CANSAT

Team Air Thief

Created by **Air Thief Team**

Consisting of **Maria Matuszewska, Aleksy Chwedczuk, Henryk Nowacki, Tymon Augustyniak, Mateusz Mazurczak**

Supervised by **Dr. Jakub Bochiński**

Created by Air Thief Team
Consisting of Maria Matuszewska, Aleksy Chwedczuk, Henryk Nowacki, Tymon Augustyniak, Mateusz Mazurczak
Supervised by Dr. Jakub Bochiński

Preliminary Design Review

Abstract

The project consists of a primary and a secondary mission.

The primary mission consists of measuring the temperature and pressure throughout the whole flight of the satellite. The CanSat will therefore include an additional sensor specified to take those measurements.

The data obtained should be sent to the ground station every second to allow the team to analyze the information given and plot graphs that should facilitate the execution and organization of the secondary mission. It is important to notice that measuring both temperature and pressure, will allow us to identify the position of our satellite, as these two factors can be modelled to provide the height at which the system is placed at some point in the given time.

The secondary mission is designed to investigate the presence of viruses, additionally bacteria, at a designated height above sea level. To pursue this experiment the satellite will be equipped with three filters, enclosed in a sterile chamber, allowing the separation of the desired sample from any other contaminants and microorganisms.

The air will be pushed through the sterile chamber described above with the use of a pump to increase the possibility of collecting the samples only at the desired height. The aim of the secondary mission is also to measure the humidity at a certain height above sea level. This will be done using the same sensor as the one used in the primary mission. It is crucial to know the level of humidity to adjust for the filter air flow capacity.

Why is our mission worth pursuing?

Our idea appeared as an answer to the recently published studies of the possibility of microbes being present in the atmospheres of Mars[1] and Venus[2]. We would like to propose a new method of exploration of extraterrestrial life: an atmospheric sample return mission. This mission, as a technology demonstrator, would test the viability of our new versatile method that could be easily adapted to numerous conditions present on multiple celestial bodies throughout the Solar System.

Additionally, the results of our experiment, apart from promoting the idea that life is possible on other planets than Earth, could help understand better the life cycle of bacteria and viruses also here on Earth. Painting a big picture of growth and needs of simple microbiological organisms could help us understand how to fight the harmful ones and how to effectively make use of the neutral or beneficial organisms.

Atmospheric sample studies of viruses[3] are also a quickly growing field of microbiology and similar studies to our knowledge have not been performed in Poland so far, giving us a unique chance to contribute to the body of science.

What is most exciting about our mission is the fact that collecting samples exhibits so much about the unknown, about the area that has not been studied much in the past. It is all doable and extremely exciting, and while it will be a considerable challenge, this is what fuels our love and admiration for learning. Through this expedition we want to clearly state that no matter the conditions you are working in (like the pandemic we are currently in) there is always the possibility to contribute positively to the world.

Introduction

Team Organization and roles

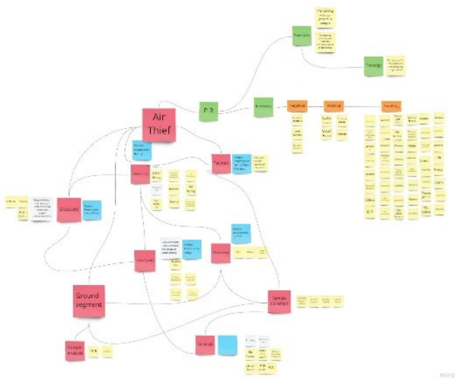
The Air Thief team is supervised by Dr Jakub Bochiński – an excellent astronomer, designer, and a constructor of robotic telescopes. Each of our team members dedicates at least 4 hours weekly for the project during our planned meetings. Apart from that all the members work on their own around 4 hours in a week not including lessons like physics, mathematics or programming that are helpful when designing a CanSat.

[1] Article presenting Evidence that liquid water flows on Mars.
[2] Research paper about phosphine gas in the cloud decks of Venus.
[3] Research paper detailing methods for sampling airborne viruses.

Air Thief consists of 5 members apart from our supervisor:

- The Team Leader and main mechanic is Aleksy Chwedczuk. For his final exams he takes physics, mathematics, and further mathematics. He is a pro designer and telescope constructor[4]. He, as well as the whole team, is mesmerized by the night sky.
- Air Thief's Sales Representative is Tymon Augustyniak. For his final exams he chose physics, economics, mathematics, and further mathematics. He is an excellent writer and is amazed by the world's unknowns. He designs and builds his own computers. His passion for drawing and sketching is extremely helpful for the project.
- Our electrician is Henryk Nowacki. For his A-levels he is taking physics, mathematics, and geography. His understanding of various, complex electrical systems designing is outstanding. He is also interested in building and prototyping planes and gliders.
- The team's programmer is Mateusz Mazurczak. He studies biology, chemistry, mathematics, and further mathematics. Apart from programming he is fascinated by viruses which is quite helpful in carrying out the mission.
- The team's Marketing Representative is Maria Matuszewska. She studies biology, chemistry, mathematics, and physics. She is also deeply passionate about astronomy and spaceflights.

Most of our work revolves around communication through social media. We often arrange specific times and dates to check if the person who is needed for the job is available, as we all have very tight schedules. Aleksy, the Team Leader, often arranges meetings in between members and sets them tasks and deadlines that fit their specializations and deadlines. Members then call each other and collaborate with each other to complete bits and pieces of said work, which is then put together by Aleksy. As a team, we prepared a 4h time slot for project-oriented activities on Saturdays from 10am to 2pm. Even though, during this time we handle most collective work, we also designated a period during the work week (Monday-Friday) where we conclude and check each other's progress. This additional period focused on running check-ups is crucial, since we all individually work on tasks throughout the week.



For better effectiveness of the work schedule, the team was divided into smaller sub-teams that are responsible for specific tasks such as electronics, 3D-modelling, marketing, software and design group that are all supervised by the Team Leader. In addition to that, a lot of the planning of our mission occurs on the Miro app, where we implement most of our ideas and divide work between each other. We decided to take inspiration from ECSS set of standards for space project management (i.e. ECSS-M-ST-10C) to have a firmer grasp of what we want to achieve in our mission, and how we want to accomplish it. The use of the ECSS standards (e.g. product tree, WBS, etc.) is essential, because thanks to its established norms it makes our project clear and available for future development.

Mission Objectives

Our mission consists of two major steps: the first one is imposed by the Competition. This mission consists of measuring air pressure and air temperature over the length of the whole flight. Our team will additionally challenge itself with measuring air humidity at an altitude of about 1-2km above the ground. The CanSat will be programmed specifically to measure the desired variables every second to leave the team with as much data as possible.

The parameters acquired should be transmitted as telemetry to the ground station to be further analyzed.[5] Graphs that would be useful in investigating the secondary mission's outcomes should be plotted. The secondary mission is our team's original idea; this is the notion of collecting an air sample from the designated altitude to then later measure and detect the number of viruses present in our sample.

The CanSat will consist of the main part, similar in all satellites, and an additional sterile chamber equipped with 2 filters that are specially designed to separate viruses from any other contaminants and microorganisms.[6] Additionally, our satellite will be equipped with a hygrometer – the level of humidity is extremely important regarding our filtration mechanism. The permeability of the filters is strongly dependent on the humidity. The amount of water molecules present can close the pores of the filters affecting the amount of data collected. We will therefore have to conduct a test to calculate the impact a certain level of humidity would have on the permeability of the filters.

---

[4] Website presenting a DIY telescope created by Aleksy Chwedczuk
[5] Tests concerning the final on-ground analysis will be performed using the same collected data separated into equal parts.
[6] Bacteria viability protocols and test kits

To analyze the collected data, we will be using flow cytometry[7]. The equipment needed to conduct this analysis will be provided to us by Adamed[8]. Prior to running this investigation, we will prepare our data accordingly to generally accepted protocols. Our team has contacted dr. Rafał Mostowy from Microbial Genomics Group and mgr. Edyta Żyła from the Jagiellonian University of Kraków – Faculty of biochemistry, biophysics, and biotechnology, and has gotten an official approval of the methods[9] of analysis used in our project.

The crucial part of our secondary mission is to perform numerous tests prior to launching the satellite. The team will have to perform at least one positive, one negative, and one control test of the filtration mechanism and the sample collection system. The positive control of the sample analysis will be performed to show the results that we should be expecting during the final analysis. This test should also be done to investigate the sterility of our sample collection system and the level of contaminants found within the chamber or test tubes. The negative control is to calibrate the cytometer and to analyze the cellular autofluorescence.

Lastly, the control test will be performed using agar plates or any other method to analyze the viability of bacteria, collected using the F9 filter, which could be possible hosts for viruses. If the bacteria show even the slightest sign of viability, we could include them in our further flow cytometry analysis. Furthermore, during our control test we should investigate the presence of duplexes which could affect the results.

An additional step will be required whilst investigating the samples – it is to use a fluorescence label specific for viruses and bacteria. Prepared samples should be assembled in a test tube with both virus and bacteria specific dye to eliminate any errors that could occur due to unsterile handling of data. Each dye will re-emit light upon light excitation resulting in diverse colors, thus making the obtained results easier to read.

We estimate that the results will be ready within 10 hours from the beginning of the experiment.

Basic system objective:

Element	Requirement	Mission type
Temperature sensor	Measuring temperature	Primary
GPS	Finding and relaying the coordinates of the satellite to the ground station	Primary and Secondary
Temperature-regulating system	Regulating the temperature to eliminate any errors in the temperature measurement	Primary and Secondary
Pressure sensor	Measuring pressure	Primary
Hygrometer	Measuring the humidity during the whole flight	Primary
Air filters	Separating viruses from bacteria and contaminants	Secondary
Electronics	-	Primary and Secondary
Air pump	Pumping large amounts of air into the sterile chamber equipped with two filters	Secondary
Software	Programmed to take the primary measurements every 1 s Programmed to start filtering the air at release of the satellite and closing the system after 25% of the altitude magnitude covered by the satellite during the fall. Sharing the collected information.	Primary and secondary
YAGI Receiving antenna	Will enable receiving sent from the CanSat with important data from the sensors and the location from GPS	Primary and secondary
Beeper	Will transmit loud 80dB beeps to help find it.	Primary and secondary
Ground station	Receiving the collected information, plotting graphs	Primary and secondary

Primary mission: When will the launch be considered successful?

- The collected data parameters should be transmitted to the ground station at least every second.
- We should collect enough data to plot a graph.

Secondary mission: When will the launch be considered successful?

- The system should pump not less than 0.5 liters of air
- We should be able to collect any number of viruses considering the permeability of the filters
- The temperature-regulating system should start cooling the satellite as soon as the temperature exceeds 20°C

[7] Flow Cytometry protocols, Direct flow cytometry protocol, Cell surface staining, Filtering protocol
[8] Letter of Intent from Adamed
[9] Letter of Intent from a representative of Jagielloński University, mgr. Edyta Żyła

- The CanSat's temperature-regulating system should maintain a stable temperature between 14-23 °C
- The pumping system should stop working before reaching one kilometer above Earth
- The chamber should be tightly sealed
- The parachute should provide a safe landing so that the chamber does not burst when hitting the ground
- Ground part: We should prepare the data prior to flow cytometry analysis
- Ground part: We should be able to successfully perform the cytometric analysis

Expected results:

- The primary mission's data transmission will be successful – we will receive data every second
- The temperature-regulating system will maintain a stable temperature in the range of about 14-23°C
- The parachute will promote a safe landing in alliance of a material capable of absorbing impacts

How will our secondary mission contribute?

Exploring the uncharted field might promote further investigations regarding extraterrestrial life similarly to the previous research on Venus and Mars. Our mission is intended to be a technology demonstrator for future space missions. Recently, scientists were able to prove that in Venus' atmosphere a chemical – Phosphine – was present[10]. What is interesting about that is the fact that this chemical's source can only be explained by alive organisms present in this planet's thick atmosphere. Scientists consider microbes as a possible factor causing the presence of phosphine. To date, research conducted on this matter was only thanks to the use of telescopes, however it is already said that future space missions will be conducted to scrutinize this subject more. Our mission would fall perfectly as an example of such a mission since we are analyzing microbes in the atmosphere as well. Some variables would have to be adjusted; however, this represents a possible solution for tests that will be conducted in Venus' atmosphere soon. Our project presents a new method of exploration of extraterrestrial life that could be easily adapted in the search for other variables in the atmosphere of a planet. We hope that our satellite will create a new trend in the scientific world and will be further continued by others.

Examining viruses at a certain height that can live without a contiguous, natural host might promote a more in-depth research regarding the growth and life of viruses. There is recent research (Reche et al. 2018) presenting concrete evidence for the existence of a vibrant and plentiful viral community present at high altitudes, above the mountains of Sierra Nevada, Spain, at an altitude higher than the atmospheric boundary layer. Similar research has not yet been performed above the territory of Poland, but it is likely that viruses would be detected – we have contacted a polish microbiologist and bioinformatician Dr. Rafał Mostowy and he believes that this proposed research is plausible and would hold value for the scientific community. It is a rather complex design and collaborating with companies is undeniable resulting in more future-related experience for the Air Thief's members.

CanSat description

Mission overview

We are planning on designing and building a CanSat satellite that will be later launched 2km above the ground or dropped from around 500m by a drone that is able to carry up to 10 satellites. The CanSat will descend at a speed of around 7m/s. We will be using a parachute to slow down the fall of our CanSat to prevent it from falling out of the competition's set boundary. To accomplish the primary mission, we will be using a pressure and temperature sensor to measure the temperature and pressure at this altitude.

Our secondary mission's main goal is to collect, filter through, and then determine if viruses are present in our sample. To do this, we will use an air pump to collect an air sample during the flight of the satellite. This air will then be pumped into a sterile container, which will be filtered through three air filters so that we can separate the viruses from other unwanted particles such as bacteria and dust. Although hard, we are developing and designing techniques which would allow us to get the sample completely sterile. After we retrieve the satellite, we are planning on detecting the viruses using flow cytometry. We also considered using the PCR method and the use of a fluorescent microscope, however, this proved insufficient and too costly, as our goal is to prove that viruses are present in our sample, not identify them.

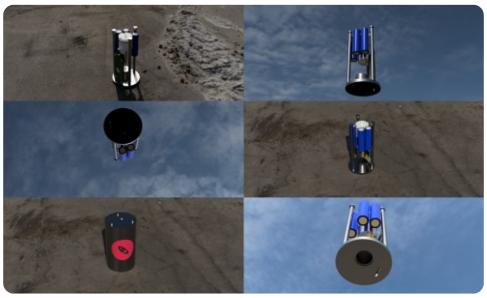
We also made sure that the mission concept is compatible both with Polish and European CanSat competition guidelines. As this year the European final will take place without student on site, and SD cards with recorded data will be mailed back, we reached out to ESA to verify if the same could be done with a sterile sample container we plan to include in our mission. The reply was positive[11] and a special exception will be made for us, if we get to the finals, due to great scientific merit of the proposed mission.

---

[10] Research Paper about Phosphine in the cloud decks of Venus.
[11] Screenshot of mail from ESA.

Mechanical & structural design

Our main core of the satellite will be designed using AutoCAD software – Fusion 360. This program will allow us to create a precise 3D-model that will fit all components in the most efficient way regarding the space covered. We decided to collaborate with Cubic Inch[12] to use their expertise and technologically advanced tools to print our main core of the satellite. This company uses the Multi Jet Fusion technology provided by HP.



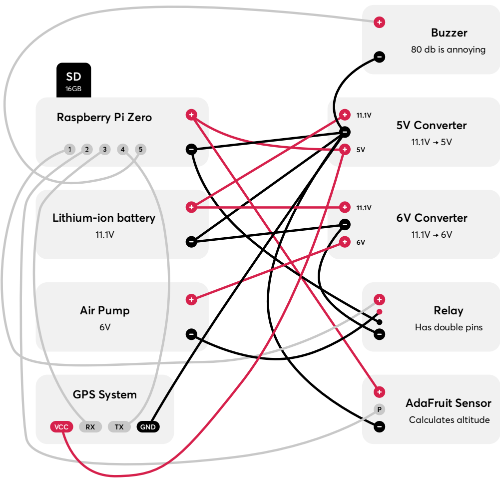
This is crucial for our project because this technology allows the printer to create solid parts that are very precise in shape up to 0.3mm. The materials used by such a printer is the Polyamide PA12 which is a strong and durable material, therefore our satellite and its components will be protected in the case of hitting the ground during the fall. The use of this collaboration can be explained as well by stating that its work surface is 380x280x380mm, which enables us to print our model without the need of attaching additional parts to it via other materials. Cubic Inch agreed to support us in this project by sharing their knowledge with us and they vouched that our project and all prototypes will be printed at their cost.

More detailed renders can be found by clicking on the preview above. This is a mockup 3D model to show that all components fit into the structure. Please note that the system of sample collection is connected to the pump via a pipe – not visible on renders. Additionally, the mechanism will consist of a set of F9 and HEPA filters.

Electrical design

General Architecture

Our CanSat is made up of a couple specific components, each has its one role in the mission. The main controller board is the brain of the operation; it will be used for measuring the primary and controlling the secondary mission. The core of our primary mission will be an ADAFRUIT temperature and pressure sensor, which will record the data every second to give us an accurate depiction of the attitude that the CanSat is at. The core of our secondary mission will be the NW Air Pump which will be used to push air from a high altitude through a filter. To power the NW Air Pump with 6V and 400 mA current a step down converter (D24V5F6) will be used to change the battery voltage of 11.1 V, also a second step down converter (D24V10F5) will be used to power the main controller with 5V and 700 mA. To power the CanSat a lithium-ion 750 mAh 3x battery will be used and the voltage will be stepped down for the other components. To turn on the pump a relay will be used for safety in case of a short in the motor the motherboard will not be damaged. It is very important for our secondary mission that the CanSat will be found due to the physical sample that we need to analyze in a lab, therefore a GPS module will be used to determine the coordinates of the CanSat and these will be sent to the ground station. To help with finding the CanSat after landing an 80dB buzzer will be used, if the CanSat is hard to find visibly it can be also found using sound.



[12] Letter of Intent from Cubic Inch.

Primary mission devices

The primary mission is a part of the criteria that is obligatory for each CanSat; this is the task of recording pressure and temperature. We will be using an Adafruit pressure and temperature sensor to measure the parameters with a set interval of one second, and the measurement will be taken by a Raspberry PI Zero micro controller. The data will be transmitted through a radio connection made between the CanSat and a ground station. It is important to realize that the sensor needs to be placed in the correct spot for the pressure and temperature measurements to be correct, due to the heat emission from the electronics it needs to be isolated and a certain amount of air flow needs to be available for the sensor to reliably measure the temperature across the altitude. Therefore, the sensor needs to have line of sight out of the CanSat and have separation between the other electronics for example Styrofoam which is a great insulator.

Secondary mission devices

The secondary mission will be conducted using almost all electrical components. The electric air pump is connected to a power converter (thru a relay) that drops the voltage from 11.1V to 6V due to the requirements of the motor, the Raspberry Pi Zero controls the air pump by the use of a relay that will protect the motherboard in case of a short in the motor, the relay has a 12 A max current therefore the over current regulation of the power converter should shut down the motor.

The main controller will be powered by a converter that steps down the voltage from 11.1V to 5V due to the Raspberry PI Zero requirements, this stepped down voltage will also be used for the AdaFruit sensor that will measure the height at which the CanSat at the moment in time, this will be used to turn off the air pump at a certain height.

There are no real parameters or measurements made by the electronics; the focus of the secondary mission will be to collect a sample of the cloud Virome and bring it to the ground for testing.

Power supply

The power supply will be constructed of 3 lithium-ion batteries in series to step up the voltage to 11.1V and a total capacity of 2250mAh. Each of the batteries will have a voltage of 3.7V and a capacity of 750 mAh. From the calculations given the lifespan of our can sat would reach almost 10 hours, this comes to show that it can withstand the long waiting time for launch and the recovery of the satellite.

Secondary mission power consumption:

$$Ah = h \times A$$

$$u = 0.017h \times 1.32A$$

$$u = 0.02\ Ah$$

Consumption while in standby for launch:

$$Ah \div A = h$$

$$2.141\ Ah \div 0.215 = 9.96\ h$$

Consumption during recovery:

$$Ah \div A = h$$

$$(2.25 - (0.02 + 0.089)) \div 0.215 = 9.96\ h$$

Consumption during flight:

$$Ah = h \times A$$

$$u = 0.089h \times 0.92A$$

$$u = 0.082\ Ah$$

Power consumption budget:

Component	Consumption during secondary mission ~60 sec	Consumption During flight ~5 min 21 sec	Consumption during recovery of the satellite u > 6h	Consumptions while in standby for launch
Raspberry PI	700 mA	700 mA	80mA	80mA
Air pump	400 mA	0	0	0
Converter 1	40 mA	0	0	0
Converter 2	40 mA	40 mA	40 mA	40 mA
AdaFruit	No data	No data	No data	No data
Relay	0	No data	0	0
Radio	130 mA	130 mA	95 mA	95 mA
GPS	50 mA	50 mA	0	0
Total	1.320A	920 mA	215 mA	215 mA
Total	0.02Ah	0.082 Ah	2.141 Ah	2.141 Ah
Work Duration	1 min	5 min 21 sec	9.96 h	

Communication system

The communication between the CanSat and the ground station will be one directional (ground station as a receiving factor), as there is no need to communicate with the CanSat. It will be programmed to send its location, as well as notify us if everything regarding the secondary mission went according to plan.

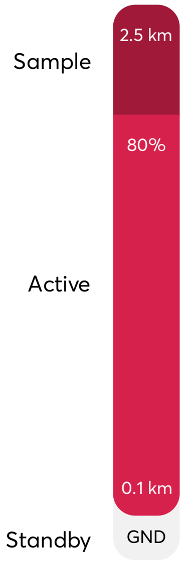
For this purpose, a monopole antenna will be mounted on the CanSat with a length of 18 cm to send radio signals with its location and primary mission data. The ground station will be using a Crossed YAGI antenna to receive the signal and save it on the computer. The receiver and transmitter that we will be using are the **RMF95**. The proper antennas that we will use were picked with the help from the company Thorium Space represented by: Seweryn Ścibior, Przemysław Radzik and Marcin Niewiarowski[13]. Furthermore, the people who we cooperated with helped us with calculations of the distance that the receiver can reach. An online site called the link budget calculator was used to calculate the distance that the satellite can send data to the ground station. The parameters required for this operation are the distance, the frequency, the gain of the transmitting antenna and the gain of the receiving antenna. The minimal height that the CanSat can communicate with the ground station is directly dependent with the line of sight. If there are no obstructions in the line of sight, the range is good up to 15 km.

Software design

The primary onboard computing unit for our CanSat is a Raspberry PI Zero that supports Python. It is going to run all the programs necessary for the functioning of the CanSat and all onboard equipment and experiments.

The flight plan for individual atmospheric Virome soundings can be fine-tuned, which is helpful. The data will be recorded to a micro SD card, which will probably have such high storage capacity that it will be virtually infinite for our purposes (16 GB, around 30 zloty).

The program is going to have 3 main modes, controlled based on the current altitude measured by the temperature-pressure sensor. This is going to ensure the correct data is always transmitted and minimum power is consumed. If the AdaFruit sensor detects an anomalous result, the mode will have a 3 second switch cooldown so that it is not turned on preemptively. Our reasoning is that since the primary mission is so important, relying on it for data is quite sensible.



Flight States

Example flight states & vertical AGL.

Standby – When the satellite is waiting on the launchpad and when it has landed post-experiment are similar flight conditions and require a similar approach. Thus, Standby mode is active when the CanSat elevation reported via the AdaFruit array is less than 100 meters AGL. During this mode, the CanSat is only running the first experiment, sampling the ambient temperature and pressure, and computing the altitude at regular 10 second intervals, ready to switch into active state when the altitude goes beyond 100 meters. (It is possible the GPS sporadically turns on to self-validate the readings of the AdaFruit.)

Active – When the satellite is in flight, above 100 meters AGL, it constantly calculates its position and AGL via the GPS and AdaFruit sensors. These parameters are then transmitted to the ground station, so that a flight profile can be determined. If the altitude were to increase or decrease, Sampling or Standby modes would be engaged, respectively. (Additionally, during this time, the hygrometer reading is performed sporadically.)

Sampling – The pump powering the secondary experiment is enabled. It runs constantly until either the total runtime requirement is satisfied (so as not to overshoot) or until the CanSat goes below 80% of the mission altitude (2 km for a 2.5 km mission, for instance, this is configured pre-launch). That way the sample is collected from the correct experimental band that was being sampled (for instance one that has a height of 0.5 km). During Sampling, the Active activities are also conducted. Additional hygrometer readings are performed to determine the validity of our research (sample viability). If the sampling altitude is passed and the CanSat begins heading down again, Active, and then finally Standby modes are engaged.

The data recorded via the SD card, and the outgoing transmissions sent out via radio will have a specific format that will minimize their size, enabling higher efficiency. The ground station program is coded in JS for the frontend, and in Python3 for the backend.

Recovery system

The recovery system that will be used for the CanSat is a simple parachute like the one in the demo CanSat. It will have a hole in the middle of it to help with stabilization issues. The speed of the fall in our case is crucial due to the sample we are collecting in the clouds. It needs to be slow enough so that the CanSat has time to collect the sample, and fast enough so it does not fall too far from the launch site due to the increasing risk of not being able to find it. From our calculations, we are estimating that the speed will be around 7m/s.

[13] Letter of Intent from Thorium

The parachute is still in the design phase – the material used for the parachute needs to be strong and light so something like a Kevlar would be a good choice, or a strong fabric.

The suspension lines that will be connected to the parachute will need to have a length of more than 18 cm to be able to connect the monopole antenna to them. The hole in the top of the parachute can and will be calculated with a program, same goes for the area of the parachute.

The size of the parachute was calculated with the maximum weight and a falling speed of 7 $m \times s^{-1}$ which gives us 1729 cm^2, which was calculated using the formula:

$$s = (2 \times m \times g) \div (v^2 \times c \times d)$$

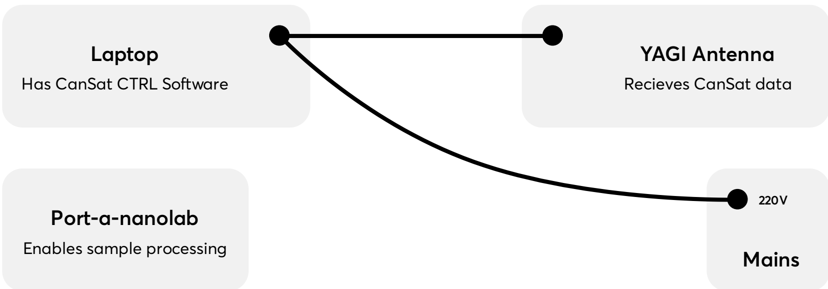
Furthermore, another part of the recovery system is the audio and radio signals sent out by our CanSat after landing on the ground; it is important to note that the monopole antenna will be unable to send a signal if it lands in a certain position, therefore the most recent GPS coordinates sent by the satellite during the fall will be relied on for finding it.

Also, the CanSat will beep at a constant rate with a sound about 80 dB, which can be heard for around 50 m if there are no obstructions. This sound will be produced by a beeper. Moreover, the CanSat cover and parachute will be painted in a bright color, such as red, to help with finding the satellite.

For now, we are thinking about using the **Rocket-model Klima GmbH** 55 cm, as it fits our requirements for a light parachute. It has an area of about 2376 cm^2. To compensate for the area as well as a lack of a hole, we will cut out a hole in the middle of our parachute.

Ground support Equipment

The POCU handles only basic data processing, handling & categorizing. Additionally, there is more data sent out via Radio than is saved to the SD card (since the ICAR pings and other health information are only saved on the ground station).



The ground station is composed of these important things:

- Laptop running the backend and frontend for the communication with the satellite. The frontend handles the display of data on screen and the issuing of commands to the CanSat, and the backend communicates directly and writes to files, etc. The frontend is written in JS. The backend works in Python3.
- A YAGI directional antenna that will send and receive data from the CanSat. It is connected to the Laptop.
- A power supply for the laptop and the antenna. This is a backup, as there is most likely mains power *in situ* at the launch site.
- A port-a-nanolab with materials applicable for the final selected procedure, that is Flow Cytometry:
    1. Lab safety equipment (coat, glasses, gloves)
    2. Portable flow virocytometer from Adamed[14]
    3. Cytometry prep kit
- Alternative support equipment that we considered to conduct the analysis of the viruses (provided by Adamed) that might be used as a backup form of conducting the analysis:
    1. PCR ThermoCycler with master mix, primers, etc. for Virus DNA amplification
    2. Electrophoresis equipment for DNA electrophoresis post-PCR
    3. SYBR Green Dye dispenser, plus other dyes and chemicals needed for the procedure
    4. Viral genome extraction equipment
    5. UV-Vis spectrophotometer for virus quantification
    6. Lab-grade Fluorescent Microscope
    7. Accurate scale and other basic measurement equipment

[14] Letter of Intent from Adamed

Test campaign

Primary mission tests

We will take a measurement of the temperature and pressure on the ground using our apparatus, as well as a thermometer and barometer. We will be regulating the temperature and pressure in controlled conditions and observing the differences in our results. If any consistent uncertainties arise, we will have to look for the errors causing them and potentially adjust our apparatus. For example, we will decrease the temperature of the room using AC until the thermometer shows 1℃ change and compare the results from our apparatus. We will do the same by increasing the room temperature to 1℃ and check our sensor's results. We will do the same for pressure, inserting our sensor into an environment where we are able to control pressure. We will create positive pressure in the environment to +1kPa and compare the results of the barometer with our sensor's. The same will be done with negative pressure. If our measurements correspond with each other, we take our testing to the next step, which will be flying our apparatus 1km above the ground with the use of a drone. This data will be transmitted through a radio signal coming from a transmitter to the ground, which will allow us to view it in real-time. If our results are adequate, we will proceed to use this method. We would be able to calculate the approximate temperature and pressure at our designated altitude by using the functions:

$$T = T_a - 0.0065 \times (h - h_a)$$

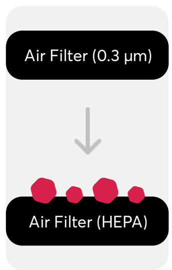
where T is temperature, T_a is temperature at base altitude, h is height, h_a is height at base altitude,

$$P = P_0 \times (1 - (0.0065h / (T + 0.0065h + 273.15)) \times 5.257$$

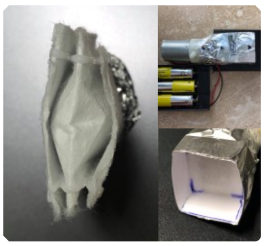
where P is pressure and P_0 is pressure at base altitude.

Secondary mission tests

The secondary mission for our CanSat is the collection of airborne viral biomaterial from an altitude of 1 km above ground. This will be done using a system composed of two filters, one to capture the viruses and another to prevent contamination by larger molecules containing genetic material and unnecessary contaminants. Air will be forced through the filters by a vacuum pump. This system is being tested by simply creating a prototype device and running it for a long duration at ground level. Currently we have created a simple prototype of the device using F9 and HEPA12 grade filters, printing paper, strong plumbing tape and aluminum foil wrap on the outside to prevent early contamination. The pump used in our prototype is weaker than the one we are planning on using; however, it is still capable of forcing the air through the system without any problems. We believe this device to be functional so far based on this prototyping. Additionally, eventually, the material captured on the HEPA filter will be analyzed by us, using laboratory equipment from Adamed[15]. We will do this by using a flow virocytometer that is able to detect individual viral particles in the solution. By running this experiment we can fine-tune our procedure, however we assume that the bottom air filter will succeed in capturing enough viral material (Reche et al. 2018). If due to Covid-19 restrictions this turns out to be impossible, the upper air filter will at least be checked for the presence of bacteria and other microorganisms by using a standard optical microscope (which we have at home), and possibly also on an agar plate. Alternatively, virus presence can be determined by using a plaque assay.



Sampling Device
Airflow causes virus collection on lower filter



Tests of recovery system

Testing of our recovery system will be conducted throughout two different experiments. The first one will be throwing our CanSat from our school building to calculate the speed of the falling satellite. A second test will be conducted with a drone, to test the reliability of the parachute from a higher altitude, as well as to test different techniques of how to fold the parachute in case it will be thrown out of the drone. Furthermore the GPS and antenna will be range tested with the use of the drone – it will fly at set distances and heights and the data will be transmitted between the ground station and the satellite in real-time to ensure the reliability of the satellite. Also, it is important to note that the recovery system needs to be able to withstand the acceleration created by the rocket during the propulsion stage. This is hard to test in real life, as the acceleration created by such a rocket can be over 6G, which is very hard to recreate, therefore the best way to do it is to use a design software that has an option of stress test of parts. This still would not be entirely accurate; however, it would give us an idea of how strong we should make it.

---

[15] Letter of Intent from Adamed

Communication system range tests

The communication system range test will also be conducted with the use of a drone. We will test the range at different heights and distances – the CanSat satellite will be suspended using a string from the drone to decrease the electrical interference from the motors. We will then use the drone to fly to different distances at different heights, also the test will be conducted in harsh conditions in dense forest to simulate the situation at the test site. This will help us determine if we should increase the range, so that we can increase the probability of finding the CanSat. It is especially important to find it due to the sample on board that needs to be recovered and tested in the lab.

Energy budget tests

The energy budget test has not been conducted yet due to the lack of components that will be used in the CanSat. Furthermore, the test is crucial to ensure that the predicted battery life time is true; this will ensure that the CanSat can send radio and sound signals for multiple hours after landing to ensure that it is found and the sample taken is retrieved. We are also going to test the temperature of the CanSat in different temperatures to ensure that it will not overheat. The calculation for time the CanSat can withstand with the current battery capacity is almost 10 h, so in this case it fully satisfies the 6 h requirement of the regulations.

Project planning

Task	Due Date
Filters ground pre-test	20-21.10.2020
Filters final ground test	12.2020
Finish Preliminary Research Paper	Beginning of January 2021
Finishing touches to final research paper	Near FDR
Creating Social Media	18.10.2020
PDR pre-design	18.10.2020
Dividing Writing Tasks Regarding PDR	17.10.2020
Verifying PDR elements	21.10.2020
Reaching out to companies	
Presenting the project to possible investors	soon
Buying and gathering products	As fast as possible
Meeting with Thorium	16:00-18:00 22.10.2020
Establishing communication	25.10.2020
PDR submitting	27.10.2020
Prototyping the Satellite	10/11.2020
Designing the satellite in CAD	10/11.2020
Finishing touches to final (CDR) satellite structure design	Mid 11.2020
CDR dividing writing tasks	19.11.2020
CDR pre-design	20.11.2020
Satellite structure check up	End of 11.2020
Start of building the satellite	End of 12.2020
Finishing touches to satellite	10.02.2021
Testing the collection method from the chamber	Mid-February
Final Communication System Test	Mid-February
Final Satellite Structure test	Mid-February
Final Ground Segment Test	Mid-February
Final Communication System Test	Mid-February
Verifying CDR elements	07.01.2021
CDR submitting	15.01.2021
Exam Session	14-18.12.2020
Christmas Break	21.12-06.01.2021
CDR submitting	15.01.2021
Landing test	Beginning of March
FDR dividing writing tasks	01.02.2021
FDR pre-design	01.02.2021
Verifying FDR elements	25.02.2021
FDR submitting	01.03.2021
Final satellite check-up	08.03.2020
Laboratory organization	03.2021
Launching the satellite	March 2021
Sample collection and analysis	End of March 2021
Results	April 2021

Task list

State	High Level Task		-
-	-	Lower Level Task	State*
In Progress	Writing PDR	Overall design	Done
		Dividing work	Done
		Checking Specific Parts	In Progress
		Submitting PDR	In Progress
In progress	Writing Final Research Paper	Overall design	Done
		Dividing work	Done
		Contacting Professors	In Progress
		Checking data	In Progress
		Checking Specific parts	In Progress
Done	Writing preliminary research paper	-	-
In Progress	Filters Ground pre-test	Choosing and buying filters	Done
		Assembling the filters	In Progress
		Collecting data	In Progress
		Investigating data	In Progress
		Comparing obtained data to theoretical data	In Progress
In Progress	Outreach Program	Creating Instagram account	Done
		Creating Facebook account	In Progress
		Creating project's website	In Progress
		Advertising project and companies	In Progress
		Creating brochures	In Progress
In Progress	Presenting the project to investors	Creating a presentation	Done
		Writing a script	Done
		Q&A regarding the mission	Partially done
		First trial of presenting	In Progress
In Progress	Satellite	Prototyping the satellite	Done
		Designing the satellite in CAD	In Progress
		Buying materials	In Progress
		Building the satellite's skeletal	In Progress
		Printing the satellite's frame	In Progress
		Assembling electronics	In Progress

		Programming the satellite	In Progress
		Designing the parachute	In Progress
In Progress	Ground tests	Satellite's test from a drone	In Progress
		Filters final test	In Progress
		Parachute's test	In Progress
		Overall test	In Progress
		Checking the measurements	In Progress
In Progress	Writing CDR	-	-
In Progress	Writing FDR	-	-
In Progress	Gathering primary sensor data	Choosing sensors	Done?
		testing temperature sensors	In Progress
		testing pressure sensors	In Progress
In Progress	Establishing communication	Choosing radio module	Done
		Testing radio module	In Progress
		Choosing antenna design	Done
		Designing antenna	In Progress
		Testing antenna	In Progress
In Progress	Structuring clean chamber	Making the inside of CanSat sterile	In Progress
		placing a sterile case inside CanSat	In Progress
In Progress	Collecting samples at ground level	Preparing and analyzing viruses	In Progress
		Checking if method of collection is successful	In Progress
		Checking if method of separation is successful	In Progress
In Progress	Minimization of sample uncertainties	Reducing unsterile surface area of satellite	In Progress
		Calculating the possible number of viruses commonly found near the ground	
In Progress	Locating the satellite	choosing GPS module	Done
		choosing GPS antenna	Done
		testing GPS module and antenna	In Progress
		testing minimal height, accuracy, and reliability of the GPS module	In Progress
In Progress	Landing of the satellite	choosing a parachute	In Progress
		testing parachute's durability, rate of fall and ability to deploy reliably	In Progress
		testing the stability of CanSat's base	In Progress
In Progress	Picking an onboard computer	testing the onboard computer	In Progress
In Progress	Casing of the satellite	choosing a material	In Progress
		testing the material's durability in extreme conditions	In Progress
		CAD model for casing	In Progress
		testing the casing	In Progress

Resource estimation

Budget

Product	Price	Availability
Adafruit composite Altitude Pressure/Temperature sensor.	50.00zł	-
NW Air Pump 3.2 l/min strong miniature vacuum pump	40.00zł	-
Raspberry Pi Zero – input voltage 5V	59.90 zł	-
Lithium-ion - 3.7 V 750 mAh 3x	13.79 zł	-
Relay - coil 5V 12A 19.5 x 15.6 mm, height: 15.3 mm	03.70zł	-
Converter 5V - Output 5V Input 6V - 42V max elec 600 mA	23.90 zł	-
Converter 6V - output 6V input 6.1V - 36V max elec 0.5 A	19.90 zł	-
Defro Air Filter precise F9 class	147.60zł	Received
NanoProtect HEPA Filter	76.00 zł	Received
YAGI Antenna	177.00 €	-
Buzzer	11.50 zł	-
GPS - input 5V/50mA	44.80 zł	-
Total onboard CanSat	491.10 zł	-

External support

We have contacted an overall of 58 companies from around the World. The companies were mainly from Belgium, Poland, USA and Switzerland, France and three other countries. Until the 21st of October 2020 we have received a positive response from 4 companies: Adamed, Thorium Space Technology[16], Cubic Inch and Cloud Ferro. All the companies agreed on collaborative work with the Air Thief Team and provided a letter of intent. The focus of our partnership is substantial and material support with a potential to further develop into financial support as the project proceeds successfully.

Adamed agreed upon helping us with the ground segment of our mission including the provision of specialized equipment, private workshops, and a letter of intent together with an acceptance of our analysis. Thorium Space Technology gave us a helping hand regarding our satellite communication system and officially approved of our telemetry system. There is a possibility of receiving financial support if the mission turns out to be positively influencing the space exploration and aerospace engineering fields. Cubic Inch has confirmed the collaboration with our team regarding using 3D technology to improve the overall design and functioning of the satellite. Cloud Ferro has proposed to support the team substantively mostly by giving us access to CREODIAS and the possibility to work with the company's specialized teams. Finally, we have received an official acceptance letter of the methodology used in quantifying cloud Virome from dr. Rafał Mostowy.

Our team has also received two negative responses from Planet Partners and Blue Dot Solutions. Planet Partners has already started working on the ECR project therefore is unable to support our mission. Blue Dot Solutions does not have enough budget and personnel to take on a new project. The team is still awaiting responses from the remaining 51 companies.

Outreach program

Our way of reaching out to potential investors and supporters of the project is mostly by direct interaction with them, such as via email, phone calls as well as social media. In the future we are planning on sending out brochures and taking part in a radio interview, writing articles in local science journals and presenting our obtained data at school or local events either held by school or any of our promising investors.

We believe that the educational value of our mission is important for every demographic, therefore our project will be shared on an open source platform, giving an insight on our achievements to outsiders interested in the mission. Furthermore, we are planning on conducting numerous webinars regarding the organization of such a project and how to execute it.

Additionally, we are planning on creating short instructional videos covering the mechanical design of our satellite, which we believe might be beneficial for students aspiring to participate in the CanSat competition or for anyone interested in building their own satellite. Air Thief is also opened to giving lectures to younger students helping them to understand the basics of building a satellite and conducting meaningful experiments.

We will challenge ourselves with publishing various articles both in science journals like the Journal of emerging investigators and our schools newspaper. Moreover, the team will organize multiple experiment exhibitions either online or stationary to promote interest among young minds. We are aiming to advertise our project in the Copernicus Festival: 'Czas' magazine, because we think that they have an audience that could be fascinated with our research.

[16] Letter of Intent from Thorium

Our team has already contacted many companies and is planning to take part in various school events soon to expand the horizons of the young and ambitious students. We believe that sharing our progress with the world is meaningful and can inspire Many to conduct similar experiments. On the other hand, publishing articles requires results, therefore, as our mission proceeds, we will take on the task as soon as we obtain valid and relevant data.

Other actions:

- Instagram: **airthief_cansat**
- Facebook: **airthief.cansat**
- Radio interview
- Brochure emailed and posted around
- Presentations given by the team members, e.g. at the school or a local event
- Publishing an article in AHS's newspaper
- Designing logo
- Exhibitions of the experiment, e.g. at a fair or school open day
- Website: (not done yet)