High Altitude Student Platform (2021)

Final Science report

Universidad Nacional de Ingeniería

WANKA – A Mission to Measure Stratospheric Aerosols Parameters Using Low - Cost Commercial Sensors

Payload class: Small

Payload number: 05

HASP student team lead

Ramiro Tintaya <rtintayaq@uni.pe>

Non - Faculty advisor

Luis Suarez-Salas

Student team

Alondra Alfaro, David Arrústico, Giusep Baca, Marco Chiroque, Antony Dávila, Anibal Esquiembre, George Fajardo, Dario Huanca, Julver Marrufo, Miguel Morales, María Muñoz, Michael Quiquia, Zedrix Quispe, Germain Rosadio, Martin Salazar, Fredy Segama, Lucas Taipe, Ramiro Tintaya.

Abstract

Interest in the study of stratospheric aerosols has increased due to their effects in the Earth's radiative forcing. However, there is uncertainty about effects they cause, due to their high spatial and temporal variability, and physical and chemical processes to which they are exposed. This project develops a cost-effective way to measure stratospheric aerosol concentration using two low-cost commercial light-scattering-based particle matter sensors. The payload will use a Plantower PMS 7003 and a GP2Y1010AU0F to quantify aerosol concentration after an air heating process, however PMS7003 did not work as expected, which means that it is not expected to work at stratospheric conditions, GP2Y1010AU0F worked and its data is being used to understand the presence of some particles. The team is composed of students from different academic years and is advised by an engineer from Geophysical Institute of Peru. Payload weighed 3.255 kg including the payload plate, its dimensions were 5cm x 15 cm x 28.42 cm. Its maximum consumed power was 10.5 Watts of power and its downlink rate was 310 bps.

Contents

1. Project overview

1.1. Scientific Background

During the last decade the interest in the study of stratospheric aerosols has increased, mainly due to their increase since 2000, and their potential applications to control global warming due to its negative effect on the Earth's radiative forcing. They are usually considered as the particles suspended in a gas, without a constant composition [1]. They affect the earth's radiative budget, absorbing and scattering the radiation that enters or leaves the planet. Working directly or indirectly, affecting the radiative properties and the lifetime of the clouds [2]. However, there is a lot of imprecisions regarding the effect that they cause in the radiative forcing as it is shown in Fig. 1, where the aerosol parameters indicate high uncertainty. Stratospheric aerosols are found from the end of the tropopause up to a maximum height that depends on the sedimentation and evaporation process generated by the increase in temperature with the altitude and are mainly composed by stratospheric sulfur from different gaseous molecules as sulfur dioxide (SO2), carbonyl sulfide (OCS) and sulfuric acid (H2SO4), the ones that are produced mainly due to volcanic injections of SO2 and aerosols. [1]

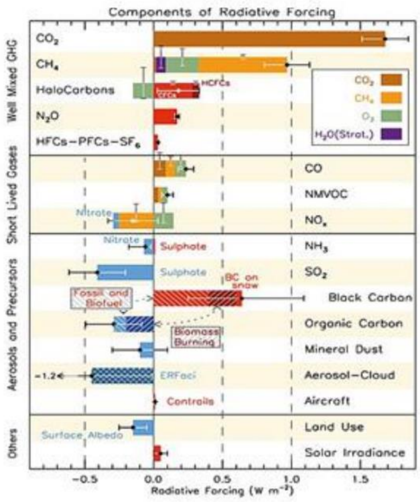

Fig. 1. Components of Earth's radiative forcing with their corresponding uncertainty (Source: Adapted from [3, Fig. 8.17]).

There are different ways to measure stratospheric aerosol parameters: in situ, ground-based and space-based. Space based missions use mainly satellites, as CALIPSO, which provides backscattering profiles assuming a static lidar ratio for all the latitudes and longitudes, or the SAGE missions that calculate backscattering coefficients using coefficient extinction and use data provided by ground-based systems to verify its algorithms. Ground based measurements use powerful lidar systems. There are many places in the world with this instrument, as Table Mauna Loa at USA or the "Observatoire de Haute-Provence" at France [4], and different instruments that can acquire this data as the Raman Lidar or Ceilometers [5]. One of the ceilometers used to measure these parameters is the CL31, which works at 905 nm, a wavelength where the molecular scattering is very weak, usually below the sensitivity of the instrument. [6]

In situ measurements are the most affordable way to measure stratospheric aerosol parameters, they can be sent to the stratosphere using balloons, and its payload can be composed by commercial sensors and actuators. They are not supposed to replace the other techniques, but can provide highly complementary information, and can be built by students from different academic years [7]. One of these missions is Compact Optical Backscatter Aerosol Detector (COBALD), which provides high precision measurements of optical parameters as the Backscattering coefficient at 455 nm and 940 nm, but cannot work during the day [6]. Another mission is developed by High-Altitude Balloon for Outreach and Research (HARBOR), which measures aerosol and gases concentration using low-cost commercial sensors [8].

1.2. Project description

The main objective of the WANKA mission is to develop a payload able to measure stratospheric aerosol parameters using low-cost commercial sensors. To achieve it, two methods of measurement are going to be implemented. First one is using a PMS7003, which is a low-cost Optical Particle Counter (OPC), which measured a great number of parameters, as PM1.0, PM2.5 and PM10. Second method involves the use of Sharp GP2Y1010AU0F, a low-cost particle matter (PM) sensor, which is very popular due to its high availability and simple interfacing [9]. To use both methods, air must be heated up to a temperature where the sensor works optimally as the temperatures outside the payload does not allow the sensors to work. This project is expected to be a major step in the development of payloads for stratospheric aerosol parameters measurement designed and implemented by undergraduate students at an affordable cost.

At the beginning it was proposed the use of a Lidar V3HP to measure the Backscattering Ratio using the Lidar equation, this parameter helps us to know how the radiation incoming radiation is reflected in the atmosphere. It was planned to compare the acquired data with the provided by the Calipso satellite, the one that had already been acquired (Figure 2). However, after performing different test of the sensors and consulting Plantower, the company that manufactures the sensor, we concluded that the sensor was not suitable for this application, because even though its wavelength is near the one used by the satellite, its measurements did not change when it was exposed to some aerosol samples, and also it was not possible to acquire the received power in Watts, so it was not possible to use the Lidar equation to calculate the Backscattering ratio. It is planned to find an affordable way to acquire these parameters in further launches.

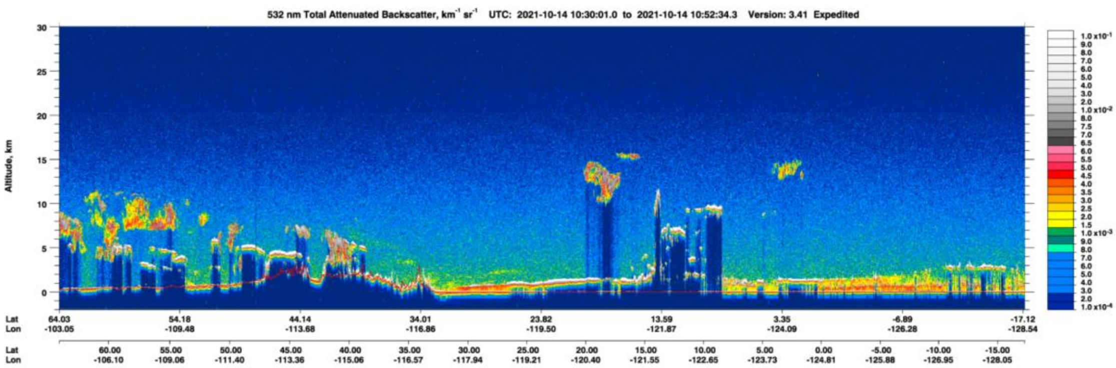

Fig. 2. 532 nm Total Attenuated Backscatter. UTC: 2021–10–14 10:30 to 10:52 [10]

2. Payload design

WANKA payload uses low-cost commercial sensors to obtain aerosol data. However, most of these sensors can not work under stratospheric conditions. For this reason, it was developed an air acquisition system which warms the incoming air before being analyzed by the sensors. Figure 3 shows how the payload was assembled, as different changes were made during the integration test. Air is absorbed using a fan through the copper pipe, which is covered by two heating pads, that warm the incoming air. Then the sample enters the sensor box, where some sensors measure different parameters from the sample (Figure 4). Finally, the sample exits the payload through a little pipe which is connected to a sensor flow Honeywell AWM5000. The external structure is made of carbon fiber, whit some aluminum brackets to support the structure, then it is covered by a polyurethane foam layer, which provides thermal isolation, finally, the sensors are inside a PETG box, which was used to maintain the air sample inside the circuit.

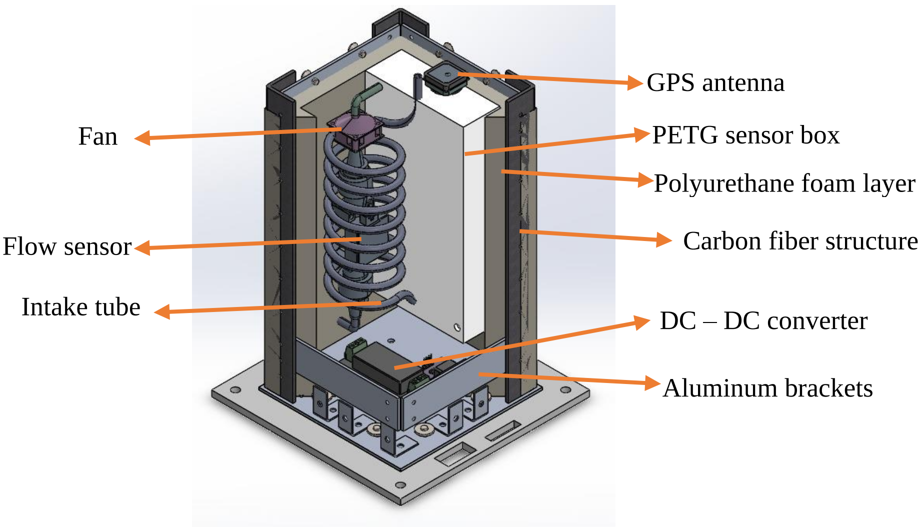

Fig. 3. Payload structure

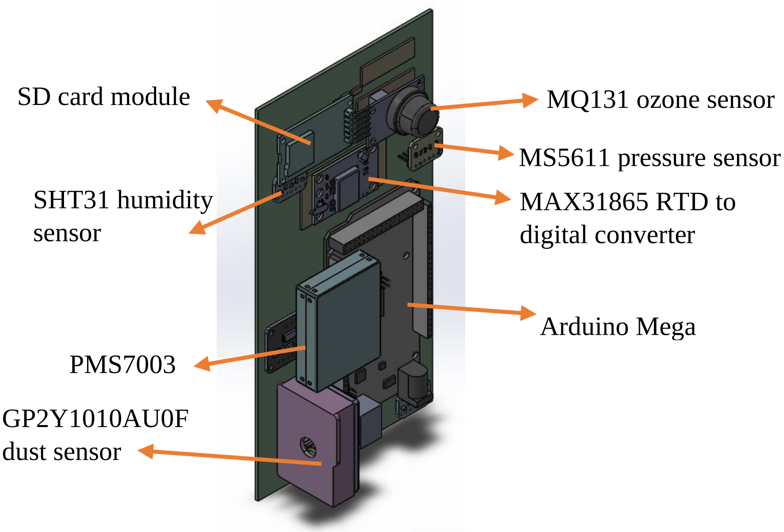

Fig. 4. Sensors inside the PETG box

Different components were located inside the PETG box, as it was planned to test the performance of different sensors at stratospheric conditions. SHT31 measures the temperature and humidity, MAX31865 measures the pressure inside the payload, MQ131 measures ozone concentration in ppm, PM7003 measures particle matter of different sizes, as PM1.0, PM2.5 and PM10, GP2Y1010AU0F measures dust concentration in mg/cm^3. Finally, all this data is acquired using an Arduino Mega, then it is sent through a serial port and stored in a SD card every 10 seconds.

Some electronic components are also shown in Figure 3, as the DC-DC converter, which provide an output voltage suitable for all the components, a fan that generates the flow, and a GPS that provides the location of the payload.

3. Payload performance

Before the integration test, the systems of the payload were tested under environmental conditions, however, it was not possible to test its performance under stratospheric conditions, because it was not possible to acquire the right equipment and environments due to the covid pandemic. The payload was tested under stratospheric conditions for the first time during the integration test.

3.1. Integration and thermo vacuum test

During the integration test, the payload showed a good performance, since all the commands worked, and the communication system worked as expected. However, during the thermo vacuum test some of the sub systems failed.

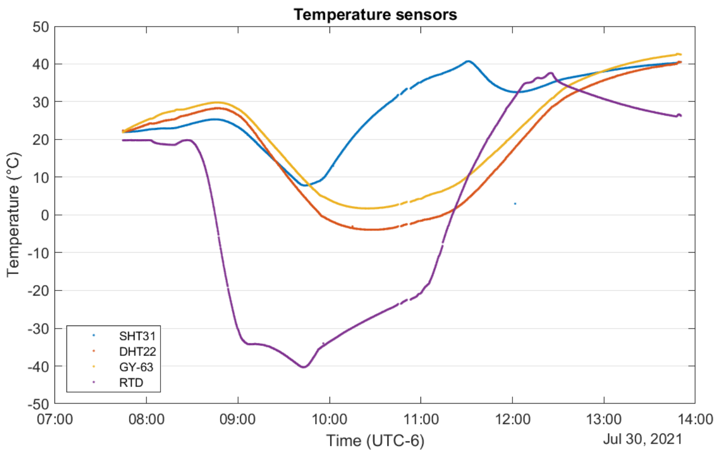

Fig. 5. Temperature sensors during thermo vacuum test

Figure 5 shows how the data acquired by the temperature sensors changed during the thermo vacuum test, RTD measures the temperature outside the payload, SHT 31 was located outside the PETG box, near the heating pad, so its measurements are directly affected when the heating pads are turned on. As it is shown at 09:35 where it temperature began to increase. DHT22 and GY63 were located inside the PETG box, its values are different because they were located at different places of the box, however, GY63 is more precise than DHT22, so its data is considered as the temperature inside the box.

Figure 6 shows how the pressure changed during the thermo vacuum test, it is shown because the performance of the sensors were related with these information. Figure7, 8 and 9 show the performance of the main sensors, MQ131, PMS7003 and GP2Y1010AU0F.

MQ131 and PMS7003 did not work in the vacuum, however, they acquired data under environmental conditions, MQ131 data showed a good performance, its data seems right, however, there is not a way to analyze its performance, as there are no data to compare it. PMS7003 worked only after the rise of pressure at 11:00 am. When the data does not change, it means that the sensor is not acquiring new information, as it is shown in Figure 7 after 12:30.

GP2Y1010AU0F had a strange performance during the test, since it worked during the vacuum, but only after 10:00 am, as it is shown in Figure 9. Its values are under the expected range, as it shows a similar behavior as the PMS7003 when it acquires new data.

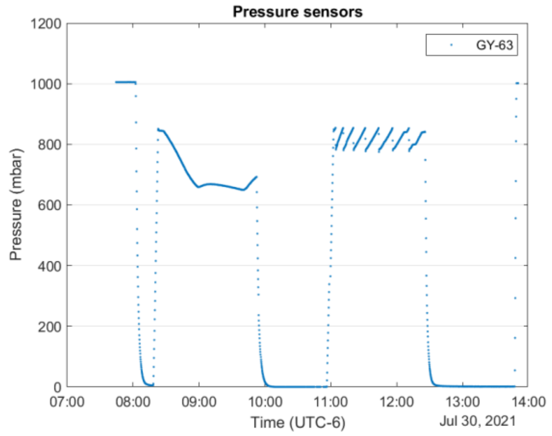

Fig. 6. Pressure sensor measurement during the Thermo vacuum test

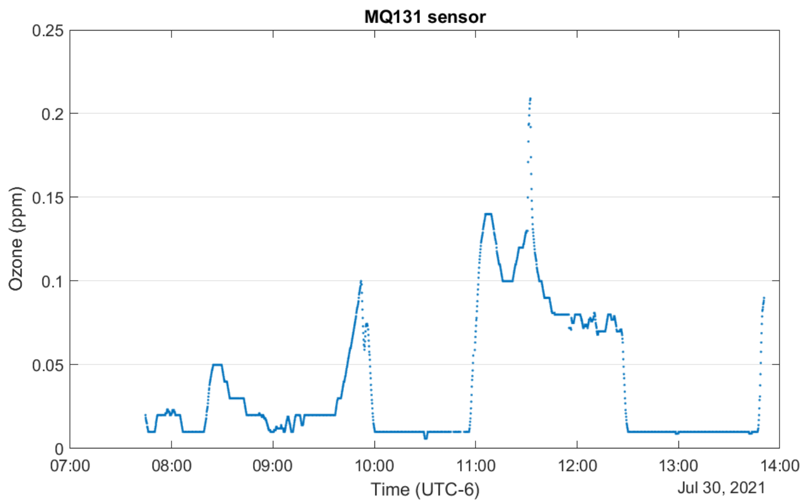

Fig. 7. MQ 131 measurement during thermo vacuum test.

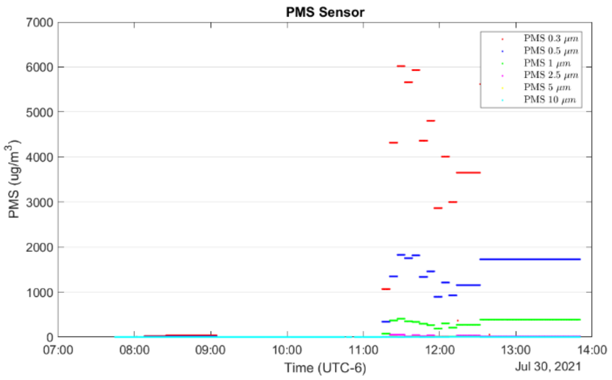

Fig. 8. PMS measurement during thermo vacuum test

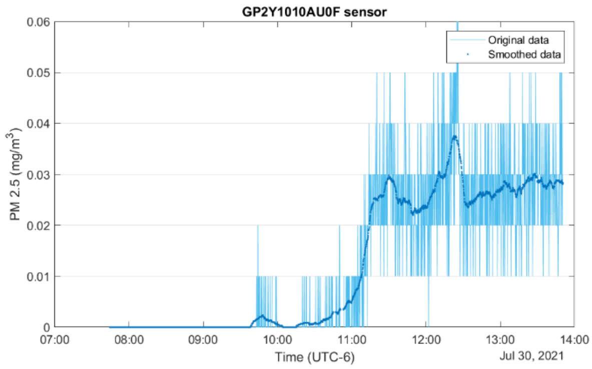

Fig. 9. GP2Y1010AU0F measurement during thermo vacuum test

3.2. Flight performance

During the launch of the payload some systems worked as expected. However, PMS, GPS and current sensors did not work as expected. Temperature, pressure, MQ131 and GP2Y1010AU0F acquired more reliable information, which will be further analyzed.

HASP current sensors had a strange performance during some moments of the flight, Figure 10 shows how its data changed during the flight. Wanka current showed a different behavior from the one acquired by the HASP sensors. It has to be considered that the HASP voltage was 30V and the Wanka sensors measured the current at 5V. However, there is not a relationship between both sensors.

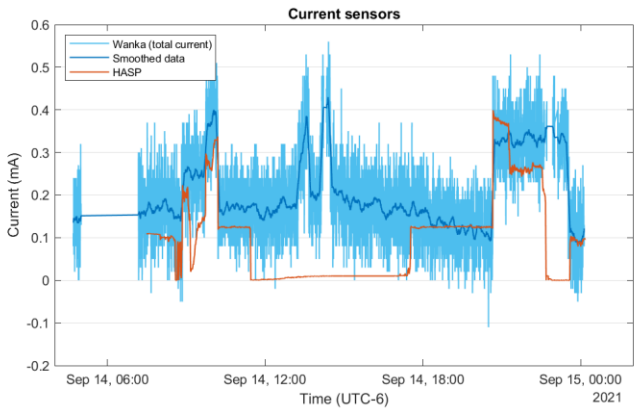

Fig. 10. Current sensors flight data

Temperature inside the payload was always inside the optimal parameters for the sensors to work. RTD was located outside the payload, and it showed a similar behavior to the shown by the HASP sensors. Its data was very similar to the one from HASP after 19:00, but it had a great difference when the temperature was above -20°C. It must be considered that the RTD and HASP sensors are in different positions, which is the reason of this difference. SHT31 is a sensor located outside the PETG box, and near the heating pads, so it is directly affected when the heating pads are turned on. GY63 and DHT22 are located inside the PETG box, so it is the temperature which the sensors are exposed, GY63 is more reliable than the one acquired by the DHT22. The polyurethane foam layer is the part of the payload that protected the sensors, so it is considered that it worked fine.

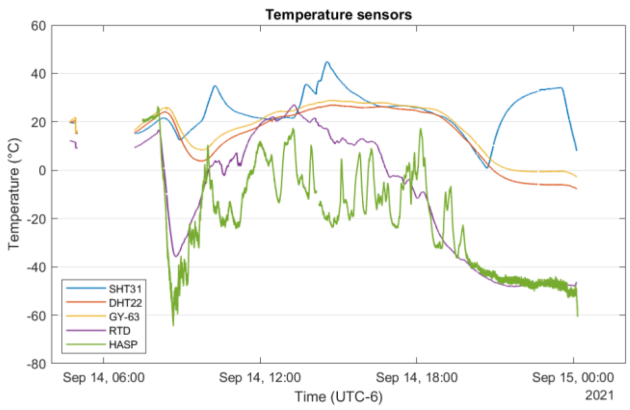

Fig. 11. Temperature sensors flight data

PMS did not work as expected, it worked before the launch and during the first minutes, but then it stopped working.

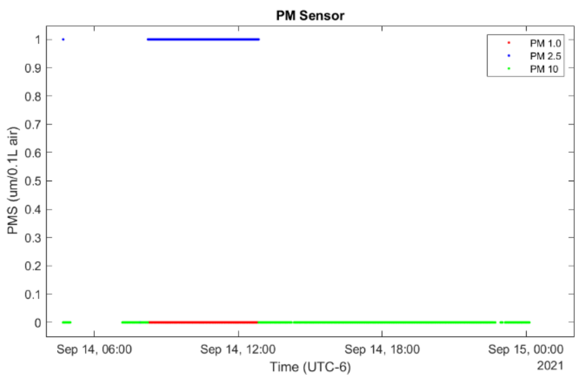

Fig. 12. PMS flight data

GP2Y1010AU0f worked as expected, and its data is considered the most valuable from the launch, the sensor is low cost, which is the reason why its data had to be smoothed to understand its behavior.

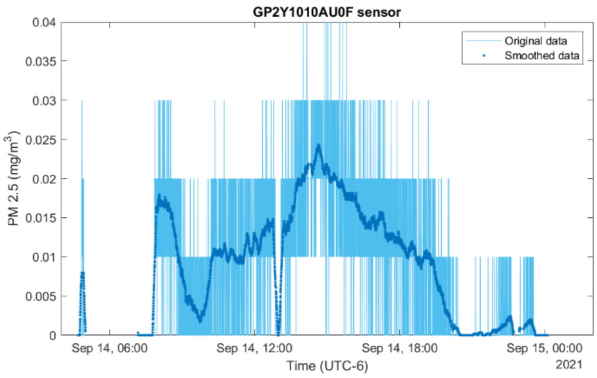

Fig. 13. GP2Y1010AU0F flight data.

Finally, MQ131 worked during the flight, its data was continuously acquired, but it did not show a good performance, which will be analyzed in the next section.

3.3. Thermal analysis of the payload

A thermal steady state analysis was performed to show the temperature variation through the payload. The input temperature was used according to the shown in Figure 11. Thermal properties of the materials were acquired from [11].

The simulation conditions were:

- External temperature: RTD sensor (Figure 11).
- Isotropic thermal conductivity of Aluminum: 237.5 W/m.°C
- Isotropic thermal conductivity of Polyurethane foam: 0.026W/m.°C
- Isotropic thermal conductivity of PCB: 0.35W/m.°C

The simulations considered conduction through the aluminum structure and the polyurethane foam and convection though air inside the payload. The results of the thermal simulations are shown from Figure 14 to 17, where 4 outside temperatures were considered (-35.81 °C, 26.61 °C, 10.61°C and -45.13°C).

STATE 1:

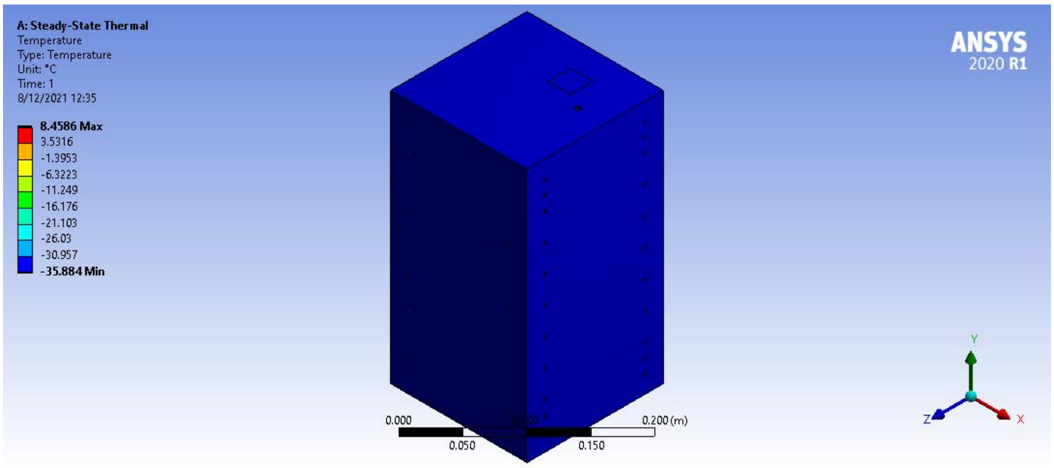

Fig. 14.1. External payload temperature at an outside temperature of -35.81°C

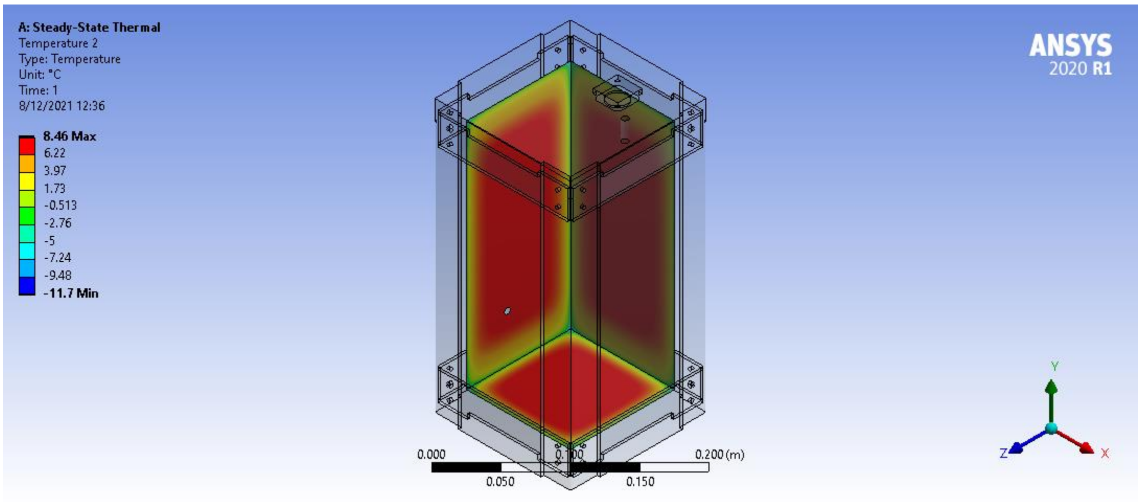

Fig. 14.2. Temperature of the inner wall of the payload insulation at an outside temperature of -35.81°C.

STATE 2:

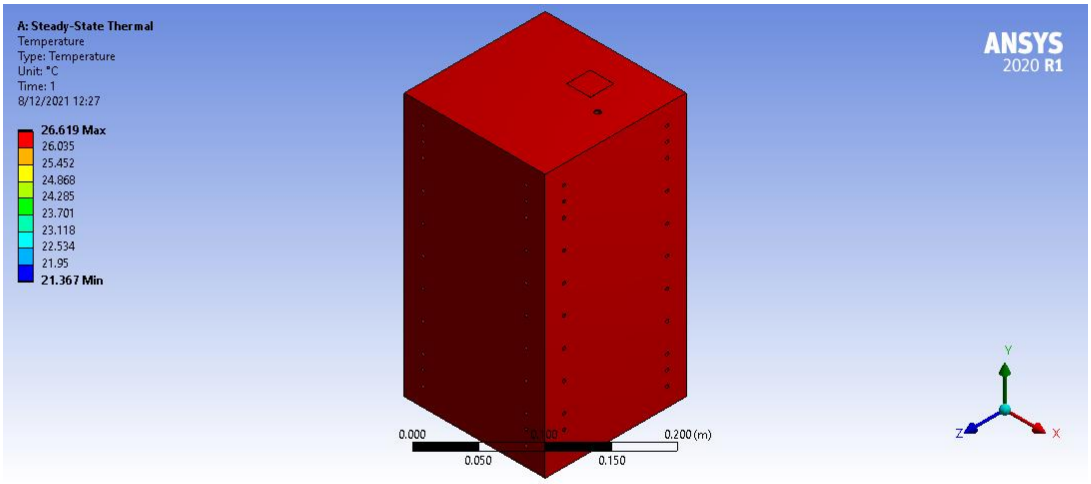

Fig. 15.1. External payload temperature at an outside temperature of 26.61°C

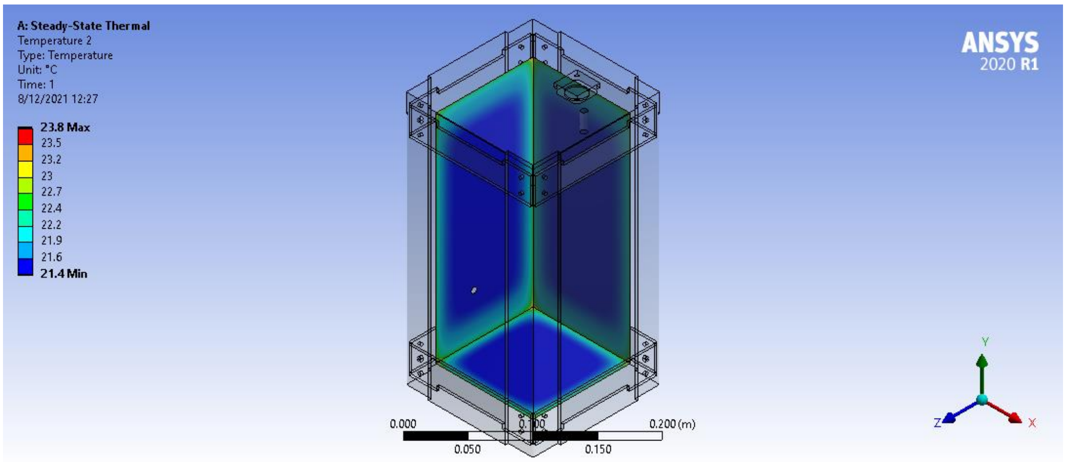

Fig. 15.2. Temperature of the inner wall of the payload insulation at an outside temperature of 26.61°C.

STATE 3:

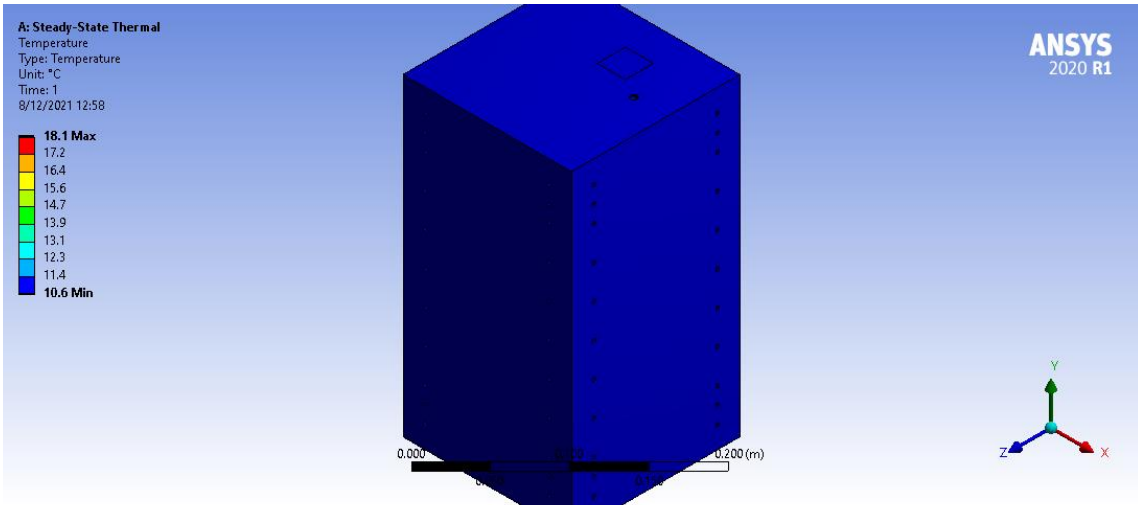

Fig. 16.1. External payload temperature at an outside temperature of 10.61°C

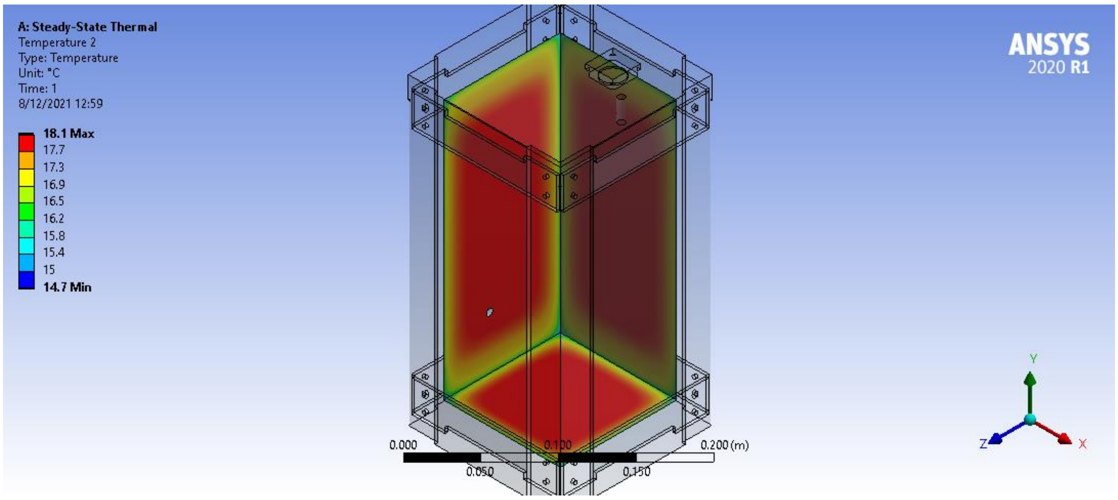

Fig. 16.2. Temperature of the inner wall of the payload insulation at an outside temperature of 10.61°C.

STATE 4:

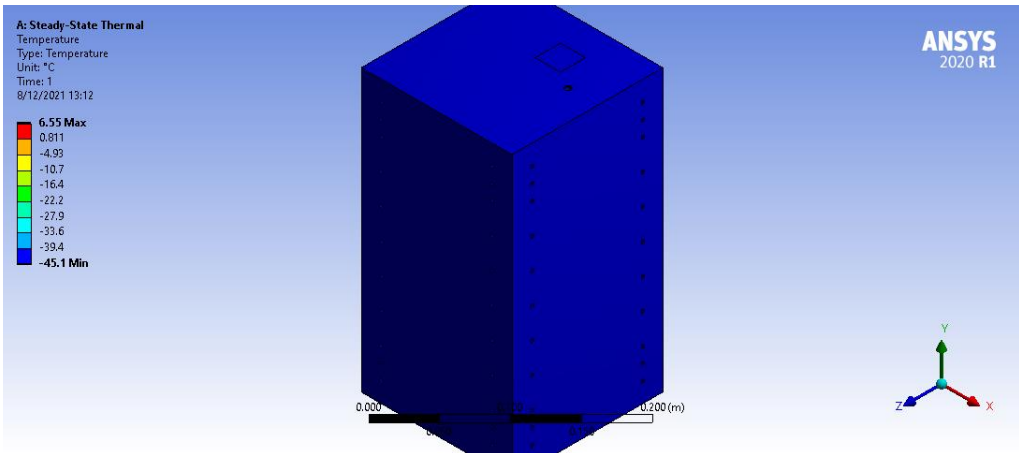

Fig. 17.1. External payload temperature at an outside temperature of -45.03°C

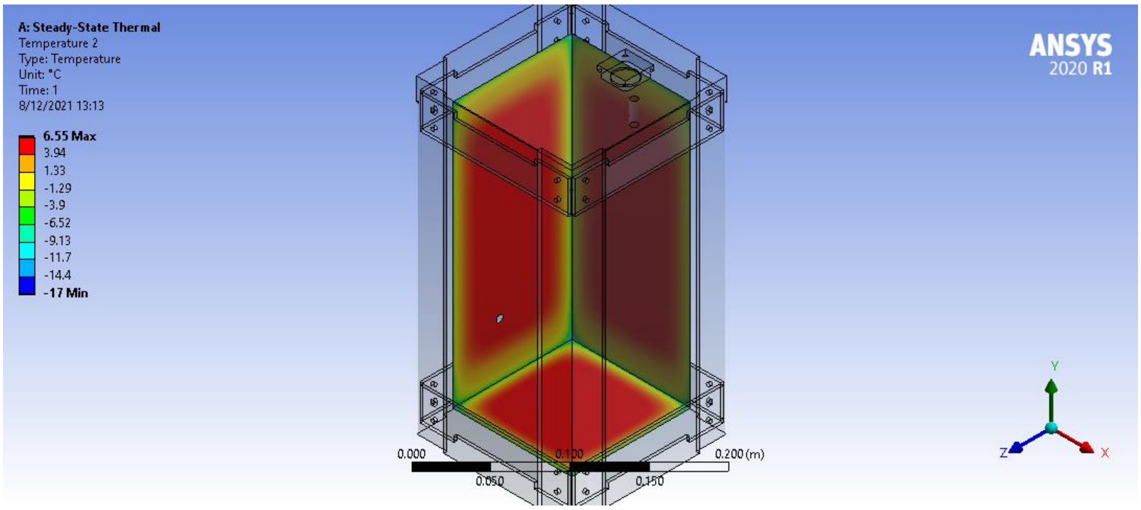

Fig. 17.2. Temperature of the inner wall of the payload insulation at an outside temperature of -45.03°C.

Finally, Table 1 shows the difference between the temperature measured by the sensors and the acquired through the simulations. It must be considered that the internal temperature is acquired from the SHT31, and the simulation is not considering some elements inside the payload, as the copper pipe or the PETG box. The RTD data is considered as the input for the simulation, so the external temperature from simulation has a similar value. There were considered points were the SHT31 was lower than the one acquired from the DHT22 and GY63,

Table 1. Acquired and simulated temperature comparison

Time (UTC-6)	SHT31 temperature (°C)	Internal temperature from simulation (°C)	RTD temperature (°C)	External temperature from simulation (°C)
STATE 1				
08:45:24	15.45	-11.47 - 8.45	-35.81	-35.88
08:46:24	15.24	-11.47 - 8.45	-35.81	-35.88
STATE 2				
13:13:24	21.59	21.46 - 23.8	26.61	26.61
13:20:24	22.5	21.46 - 23.8	26.61	26.61
STATE 3				
07:24:24	15.71	14.7 - 18.1	10.61	10.6
07:24:24	15.72	14.7 - 18.1	10.61	10.6
STATE 4				
20:44:24	2.18	-17 - 6.55	-45.03	-45.1
20:44:24	2.31	-17 - 6.55	-45.03	-45.1

4. Data analysis

In this section it will be analyzed the data from the GP2Y1010AU0F and MQ131 sensors, as they are the most important part of the flight, The rest of the sensors were mentioned in the part 3, and the reason of their behavior will be explained in the part 5.

To analyze the acquire data, two conditions will be considered, the first one will be the rise of the payload, which is considered since the payload was launched until it reached its top altitude, from 08:02:00 to 09:53:00 UTC-6, and the second part last until the end of the flight at 00:03:00 UTC-6. The flight profile was used to synchronize the data acquired by the payload with the position and timestamp provided by HASP, so that the graphs show reliable information regarding their position and the timing of the measurements.

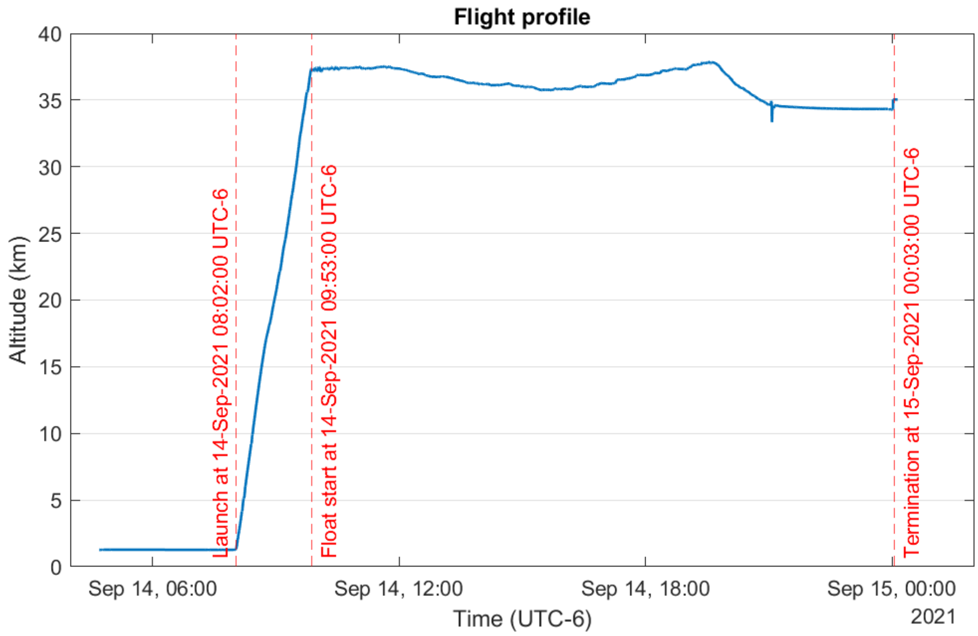

Fig. 18. Flight altitude

MQ131 is a low-cost ozone sensor, it was used because ozone concentration is one of the parameters that are commonly studied in Peru. The objective of using this sensor was to analyze its performance, so it can be used for future launches.

MQ131 measures ozone concentration through its conductivity, when the gas concentration rises, the sensor's conductivity gets lower. It must be heated a certain time before acquiring data, this time is calculated using a calibration process before the launch of the payload. During its calibration, it acquires ozone concentration once per second until it acquires the same value 15 times. The time it takes for the sensor to do this is the time it will consider acquiring data, as it considers that this is the time necessary to have stable measurements. However, it is expected to work in an environment without a constant change on its conditions, and has correction ratios for some situations, depending on the temperature and the humidity. Unfortunately, during a High-Altitude Balloon flight environmental parameters change constantly, and the sensor can not calibrate adequately, which leads to a constant error in the acquired data.

To solve this problem the team worked directly with the data acquired from the analog input of the sensor, processed its information after the flight considering the correcting ratios for the different environmental conditions during the flight, which generates the graph shown in Figures 19.1 and 19.2. Figure 19.2 shows how the ozone concentration variated during the flight and considering its georeferenced. Figure 19.1 shows a good performance, as the ozone concentration has a peak at 25 km where the ozone layer is located. However, during the first 10 km of the ascent the measurements acquired by the sensor did not show an adequate performance. This is because in this section the humidity and temperature change very fast, and the sensor is not adapted to work under these conditions.

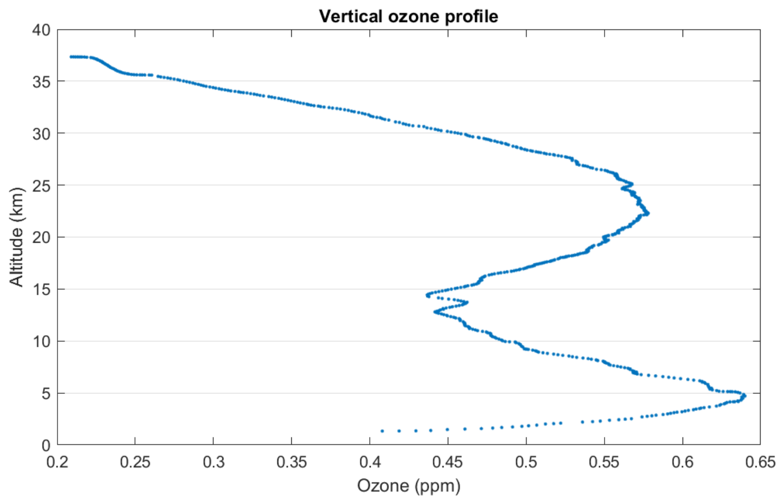

Fig. 19.1. Ozone vs altitude

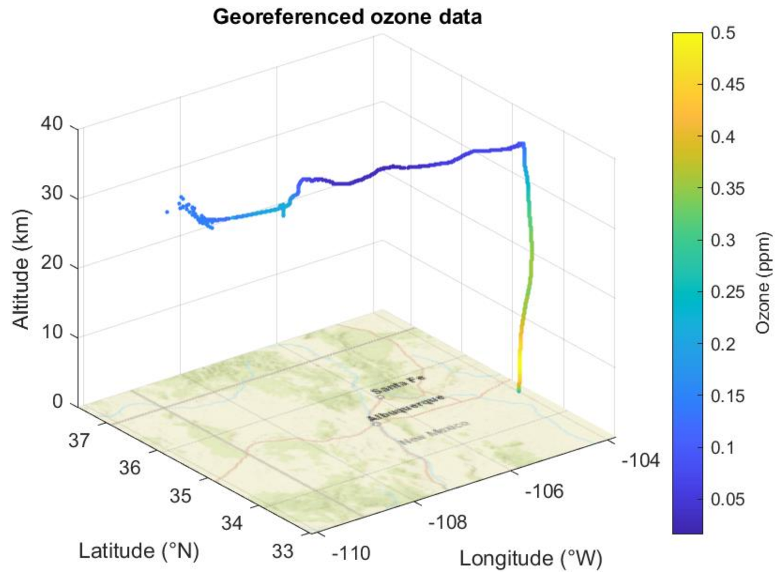

Fig. 19.2. Georeferenced ozone data

GP2Y1010AU0F is the sensor used to measure dust concentration in mg/m^3, it uses an optical system to measure this parameter. It uses a light emitted by a LED, which is spotted with a lens and a slit as it is shown in Figure 20. Also, the light detector uses lens and a slit in front of it to cut disturbance light and to detect light reflection. The detector detects the light reflected by the particles, current in proportion to amount of the detected light through the analog output port, after the amplifier circuit amplifies the current from the device.

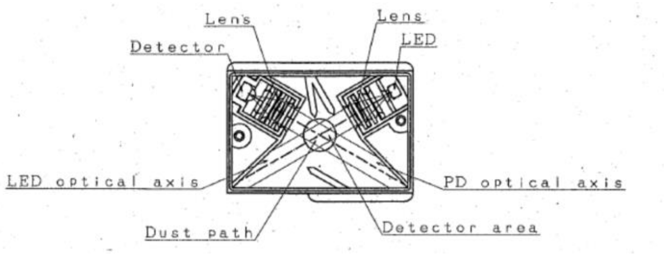

Fig. 20. GP2Y1010AU0F internal configuration

This sensor acquired data during the whole flight, as it is shown in Figure 21.1, where it is shown how the dust concentration variated during the ascend of the payload, and in Figure 21.2 where it is shown how it changed during the flight in different places.

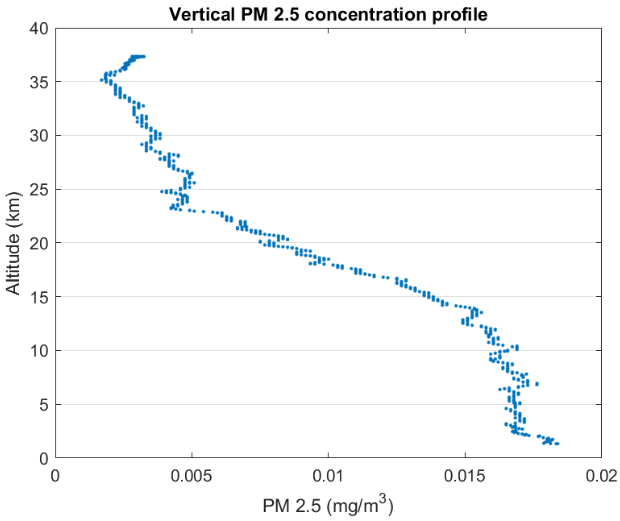

Fig. 21.1. Dust concentration vs altitude

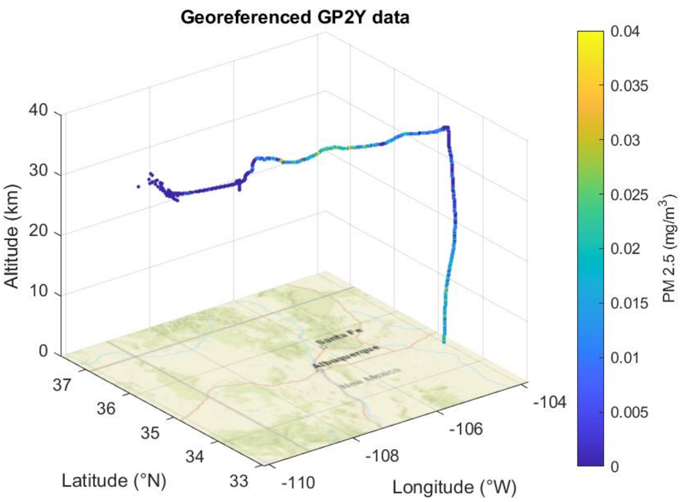

Fig. 21.2. Georeferenced dust concentration (mg/m^3)

Acquired data showed a good performance, as it was expected to have the profile obtained in Figure 22. Unfortunately, it is not possible to compare it directly with data from any satellite, as the research to acquire the aerosol concentration from satellite data is recent and it is still ongoing. [12].

Previous works have already launched this sensor and obtained dust concentration using it. These launches were made from the Pontiac Township High School, Illinois, USA, in June 2017. The data acquired in this launch is like the one acquired by the WANKA payload, with a similar range and variation with the altitude.

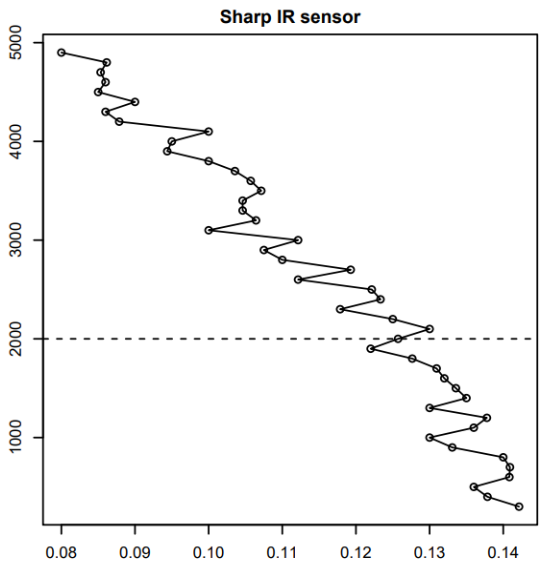

Fig. 22. Dust concentration (mg/m^3) vs altitude (m)

5. Conclusions

About the thermal analysis, SHT31 data is in the range of the internal temperature acquired through the simulations, expecting State 1, which can be explained by the thermal inertia of the thermal insulation. The polyurethane foam box helped to keep the sensors in an environment with a temperature above -5°C, which allowed them to work during the whole flight.

Temperature sensors worked fine, as it is shown in Figure 11, where the RTD showed data like the acquired by the HASP temperature sensors, and the rest of the sensors acquired data as expected because of the position where they were located.

Current sensors did not work fine, as it is shown in Figure 10, they acquired data that had a different tendency to the acquired by the HASP sensors.

GPS did not acquired data, it was tested after the flight and worked fine. Therefore, it can be deduced that there was interference with the acquired signals.

PMS did not work as expected as it is shown in Figure 12. It was tested after the flight and the acquired data is like the one acquired during the flight. It is suspected that the sensor was broken during the thermal vacuum test. It is not possible to know the reason why it is not working fine, as we can not know how the sensor works internally.

GP2Y1010AU0F acquired data during the whole flight. However, as it is shown in Figure 13, the sensor does not have a good sensitivity to perform these measurements, as it is expected to work in different environments as in industry or to measure the pollution of different cities.

MQ131 acquired data during the whole flight, but as it is shown in Fig.19.1, it did not have a good performance during the first 10 km of the ascent. As it has a peak at 5 km, and other at 22 km, which does not make sense, as there should be only one peak indicating the presence of the ozone layer, as it is shown in Figure 23.

It is expected to solve these problems in future launches, due to the COVID pandemic, it was not possible to test the payload under stratospheric conditions before the launch, but our team has made arrangements for the use of the appropriate equipment.

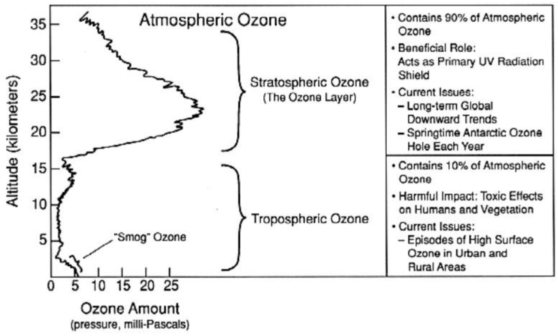

Fig. 23. Typical ozone sonding. [13]

6. Participation in events

- QHAT UNI (VI book, scholarship, and art fair), October 15, 2021.
- Television interview published on TV Peru on May 3, 2021 (https://www.facebook.com/centrotecnologiasuni/videos/651692892287172)
- Television interview published on TV Peru on September 6, 2021 (https://www.facebook.com/UNIoficial.pe/videos/181976027369720)
- Television interview published on Canal N on September 6, 2021. (https://www.facebook.com/UNIoficial.pe/videos/947755389114926)
- Television interview published on Panamericana TV on May 3, 2021. (https://www.youtube.com/watch?v=mVnZFXSmTa0&ab_channel=PanchoCavero)
- Peru 21, Article published in the newspaper on September 28, 2021. (https://peru21.pe/ciencia/nasa-jovenes-estudiantes-peruanos-llevaron-su-investigacion-a-la-estratosfera-con-la-nasa-uni-espacio-hasp-noticia/)
- TECNOTIC "Virtual conferences on innovative technologies for education", organized by the Peruvian Ministry of Education on March 15-27, 2021.
- Award ceremony organized by the rector of the Universidad Nacional de Ingeniería. (https://www.facebook.com/watch/live/?ref=watch_permalink&v=1044805392974378)
- It will be sent an abstract to the "ICCEMAE 2022: 16. International Conference on Computer, Electronics, Mechanical and Aerospace Engineering" which will take place in Brazil on March 03-04, 2022.

7. Placement of graduated students

Many of the members of the HASP team are already graduated, and working in many important companies, studying a master's degree or working on a thesis:

- Ramiro Tintaya is working in Cerro Verde, the fifth biggest copper mine of the world, which is administrated by Freeport McMoran Corporation.
- George Fajardo is working in Jicamarca Radio Observatory from the Geophysical Institute of Peru, which is the premier scientific facility in the world for studying the ionosphere.
- Germain Rosadio was accepted to work at Jicamarca Radio Observatory next summer, and to make an internship in the Alberta University, Canada.
- Anibal Esquiembre is working in Engitronic, a company dedicated to teaching robotics to kids.
- Giusep Baca is studying a master's degree in mechanical engineering at the Universidad Estadual Paulista "Júlio de Mesquita Filho", in Sao Paulo, Brasil.
- Dario Huanca is working in TUMI, a company dedicated to the construction of autonomous robots.
- Fredy Segama is working for an electrical installation company in Peru.
- Antony Davila is working on his thesis studying the performance of fluids in hidro electrical generation.
- Maria Muñoz is working on her thesis studying the performance of electronic systems at the stratosphere.
- Andre Robles is working in Mazbe Engineering, a company that provides industrial equipment.
- Lucas Taipe is working in the Universidad Nacional de Ingenieria, as part of the Biomedical Engineering, Materials and Medical Physics Laboratory

8. Testimonials from participants

- Julver Marrufo: "The experience I lived in the development of the payload was incredible because I was able to learn new things and enhance my knowledge with this rewarding experience, so when I finish my undergraduate stage, I would love to develop professionally in the aerospace area"

- Maria Muñoz: "This project has been my main motivation in the choice of my thesis topic and in the decision to be part of two projects aiming at space exploration. I plan to continue my master's and doctoral studies in related topics. I would like to continue participating in NASA programs and why not, someday be part of this institution where such important advances for humanity have been achieved."

- Miguel Morales: "I oversaw the electronic part, the experience of working in a multidisciplinary project is very rewarding, because you can acquire knowledge of many areas other than electronics, this allows you to have a bigger picture and to develop better and innovative projects in the future. Also, the experience of making friends with whom I had the opportunity to live this. It was amazing to work with

LSU and NASA and I thank you for giving us the opportunity to work with you. My future plans are to continue working with you and also to be able to specialize a little more in the computer knowledge part and continue updating myself with technology."

- Lucas Taipe: "Participating in the HASP program has allowed me to understand more about the operation of space platforms and the importance of developing new payload technologies for data collection; the program has certainly allowed me to develop my skills in aerospace issues as well as my communication skills, and that is why after my participation in the project I decided to join another student research group at my university, where they plan to develop a nanosatellite, I hope the HASP program will continue helping many more students and making the dream of aerospace research a reality."

9. References

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10. Full team personnel for HASP 2021

Name	Start Date	End Date	Role	Student Status	Race	Ethnicity	Gender	Disabled
Luis Fernando Suarez Salas	1/11/20	Present	Principal Investigator	Graduate	Latino	Hispanic	Male	No
Fredy Abel Segama Salvatierra	3/21/21	Present	Electronic team consultant	Graduate	Latino	Hispanic	Male	No
Ramiro Gustavo Tintaya Quispe	1/11/20	Present	Project Manager-PM sensor processing team leader	Graduate	Latino	Hispanic	Male	No
George Steve Fajardo Soria	1/11/20	Present	PM sensor processing team member	Graduate	Latino	Hispanic	Male	No
Zedrix Augusto Quispe Carrillo	1/12/20	Present	Management team member - Thermal and mechanical simulation team member	Undergrad	Latino	Hispanic	Male	No
Dario Adolfo Huanca Paredes	1/11/20	Present	PM sensor processing team member	Undergrad	Latino	Hispanic	Male	No
María Nimia Muñoz Díaz	15/1/21	Present	Satellite data processing team member-Management team member	Undergrad	Latino	Hispanic	Female	No
Michael Jean Pierre Quiquia Martinez	10/4/21	Present	Management team member	Undergrad	Latino	Hispanic	Female	No
Germain Rosadio Vega	1/12/20	Present	Satellite data processing team leader	Undergrad	Latino	Hispanic	Male	No
Alondra Janelle Alfaro Condori	3/10/21	Present	Satellite data processing team member	Undergrad	Latino	Hispanic	Female	No

Giusep Alexander Baca Bernabe	1/12/20	Present	Thermal and mechanical simulation team leader- Thermal control team member	Graduate	Latino	Hispanic	Male	No
Jose Maria Chong Luna	1/12/20	1/3/21	Thermal and mechanical simulation team member	Undergrad	Latino	Hispanic	Male	No
Antony Josel Dávila Paredes	1/4/21	Present	Thermal and mechanical simulation team leader	Undergrad	Latino	Hispanic	Male	No
Williams Kevin Solis Quispe	1/4/21	1/10/21	Thermal and mechanical simulation team leader	Undergrad	Latino	Hispanic	Male	No
Marco Enmanuel Chiroque Espinoza	1/11/20	Present	Thermal and mechanical simulation team member	Undergrad	Latino	Hispanic	Male	No
Julver Renaldo Marrufo Palli	1/12/20	Present	Thermal and mechanical simulation team member	Undergrad	Latino	Hispanic	Male	No
Martín Santos Salazar Macalupu	10/4/21	Present	Thermal and mechanical simulation team member	Undergrad	Latino	Hispanic	Male	No
Jean Piere Cholán Llamoga	1/11/20	1/10/21	Thermal and mechanical simulation team member	Undergrad	Latino	Hispanic	Male	No
Jose Andre Robles Loro	1/12/20	1/10/21	Thermal control team leader	Graduate	Latino	Hispanic	Male	No
Josue Santos Huaroto Villancencio	1/12/20	1/4/21	Flow control team leader	Undergrad	Latino	Hispanic	Male	No
Anibal Esquiembre Quiros	1/12/20	Present	Flow control team member	Undergrad	Latino	Hispanic	Male	No
Moises Stevend Meza Rodriguez	1/12/20	1/4/21	Microcontroller consultant	Graduate	Latino	Hispanic	Male	No
Miguel Morales Gonzales	1/12/20	Present	Electronic design team leader	Undergrad	Latino	Hispanic	Male	No
Lucas Nicolas Taipe Ramos	1/12/20	Present	Electronic design team member	Undergrad	Latino	Hispanic	Male	No
David Sergio Arrustico Villanueva	1/12/20	Present	Electronic design team member	Undergrad	Latino	Hispanic	Male	No