CFP-18-Zephyrus II

FINAL PAPER

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The Satellite of our team is a versatile mission module delivery platform to be used scientifically or otherwise. A wide range of missions can be carried out by a fully independent payload module, compatible with the delivery mechanism. Delivery is achieved by an autonomous algorithm controlling the braking lines of a ram air parachute by servos during flight. Although our algorithm guides the cansat autonomously, changes in the parameters can be made remotely by our software, while full flight telemetry is available as well. The payload mission that we will showcase is determining whether a planet can sustain terrestrial life by broadcasting and examining its abiotic factors. Those are light intensity, magnetic fields, UVA, VOCs,CO2, pressure,temperature, humidity, gravity acceleration.

I. Introduction

a. Primary mission For our Primary mission "Zephyrus II" is equipped with Adafruit's BME 280 sensor to measure temperature and pressure and a RFM96 LORA radio to beam it to the ground station.

b. Secondary mission Our secondary mission was the creation of a versatile mission module delivery platform to be used scientifically or otherwise, and the design of an equally important compatible showcase mission to make use of it.

II Project description

Our CanSat performed an autonomous, targeted, GPS guided landing, by ram - air parachute and provided flight telemetry data such as distance to target, or required direction.

- It features two way communication to the ground station. Apart from the constant incoming telemetry, commands can be sent to our CanSat, changing parameters like the flight scenario or the target, in real time.
- Modular design. Our CanSat (flight module) can carry and deliver any compatible module (payload module) to the target. Payloads are easily interchangeable and operate completely independent, in every aspect, from the flight module.
- We created a compatible scientific payload module to assess the possibility of terrestrial life on another planet. This is achieved by measuring a range of abiotic factors like light intensity (RGB), UVA radiation, Volatile organic compounds, humidity, CO2, magnetic field strength, pressure and temperature.
- A 30fps full HD camera will record the ground during the descent. Video frames were used for surveying the landscape by creating a composite image.

II.I Materials and structural design

For both test models and the final model a 3D printed structure was selected using PLA filament (poly lactic acid). Tests showed us that printing with 40% infill has the best strength - elasticity combination. No metallic supports are required since the PLA casing is very strong and elastic enough not to crack easily. Our models (Available at our open source package) were created with Solidworks.

On the inside, electronics components are being placed in slots. Screws are added where necessary to stabilize the parts.

The 0Flight Module has a cylindrical shape open at both ends. On one side a cap protects the servos and on the other side the payload is inserted. There are slots for batteries, servo mechanisms and all the electronics.

On top an opening is present for the GPS antenna that also allows air to flow to our BME280 sensor. (Press. Temp. Humidity)

Two circular openings allow for the parachute breaking lines to connect to the servomechanisms inside. Side slots are present for inserting the SDcard, for accessing the master switch and view the I/O LED. Connecting USB either for charging or uploading code is also done through slots. On the bottom a hole allows the camera to record the ground.

The Payload Module consists of a thick cap with holes for the sensors and an extruding casing designed to exactly fit on the inside of the flight module. Inside the casing a 3 level electronics assembly is attached with screws. As with the flight module holes are there for USB, SDcard, master switch, and I/O LED.

The Camera case carries the electronics and the battery of a SQ11 full HD camera. It is positioned in slots on the bottom of the flight module. It is fixed in place with the insertion of the Payload Module.

b. Parachutes Our choice for the recovery system was a ram-air parachute. This decision was made based on the fact that this specific type of parachute has some basic capabilities such as:

The ability to perform a multidirectional flight through a break system steered by servo motors

It is capable of a variable glide ratio as well as a variable decent rate which can be adjusted through the break system.

Resistibility in wind gusts provided mainly by the stabilizers on the side of the airfoil

We have created several parachutes for testing. Two of them, with different sizes were chosen by trial and error for the CanSat in Greece 2018 competition. Our goal was to achieve different descent rates for different locations. The bigger parachute has a descent rate of 4.3m/sec and slightly unstable at this weight. The smaller one, that was actually used, has a descent rate of 5.2m/sec that increases by spiral descent to 7m/sec.

We have constructed another two parachutes for testing. Our goal was to create a 3rd smaller parachute for use in the strong wind location of the European Competition. After testing, one of them we found that it was stable enough and with the required basic descent rate of 8m/sec. We needed to test the parachute for determining the maximum descent rate. This was be our choice for the competition and there was some more testing required. We strove for a big descent rate to eliminate the possibility of strong winds pushing our CanSat to the Sea.

The material selected to be used is skytex-27. Its weight (27gr/m2) and durability led us to choose it. The airfoil's aerodynamic elements like the drag coefficient, lift production, lift-induced drag, angle of attack are still being adjusted and selected through trial and error tests.

Multiple aerodynamic tests were conducted at a SolidWorks environment to determine possible corrections in the design. The only helpful estimate was that of the angle we should use to the horizontal plane. Trial and error is by far our main way of development.

Design: Our parachutes are Ram – air parachutes. Open at the front and sealed in the back, the design allows the air to enter the cells of the parachute and inflate them. That creates a wing suitable for flight. We have opted for a straight design with vertical stabilizers instead of a curved one for practical construction reasons, but also to make necessary calculations easier.

Our design had three line zones. Front, Middle Back. The back zone lines can be pulled by the servo motors and are being used as brakes. The braking lines connect to both the servos and the casing alike. When the servos retract to zero the casing receives the entire pull of the lines. That is to

make sure that the servos don't get damaged during the expected violent release. After the release, we initiate by command, the chosen flight scenario for the servos to start working. On every zone lines connect between cells and on the stabilizers leading to 7 lines per zone.

The parachute has 6 cells created by 5 separators. They inflate by incoming air pressure.

The latest design being tested has:

-20o angle of attack

40cm centre cord length

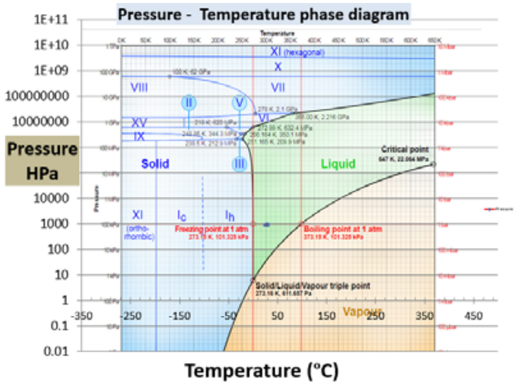
550 cm2 new area of action.

Different profiles were available. The bigger parachutes have a thicker profile but the smaller one, that we used, had a sleek faster one for speed. The first profile was copied from a DIY internet video while the second was found here. Since nothing existed on the internet at our size, trial and error was the way to develop a parachute.

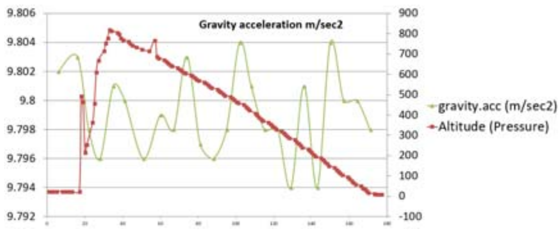
Calculations: We used a terminal velocity calculator to estimate the required area for a specific descent rate.It should be mentioned that it is not entirely correct for a gliding parachute, since it disregards lift created by the wing shape. We also found out that speed does not increase inverse proportionally to parachute area but rather does as shown on the graph.

III Scientific results

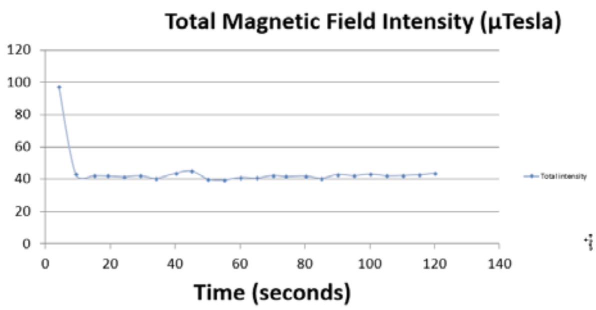
Telemetry provided continuous measurements since no technical issues were present. The device gather data reliably, at low cost, and its modularity proved practical for a change in missions. The only change of plans is the use of a drone instead of rockets for the ascend. This was a last minute change as the rockets proved to be unstable and unreliable. The graphs include the ascend of the drone in order to achieve an adequate dataset for plotting



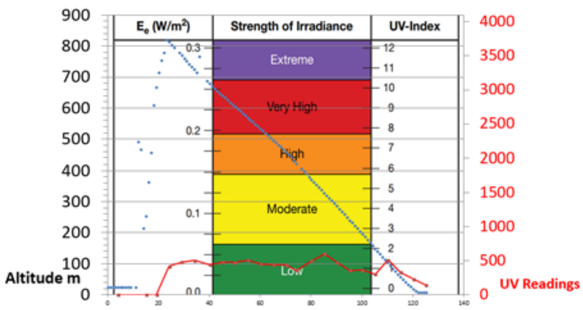
We used a phase diagram of water from the website of water structure and science. On this we placed the pressure values at y axis and temperature at x axis. The values we managed to acquire are the dots in the liquid part of the diagram as expected because the experiment took place on earth. Due to the wide range of the chart, all values will be in one spot. That is because the max height we reached was about 600m thus the pressure was 9465 Pa and the temperature was around 25-30 degrees . Hence not providing that wide range of measurements to be able to be depicted .



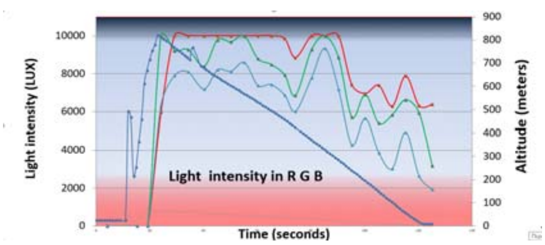
In the graph we can see the gravitational force at different altitudes which is as we expected different and can help us calculate the the mass and radius of a planet.



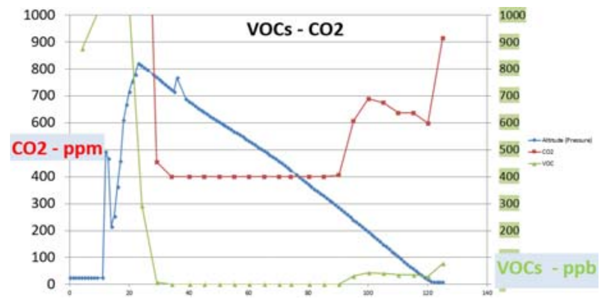
In this graph we depict the intensity of the magnetic field in relation to time which is as we expected somewhere in the range of 40-45μTesla which depends on the position of the satellite on a planet. For instance earth poles have approximately an intensity of 66μTesla whereas in Azores we can see we got most values in the range of 40-45μTesla



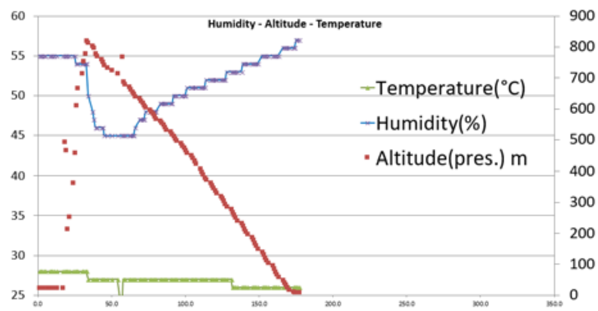
We chose to measure UVA because it penetrates the skin and creates mutations also a new sensor with UVA and UVB came out a few days before the final experiment. We found moderate UV intensity that allows the existence of single cell organisms but also provokes mutations and evolution as a result. Referencing the graph above we can see the altitude with the blue line and the intensity of UV with the red line. The values we received were arbitrary ,however based on the datasheet of our sensor they were matched with the Uv hazard intensity and intensity in W/m2



We measured the intensity of visible light in RGB . Our sensor detects up to 10000 lux. This is the usual limit over which photosynthesis ceases to improve in efficiency. The minimum threshold for effective photosynthesis is 1000-2000 lux. We found values in red and blue light between the two limits thus proving that photosynthesis can be efficient. Autotroph organisms on earth can absorb the red and blue light spectrum for photosynthesis. Hence if the experiment were to take place in another planet we would want to find similar chemistry correlations



We detected and retrieved data from our sensor about organic volatile compounds in (ppb) and indirectly Co2 in (ppm) .The values we received were over 400 ppm which means that there is a mild greenhouse effect.This combined with temperature and water existence can mean that the planet is quite far away from the parent star



Humidity of the atmosphere depicted using the blue color is reduced when the altitude is increased and is increased when the altitude decreased This lead to the conclusion that the source of humidity is the ground which indicates that there might be water on the surface of the planet.

IV Discussion

The experiment must be considered a success, since the measurements were confirmed either by external data or by theoretical models . Conclusions drawn from the data confirm that this is a habitable planet something we know to be true since we are on earth . A magnetic field is present, gravitational acceleration is optimal, there is carbon in the atmosphere meaning there is organic chemistry of some kind, uv radiation is within safe levels, while enough for mutations, and water is present and in liquid form as deduced from Pressure Temperature and Humidity data.

V Conclusions

In this section it is worth mentioning that all the subsystems of our Cansat's payload functioned as expected. The values we received from our sensors lived up to our expectations with only two exceptions, the gravitational acceleration sensor and camera. The values we received were ideal up until the third decimal. However the 4th decimal fluctuated a lot not allowing us to get accurate calculations. This problem was encountered due to the extreme acceleration that occurred during the launch not allowing us to get accurate enough values for calculating a planet's mass and radius.This problem could be resolved with the use of a better sensor. However due to the very strict time frame we had to manufacture the payload we could not research further. As for the camera that would map the ground the g force made the sd come free not allowing us to record video.This problem could be resolved easily by using a printed support for the sd card. Furthermore a current design flaw lies in the materials used for our payload. At this time it is mainly plastic as we used a 3d printer to be able to create different versions fast. However this was necessary in order to stay within the 300 to 350 gram limitation. This problem could be resolved in the future by ordering fabricated metal parts from 3rd party sources.Furthermore sufficient research there has been made about the addition of a Geiger counter. However most of these are fragile so we have discovered that insulating a photodiode such as a solar panel from radio and light interference can help us measure alpha and gamma radiation which would be a great addition to our cansat as it would allow us to further understand the conditions on the planet. This experiment has proved that it could be viable to drop micro satellites in a planetary system like the newly discovered trappist-1. Hence comparing the values of each planet we could decide which has the highest possibility of being able to support life.

It is hoped that the adoption of the project's conclusions will act as a starting point for future research. The improvement of the design (e.g. fixing some minor design flaws such as the one that occured with the sensor of gravitational acceleration malfunctioning) will enable us to confront the limitations already mentioned .