CFR-19-Charles 4th

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Contents

ABSTRACT

Context.

This work deals with the events and work of the Charles the Fourth team in CanSat 2019 in Bologna, Italy, between 24 and 28 June.

Aims.

The aim of the thesis is to present an analysis of data collected by CanSat during the flight and after landing. There is a summary of the work that has passed between the national and European competition rounds.

Methods.

Optical analysis conducted by functional HD camera onboard the CanSat. Calculations and data interpretations of the obtained data from installed sensors.

Results.

Our CanSat was tested in earthly conditions. It worked well and we confirmed that it is capable to evaluate the landscape of the exoplanets and prove or disprove possibility of landing for bigger probes or rovers.

Conclusions.

The mission was successful. Cansat measured all the data and there was no electrical or structural failure. In the meantime, we encountered errors regarding additional features or errors that did not directly affect Cansat’s functionality

Key words:

CanSat, Exoplanet Features, Trappist, Long Term Data, Spectroscopy, Air Properties, Probe Operation

I. INTRODUCTION

Our CanSat's objective is to explore planets outside of our Solar system, called exoplanets, that might host suitable conditions for life. We named our probe EVA (Environmental Vocation Architecture) and it will serve as a preparative exploration module of the unexplored planets. Our mission solves the best landing site localization problem for a future larger probe or rover which will land in a planetary system TRAPPIST-1. Our mission will be part of a larger project with the goal of better understanding this system. It means that our 3 EVAs will be **tiny payloads with the huge benefit for space research**. Each of them will land on one planet in this system meantime the parent main probe will orbit the star and do the advanced research from the heliocentric orbit. In our mission we want to build our research on achievements of one of the greatest ESA's missions, JUICE (Jupiter Icy Moons). JUICE is planned for launch in 2022 and arrival at Jupiter in 2029, it will spend at least three years making detailed observations of the giant gaseous planet Jupiter and three of its largest moons, Ganymede, Callisto and Europa which can possibly host life beneath their ice crust. [1] JUICE mission inspires us a lot and we would like to do one step further and present where the future exploration should point. To exoplanets and search for life in future.

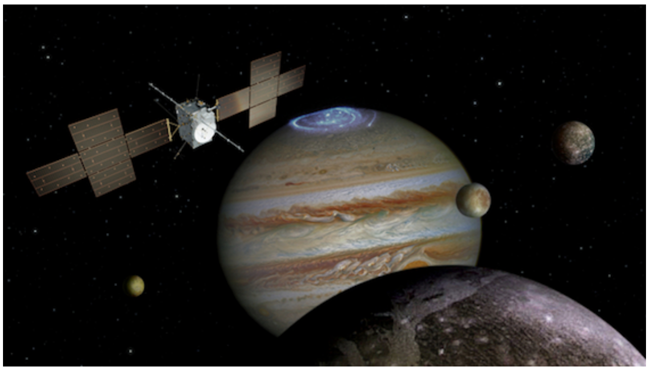

Figure 1: JUICE mission [1]

We want to make next giant leap for mankind so we have to monitor (study) the landing site for future advanced missions on each exoplanet as best as we can. We equipped our EVA with the camera so we got ability to monitor visual information about the landscape. Our main inspiration in adding camera was the rover Sojourner from mission Mars Pathfinder by NASA which have had also a very important tasks in searching for extraterrestrial life on the surface of planet Mars.

Next giant leap we CAN do only if we cooperate, share our knowledge and inspire each other. Our mission combines ESO, ESA and NASA projects.

II. PROJECT DESCRIPTION

Our goal is to create a functional probe able to measure and send a huge amount of data back on Earth from 3 different exoplanets in the TRAPPIST-1 system so we can analyze and select the best planet for landing the next advanced mission. Due to fulfilling of all goals is necessary to consider our mission as successful. Except for technical aspects of the mission, we also planned to visualise data in real time on our website. After landing the saved data were visualised in virtual reality by headset HTC Vive and we also developed action for Google Assistant that can answer the questions about our mission. We have done all these visual and attractive data interpretations because it is very necessary to show data and scientific research to general public in understandable way. In the following paragraphs, you can read technical details about our mission.

II.I Material and structural design

Our planetary probe EVA is of cylindrical shape with a diameter of 65.5 mm and height 115 mm. The whole construction was created in program Fusion 360. Fusion helped us to find an optimal ratio between weight and strength. All parts of the construction were printed on FMD printer with a combination of three materials - PETG, PA-jet, Polycarbon. These three materials were selected on the base of studying datasheets and following tests. Unlike previous construction used in national finals, the new construction is not made by filaments with scattered reinforcement made of steel and carbon cables. The scattered reinforcement can negatively affect radio transmission.

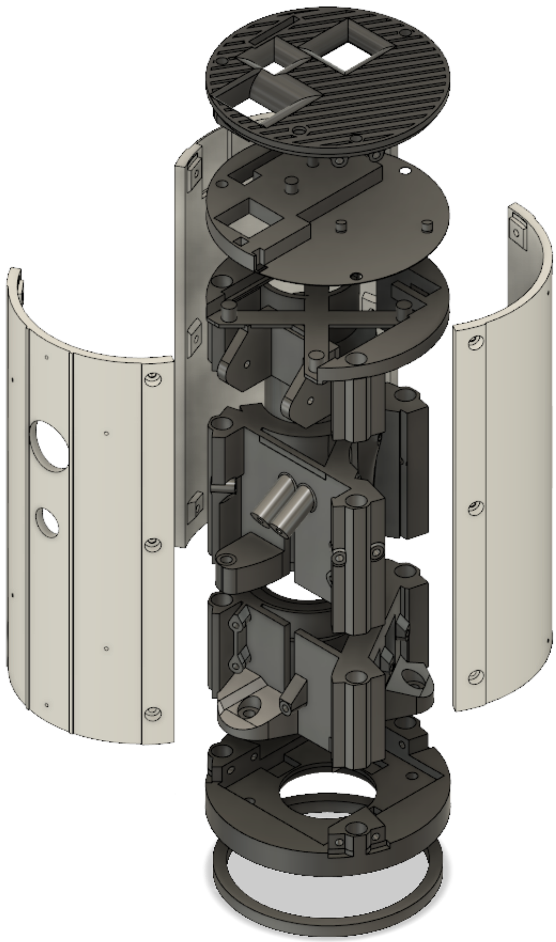

Figure 2: Construction model

The core of the construction was printed from very light PAjet filament. In the case of optimisation, the core is split into three parts. These parts are connected together with carbon tubes with an inner diameter of 3 mm and an outer diameter of 5 mm. By using carbon tubes to fix parts together, we could omit glue and tapes. All sensors are screwed to the core of construction and the cables are safely lead via the triangular hole in the middle. This triangular hole also allows optimal airflow through the whole probe.

Upper and lower parts are printed from Polycarbon because of their strength during the landing and also due to their chemical stability. Both parts have holes allowing regular air flow. The carbon tubes that connect the whole core of construction are fixed in the lower part. Parachute strings are lead through these tubes and are fastened to the strong rubber ring at the bottom part of the probe.

The whole probe is covered by a triad of covers printed from PETG. PETG filament is very hard and chemically resistant as well. Every single cover has a unique shape with groove fitting the right place in the probe core. In addition, covers are screwed together which makes the probe very resistant during the landing.

II.II Electronic components

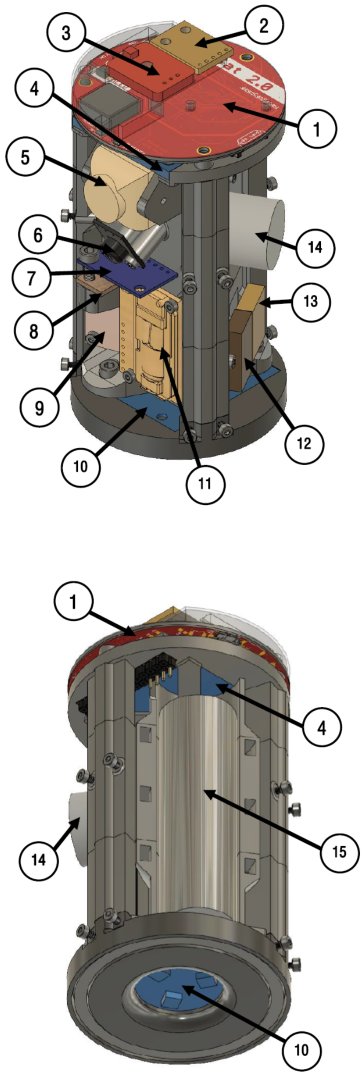

Figure 3: EVA model

1) openCanSat mainboard
2) Light intensity sensor
3) UV Sensor
4) Camera board
5) Camera
6) Infrared thermometer
7) MPU 9250
8) BME280
9) Air quality sensor
10) Spectroscope
11) CO_2 sensor
12) Step-up module
13) Step-down module
14) O_2 sensor
15) Battery

II.II.I openCanSat mainboard

Mainboard of our CanSat which features the same MCU as the Arduino M0 board and can be programmed using the Arduino IDE. It also contains a radio module, GPS module and BME sensor for temperature and pressure measuring.

II.II.II Light intensity sensor BH1750

The sensor converts measured light intensity into digital output and in the form of numerical value. Measured values are in lx and can be in the range from -40 °C to 85 °C and it is connected via the I2C interface.

II.II.III UV sensor

Measures UV index with sensitivity ±1UV INDEX and works within a wavelength range is 200 - 375 nm. Its operating temperature is from -20 °C to 85 and is connected to the mainboard via analog pin.

II.II.IV Camera RunCam Split 2S

The camera records video in FullHD resolution with 60 fps and 170° point of view. The video is saved onto SD card and can be transferred via the transmitter. It is a separate circuit which means that it does not affect the functionality of CanSat mainboard.

II.II.V Infrared thermometer

This sensor measures two temperatures - ambient temperature (temperature around the sensor) and temperature of the object in a maximum distance of 1 meter. The ambient temperature can be measured in a range between -40 and 85 and the object temperature can be measured in a range between -70 and 380 . With the increasing range of the object, the sensitivity decreases. According to the datasheet, the sensitivity of the sensor is 0.5 °C. It is connected via the I2C interface.

II.II.VI MPU 9250

Gyroscope, accelerometer and magnetometer all in one. The measured range for gyroscope is ±250, ±500, ±1000 or ±2000dps, the accelerometer range is ±2G, ±4G, ±8G, ±16 G and the magnetometer range is ±4800 uF. The measured ranges depend on initial setup. It also measures temperature within a range from -40 °C to 85 °C. It is connected to the mainboard via the I2C interface.

II.II.VII BME280

The sensor measures temperature in a range between -40 °C and 85 °C, humidity in a range from 0 to 100 %, pressure in a range between 300 and 1100 hPa. The temperature sensitivity is ±1 °C, humidity sensitivity ±3 % and pressure sensitivity ±1 hPa. The sensor is connected to the mainboard via the I2C interface.

II.II.VIII Air quality sensor CCS811

The sensor measures total volatile organic compounds (TVOC) in a range from 0 to 1187 ppm, CO2 concentration in a range from 400 to 8192 ppm. Its operating temperature is from -40 °C to 50 °C and it is connected to the mainboard via the I2C interface.

II.II.IX Spectroscope AS7265x

The triad of spectroscopes measures 18 different wavelengths with an accuracy of ±12 %. Its operating temperature is within a range from -40 °C to 85 °C and it is connected to the mainboard via the I2C interface.

II.II.X CO_2 concentration sensor

The sensor measures CO_2 concentration within a range from 400 to 10000 ppm with an accuracy of 30 ppm. It also measures temperature in a range from -40°C to 120°C with an accuracy of 0.5 °C and humidity from 0 to 100 % with an accuracy of 2 %. It is connected to the mainboard via the I2C interface.

II.II.XI Step-up module

Increases voltage for camera, oxygen concentration sensor and CO2 concentration sensor.

II.II.XII Step-down module

It should decrease the voltage from solar panels to 3.3 V to enable safety battery recharging, however, it was not mounted in flight version, because we did not receive solar panels.

II.II.XIII O_2 concentration sensor

The sensor measures oxygen concentration within a range from 0 to 25 %. Its operating temperature is from -20 °C to 50 °C and is connected to the mainboard via analog pin.

II.II.XIV Battery

Our battery has capacity 5100 mAh and with calculated power consumption is 628 mA, our probe's calculated lifetime is about 8 hours or more.

II.III Electronic circuit

The probe is based on the openCanSat kit 2.0 which features the same MCU as the Arduino M0 board and can be programmed using the Arduino IDE. All sensors are connected to the mainboard (the main part of the kit, which includes the major circuit). The vast majority of the sensors, which we use, are connected to the I2C serial bus and 3.3 V supply voltage. But some sensors and camera require 5 V, so we used the step-up module to increase the voltage from 3.3 V up to 5 V. All the sensors are connected via flexible silicon wires that perfectly fit into our construction. We also planned to add solar panels as another power source, but unfortunately, they did not arrive in time.

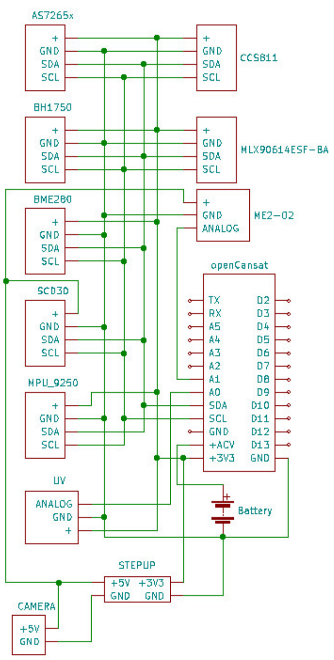

Figure 4: EVA circuit

II.IV Firmware

Since our probe's main board is based on Arduino platform, whole firmware is written in the Wiring programming language. The biggest advantage of Arduino platform is the huge amount of libraries for working with sensors and other components. Probe's program can be described as an infinite loop, in which probe measures data, saves them and transfers them via radio. Due to huge amount of data that would overflow buffer of our radio module RFM69W, we had to split data into 4 types of packets. Each packet type contains different part of the data measured. In the diagram below, you can see our probe's firmware.

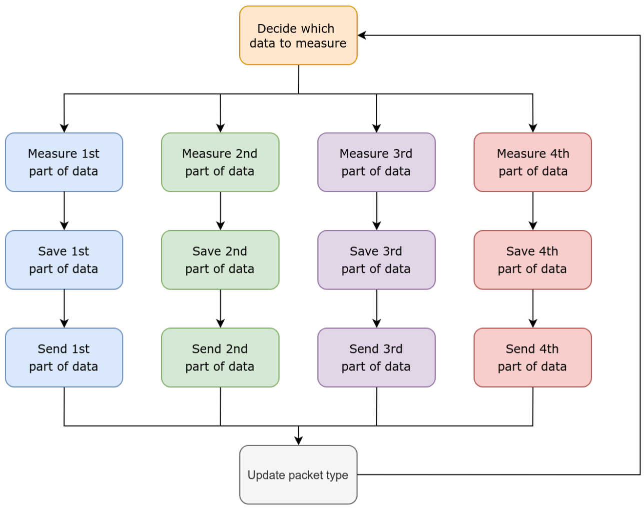

Figure 5: EVA firmware

II.V Data backup system

We are taking data seriously because it is the most valuable commodity of our mission. That's why we used two separate aerials during the flight. Another part of the mission was also a multi-level backup system. All measured data should be saved on the probe's microSD card, however, thanks to an inappropriate plugin, the probe was not able to save data to its microSD card. Thanks to the separation of systems, this problem did not affect data transfer from the probe to the ground station TOM, which saves them and sends them via USB cable to the connected laptop. Express server, which is running on the laptop, reads all the data and saves them to the local database and sends them to the cloud database of Firebase. Due to problems with the internet connection on the launch field we were not able to send data via the internet to the cloud, however, received data were still stored on two separate places - on both laptops and both ground stations.

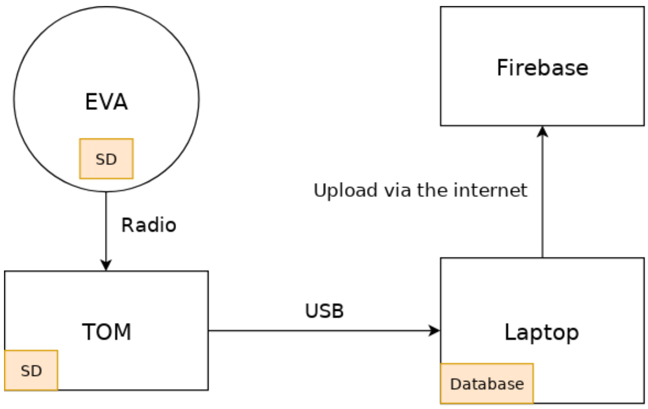

Figure 6: Data backup system

II.VI Recovery system

Our probe uses parachute of a circular shape as a recovery system. Originally, we designed parachute for European finals with a vault of 70 cm diameter with a middle cutout of 7,5 cm diameter. It is sewed from the light fabric used for gliders (27g/m2). The fabric is also hard and inflexible. The final design of value is tricolor (white, red and blue). Length of the line is 80 cm and the weight of the parachute is 15 grams.

This parachute was not used for launch due to failing in tests during national finals. Our beta CanSat was descending at the edge the allowed speed limit, so we decided to use parachute from the national finals, which has value with 55 cm diameter, inner cutout 5 cm and lines with the length of 60 cm.

The parachute lines are lead through the whole CanSat and are fixed in the bottom part to the rubber ring. This fix is strong and flexible as well. In the case of breaking the rubber, the parachute will still be fixed by nylon textile braid.

Figure 7: Tricolor parachute

II.VII Web chart dashboard

Received data were displayed in real-time on the laptop screen in our localhost dashboard web app. We decided to choose the web because of the multi-platform access and ability to use it on almost any device. To be able to run real-time communication between the web server and the web client, we are using WebSocket protocol. Data dashboard app is using React library for view rendering and recharts library for chart drawing. On the screenshot below, we can see all the most important charts from the mission – map with our CanSat position, temperature chart, pressure chart, humidity chart, light intensity chart, oxygen concentration chart, CO2 concentration chart, spectroscope visualisation bar chart and altitude chart. We also planned data livestream, however, due to troubles with internet connection, we weren't able to send data to Firebase (cloud service with hosting and database) and whole data livestream was impossible.

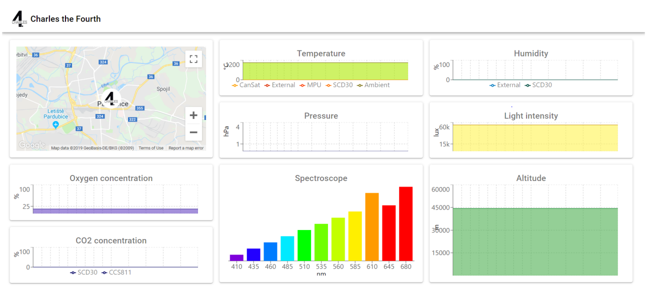

Figure 8: Chart dashboard screenshot

II.VIII Virtual reality

By showing charts in HTC Vive virtual reality headset, we are able to display more information and the user can feel a little bit like a probe's crew. The user can watch the development of each measured value and will be able to compare all measurements among one another. The whole onboard simulator is based on the Unity game engine, which allows easier development of 3D graphical applications. SteamVR library helps us with displaying the scene in VR, so we can fully concentrate on the development of our simulator. We think that adding modern technology into the presentation of whatever scientific work can lead to an increase in science popularity, especially in the young generation. These days disinterest of young generation into science is a common problem these days and scientists should take it in mind.

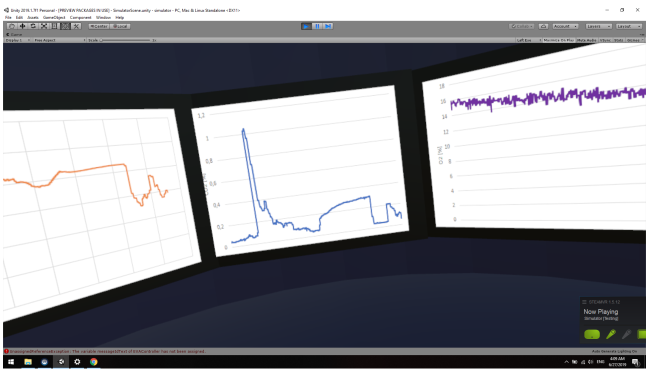

Figure 9: Virtual reality simulator

II.IX Action for Google Assistant

These days voice assistants and chatbots, in general, are becoming very popular. Big companies are investing a lot of money and effort into their development. We decided to create action for Google Assistant because of its big market share. Almost every Android phone supports it and the number of sold Google Home smart speakers increases every day. Gain information about our mission via Google Assistant is quite simple, the only thing you need to do is to call our action with the command "Talk to Charles IV" and then you can ask questions about our mission such as "Was your mission successful?" or "What was the highest temperature measured?" All the data presented by our action are simplified and for better understanding of data measured by our probe use this report instead.

III. SCIENTIFIC RESULTS

III.I Charts explanation

Due to the failure of writing data on the microSD card in the probe, we had to use the received data. To make charts clean, we decided to choose only the smaller range of data containing important milestones of the mission. We do not have more data immediately after landing because we had to move from our base to field to receive data again. Because there is significant skip between the last packet received immediately after landing and the first packet received after movement, we decided to omit these data. We tried to also add error bars to our plots, however, some plots are without them, because we did not find the accuracy of all sensors. We even sent an e-mail to sensor producers, but they did not reply.

III.II Temperature monitoring

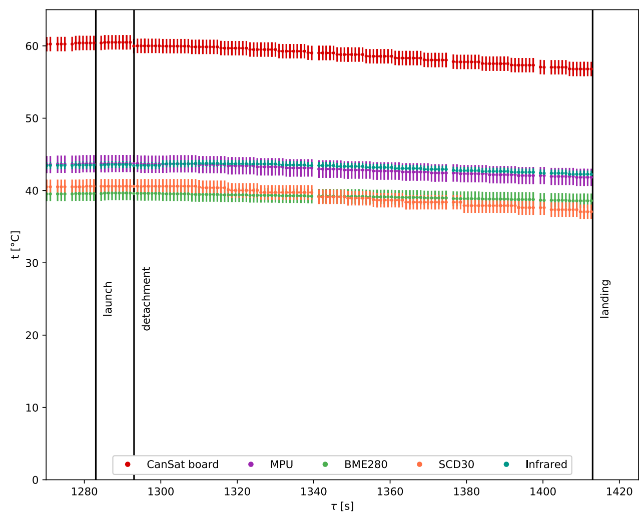

Figure 10: Temperature monitoring chart

III.III Pressure

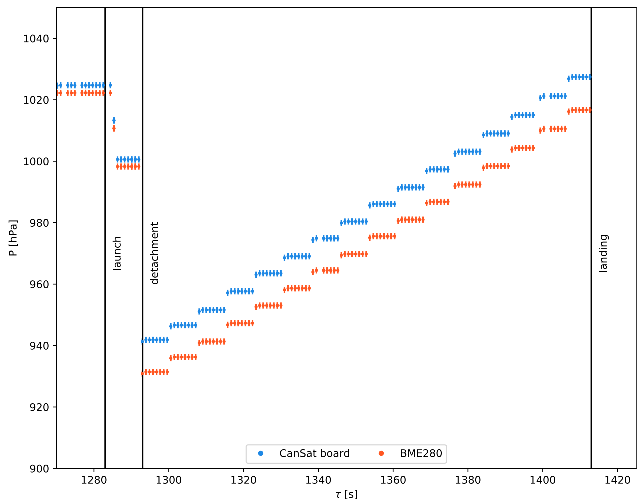

Figure 11: Pressure chart

III.IV Temperature dependence on pressure

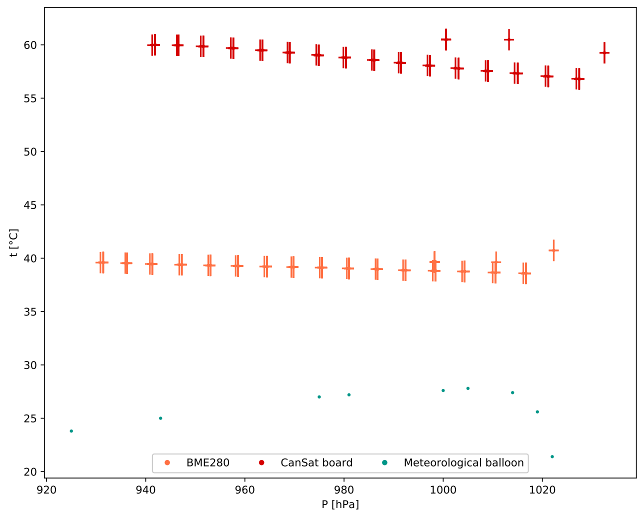

Figure 12: Temperature dependence on pressure

III.V Humidity

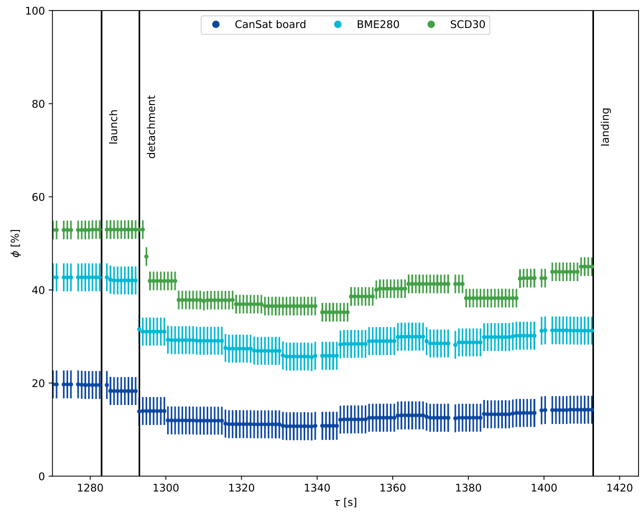

Figure 13: Humidity chart

III.VI Oxygen concentration

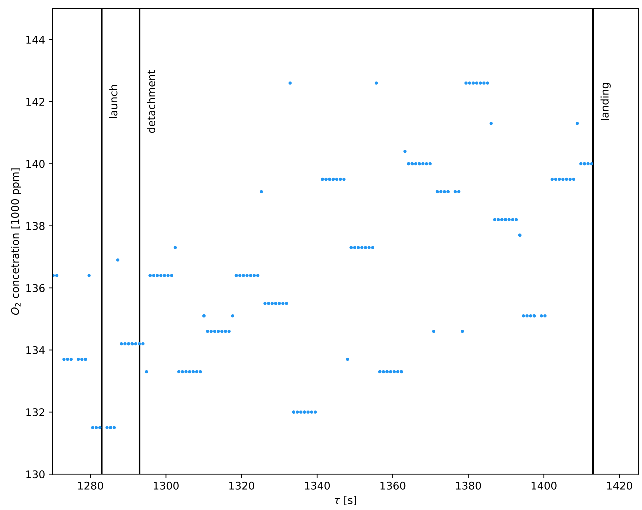

Figure 14: O_2 concentration chart

III.VII CO_2 concentration

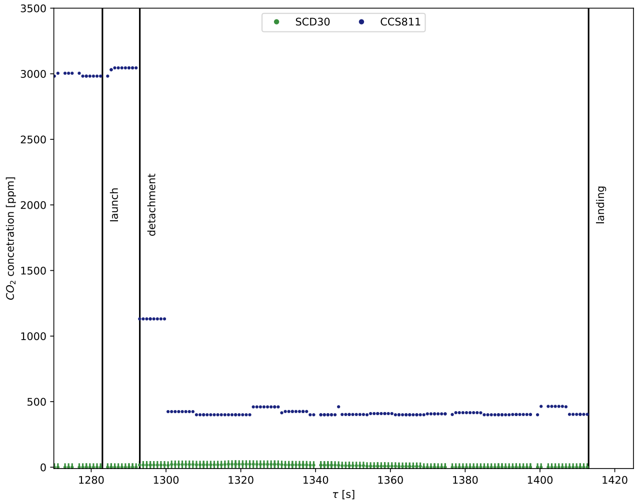

Figure 15: CO_2 concentration chart

III.VIII Light intensity

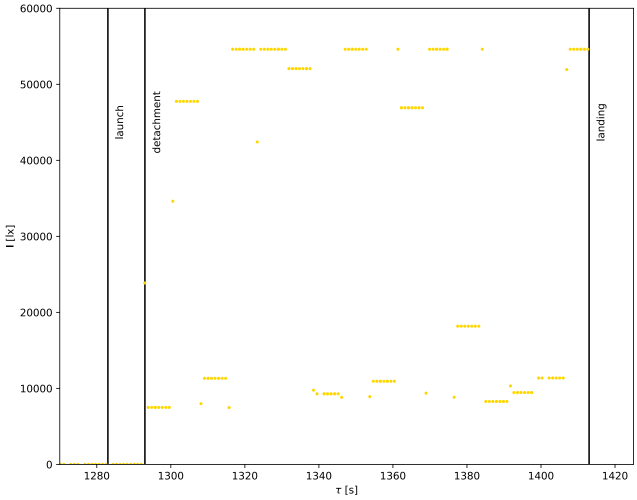

Figure 16: Light intensity chart

III.IX Altitude

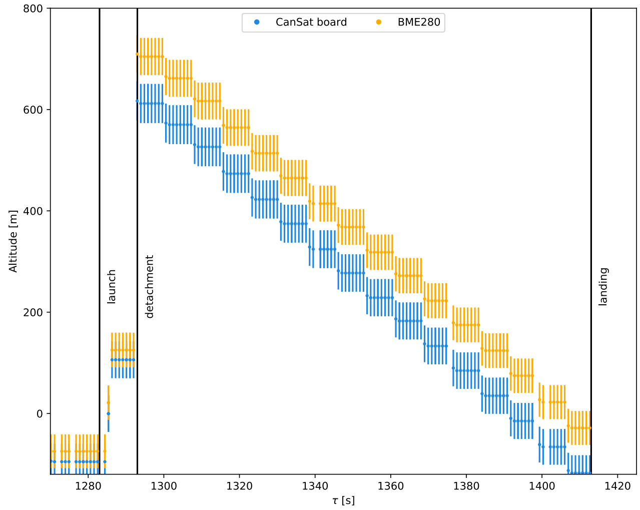

Figure 17: Altitude chart

III.X Rotation in X axis

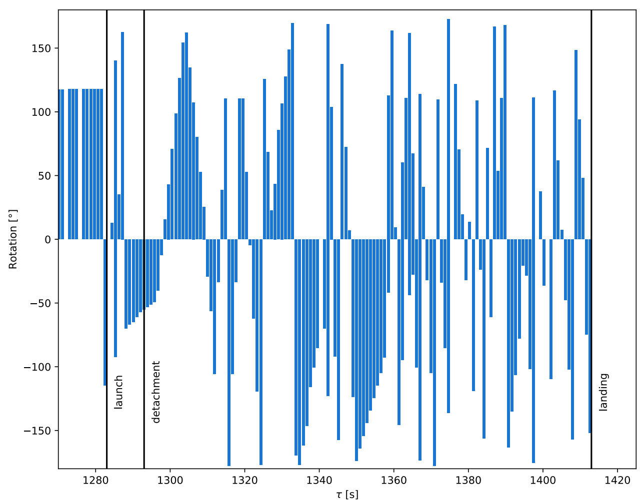

Figure 18: Rotation in X axis chart

III.XI Rotation in Y axis

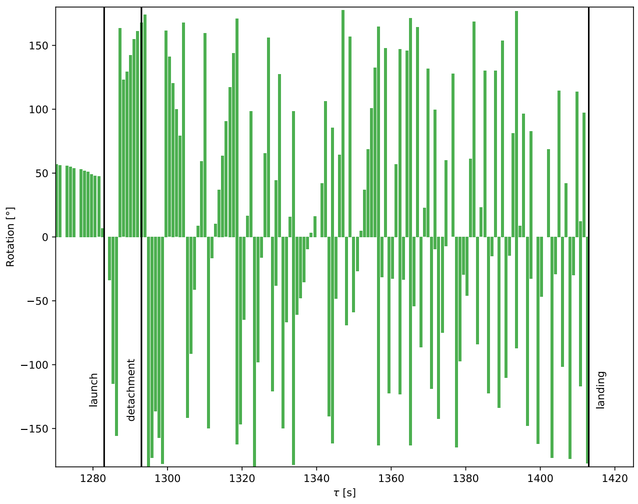

Figure 19: Rotation in Y axis chart

III.XII Rotation in Z axis

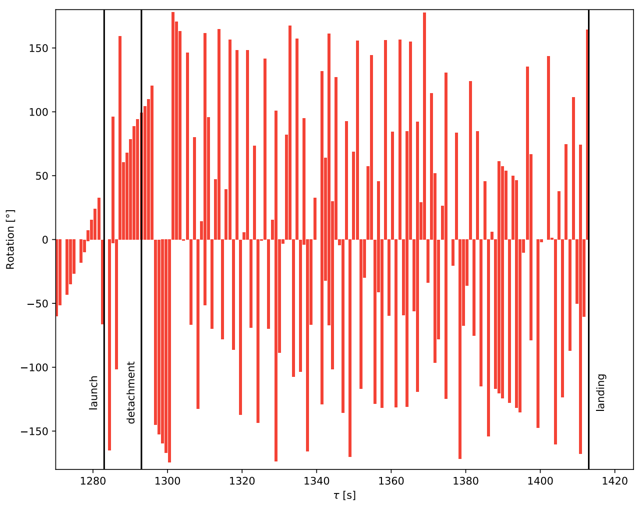

Figure 20: Rotation in Z axis chart

III.XIII Spectroscope – rocket

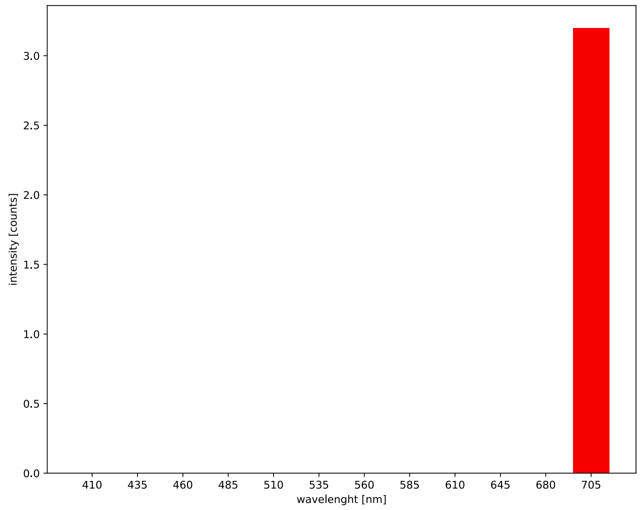

Figure 21: Spectroscope measurement in rocket

III.XIV Spectroscope – detachment

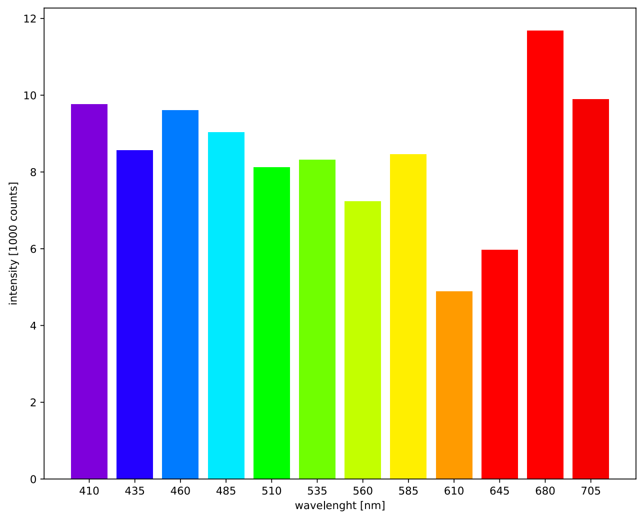

Figure 22: Spectroscope measurement after detachment

III.XV Spectroscope – descent

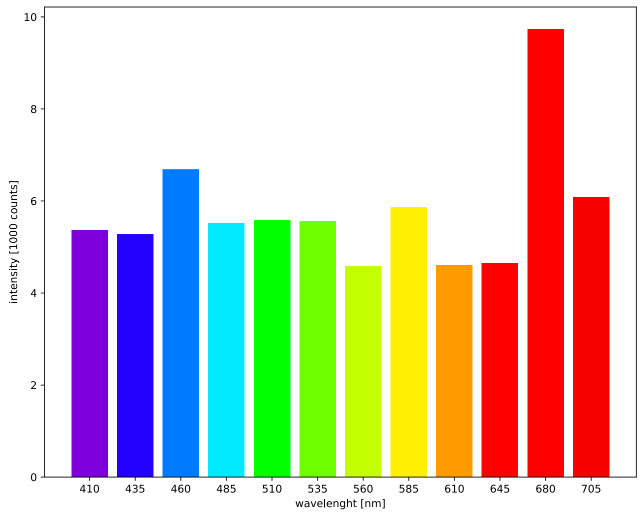

Figure 23: Spectroscope measurement during flight

III.XVI Spectroscope – landing

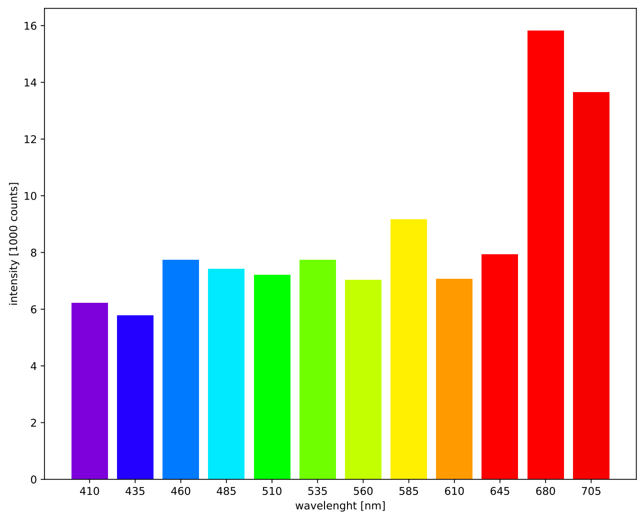

Figure 24: Spectroscope measurement after landing

III.XVII Trajectory

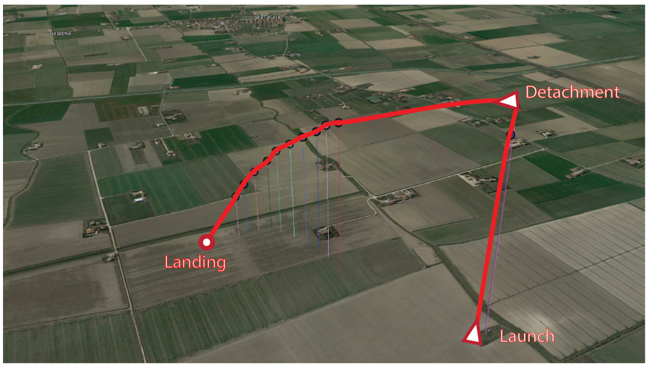

Figure 25: Trajectory illustration

III.XVIII Video

Figure 26: Video screenshot

IV. DISCUSSION

IV.I Possible target

The TRAPPIST-1 planetary system was selected from the thousands of known systems because it consists of one star and 7 planets. Even 3 of them orbit the star in so-called habitable zone. It's the area around the star where can occur the liquid water, the main ingredient of life as we know it. Planet is not too close from the star where the water immediately evaporate and also not too far from the star where the water is still frozen. This system is 39 light years far from our Solar system which is relatively close if we take into consideration that our nearest star Proxima Centauri is 4,2 light years away. Though this system is near and in the constellation of Aquarius, we can observe this system only with very advanced telescopes because the light source is a red dwarf with magnitude 18,8. [2]

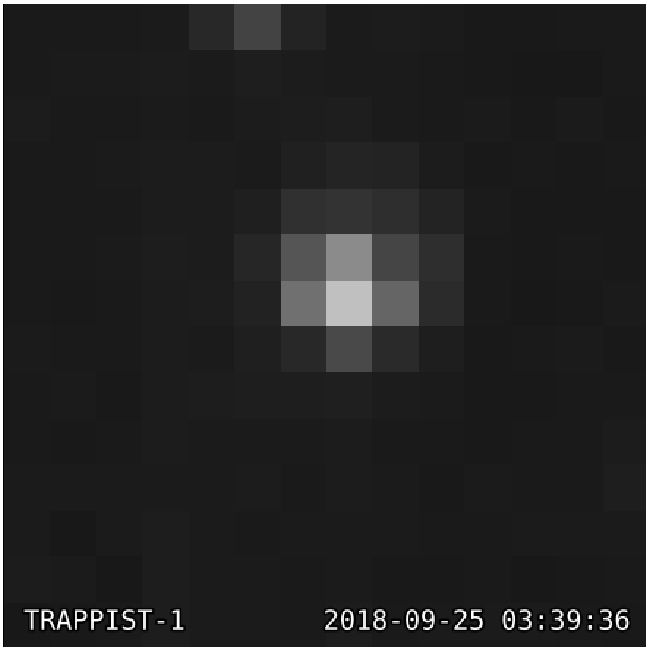

Figure 27: Photo of TRAPPIST-1 by Kepler telescope [3]

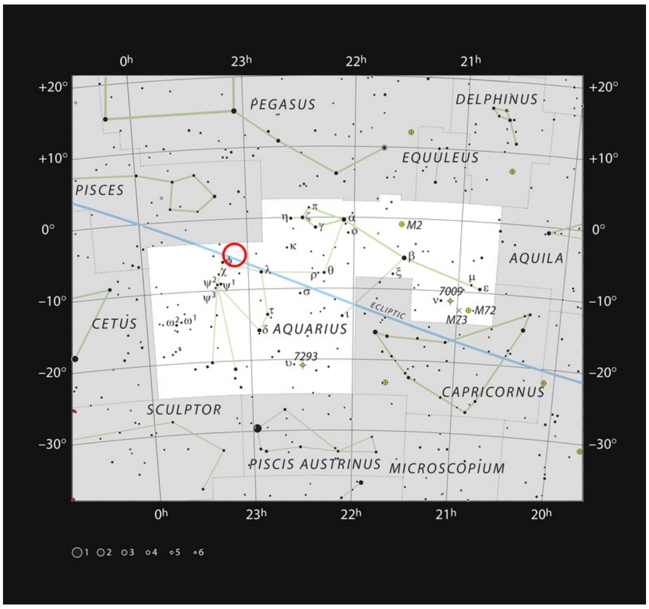

Figure 28: TRAPPIST-1 is located in the red circle [4]

The star is 12 times smaller than our Sun and it's surface temperature is only 2550 K.

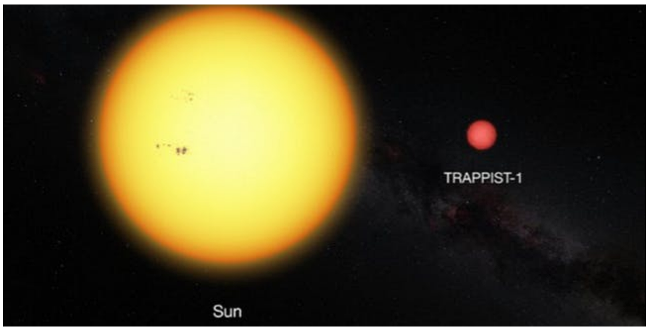

Figure 29: TRAPPIST-1 compared to the size of the Sun. [5]

It means that the habitable zone has to be closer to the star than it is in the case of our Solar system. Exoplanets e,f and g (it means 4th, 5th and 6th from the star) are in the habitable zone and these 3 are final destinations for our CanSats.

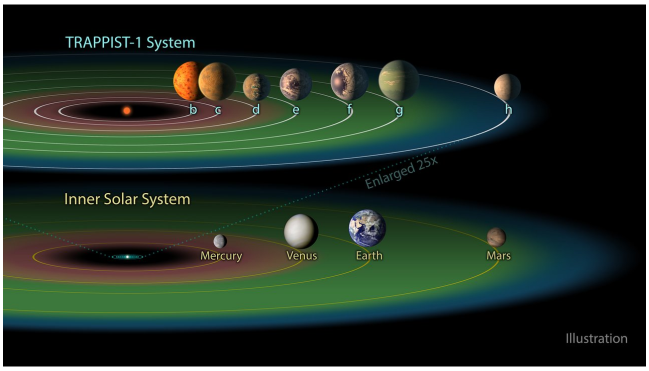

Figure 30: Habitable zone in TRAPPIST-1 system [6]

The planetary system TRAPPIST-1 was discovered by TRAPPIST telescope (a project of European Southern Observatory), which is situated high in the Chilean mountains at ESO's La Silla Observatory. It specializes in searching for comets and exoplanets by utilising transit photometry. If a planet crosses (transits) in front of its parent star's disk, then the observed visual brightness of the star drops by a small amount, depending on the relative sizes of the star and the planet. A theoretical transiting exoplanet light curve model predicts the following characteristics of an observed planetary system: transit depth (δ), transit duration (T), the ingress/egress duration (τ), and period of the exoplanet (P). However, these observed quantities are based on several assumptions. For convenience in the calculations, we assume that the planet and star are spherical, the stellar disk is uniform, and the orbit is circular. Depending on the relative position that an observed transiting exoplanet is while transiting a star, the observed physical parameters of the light curve will change. [8]

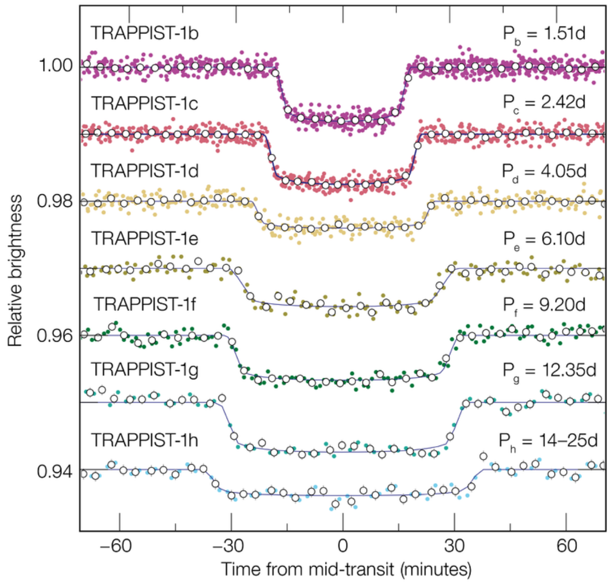

Figure 31: Tranzit data of TRAPPIST-1. [7]

Planet	Earth	TRAPPIST - 1 e	TRAPPIST - 1 f	TRAPPIST - 1 g
Orbital Period [days]	365.26	6.1	9.21	12.36
Distance to star [AU]	1	0.0293	0.0385	0.0469
Planet Radius [Earth]	1	0.91	1.05	1.15
Planet Mass [Earth]	1	0.77	0.93	1.15
Planet Density [Earth]	1	1.02	0.82	0.76
Surface Gravity [G]	1	0.93	0.85	0.87

Table 1: Data by NASA/JPL-Caltech

According to the Table 1 we see that all three planets which are subjects of our research have similar mass, radius, density and gravity as Earth so our EVAs will deal with similar conditions as we tested on Earth. These are also very good indicators for possible life which has developed here on Earth.

The spectroscope mounted to our probe could allow a more detailed exploration of the exoplanet's landscape.

In addition to the studies of exoplanet's landscape, our probe can research the atmosphere during its descent and we expect that all these 3 planets have their own atmosphere.

The largest of the worlds in the seven-planet TRAPPIST-1 system boasts the atmosphere that has evolved over time, rather than the one that formed with it.

Observations made with NASA's Hubble Space Telescope reveal that the planet's atmosphere is different from its nascent environment, meaning it's most likely rocky world similar to others in the system. [9]

IV.II Temperature monitoring

By measuring temperature with more sensors, we can monitor the temperature of each part of our CanSat. In addition, during the failure of some sensor, we have backup and we will be able to fulfil the primary mission. When we look at the chart, we can see that the highest temperature was measured by BME280 located on the mainboard of our CanSat. This measurement is affected by electronics because the GPS module and microchip is located nearby and these two components produce a lot of heat. This allows us to monitor the temperature evolution of the mainboard. The plot clearly shows that before the detachment, the temperature was increasing, because it was closed in the rocket without any chance of fresh air flow. Sensors from modules MPU-9250/6500 and infrared measured a slightly higher temperature than BME280 the SCD30 because they are closer to mainboard and camera board as well.

IV.III Pressure

As we can see in the chart, pressure measured by the CanSat mainboard is a little bit higher. It might be caused by the higher temperature of the mainboard because it contains power draining modules. The measured pressure is in the limit for ideal living conditions as we know it.

IV.IV Altitude

The altitude was counted by sensors measuring temperature and pressure. The calculation might be affected by the Sun heat and heat from electronics that caused the temperature to increase. By increasing the temperature, the altitude descends. From the chart, we can determine that CanSat mainboard measured lower altitude which is caused by the measuring of higher temperature and pressure as well.

IV.V Humidity

The shape of all humidity plots is almost the same, but they differ in shown values. If we compare the plot from the sensor located on the mainboard with BME, we can see the difference of about 20 %. This difference is most likely caused by the effect of electronics because the temperature of the mainboard is higher than the temperature measured by the BME sensor. However, why are the values from the plot of SDC30 slightly higher than the ones from BME sensor when their measured temperatures are the same? It might be caused by the location of both sensors. The BME sensor is located higher in the CanSat than the SDC30 and the higher concentration of humidity is in the lower parts than the upper parts because air with higher humidity has greater mass than the one with lower humidity. This difference may be also caused by different types of sensors.

IV.VI O_2 concentration

The sensor detects oxygen concentration by measuring current based on the electrochemical principle, which utilizes the electrochemical oxidation process of target gas on the working electrode inside the electrolytic cell, the current produced in electrochemical reaction of the target gas is in direct proportion with its concentration while following Faraday law, then oxygen concentration of the gas could be got by measuring the value of current. In the plot, we can see a group of measurements of the same value. This might be caused by the slower adaptability of the sensor. Measured oxygen concentration is ideal for life as we know it.

IV.VII CO_2 concentration

We can see that the SDC30 sensor failed and measured very low CO2 concentration under its measuring range. However, the backup sensor CCS811 worked well. From its measurements, we can see higher concentrations of CO2 before the detachment. This higher concentrations might be caused by the lack of airflow in the rocket. This measurement could be also affected by the fumes which were produced by the rocket engine. After detachment, the concentration dramatically decreased to the normal value that is suitable for life as we know it.

IV.VIII Rotation

By measuring the rotation of our can, we can determine that it rotated during the flight. These results can be confirmed using our recorded video from EVA.

IV.IX Trajectory

Thanks to the GPS module and knowledge of altitude, we were able to draw the flight trajectory of the whole mission. To draw the trajectory we used Google Earth that allowed us to plot the points into map and then we connected these points together in Adobe Illustrator. We also added important milestone points such as launch, detachment and landing.

IV.X Light intensity

Light intensity measuring was affected by the parachute, because it sometimes created the shade that decreased the measured value and sometimes the light intensity sensor was on the full sunshine and measured higher values. We can determine from these values that at the landing point there is enough sunshine that can allow plants to grow.

IV.XI Spectroscope

For visualisation of data measured by the spectroscope, we used four milestones from the flight. The first milestone is when the CanSat was in the rocket. We can see that the spectroscope measured the small number of red wavelengths. That might be caused by the reflection from the red parachute or even from the red PCB of the spectroscope. Otherwise, we can see that it was dark in the rocket. Next important milestone is the detachment from the rocket. At that moment, spectroscope measured a huge intensity of many wavelengths. This could be caused by the sunshine or reflection from the rocket because CanSat was tilted. Next interesting moment from the mission is the descent of CanSat. There is a small peak of red wavelengths that might have been caused by the field of wheat that was located just below the CanSat. The last milestone was after the landing where spectroscope measured a huge amount of red wavelengths. This might cause the parachute, but after reviewing the video, we realised that parachute was located next to the CanSat and could not affect the spectroscope measurement. In this case, it is very possible that CanSat landing into red-orange vegetation. This fact is confirmed also by video.

IV.XII Video

The video was recorded in FullHD quality and is the key factor for getting the information about the terrain in the landing zone. Thanks to video, we could find out that one of the strings of parachute cutout and CanSat start to rotate. In addition, we can say that the area around the landing point of our CanSat is full of vegetation and flat. These are the ideal conditions for the rover that will explore the vegetation and the landscape of the planet in more details. The whole video can be found on our YouTube channel [10].

V. CONCLUSION

In conclusion, our mission was successful. We measured the necessary data and also managed to record the video. The planet that our probe landed on has suitable conditions for life and also the landing area is ideal for rover landing because it is flat and full of plants that can be explored.

Unfortunately, we have encountered minor bugs. Here is a brief summary of them:

- Data was not stored on the microSD card in the probe.
  - Cause: Most likely, the microSD card was incorrectly inserted into the slot in the probe.
  - Solution: Check the insertion of the microSD card into the slot.
- We did not transfer the video from the probe.
  - Cause: Transfer video ran on an unauthorized frequency of 5.8 GHz.
  - Solution: To find out in advance. Try to get a transmitter and receiver that will run at the allowed frequency.
- We have not implemented livestream data.
  - Cause: Insufficient internet connection.
  - Solution: Get a modem with a local operator SIM card that has a signal at the launch field.
- One rope from a parachute ripped off.
  - Cause: The parachute rope ripped off either by inserting CanSat into the rocket or during

the CanSat detachment from the rocket.

  - Solution: Make a parachute ropes out of a firmer material.

- We did not receive solar panels in time, despite the fact that we ordered them a month before the European finale and we paid for express shipping.

  - Cause: They were bought in an American shop and they also stuck at customs.
  - Solution: Order components only from the EU.

V.I Achievements

- We measured all the necessary data.

- We have a video which was recorded during the mission.

- Despite the failure of the microSD card in the satellite, we have received data that we can analyze.

- Despite the fact that one rope from the parachute ripped off, our EVA satellite successfully completed its mission.

- We found the satellite very quickly thanks to the GPS module.

- We were able to display data on the computer in real time.

- We have had a lot of sponsors.

- We have overcome a lot of critical moments – for example, when the motherboard did not work.

- Backup Sensor System – In case of a system failure, we were able to measure the variables.

- We have created a working Google Assistant which we used for data presentation during the finale.

- We have programmed an onboard VR simulator.

We have learned a lot by participating in this competition. It helped us to learn how to cooperate and improve our teamwork skills. We also learned how various technologies work and how to interpret measured data from sensors. We received a lot of valuable feedback from experts and we gained many useful contacts for our future.

V. References

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