ZEPHYRUS II

GREECE

1. Table of Contents

Zephyrus II – Ioannina

2. INTRODUCTION

Our team is called **"Zephyrus II"** and we are from Ioannina, Greece.

a. Ioannina

Img. 1 - Ioannina

Ioannina is the capital and the largest city of the prefecture of Epirus. It is also known as "The city of the Silverman", as that was the main occupation during the previous century.

Img. 2 – Prefecture of Epirus

b. Team name origin

Our teams name was chosen due to our last year's mission. Zephyrus or Zephyr was a god of western winds and bringer of light, spring, and early summer breezes.

Img. 3 – God Zephyrus

c. Members

Our team consists of 13 members, 11 students from different schools of our city and 2 teachers.

Img. 4 – Our team

Students	
KONSTANTINOS	PILIOS
KONSTANTINOS	LOLOS
NIKOLAOS PANAGIOTIS	KALAMPOKIS
MARIA GEORGIA	DASOULA
MYRSINI	ANASTASOYLI
GEORGIOS	KAPELIS
PARASKEVI MARINA	KANDRELI
GEORGIOS	OIKONOMOU
DIMITRIOS	GEORGIOU
PARASKEVI	KAPSALI
ELEFTHERIA	VLACHOU
Teachers	
NIKOS	MARETAS
GEORGE	SKARGIOTIS

d. Team organization and roles

Due to competition restrictions only 6 students and one teacher will participate in the European Launch campaign. This is who they are.

- **Konstantinos Pelios**

He is our Team leader. He is responsible for our mechanical design and recovery system but oversaw every part of the mission.
He was interested in robotics and spacecraft rocket-type constructions from an early age.

He was recently accepted in the aerospace engineering department of the T.U. Delft and will be continuing his studies there starting September.
This project took several hours a week, mostly after school. Especially the parachute part posed a difficult and time consuming challenge.

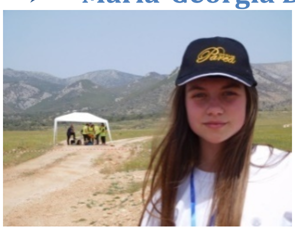
- **Konstandinos Lolos**

His field is electronics, engineering and 3d model design. Everything on our CanSat was hand soldered by him. He has created our board's layouts, our 3d printer models and assembled our printer. He is also behind our abiotic factors scientific part. He is interested in 3d printing and in becoming an electronics engineer. He is proficient in electronics from an early age. His research for this project started in summer and has spent many hours in designing and building our CanSat.

- **Nikolaos Kalampokis**

He is our lead programmer. His task was to bring our CanSat to life with his coding. He is one of our ground station operators and has a key role in data analysis. His knowledge includes programming in HTML, c++, java script, java, css, 3D design and also knows basic electronics and how to assemble simple circuits. He is interested in computer science and programming. He spent 2-3 hours in school per week and endless hours at home for this project, since programming is a solitary task.

- **Maria-Georgia Dasoula**



She is responsible for our reports and presentations. She is interested in Mathematics and physics and would like to study Geology.

She has put a lot of effort in us being able to present our work in the best possible way. Her work was mostly after school and included coordinating our members in order to produce the required reports and presentations. She still has a lot of work lying ahead.

- **Myrsini Anastasouli**

Our entire outreach program runs through her. She has contacted public figures for their support and has arranged several actions for increasing publicity. Our internet presence, but mostly our media coverage has a lot to do with her work. She is interested in economics and mathematics.

- **Giorgos Kapelis**

He is an all arounder. He has been helping out in every aspect necessary and has been our antenna guy for the last two years. His knowledge in 3D graphics, animation and digital art has been put to use quite often. He is about to begin his studies in the Audio- Visual Arts School in Corfu Greece.

- **Nikolaos Maretas**

He is our biology teacher and his being very fluent in technology helped us a lot in our effort. Together with ***George Skargiotis*** they have done a great job of coordinating our team, refining our ideas and managing the very difficult task of navigating through Greek bureaucracy to fund us and get us here.

3. OUR MISSION

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 is 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. In order to achieve this we need to meet the following goals.

➢ Mission goals

• Our CanSat will perform an ***autonomous, targeted, GPS guided landing, by ram - air parachute*** and provide 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 fullHD camera will record the ground during the descent. Video frames will be used for ***surveying the landscape*** by creating a composite image.

c. Inspiration for our mission

Inspiration for our mission came from the hurricanes that battered the US in September. Planes are known to drop data gathering devices into the storm from tubes inside the plane. We thought about the possibility of multiple deliveries from a single drop from a plane and took it a step further.

Img. 5 - Dropsonde release

A standard flight module with a simple design would drop production cost and interchangeable modules to go with it, make it versatile. The determining of terrestrial life sustainability part of our mission was inspired by the discovery of the Trappist-1 star system that contains possible habitable planets.

4. EXPECTED RESULTS

Desired Mission Execution

We aspire to present our results on the two different aspects of our mission. A spreadsheet has been created to accelerate data processing. It creates either graphs or ready to use code for octave or Google earth track creator.

a. Mission delivery platform

➢ Modular Design

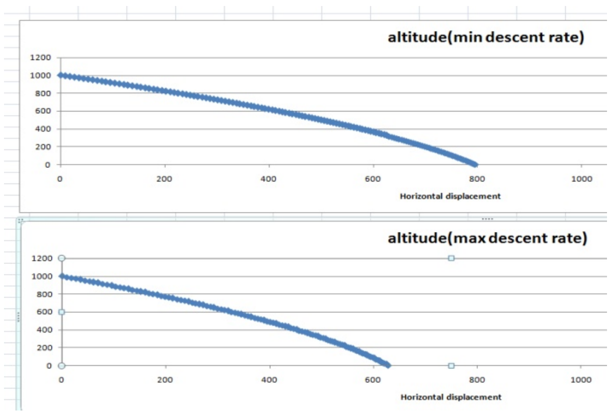
We expect to assemble our CanSat shortly before launch as we successfully did in the national competition. This will prove the practicality, of our design of easily interchangeable mission modules.

➢ Bidirectional communication

A GPS target and a flight scenario will be set for our CanSat to operate with. That will be done remotely by commands from our ground station. It was successfully done in the national competition.

➢ Targeted descend

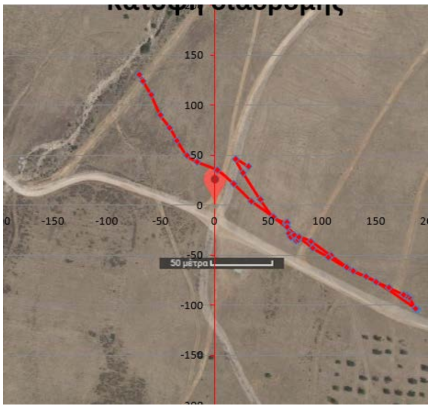
We expect a flight path that will confirm our predictions. Based on wind speed we will choose a fitting target, within our calculated landing window for our CanSat to hit. We have created a calculation model that can predict the horizontal range of our CanSat based on wind speed altitude and descent rate controlled by our algorithm.



Img. 6 - min. / max. descent rate(m/sec) projections with altitude (m).

➢ Position and direction in 3d space

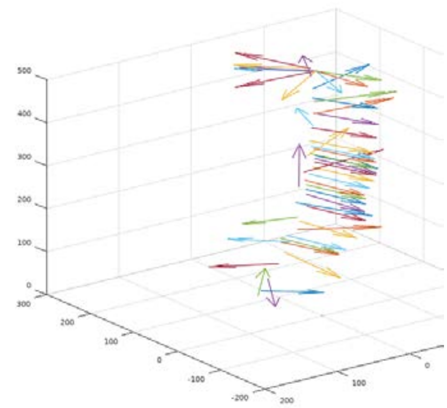
We will visualize the trajectory of our CanSat in different ways with the use of **Google earth, MS excel, and octave**.



Img. 7 – 2d trajectory plot on Google maps (CanSat in Greece 2018)

Img. 8 - 3d trajectory Google earth (CanSat in Greece 2018)

Our telemetry will provide data on location, height and direction in 3 axes. That data will be used to display our trajectory for reviewing our mission and flight descent behaviour.

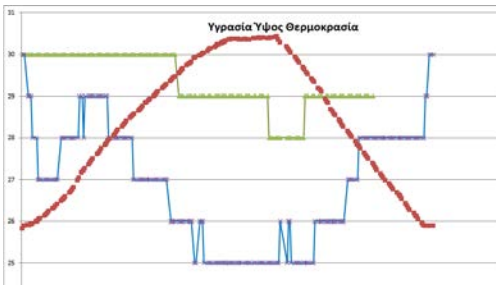


Img. 9 - Location, direction vectors - Octave (CanSat in Greece 2018)

b. Life sustainability of a planet

➢ Water presence

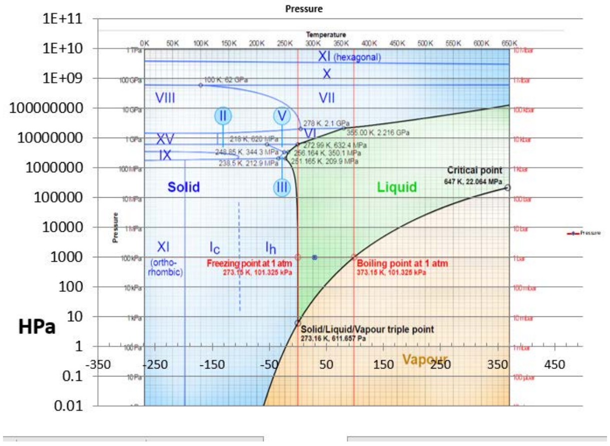
Humidity levels will be recorded by our BME280 sensor to prove the existence of water. If humidity correlates with height the source of water could be the ground.



Img. 10 - % Humidity (blue) vs. Altitude(m) (red) (CanSat in Greece 2018)

➢ Liquid water

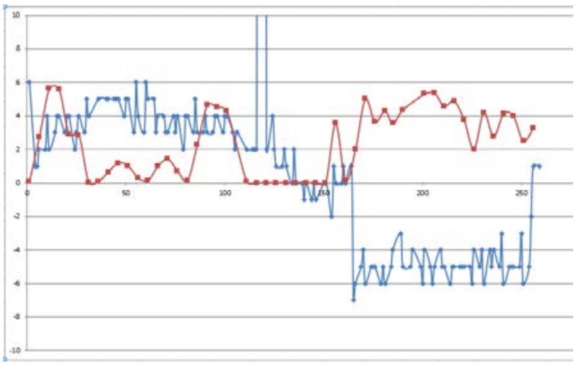
A phase diagram of water will plot our temperature and pressure data to prove the existence of ***liquid*** water.



Img. 11 - Water phase diagram Pressure (Hpa) Temperature(°C) (CanSat in Greece 2018)

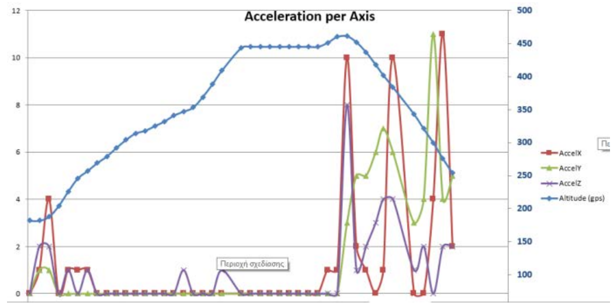
➢ Atmospheric stability

Our CanSat's speed and acceleration provided by GPS module, BME280 and BNO055 can provide us with an estimate of wind speeds and atmospheric turbulence.



Img. 12 - Horizontal & vertical speed (m/sec) (CanSat in Greece 2018)

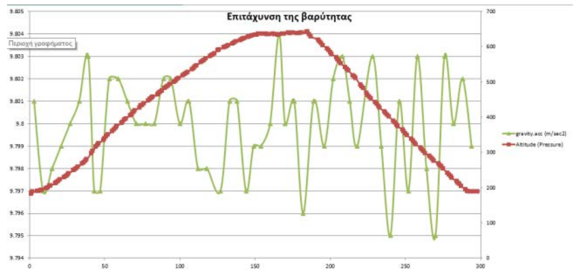
Both need to be moderate for life to survive on the surface of the planet.



Img. 13 - Acceleration per axis (m/sec^2) (CanSat in Greece 2018)

➢ Gravity acceleration

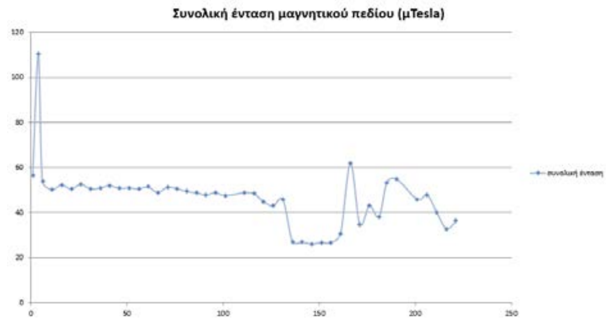
Our BNO055 sensor can output gravity acceleration even while moving. A value close to that of earth is an indicator for suitability for life. If we know the planets radius we could calculate its mean density and get a sense of its composition.



Img. 14 - Gravity acceleration (m/sec^2) (green) & altitude (m) (red) (CanSat in Greece 2018)

➢ Magnetic field intensity

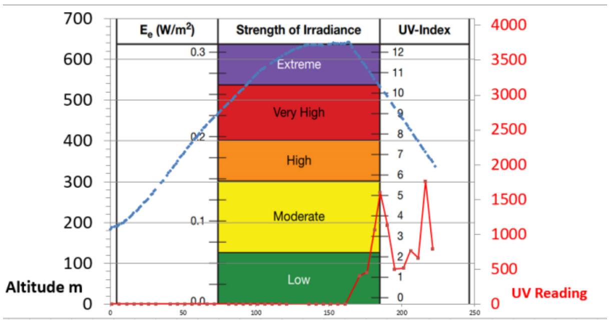
A planetary magnetic field not only protects from dangerous stellar winds but also indicates a hot, fluid Ni – Fe planetary core. Heat convection in the mantle is the main cause of geological activity, which is part of biogeochemical cycle activity necessary for life.



Img. 15 - Magnetic field intensity (μTesla) with time (sec) (CanSat in Greece 2018)

➢ UVA radiation

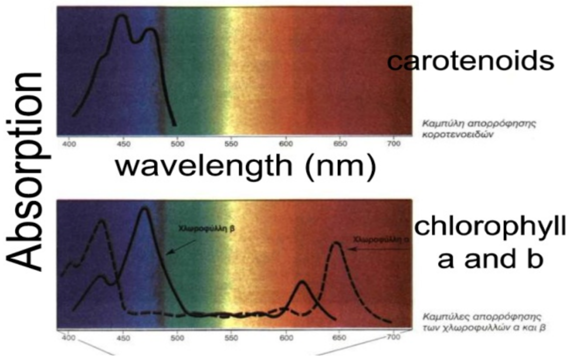
Our VEML6070 sensor measures UVA radiation at around 350nm. UV radiation in high intensity will lead to a sterile planet surface. Smaller intensity radiation can be useful in creating mutations for evolution to proceed faster.



Img. 16 - UVA radiation (CanSat in Greece 2018)

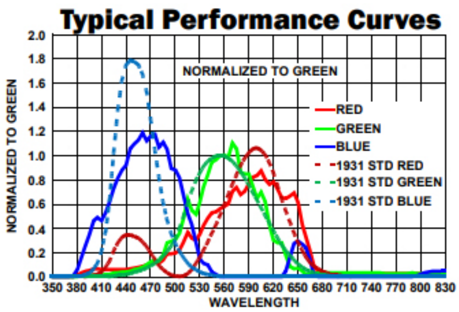
➢ RGB Light intensity

Light intensity plays a very important role in photosynthesis. On earth chlorophyll and carotenoids absorb light at the red and blue wavelength.



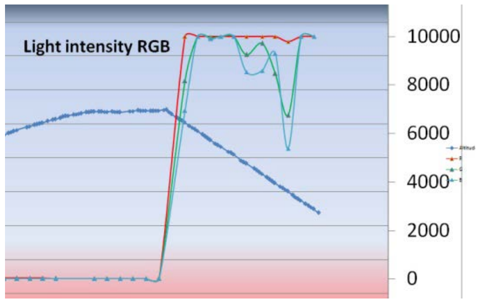
Img. 17 – Light absorption - photosynthesis (Greek school book)

Our sensor ISL29125 measures light at different channels.



Img. 18 – Sensor datasheet performance

It saturates at 10000Lux. Any values above 1000-2000Lux suggest adequate light for photosynthesis. Even a saturated sensor is no problem since photosynthesis does not increase above 10000Lux.



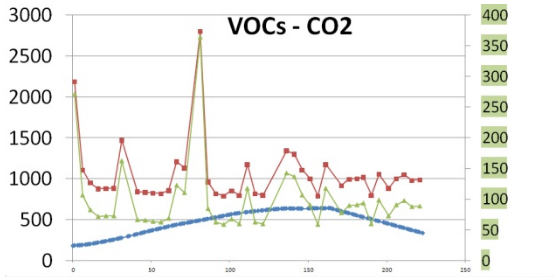
Img. 19 - Light intensity measurements (lux) (CanSat in Greece 2018)

➢ Volatile organic compounds

We will be measuring organic compounds in the air in ppb by our CCS811 sensor. The source of VOCs on a planet may not be of biological origin but the very existence increases chances of life creation.

➢ CO2 concentration (eq)

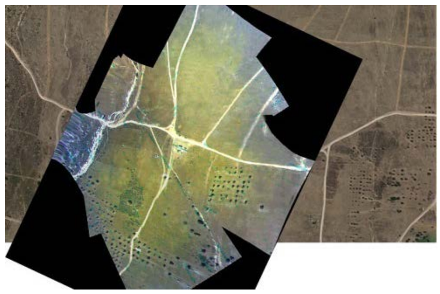
The same sensor outputs an estimate on CO_2 concentration in ppm. Earth has now more than 400ppm concentration. A relatively low concentration with earth like temperatures suggests a Greenhouse effect that is not out of control.



Img. 20 – VOCs (ppb) (red), CO2 (ppm)(green)/ altitude(m) (blue)- concentration results (CanSat in Greece 2018)

➢ Ground survey

Our camera will be used to create a composite ground image to survey the landscape for suitable landing terrain with Kolor Autopano. Clearly it is a proof of concept display since the competition takes place in an airport.



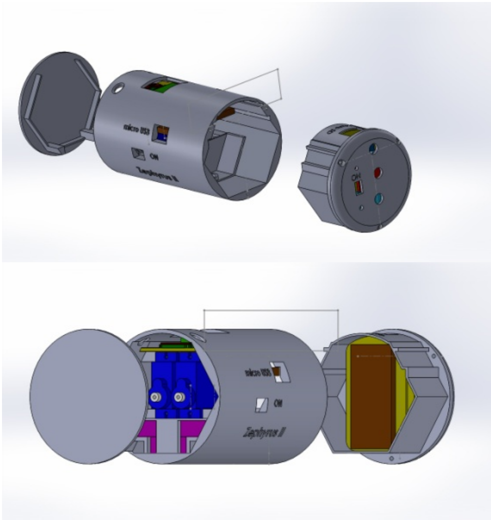
Img. 21 - Composite ground image created with Kolor autopano. (CanSat in Greece 2018)

CONSTRUCTION

a. Structure – casing

Structure: 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 *(submitted)* were created with Solidworks

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



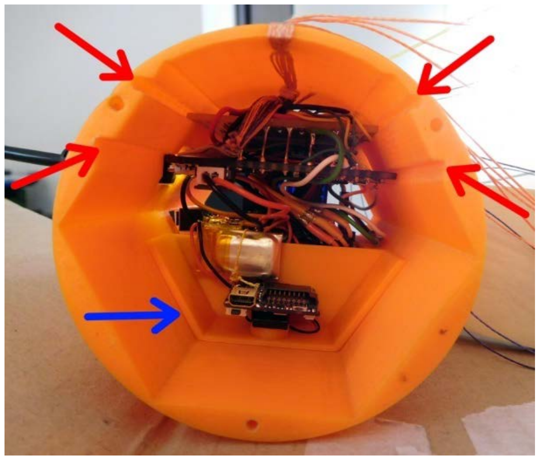
Img. 22 - 3d Models created with solidworks

Img. 23 - Cansat Modules

As seen on image 22 there is a tight fit between flight and payload module. The assembled CanSat is visible on image 23.
The camera casing fits on the inside above the camera slot.

➢ Flight Module

It 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.



Img. 24- Electronics slots (red) - Camera Case (blue)

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.

➢ Payload Module

It 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.

➢ Camera case

It 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.

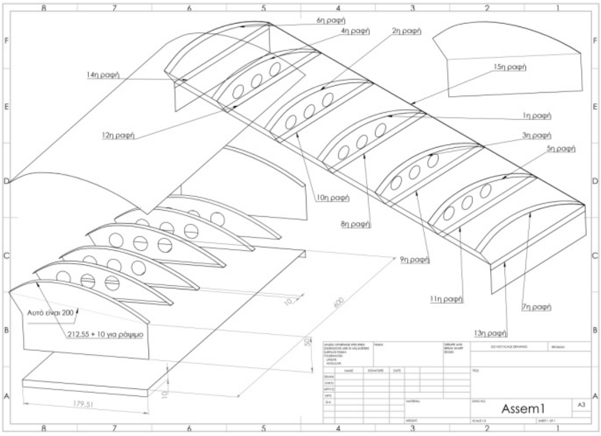
b. Parachutes

Our choice for the recovery system is 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



Img. 25 - Construction plan – sewing instruction created by our team with solidworks.

National competition

We have created several parachutes for testing. Two of them, with different sizes were chosen by trial and error for the ***CanSat in Greece 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.

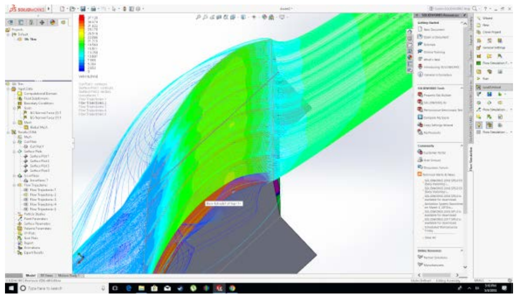
Parachute to be used

For the ***CanSats in Europe*** competition 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 was found to be stable and with the required basic descent rate of 8m/sec. We need to test the parachute for determining the maximum descent rate. This will be our choice for the competition and there is some more testing required. We strive for a fast descent rate to eliminate the possibility of strong winds pushing our CanSat to the Sea.

➢ Material

The material selected to be used is ***skytex-27***. Its weight (27gr/m^2) 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.

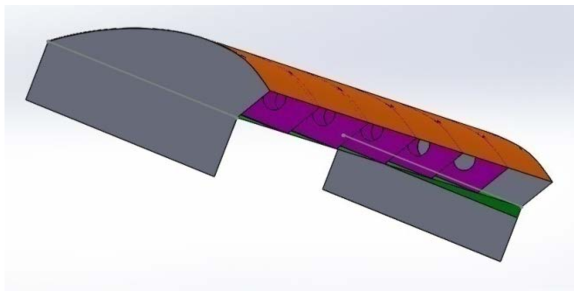
Multiple aerodynamic tests were conducted at a SolidWorks environment to determine possible corrections in the design. The only helpful estimate was that of the angle we should use to the horizontal plane. Trial and error is by far our main way of development.



Img. 26 - Airflow simulation using solidworks

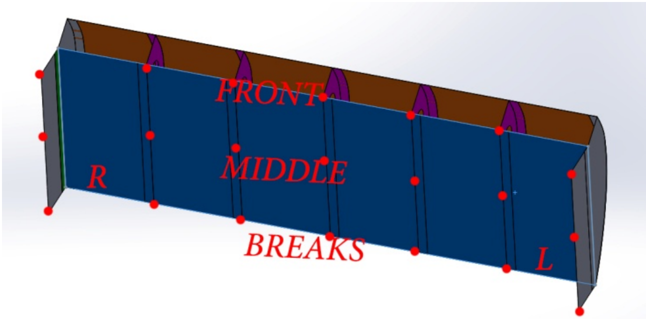
➢ Design

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.



Img. 27 - Parachute design created with solidworks

Our design has three line zones. ***Front, Middle Back***. The back zone lines can be pulled by our servos 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.



Img. 28 - Line connection points

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

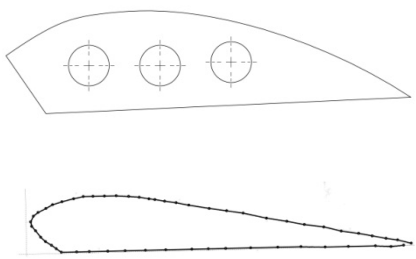
The latest design being tested has:

-20° angle of attack

40cm centre cord length

550 cm^2 new area of action.

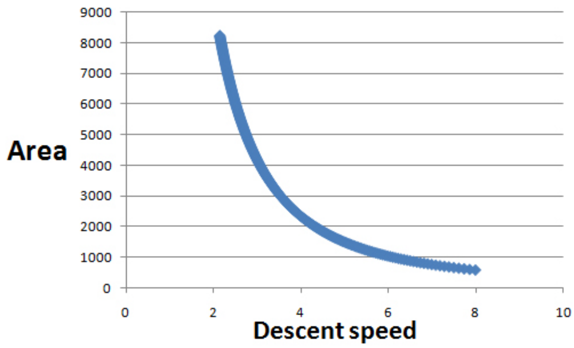
Different profiles are available. The bigger parachutes have a "fatter" profile but the smaller one, we will be using, has a sleek faster one for speed. The first profile was copied from a DIY internet video while the second was found here. Since nothing existed on the internet at our size, trial and error was the way to develop a parachute.



Img. 29 - Different profiles

➢ Calculations

Our choices regarding parachutes aren't entirely trial and error. We used a terminal velocity calculator to estimate the required area for a specific descent rate. Although not entirely correct for a gliding parachute, since it disregards lift created by the wing shape, it helped us a lot in estimating. We also found out that despite our gut feeling, speed does not increase inverse proportionally to parachute area but rather does as shown on the graph.



Img. 30 - Parachute area(cm^2) - descent speed (m/sec) for 350gr

$$Vt = \sqrt{\frac{2mg}{\rho ACd}}$$

Equation 1 - Terminal Velocity

Vt Terminal velocity
m mass
g gravity acceleration
ρ air density
Cd drag coefficient
A area

➢ Use of parachute

We can't expect a 350gr object without any means of propulsion to counter strong winds by gliding and turning. **Galileo's cube square law** at this order of magnitude makes area and the wind pushing it, very important relative to Volume (and also mass). That means that winds have a massive effect on something of that size compared to a man sized parachute. That does not mean though, that there is no use for a targeted landing. At high winds the use of parachute breaks gives us a variable descent rate and limited directional correction capabilities. By releasing our CanSat upwind we can predict the minimum and maximum distance from the release spot based on wind. That allows us to calculate a drop distance "window" for the release plane. Our algorithm will make sure it hits the target. At low wind speeds steerability increases while the drop window becomes shorter. Our 3 different parachutes allow for 3 different mission ranges by having 3 different descent rate ranges.

c. Electronics

Our electronics are composed of 2 fully independent subsystems; the flight module and the payload module. The main computing unit in each of them is adafruit's feather m0 Rfm96 which has plenty of onboard memory, and an integrated Rfm (lora) module with great range capabilities. During tests, telemetry was broadcasted up to 8Km away. Our feather features the ability to charge our batteries straight from its usb port in hotswap fashion.

Communication protocols for the sensors include I^2C, SPI, Serial.

➢ Flight module parts

Adafruit Feather M0 RFM96 LoRa Radio
M0 Processor, Radio LoRa Modulation

Adafruit ultimate GPS breakout board
Adafruit bme280
Pressure, Temperature, Humidity

2x Feetech FS90MG Servo
Metal gears, pulling force of 1.7kg/cm each.

Adafruit microSD card breakout board
Adafruit 9-DOF absolute orientation imu (BNO055)
Proprietary Sensor fusion, Gyro, Magnetometer Accelerometer

Pololu 5V Step-Up Voltage Regulator U3V12F5
702050 Lipo 3x700mah , 3.3v

➢ Payload module parts

Adafruit Feather M0 RFM96 LoRa Radio
M0 Processor, Radio LoRa Modulation

Vocs and eqCO2 sensor Adafruit CCS811
Light sensor SparkFun RGB ISL29125
UVA light sensor Adafruit veml6070
Lipo 2x700mah, 3.3v 803030

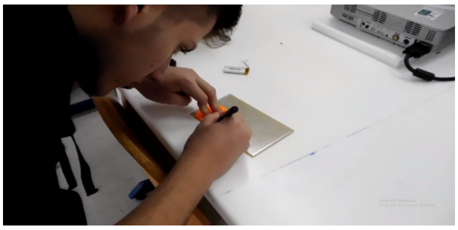
➢ Camera

Camera electronics
Full HD 30fps

Battery

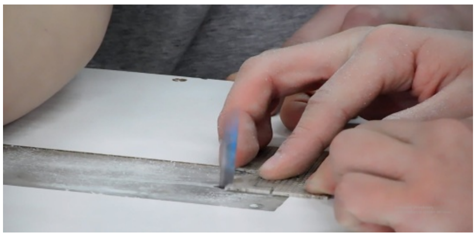
➢ Construction process

The electronics used in our CanSat for both our Flight and payload module were cut and assembled by hand (video) in order not to rely on a factory to produce and ship. It allowed us flexibility and easier adjustments.



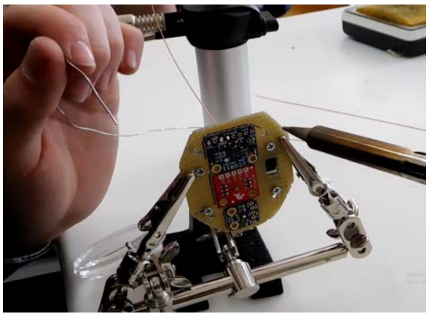
Img. 31 - Drawing desired shape

We 3d printed stencils for the shapes of our prototyping boards and cut out the shape.



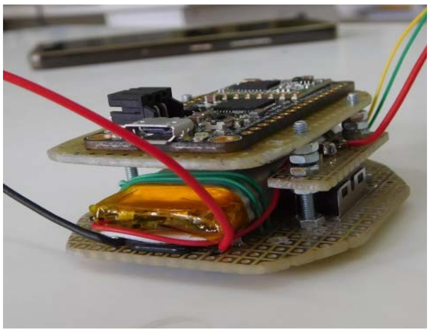
Img. 32 - Cutting out board shape

Everything was mounted with double sided tape in order to make the soldering job easier.



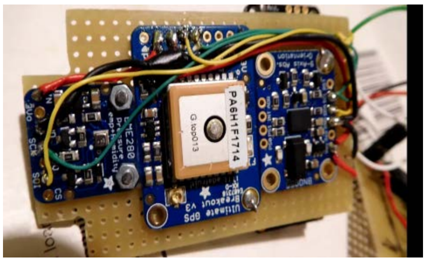
Img. 33 - positioning parts

Multilevel boards were created by using screws.

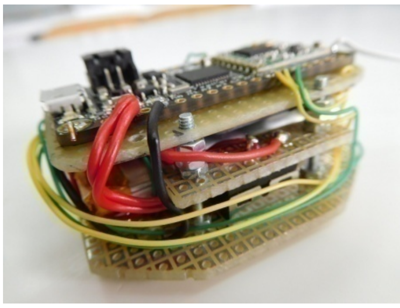


Img. 34 - Multilevel board

We wired everything with wire wrapping wire for ruggedness and small size.



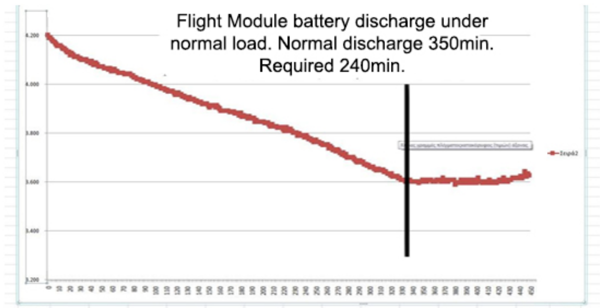
Img. 35 - Flight Module electronics (top)



Img. 36 - Science payload electronics (side)

➢ Power consumption

The following tables show power consumption per part. The batteries were tested with full load until they were drained. Minimum measured voltage was 3.6V.



Img. 37 - Flight battery discharge test under load (4.2 -3.6 Volt) 350 minutes.

Flight Module		
Sensors	Voltage	Consumption
Adafruit Feather M0 RFM96 LoRa Radio.	3.3v	100mA (max)
Adafruit ultimate gps breakout board	3.3v	25mA
Adafruit bme280	3.3v	3.6µA
Feetech FS90MG	6v	150mA (stall)
Adafruit microSD card breakout board	3.3v	100mA (Max)
Adafruit 9-DOF absolute orientation imu (BNO055)	3.3v	13.7mA
702050 Lipo 2x700mah, 3.3v	3.7v	2100mAh

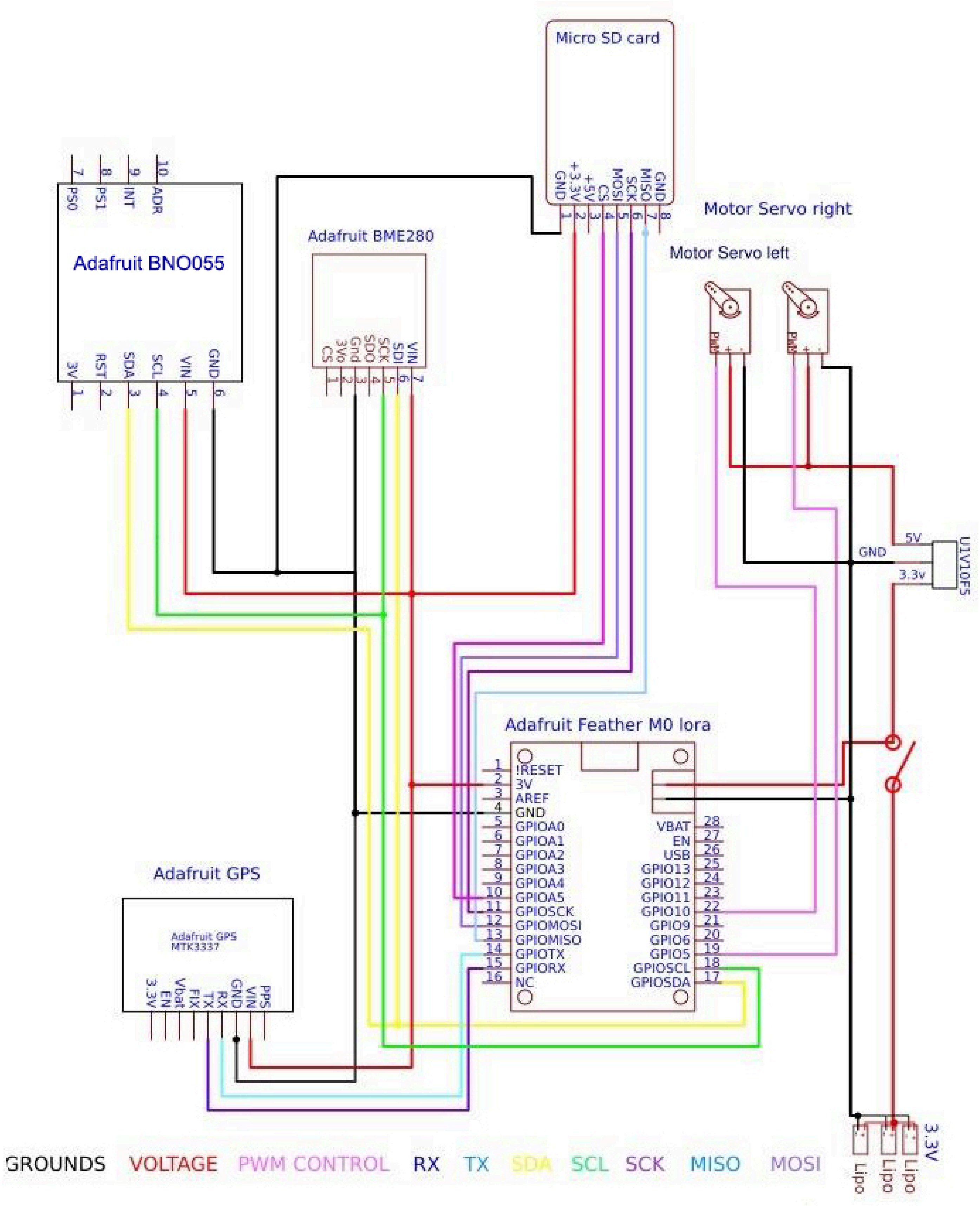
Tested Flight battery endurance: ***5h50min***

Payload Module		
Sensors	Voltage	Consumption
Processor	3.3v	100mA (max)
Vocs and eqCo2 sensor	3.3v	20mA
Light sensor	3.3v	56µA
Uv light sensor	3.3v	250µA
702050 Lipo 2x700mah, 3.3v	3.7v	1400mAh

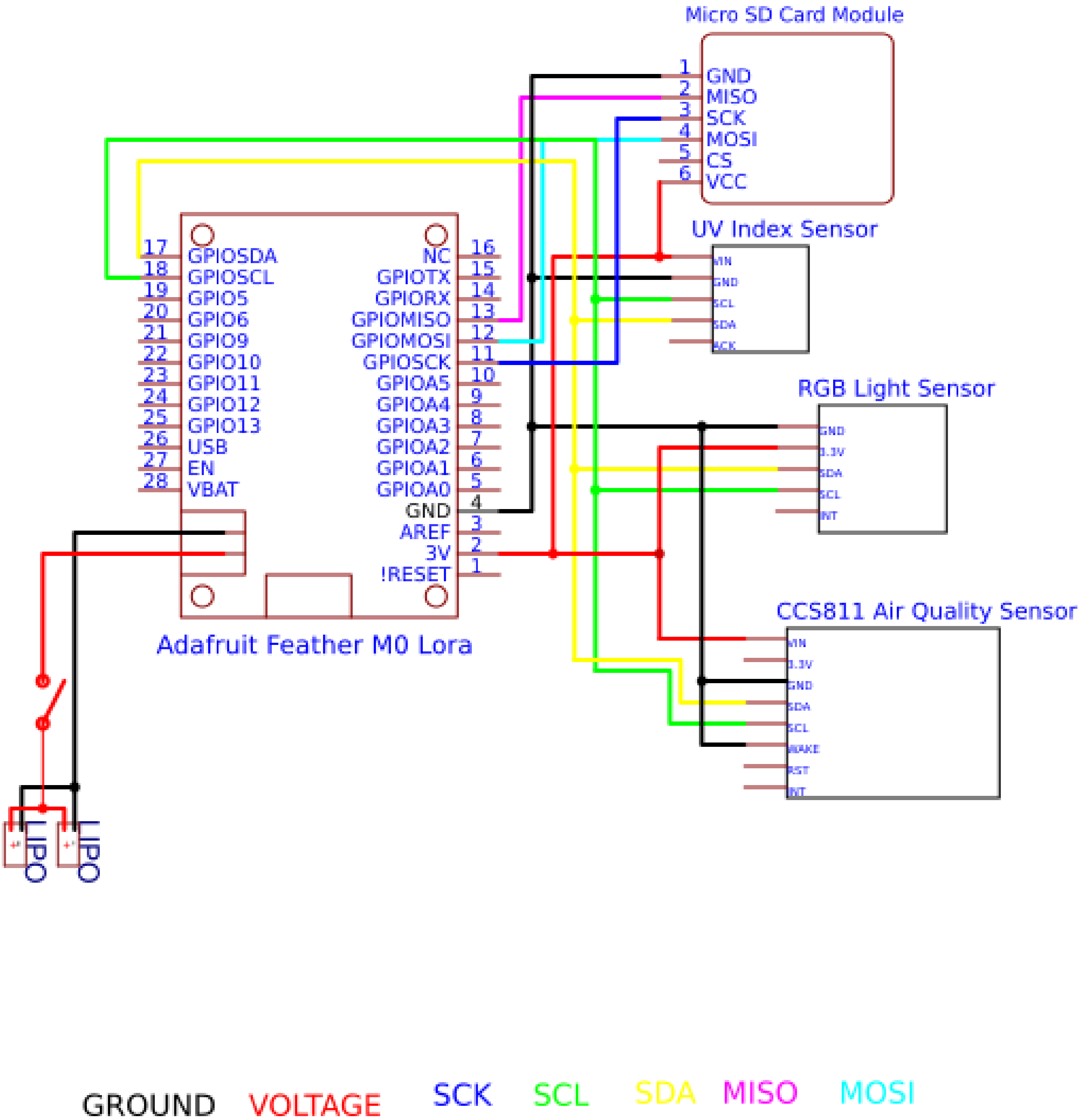
Tested Payload battery endurance: ***9h30min***

Datasheet Camera battery endurance: ***1h30min***

–



Img. 38 - Flight Module electrical design



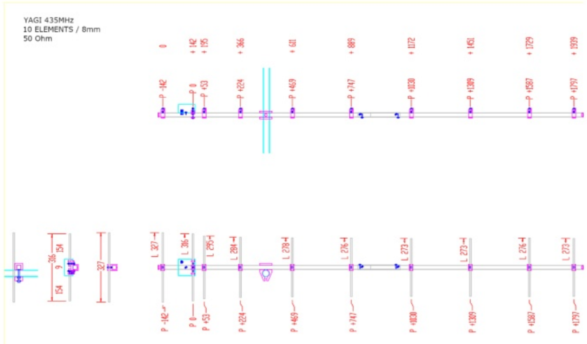
Img. 39 - Payload Module electrical design

d. Antenna – Ground station

Our mission description of a versatile mission platform requires two contradicting telemetry requirements. Range vs. portability. We are going to present both configurations. That means two ground stations as we did in the CanSat in Greece competition.

➢ Ground station 1 (Long Range)

We have built a 435 MHz yagi antenna (video) based on schematics found on github.

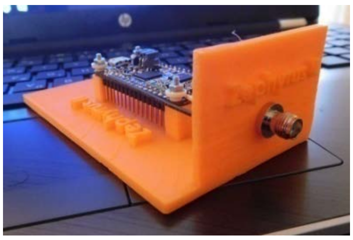


Img. 40 – Antenna Schematics

We reduced the antenna elements to 8, from 10 on the original plans, to achieve a practical size. Also despite the gain loss we have a wider beamwidth for better targeting. We have tested (video) bidirectional communication with our antenna successfully at a 8 Km distance.

Img. 41 - Our antenna

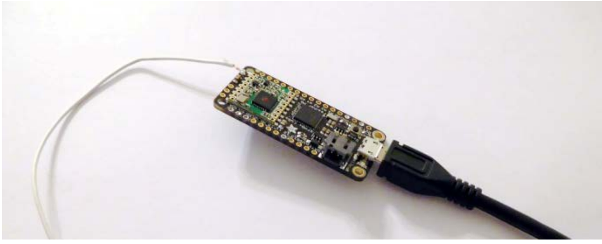
Our laptop will record the incoming data and send commands by use of the software Realterm.



Img. 42 - Antenna laptop connector

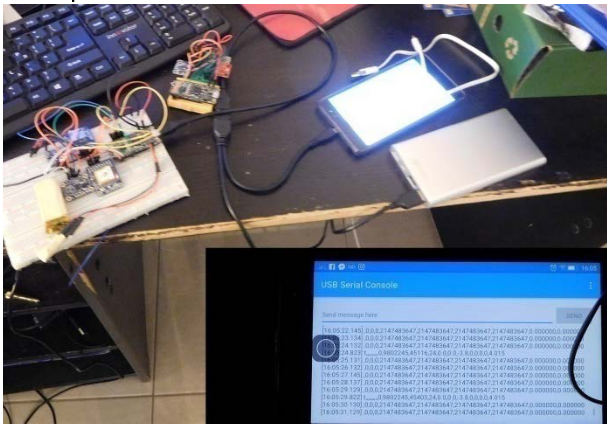
➢ Ground station 2 (portable)

We can receive telemetry and send commands from a Smartphone by use of an app called ***Serial USB terminal.***



Img. 43 – feather with quarter wave antenna

A quarter wave cable antenna is connected to our feather and it is connected via OTG cable to a Smartphone.



Img. 44 - portable ground station setup

That is a fully functional and very portable ground station. Our data will be retransmitted over the internet to our facebook page for our followers to read our telemetry live via the CameraFi Live app.

5. MODE OF OPERATION – CODE

Our feather processors were programmed using the standard Arduino IDE with the C language.

Our entire code is included in our ***open source appendix*** for any team next year to use.

Data packages are in csv form. *Placeholder commas* have been added on every package. In doing so our recorded telemetry can be imported to our spreadsheet with a single command and every value will be placed in its specific column regardless of package number, module or lost packages.

a. Flight module telemetry

Two data packages are transmitted from our flight module to the ground and are recorded on the module's onboard microSD card. The 1st is sent every second and the 2nd every 5 seconds for bandwidth reasons.

1st package contains in sequence: *GPS time, Temperature, Pressure, Humidity, Altitude (press.), Latitude, Longitude*.

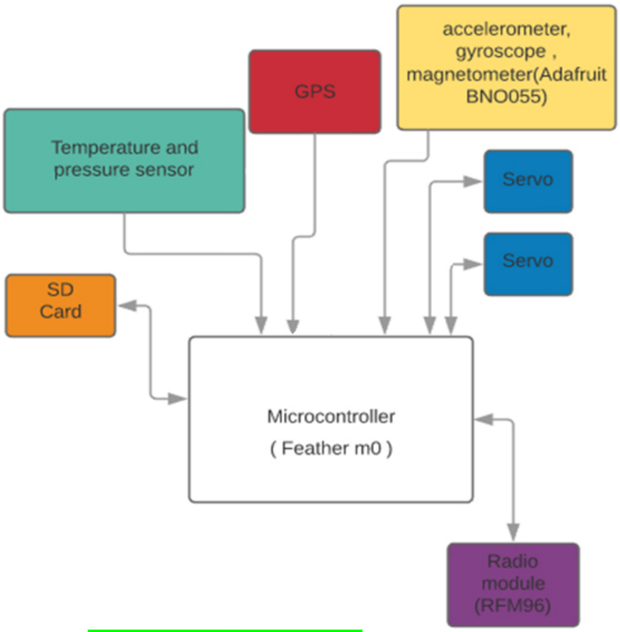
Below is a typical 1st package starting with the RSSI signal reception strength added by the ground station. Notice the initial double coma to be used as a placeholder for commands.

RSSI,-81,,11,8,6,29,976,28,313,38.055255,23.317871

2nd package contains in sequence: *send trigger, IMU calibration status, gravity acceleration, magnetic X, mag. Y, mag. Z, Acceleration X, Acc. Y, Acc. Z, BNO temperature(inside), orientation X, orient. Y, orient. Z, distance to target, required heading, Altitude (GPS), speed (GPS), Flight Battery Voltage.*

Below is a typical 2nd package. Notice the comma placeholders and the ***initial letter t***. It is received by our payload and triggers an immediate payload module broadcast. Thus both modules ***remotely synchronize their broadcasts*** and only one communication frequency is required. Modules synchronize even if they are placed far apart since no physical connection is required.

RSSI,-77,t,,,,,,,,,2,9797,-24,-17,-35,2,5,2,32,105,-3,-19,46,160,254,378,4.008



Flight module block diagram

Img. 45- Flight m. block diagram

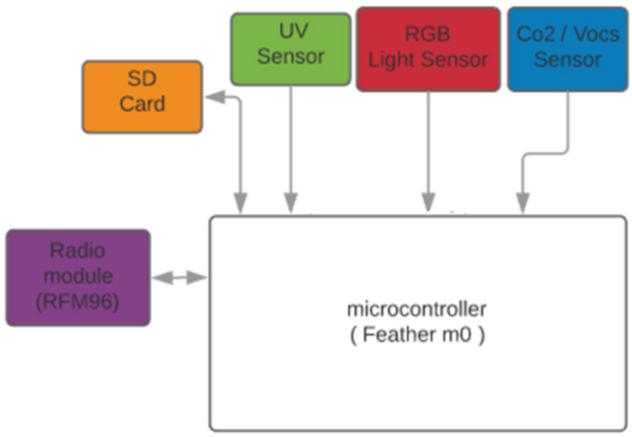
b. Payload module telemetry

Our payload transmits one data package, which is also recorded on the module's onboard microSD card. If left untriggered that happens every 6.5 seconds. In normal operation that is never the case, since the 2nd flight package triggers every 5 seconds a transmission and resets the 6.5 seconds counter. 6.5s was chosen to be longer than the trigger so as not to interfere with flight packages in a constant way in case of a malfunction.

The payload package contains in sequence: UV intensity, Light intensity Red, L.i. Green, L.i. Blue, CO_2, VOCs, Payload Temperature, Payload battery voltage.

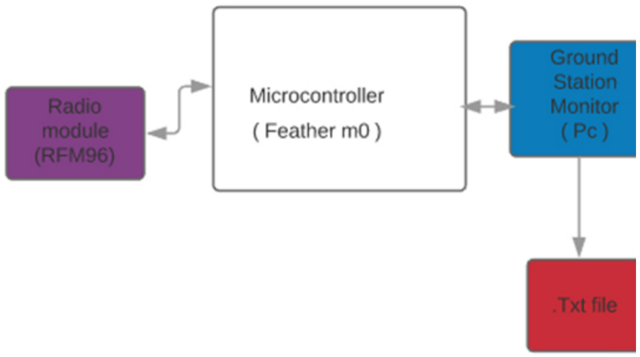
Below is a typical payload package. This being the 3rd package many placeholder commas are required.

RSSI,-87,,,,,,,,,,,,,,,,,,,,,,,,,,,411,65535,53558,45536,916,78,31,4.002



Payload block diagram

Img. 46 - Payload m. block diagram



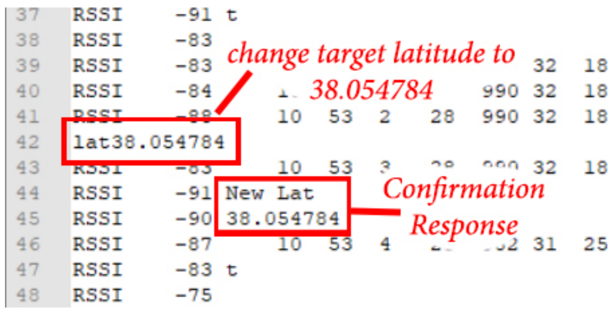
Ground station block diagram

Img. 47 - Ground station block diagram

c. Commands

Both modules have the capability of receiving commands. The code can easily be changed to add more commands if necessary, as can be seen in our ***open source appendix***.

Any command is typed and send through the ground station's feather serial port. It is transmitted "as is" through the radio and received by both modules. Since commands differ for either module, only one of them executes them. In the following page's shown flowcharts, we have included lists of used commands. For every command a specific response is send from the module, for us to know it was executed. If no such response arrives we retransmit our command



Img. 48 - command and response recorded by ground station

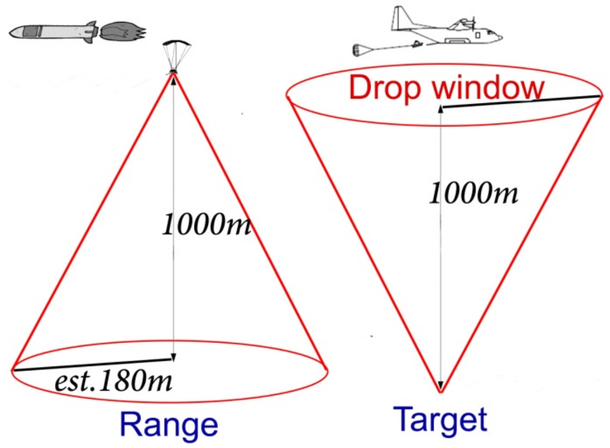
You might notice that some of the commands are in *"command"xxxxx* form. That allows us either to redefine a value like target latitude, or to define multiple cases with one command. The angxxx command sets the maximum angle the servos can rotate. The value cannot exceed 115 degrees. This limit is set for all flight scenarios. It was extensively used for testing. The pidxxx command changes the flight scenario. "pid1" turns servos off, "pid2" makes a hard right downward spiral, "pid21" makes servos react proportionately to direction change relative to target (video) etc. Our modules can also receive commands thru their serial port for debugging purposes.

d. Targeted descent

Our algorithm compares our GPS position to the given GPS target. We used snippets from an Adafruit application to calculate our distance from the target and the required absolute heading to go there. A decision is made ***every second*** by our algorithm and is then executed by the servos. Our algorithm contains scenarios that are either operational or for testing. They can be selected remotely by command.

➢ Weak or no winds

By comparing the required heading to our CanSat's actual absolute heading our servos respond. If a right turn is required the right servo pulls the right breaking lines to initiate the turn. The same principle applies for a left turn. Braking is done proportionately to the required turn. By keeping the target "in sight" and by the parachute's forward displacement the target will be hit (video). We estimate our CanSat's horizontal speed when no winds are present at 1.5 m/sec. That means a horizontal travelling distance (*range*) of 180m at a 120 sec drop.



Img. 49 - Windless drop cases

- **Strong winds**

We expect our CanSat's steerability to be eliminated by winds due to our small size. That leads us to a different calculation scenario. We can vary our descent rate by having a spiral descent. Our algorithm calculates the distance from the target and by using the GPS speed and descent rate calculated by pressure and GPS time, estimates the required descend rate to hit the target. That is only possible if the target is within our drop window. A [spreadsheet]() has been created to estimate the minimum and maximum distance travelled at given wind speeds. Clearly a real world appllication requires the release to take place within a drop window, to hit a target.

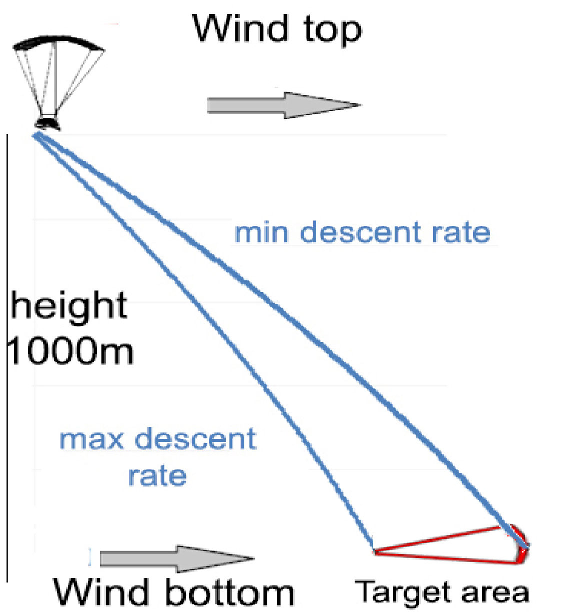
Target area

Notice the shape of the target area and the drop window. When our **descent rate is maximal**, it is done by a spiral descent throughout the drop. That provides zero steerability, thus the target is a spot. When our **descent rate is minimal** our CanSat is gliding forward, with a limited ability to turn. That makes the target an arch. Mixed flight behavior corresponds to the shape between these two extremes. Stronger winds produce a smaller arc angle.

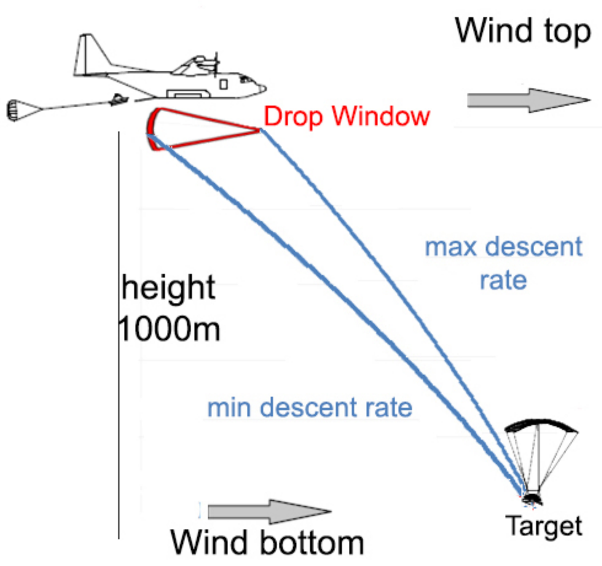
Drop window

Likewise the start of the drop window corresponds to the steerable **minimal descent rate**, thus an arc of drop spots leads to the target. When no steering is available at the **maximal descent rate** only one trajectory is possible to the target.

In both cases, as in our model, we expect **constant** winds forming a **gradient** between the wind speed on the top and on the bottom. Ideal conditions of course, seldom correspond to reality.

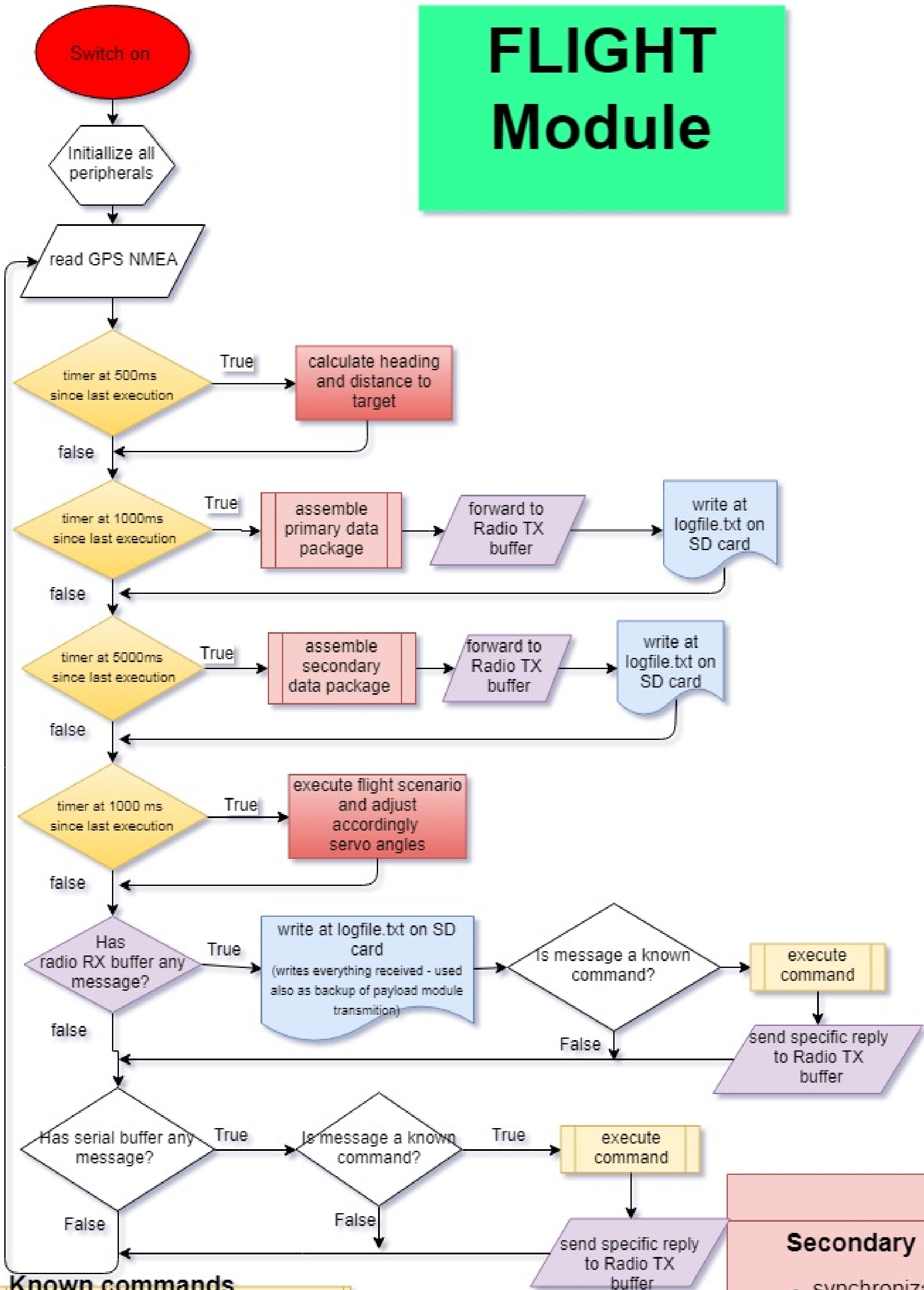


Img. 50 - Windy descent from starting point based on our model.



Img. 51 - Drop window for plane to hit target

FLIGHT Module



Known commands

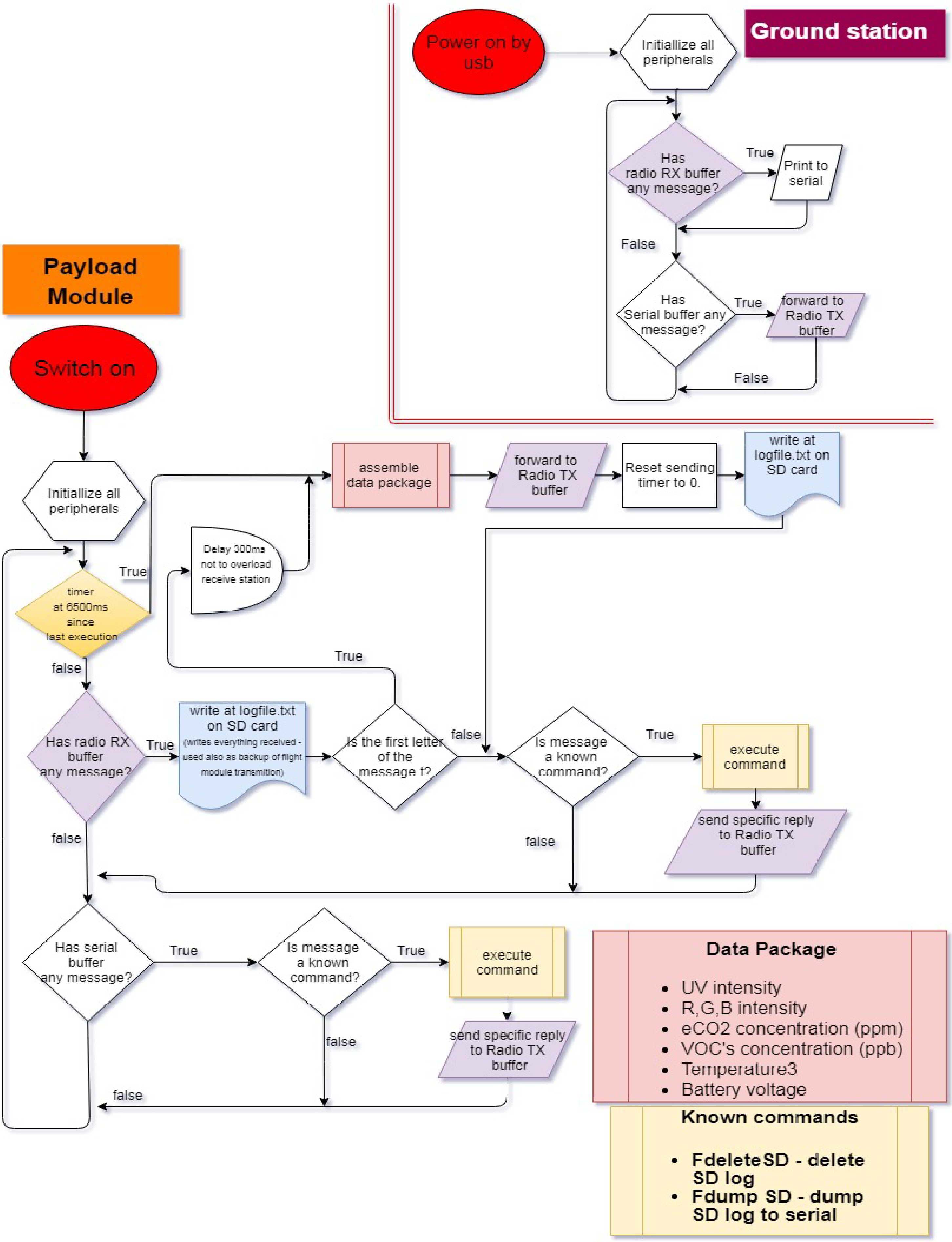
- flight - return flight param.
- gpsA, gpsB, gpsC, gpsD - change target
- latxx.xxxxxx - set new target latitude
- lonxx.xxxxxx - set new target longitude
- FdeleteSD - delete SD log
- Fdump SD - dump SD log to serial
- pidxx - set flight scenario
- angxxx - set max rotation angle for servos (min 5 -max 115)

Primary Data Package

- GPS Time
- Temperature
- Pressure
- Humidity
- Atitude by Pressure

Secondary Data Package

- synchronization letter t
- BNO calibration status
- gravity acceleration
- magnetic field at X, Y, Z axis
- Temperature 2
- Absolute heading at X,Y,Z axis
- distance to target
- heading to target
- GPS altitude
- GPS speed
- Battery Voltage

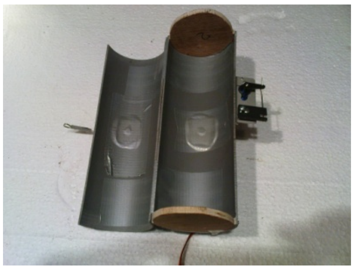

Ground station
Power on by usb
Initiallize all peripherals
Has radio RX buffer any message?
True
Print to serial
False
Has Serial buffer any message?
True
forward to Radio TX buffer
False
Payload Module
Switch on
Initiallize all peripherals
timer at 6500ms since last execution
True
false
Delay 300ms not to overload receive station
assemble data package
forward to Radio TX buffer
Reset sending timer to 0.
write at logfile.txt on SD card
Has radio RX buffer any message?
True
write at logfile.txt on SD card (writes everything received - used also as backup of flight module transmition)
Is the first letter of the message t?
True
false
Is message a known command?
True
execute command
send specific reply to Radio TX buffer
false
false
Has serial buffer any message?
True
Is message a known command?
True
execute command
send specific reply to Radio TX buffer
false
false
Data Package
UV intensity
R,G,B intensity
eCO2 concentration (ppm)
VOC's concentration (ppb)
Temperature3
Battery voltage
Known commands
FdeleteSD - delete SD log
Fdump SD - dump SD log to serial

6. PROJECT PLANNING

a. Time schedule of the CanSat preparation

Zephyrus II Time plan			
Month	Key date/ deadline	Phase	Activity
June	9	Preliminary design	Specification paper
October		Parachute	Lesson about the mechanics of a paraglider
	22		CanSat in Greece competition application form submitted
November	9	Design	Brainstorming, define required specifications and required elements for construction
	11	Teachers workshop	Supervising teacher presented our mission at teachers workshop
		Design +construction of the parachute	Design and construction of a parachute prototype
December	9	Design ,construction & tests	Mechanical ,electrical, software and further parachute design & First parachute tests
		Prototyping +Test	Testing, sensors on breadboard and telemetry
		Tests	First and second motor test
		Electronics	Electronics workshop for new team members
January	9	Design + Construction	3d model design and software development
		Construction	3d printer assembly
		Prototyping + Test	Second parachute test using ballons
		Tests	Testing gps and sensors to altitude changes
	30	Pre CDR	Preliminary CDR
February	5	Construction	Construction of our yagi antenna
		Prototyping + Test	Power consumption Tests
	9	Skype call I	First skype call on teams knowledge
		Prototyping + Test	Software integration
		Prototyping + Test	More parachute prototypes and tests
		Tests	Testing antenna and LoRa modules
	22	Pre CDR feedback	Use feedback to finalize the CDR report
	25	CDR	Critical Design Report submission
March	9	Skype call II	Second Skype call on teams knowledge
		Construction	Custom perfboards for the CanSat
		Construction	Final 3d printed body
		Test	Testing servo response in angles sent by computer commands
		Construction	Final parachute
		Assembly	Assembly of the CanSat
		Test	G force test
	25	PLR	Pre Launch Report submission
April		Test	Final test communication and sensors
	10	MOP	Mission Operation Manual submitted
		Test	Final autonomous flight test
	10	MOP	Mission Operation Manual submitted
	11	Test	Requirements check & acceptance check from organizers
	12	Launch	Launch day
	13	Analyze	Data processing and analysis
	14	Final	Final presentation and winner announcement

May	9	Design	Results analysis and possible improvements list
		Design +construction	Small changes to the CanSat model
		Research	Research on wind conditions at Azores
		Design	Design parachutes with higher descent rate
		Prototyping	Start sewing new parachutes
	16	Tests	Parachute testing
		Prototyping	Parachute modification
June	7	Tests	Parachute testing
	9	Assembly	Assemble CanSat with new parachute
		Construction	Fix minor coding bugs
		Test	Requirements check & acceptance check
	21	Final preparations	Create list of required equipment
	23	Packing	Packing of miscellaneous items
	24/25	Charging	Charging of the CanSat and various power banks
	27	Flight	Fly from Athens to Lisbon
	28	Start	Start of European CanSat competition
July	1	Finish	End of the CanSat competition



Img. 52 - CanSat release mechanism (self-made)

	Unit price	**Units**	Total cost
Parachute			
Fabric	**11,90 €**	**1**	**11,90 €**
Lines			**1 €**
Flight Module			
Voltage regulator	**5,50 €**	**1**	**5,50 €**
Radio – Feather	**29,71 €**	**1**	**29,71 €**
GPS	**33,96 €**	**1**	**33,96 €**
BNO055	**30,00 €**	**1**	**30,00 €**
BME280	**16,96 €**	**1**	**16,96 €**
SERVO	**7,90 €**	**2**	**15,80 €**
SD	**6,38 €**	**2**	**12,76 €**
battery	**6,40 €**	**3**	**19,20 €**
Payload			
Radio - Feather	**29,71 €**	**1**	**29,71 €**
battery	**6,40 €**	**2**	**12,80 €**
UV sensor	**5,06 €**	**1**	**5,06 €**
Light sensor	**6,76 €**	**1**	**6,76 €**
CO2 VOC	**24,80 €**	**1**	**24,80 €**
Camera	**18,30€**	**1**	**18,30€**
Various			**~ 10€**
Total		**274,22 €**	

b. Resource estimation

➢ Budget

Our construction budget exceeded 1000 €. Apart from the costs on the table, we had to buy duplicate parts, our ground station, balloons for testing and parts used for auxiliary purposes like the construction of a release mechanism for drop testing.

➢ External support

We need to thank Panagiotis Triantafyllou for his constant support throughout our effort. He works as technical support staff in the University of Ioannina and his field is electronics.

During the CanSat in Greece competition we were sponsored by the cooperative Bank of Epirus. Travelling costs to Athens were covered by the bank and partly by the municipality of Ioannina.

We were provided with funds for the purchase of a 3d printer by the Prefecture of Epirus.

Our participation in the European competition is sponsored by the Prefecture of Epirus, the Municipality of Ioannina and the Ministry of Digital Policy, Telecommunications and Media.

We wish to thank Mr. Stavros Kostoulas for his very useful paragliding lesson (video).

We wish to thank Mr. Petros Nikolaou for his advice regarding aerodynamics.

We wish to thank Mr. Akis Kyriakopoulos and Mr. Lakis Petrinos for offering us their time and their drones for our drop testing.

We especially want to thank Mrs. Alexandra Mareta and Mrs. Eyaggelia Triantafylloy for their work in sewing our demanding parachute designs.

Img. 53 - Mrs. Mareta and Mrs. Triantafylloy

c. Test plan

- Soldering pins were added to all of our components for extensive breadboard testing (video)
- We performed sensor functionality testing on breadboard. (video)
- We tested our code for the first time.
- We tested paraglide prototypes made of cheap fabric. A bottle was used as variable weight ranging from 300 to 350grams. Several drops were made from a 4story building in order to draw conclusions about its flight stability and steerability. Required breaking lines pull was defined at 1.5 to 2cm in order to turn adequately.(video)
- We tested and calibrated our VOCs and eCO2 sensor in order to get accurate measurements.(video)
- We tested our esc's and brushless motors thrust and power consumption.(video)
- We tested the performance of our motor inside a PVC tube and we found out that thrust was noticeably reduced.(video)
- We tested a motor parachute configuration. It was a complete failure since turning was uncontrollable. That led us to ***abandon the use of a motor***.
- We tested our batteries endurance by fully discharging them under full load.
- We tested our GPS and pressure sensor by driving uphill to an altitude of 1000m.(video)
- We tested our telemetry of both the flight and payload module inside an urban environment with a quarter wave antenna. Range was 350m.(video)
- We performed a line of sight telemetry test using wire antennas on both modules. Range was 2.1km at an altitude difference of 40 m.

Img. 54- Range testing

- We performed drop tests with helium balloons. We also tested different release mechanisms. Parachutes were made of cheap fabric.(video)
- We tested our yagi antenna at a line of sight distance of 8Km. Our modules were still on breadboards with a quarter wave length antenna. Our antenna, operated bidirectionaly, receiving telemetry and sending commands. We used a Smartphone as our ground station and

streamed our telemetry to our facebook page.(video)(Facebook)

- We constructed our electronics assemblies and reviewed every single solder joint under a soldering stereoscope for imperfections.(video)
- We tested our servos at different angles by sending commands from our ground station.(video)
- We tested the g tolerance of our CanSat using rope and a bottle. Our CanSat did withstand accelerations that peaked at 35g while fully operating.(video)
- We performed final drop tests before the CanSat in Greece competition. Our CanSat aligns with the target and turns towards it.(video)(video)
- We performed handheld tests and a close look at the algorithm reacting to the change of heading towards the desirable target.(video)
- Returning from our CanSat in Greece competition we drop tested by drone different successful and unsuccessful parachute configurations to determine our needed adjustments for the strong winds of the Azores islands.(videos)
- Two new parachutes were sawn and are being currently tested.
- A second Azores parachute test was carried out (videos)

d. Lessons learned from the CanSat in Greece launch campaign.

Our participation in the CanSat in Greece competition was quite successful. Almost everything went according to plan and our previous experience from last year's participation and extensive testing showed.

There is though one important aspect of our mission that was not as expected and needs revisiting, since conditions in the Azores are expected to be more difficult.

We noticed that our parachute has reduced steerability at even moderate winds. That is attributed to the small size of our device.

We also need to increase our descent rate to avoid being pushed to the sea by the wind.

We also need to present comprehensively a very extensive work done, in 7 minutes and not in our mother tongue. We found out that time was barely enough in Greek and need to decide what to leave out and how to be as efficient as possible in our presentation.

7. OUTREACH PROGRAMM

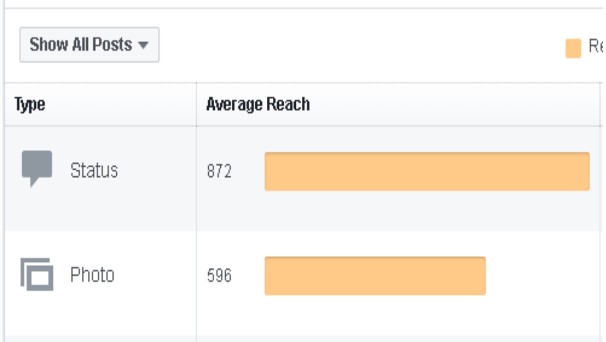
a. Outreach overview:

Our outreach effort has different aspects. A strong internet presence followed by a strong media presence has made us known not only locally but as far as the Greek community of Melbourne Australia. We secured the support of public figures adding to the hype created and held an event for the public in our town. We participated in international and national conferences and received awards for our work.

b. Internet presence

Facebook page (Link)

Our facebook followers and people who like our page are constantly and steadily increasing. At this moment we have 772 followers and 762 likes. Most of our posts perform well having an average reach of 872 and a maximum reach of 4000, an average of 94 reactions and an average of 86 clicks on our posts.



Img. 55 - Facebook stats

Instagram (Link)

Our instagram followers are constantly on the rise. At present we have 133 followers including CanSat teams from other countries and some even from the NASA CanSat competition.

BlogSpot (Link).

We have created a blog to work with our webpage.

Website (Link)

This is the Website of the team. It's also in English. Here you can find photos from our effort throughout the competition. We currently have 5000 clicks which can be displayed on the bottom left of the screen.

YouTube channel (Link).

An extra effort was taken to video document our entire effort. Almost every part of our work was made into a video. Our YouTube channel is the ***reference basis*** for almost all our posts. It is used as an ***outreach tool*** *but also* ***as documentation tool*** for our work.

c. Scientific conferences

ACSTAC

Our team participated in the science conference, 'ACSTAC' (Anatolia College Science and Technology Annual Conference 2017) , conducted by Anatolia College in November. We presented our last year's work and this year's plans presenting our planned secondary mission. We received praise and attracted a lot of interest from judges and visitors alike, leading to a ***first price in the exhibitions-constructions category***. (Photos)(photos2)

This brought extensive media coverage.

A link from the article of Anatolia College on its official page

The radio interview of our supervising teacher on one local radio station

The Tv interview of the team members on the local station TV1.

ICYS 2018 BELGRADE

Two of our members presented scientific papers based on our work, in the International Conference for Young Scientists (ICYS 2018 Belgrade). 230 papers from 32 countries were presented there. 2 of the 12 members of the Greek National delegation were from our team. They brought home a ***bronze medal in engineering*** leading to more media coverage (video) about CanSat and what comes from it.

Photos from the poster and oral presentations can be found here.

A link from the article of Anatolia College on its official page.

This news was picked up by a ***Greek radio station in Melbourne Australia***, and an interview was given about our entire effort (video). They will be following us during the ESA launch campaign.

EUCYS 2018 DUBLIN

Our country is going to be represented at the ***EU Contest for Young Scientists 2018*** in Dublin by 3 members of our team. The Greek committee has approved our submitted proposal, based on this year's CanSat project, as the ***only one*** good enough to represent Greece at the EUCYS. We expect the connection between CanSat and solid scientific work, established in the media, to be brought into the spotlight once more.

d. Additional actions for outreach

Wikipedia

A Greek Wikipedia page about the CanSat competition was not present so we created one.

Public figures

Support videos were created by the following well known Greek artists.
Thanasis Aleuras (actor). (video)
Konstantinos Argyros, (singer) (video)

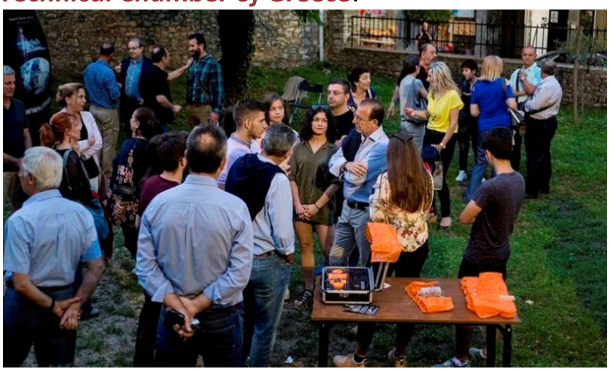
Teachers 4 Europe

We presented our work in the local silversmithing museum as part of the Teachers 4 Europe day.

Img. 56 - Teachers 4 Europe presentation

Outreach Event

We co organized an event for the public to know our work. Our mission and the CanSats in Europe competition was the main event. It was a joint effort by ***our team, the portable digital planetarium, the municipal regional theater of Ioannina and the Ioannina section of the Technical Chamber of Greece***.



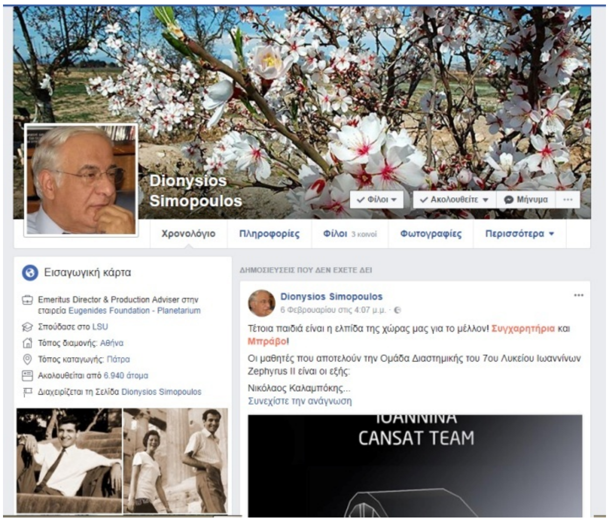
Img. 57- Mayor of Ioannina visiting our event

Free shows were held by the planetarium for two hours outdoors, leading up to the main event that was our mission presentation to the public. This video includes the press conference preceding the event, photos and our entire presentation (**video**).

Img. 58 - Before the event

Support from well known scientists

We contacted prominent Greek scientists, such as the astrophysicist and CEO of the "Eygenideion" planetarium Dionysios Simopoulos, ESA doctor Dr. Adrian Golemis and Mrs. Athena Kousteni who is an astrophysicist in the Observatory of Paris. We were happy to find out that they were willing to promote our team's actions, as they did through their social media accounts.



Img. 59 - Post by Dionysios Simopoulos - Astrophysicist

Img. 60 - Our page reposted by Adrian Golemis

Overview of interviews and articles

More than 15 interviews about our work were given, most of them available on our channel. (Interviews)

Below is our media coverage in numbers still rising as we approach the ESA launch campaign.

	Newspaper Articles	Website Articles	Radio Interviews	TV Interviews
National	9	31	5	4
Local	7	12	5	6

(Media coverage Links)

An interview is scheduled to be held with national TV station ET3 (Greek public TV 3) regarding our participation in the CanSats in Europe competition.

8. CANSAT REQUIREMENTS

Characteristics	**Figure (units)**
Height of the CanSat	115mm
Mass of the CanSat	348gr
Diameter of the CanSat	66mm
Length of the recovery system	400mm
Flight time scheduled	125sec max (***variable descent rate mission***) (drop 1000m)
Calculated descent rate	8 (tested) – 9(still under testing) m/sec (***variable descent rate mission***)
Radio frequency used	433.55 MHz
Power consumption ***(Test based)***	Flight Module 340mA / Payload M. 150mA
Total cost	274.22Euro

On behalf of the team I confirm that our CanSat complies with all the requirements established for the 2018 European CanSat competition in the official Guidelines.

Nikolaos Maretas

Ioannina, Greece
09 June 2018