parachutes and different configurations by troughing it out of a window 12 meters high up. We came to the conclusion that 8 Suspension Lines and a 1 cm in diameter Vent would be our best way to go .



We are also using the included APC220 module to transmit data to our ground station which will save the received data to a file. The Arduino will also simultaneously save recorded data to a microSD card in case we have an issue with the ground station or the CanSat gets out of RF range.

2.7 Testing

After having created the circuit diagram described in 2.3 Electronic Design, we have recreated the circuit (from Figure 1) using the provided jump cables and breadboard for initial testing (Figure 6).

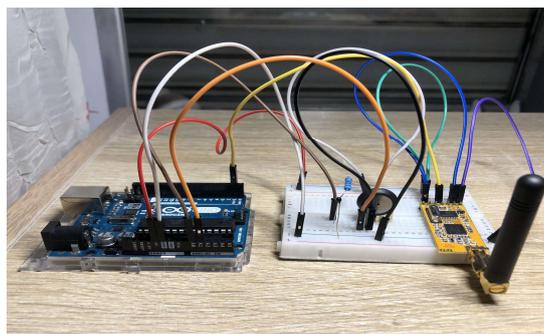


Figure 6



Our team has managed to write an Arduino program to record temperature and pressure values, and then transmit them to the ground station via the radio antenna (Figures 7 and 8).

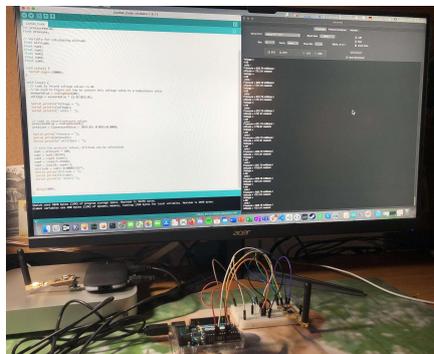


Figure 7

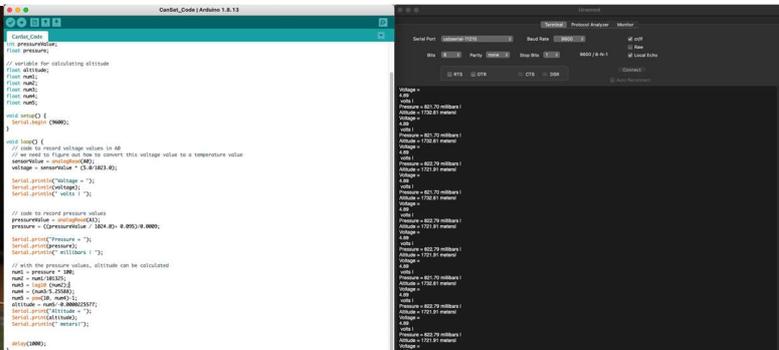


Figure 8

After having ordered and received the additional components for our secondary mission, we began with the further testing stage. During the developmental process of the final circuit diagram (Figure 2), we extensively tested the components using additional breadboards and jumper wires which we ordered (see 4.3 Budget). Below are several photos taken throughout the testing phase (Figures 9-10).

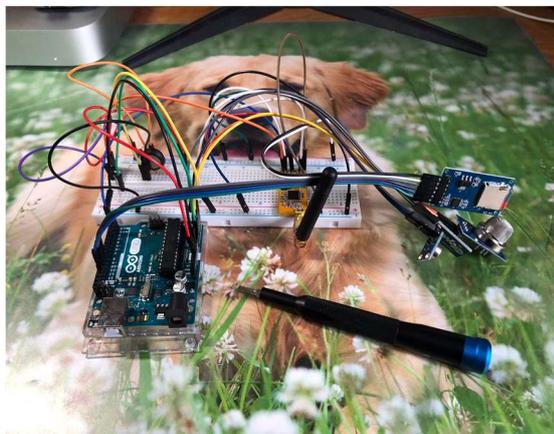


Figure 9

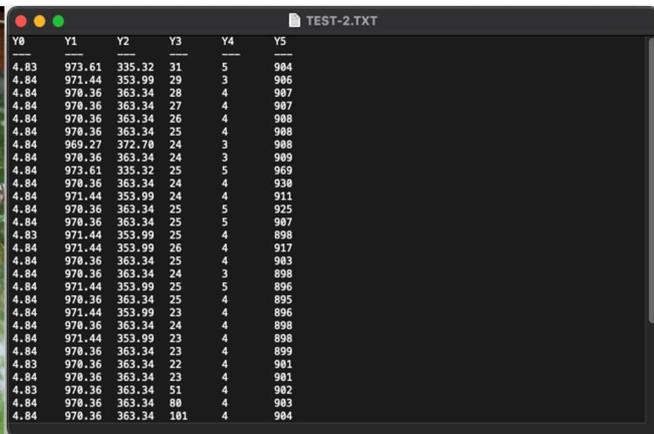


Figure 10

Once the testing phase was complete and the circuit diagram was finalised, the next stage was to solder all the components onto the CanSat. It was somewhat of a challenge to fit all the components attached to the Arduino into the small space of the CanSat chassis, but with the stacking of components and efficient wiring, we managed to fit everything inside the CanSat (Figures 11-12).



Figure 11

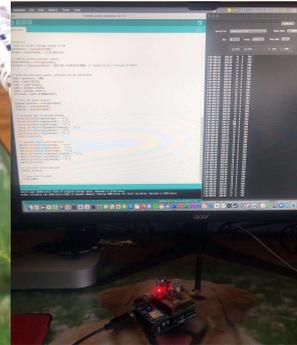


Figure 12

After further fine-tuning the Arduino code and soldering the cables with the switch to connect the battery, the development of the CanSat in terms of the circuitry for both the primary and secondary missions was complete (Figures 13-14).

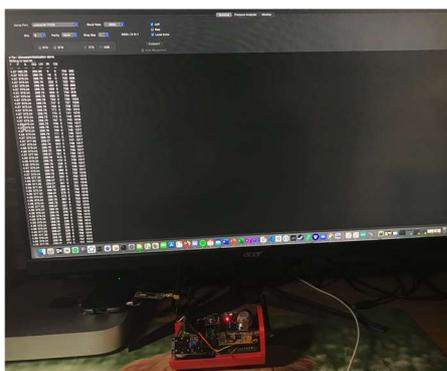


Figure 13

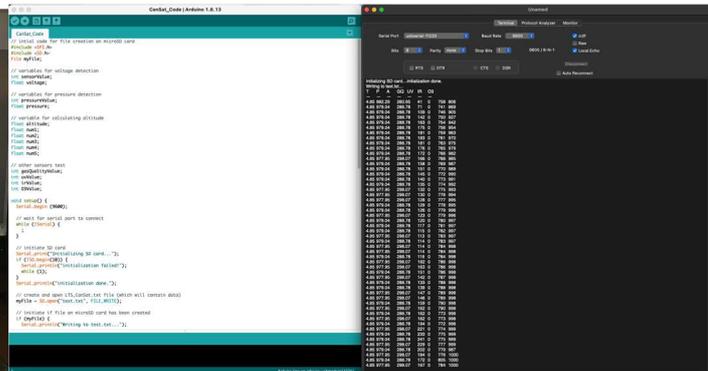


Figure 14

Figure 15 - Using old tissue one of our teammates had laying around first tests of the parachute were created



Figure 15

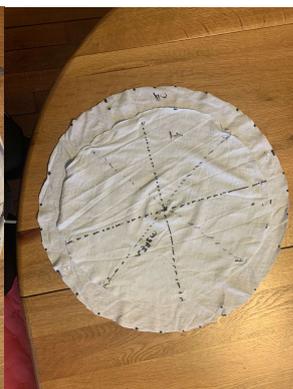


Figure 16

Figure 16, 17, 18 - Creating multiple parachutes with different sizes, with and without Vents and support lines of different lengths helped figure out what would work best.



Figure 17

Figure 18

Requirements

Our team has fulfilled all the stated design requirements from the Team Manual - CanSat2021. The checked requirements are listed and described under Appendix - Design Requirements.

3. Overall progress

3.1 Human resources

Antonio Del Rio, 19, is a LevelUp at the Luxembourg Tech School. After having graduated from the International School of Luxembourg last school year, he is taking a gap year in Luxembourg. He likes challenges, and therefore takes part in projects and competitions in the fields of science and technology. CanSat 2021 competition is one of them.

Eva Hegazy, 17, is a student at Athénée de Luxembourg. She's in a 2ieme D and also a student at the Luxembourg Tech School. Interested in learning new technology and science related skills, she saw CanSat as a good opportunity.

Hannah Toussaint, 17, is a first-year student at the Luxembourg Tech School. She attends the Athénée de Luxembourg and is in 2ieme D. Being invested in informatics and science, she thought CanSat was a great chance to learn and discover new things.

Félix Gasiaux, 16, is a LevelUp student in LTS. He is currently in 4ieme in the Lycée de Garçons Luxembourg. Having participated in FGC 2019 and other challenges he thought CanSat would be a very exciting opportunity enabling him to learn new things about technologies and space exploration.



Team Member	Antonio Del Rio	Félix Gasiaux	Eva Hegazy	Hannah Toussaint
Tasks	-Team Lead -Initial research -Programming of Arduino -Testing and assembly of electronic components -Data processing -Design Report	-Initial research -Research and design of the parachute	-Social Media -Design Report	-Data Representation -Design Report

3.2 Planning

Section	Duration (hours)	Status	Planning adaptations
Mechanical design			
Parachute	8	100%	
Chassis modelling	NA	NA	We ended up using the CanSat chassis model provided by ESERO Luxembourg. The printing has been done at NewOne.lu.
3D printing of chassis	NA	NA	
Electronic design			
Circuit diagram for primary mission	1.5	100%	Working on a diagram combining both missions
Circuit diagram for secondary mission	2	100%	
Components that will be used	1.5	100%	
Components obtained	N.A	100%	
Solder board and components	8.5	100%	
Ground station design			
Computer	0.25	100%	
Antenna	0.75	100%	
Data storage	1.5	100%	
Software design			
Arduino Code	3.5	100%	
Recovery system			



Parachute size calculation	1.5	100%	Calculated using the maximum weight allowed
Building	5	100%	
Data recovery	2	100%	MicroSD card on board as backup
Testing			
Testing of components	3.5	100%	Recreation of circuit for initial testing
Testing of code	0.75	100%	Worked in stand-by

3.3 Budget

For the completion of our primary and secondary missions, as well as for the testing and building of circuitry, our team has ordered the following components:

Sensor Name	Sensor Type	Price (EUR)	Power Needs (mA)
Tecnoiot MLX90614ESF	IR temperature sensor	32.96	2mA
Waveshare B00NL9XNN8	UV sensor	12.99	1mA
ZHITING MQ135	Air quality sensor	8.29	160mA
Wzle-Ryp MQ131	Ozone sensor	34.13	180mA
KWMobile 40811	microSD card module	6.99	150mA
Panasonic 9V Battery	Battery	7.00	600mA

- Sunfounder Breadboards Kit 3 - EUR 11.99
- Ripstop Fabric Nylon Meterware - EUR 8.00
- 16x Pressklemme/ Uelsen - EUR 0.29
- Ösen/Eyelets - EUR 4.99
- Rope/ Vielzweckschnur - EUR 6.79

All the above components were purchased either from Amazon.de or at the hardware store in Bettembourg (Globus Baumarkt). The total cost of all the ordered components is 140,86 EUR.

3.4 Outreach

We created an @LTS_CanSat Twitter account ([link to account](#)), where we regularly post our processes and what we are working on at the moment. We plan on making around two posts per week throughout the project development.



We hope that us being active on social media and showing the different stages of project development of the CanSat can encourage the younger population to become interested and excited in the areas of science and technology.

We also plan on designing posters that we will hang at our schools to raise awareness of our project and promote our social media account. These posters will contain our logo, a short description of our team and our goals and a QR code to our Twitter account.

4. Scientific results

Our team has successfully obtained data recorded by our CanSat during the launch on 22 May 2021 at the Elsenborn-Butgenback Air Base. The original data collected and processed data have been submitted alongside this report.

For the primary mission, we compared the recorded temperature values to the pressure values. Figure 19 below shows a scatter diagram of the variation of pressure and temperature throughout the duration of the CanSat launch.

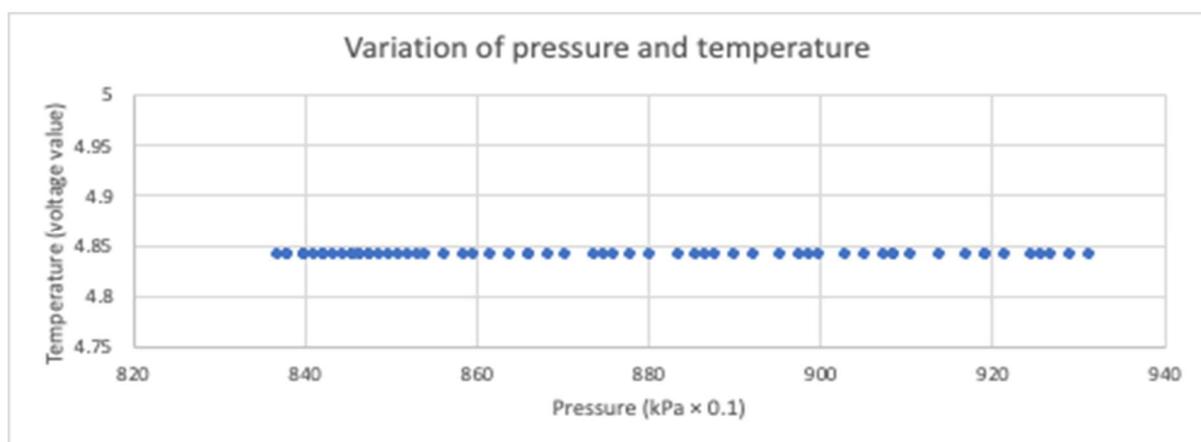


Figure 19 - Pressure against recorded temperature

The above graph shows that as the pressure increases the temperature remains constant, retaining a voltage value of 4.84V. This relationship is not what our team expected, as we thought that increasing pressure would increase temperature.

This relationship could be explained by the fact that the thermistor was positioned inside the CanSat, without an opening for the component to stick out and measure the temperature of the outside environment. In addition, we noticed after the CanSat launch that each of the components inside would heat up while turned on. This would mean that, even with a change in temperature inside, the thermistor would have recorded a higher temperature.



Within our CanSat code, we also included a calculation method to convert the recorded pressure values into altitude values using the equation derived in 2.5 Software Design. Using the relationship between altitude and temperature included in the CanSat Technical Guide and the starting temperature of around 8°C on the day of the launch, we plotted altitude against temperature (Figure 20):

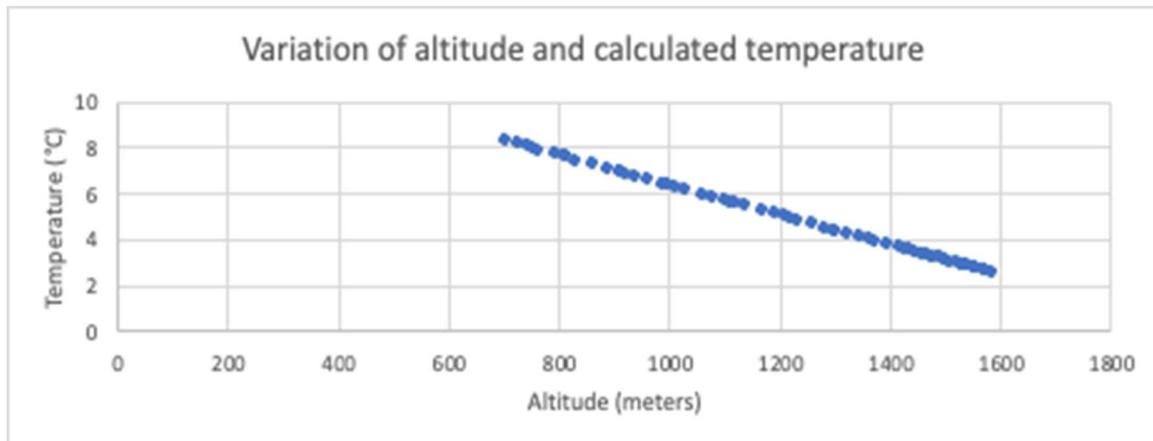


Figure 20 - Altitude against calculated temperature

As part of our secondary mission, we wanted to determine the relationships between the altitude and the gas quality (presence of pollutants such as Carbon and Nitrogen Oxides), UV radiation, IR radiation, and Ozone presence. At the end, we determine the relationship between the gas quality and ozone presence. We accomplish this by plotting the respective values against the recorded altitude. Each of the sensors used for the secondary mission gave an analogue output, a value with no specific units that increases with an increase in the amount / presence of what the sensor is measuring.

1. Altitude vs Gas Quality (Carbon and Nitrogen Oxides)

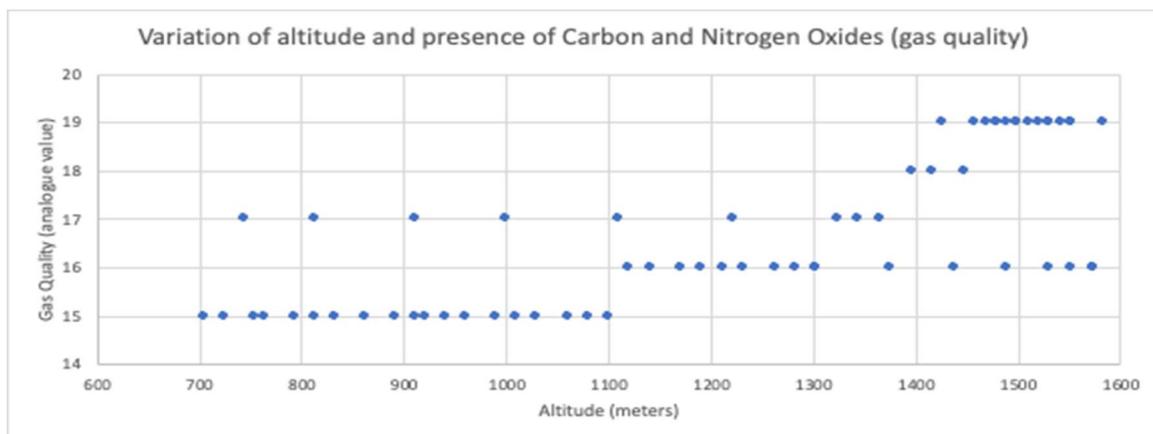


Figure 21 - Altitude against gas quality (unprocessed)



Figure 21 shows that positive correlation exists between the altitude and gas quality. However, because the analogue output is only in integers, the graph shows that ranges of altitudes share a common gas quality value (e.g. 700m to 1100m shows a gas quality value of 15).

For further data processing to determine a true relationship between the two values, we calculated the average recorded altitude for each gas quality value, determined the percentage change in gas quality from the launch site, and eliminated any clear outliers. Figure 22 shows the graph plotting average altitudes against their respective change in gas quality percentages:

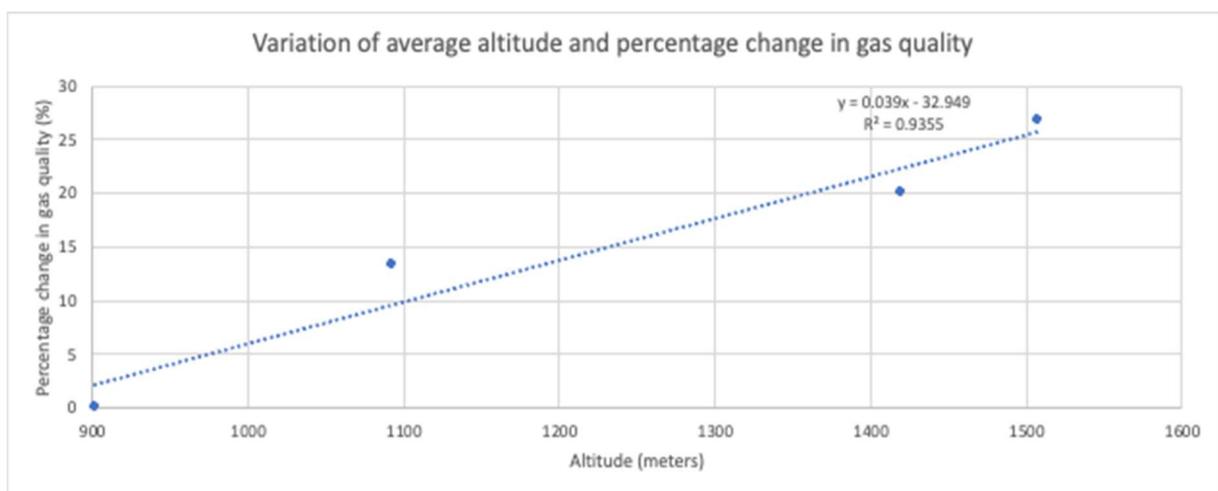


Figure 22A - Average altitude against percentage change in gas quality from ground (processed)

Figure 22 shows that a positive linear correlation with a fairly strong correlation strength of 0.9355 exists between the average altitude and percentage change in gas quality.

For the other relationships, it became evident that, similar to what is shown in Figure 21, the analogue values from the sensors remain constant for a range of altitude values. Therefore, for the remaining relationships the average altitude values will be calculated for each analogue value from each sensor, which will then be plotted to determine a true relationship.

2. Altitude vs IR radiation

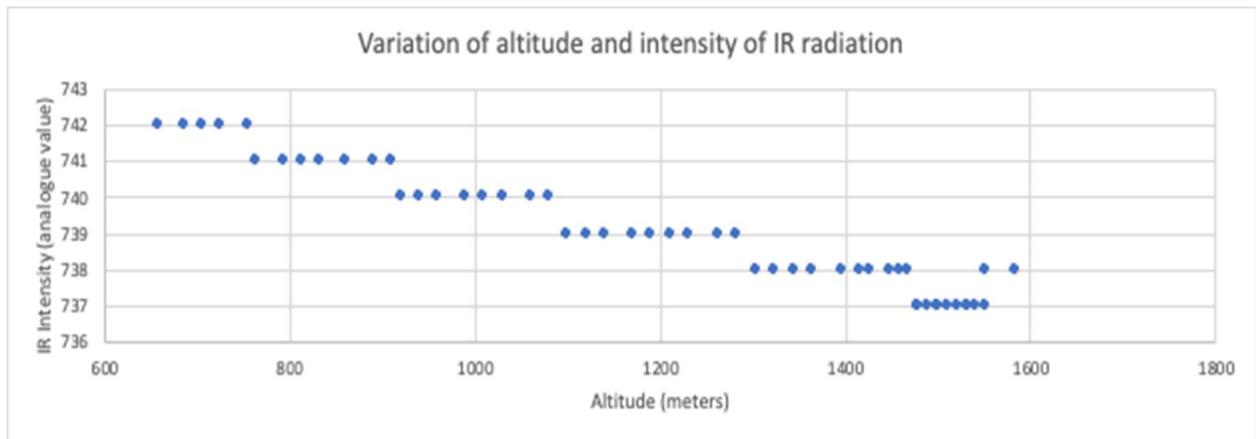


Figure 23 - Altitude against IR radiation intensity (unprocessed)

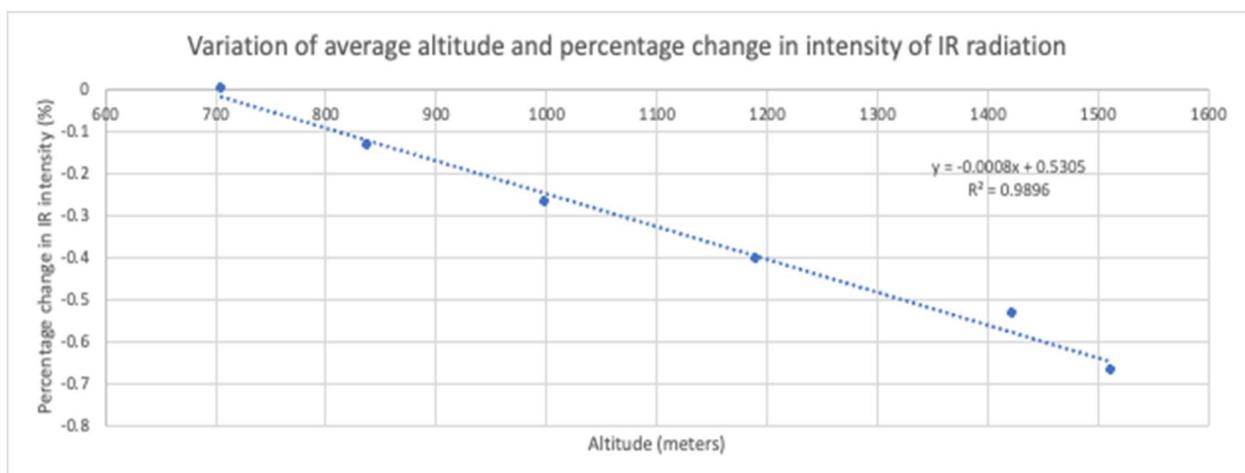


Figure 24 - Average altitude against percentage change in IR radiation intensity from ground (processed)

Figure 24 shows that a negative linear correlation with a strong correlation strength of 0.9896 exists between the average altitude and percentage change in IR intensity.



3. Altitude vs UV

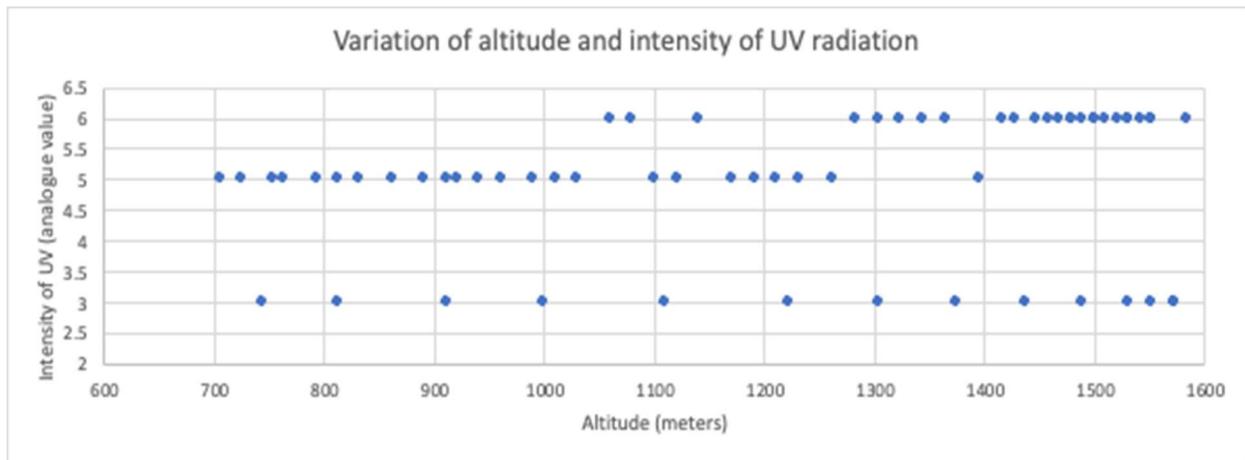


Figure 25 - Altitude against UV intensity (unprocessed)

From the above graph, it is evident that the data shows no correlation, as all three recorded UV analogue values (3, 5, and 6) range across most, if not all, of the altitude values. Further processing of the data was attempted, but no correlation appeared.

We believe that this because the UV radiation, which is of higher energy compared to IR radiation, was not able to penetrate through the plastic CanSat housing to be detected by the UV sensor. As a result, the UV sensor was not able to take an accurate recording of the variation of UV levels at different altitudes.

4. Altitude vs Ozone presence

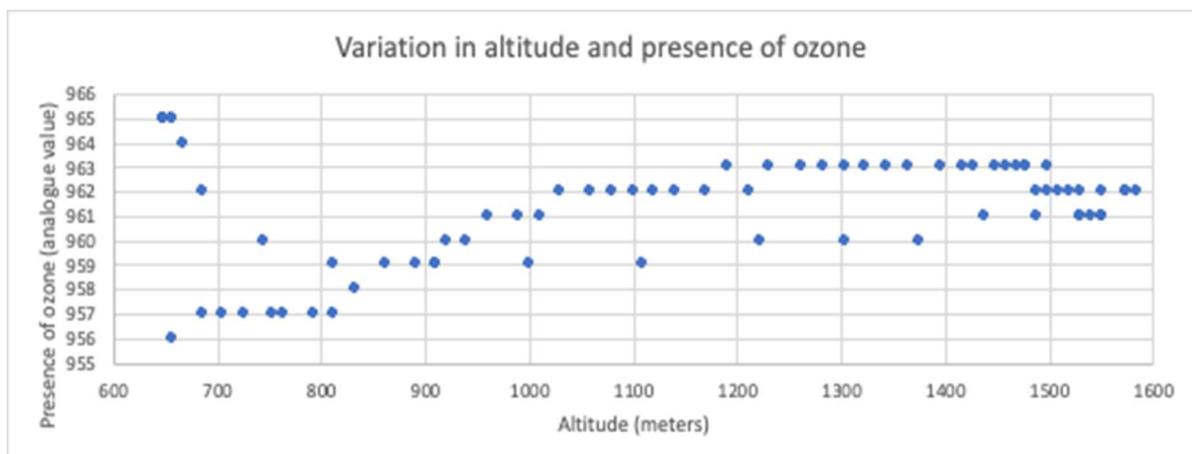


Figure 26 - Altitude against Ozone presence (unprocessed)

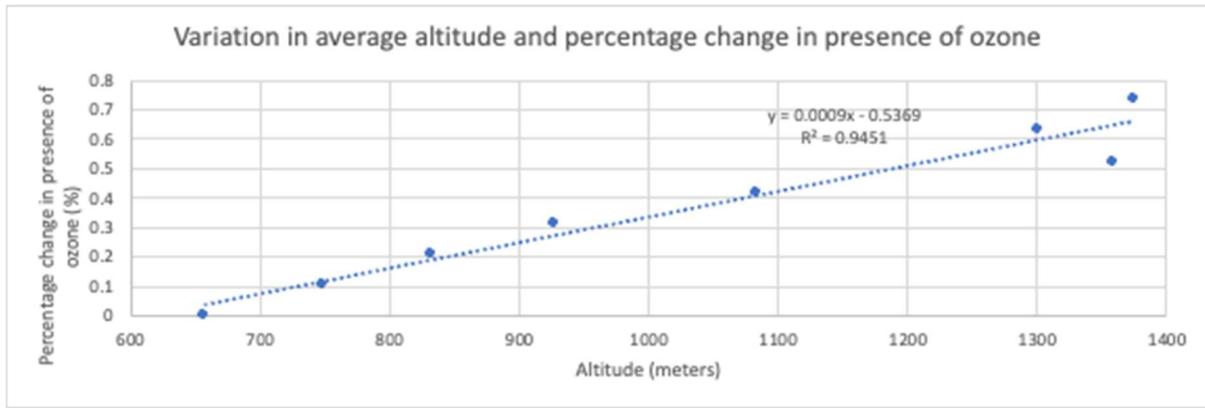


Figure 27 - Average altitude against percentage change in Ozone presence from ground (processed)

Figure 27 shows that a positive linear correlation with a fairly strong correlation strength of 0.9451 exists between the average altitude and percentage change in presence of Ozone.

5. Altitude vs Ozone presence

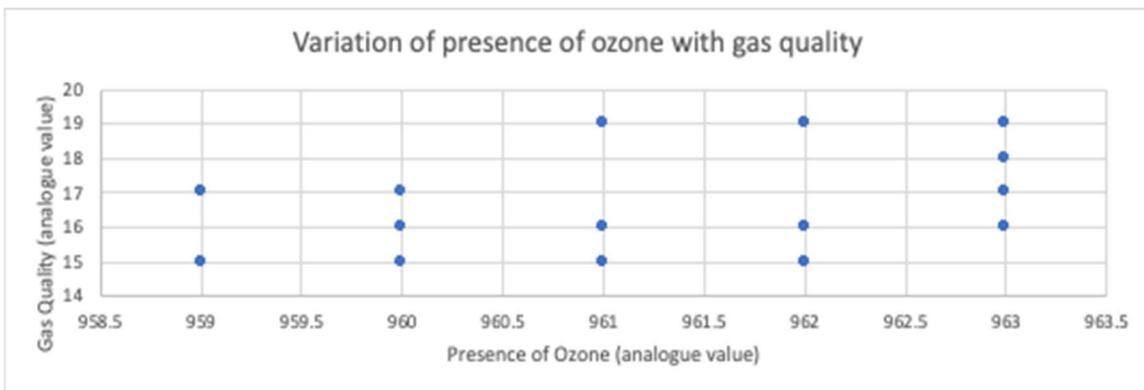


Figure 28 - Presence of Ozone against gas quality (unprocessed)

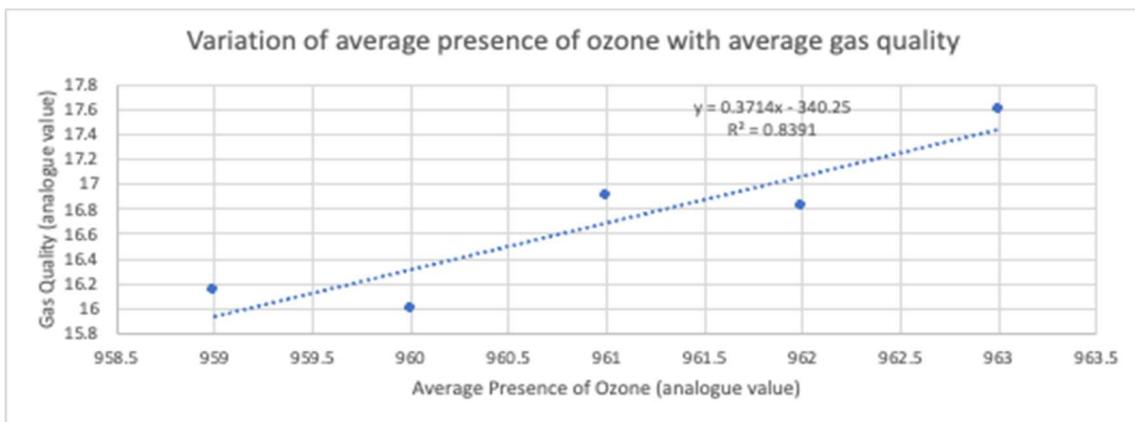


Figure 29 - Average presence of Ozone against gas quality (processed)



Figure 29 shows that a positive linear correlation with a correlation strength of 0.8391 exists between the average presence of Ozone and gas quality. This is a very important relationship that has been determined, as it: 1. Shows that the gasses that could cause ozone depletion are present in greater quantities where there is more ozone, and 2. More UV is present the greater the altitude, as UV radiation is required in the formation of Ozone in the first place, and yet can also cause the catalytic destruction of Ozone if too many Nitrogen and Carbon oxides are present.

5. Discussion

Overall we feel that our project was a success. Even though the results obtained from the thermistor and UV sensor ended up not being accurate, we were still able to find interesting trends from the data obtained by the other sensors.

Future improvements to the project could be to:

- Design the CanSat housing to allow outside air to flow into the CanSat more easily to take accurate measurements of temperature
- Position the UV sensor outside of the CanSat plastic housing to take accurate measurements of UV intensity
- Use a wider-range antenna to not rely solely on the data being saved to the microSD card

6. Conclusion

Our team's initial goal was to build a CanSat to gather information on air temperature and air pressure, as well as greenhouse gas concentrations and radiation presence during its time in the air, so that we can investigate Ozone depletion and climate change. After months of research, planning, preparation, building, and testing, our team has managed to build a CanSat with all the necessary sensor modules, have our CanSat launched to an altitude of nearly 1600 meters above sea level, and retrieve the collected data for data analysis successfully.

After having processed data for temperature, pressure, gas quality, IR and UV radiation, and Ozone presence, we have determined key patterns and relationships that provide further insight to the conditions of Earth's higher atmosphere. Specifically for our secondary mission, we determined that linear relationships exist between altitude and gas quality, IR radiation, and Ozone presence, as well as gas quality and Ozone presence.

From these relationships, we have determined that the higher atmosphere has a greater presence of Ozone, UV radiation, and Carbon and Nitrogen oxides, making the higher atmosphere ideal for the production, but also the depletion, of Ozone. Increased human activity and pollution is increasing the quantity of Carbon and Nitrogen oxides present in these Ozone- and UV-rich conditions,



resulting in the catalytic destruction of Ozone rather than the production of Ozone.

As Ozone plays an important role in shielding the Earth from harmful UV radiation and is a key component of Earth's atmosphere, we hope that the results of our project will contribute to the understanding of Earth's atmospheric conditions, the harmfulness of Carbon and Nitrogen oxide emissions from human activities, and the importance of Ozone in Earth's atmosphere.

References

Freescale Semiconductor. "Integrated Silicon Pressure Sensor Altimeter/Barometer Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated." Freescale Semiconductor, Aug. 2006, https://www.nxp.com/files-static/sensors/doc/data_sheet/MPX4115.pdf. Accessed on 14 February 2021.

"Atmospheric Pressure vs. Elevation above Sea Level." *Engineering ToolBox*, www.engineeringtoolbox.com/air-altitude-pressure-d_462.htm. Accessed on 14 February 2021.

Formula used to calculate the parachute. <http://www.rocketmime.com/rockets/descent.html> Accessed on 15 February 2021.

The references used for calculating the different mA values of the components. In most cases you can calculate the mA's using the power and Watts used:

- MQ131: https://www.allelectronics.com/mas_assets/media/allelectronics2018/spec/MQ-131.pdf
- MQ135: <https://pdf1.alldatasheet.com/datasheet-pdf/view/1132551/HANWEI/MQ-135.html>
- microSD card reader (similar model): <https://www.adafruit.com/product/254#description>
- Tecnoiot MLX90614ESF: <https://www.generationrobots.com/fr/402119-capteur-de-temperature-infrarouge.html>



Appendix - Design Requirements

Requirement	Fulfillment of Requirement
1. Size of the CanSat	Our CanSat fit into the rocket. ✓
2. Weight of the CanSat	350 grams. ✓
3. Explosive/flammable material	We didn't use any. ✓
4. Power/Battery	We used a 9V battery although we estimated we would only be able to power our CanSat for an hour. Around 542mA with the Arduino.
5. Switch	Our switch was located inside the CanSat as was our battery. ✓
6. Parachute	We used bright red Ripstop tissue. ✓
7. Attachment	The parachute is attached via multiple points. ✓
8. Descent	8 m/s ✓
10. Acceleration	Our electronics are all soldered together, and the battery is fitted into place. ✓
11. Duration of the flight	We did not exceed the time. ✓
12. Budget	Our total budget was 140,86€. ✓
13. Sponsor	We did not have any sponsors. ✓
14. Temperature measure	The CanSat measured the temperature and air pressure. ✓
15. Frequency	We respected our assigned frequency. ✓