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UNIBS CANSAT TEAM Galileo Primo

Primary mission

Measure air pollution after release and during descent and transmit these data as telemetry to the ground station at least once every 2 seconds

Secondary mission

Each team through its Ground Station must be able to send a telecommand (uplink) to CanSat, during the descent, which must be possible to register visually by the Jury (e.g. deploy of some parts, fake

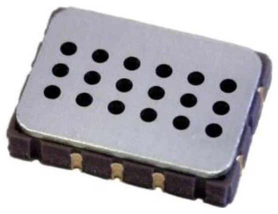
Measuring air pollution

PM is a common proxy indicator for air pollution. The major components of PM are sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water.

It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air.[1]

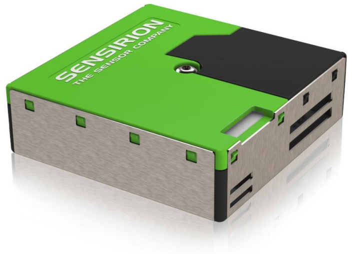
1) https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health

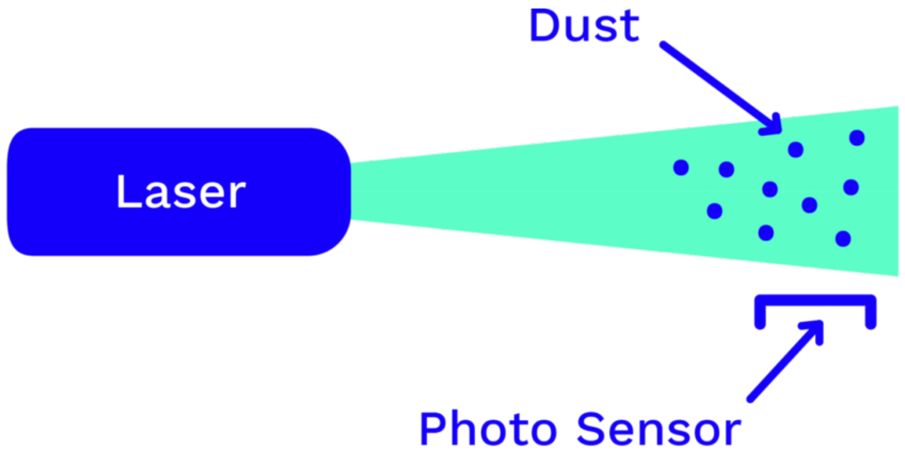
Air pollution - Gas sensors



MICS-6814:
-NO2
-CO
-NH3

SENSIRION SPS30:
-PM0.5
-PM1.0
-PM2.5
-PM4.0
-PM10

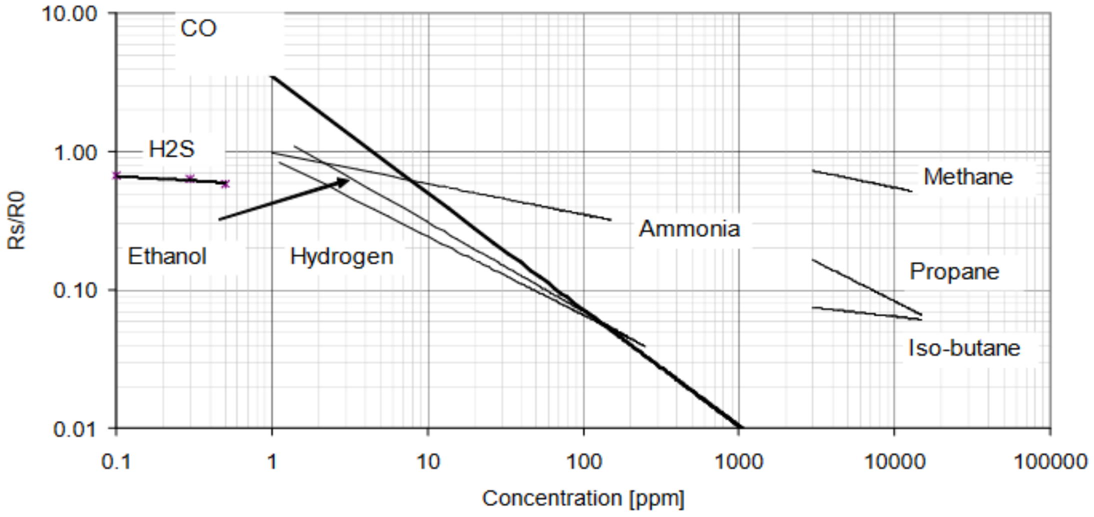




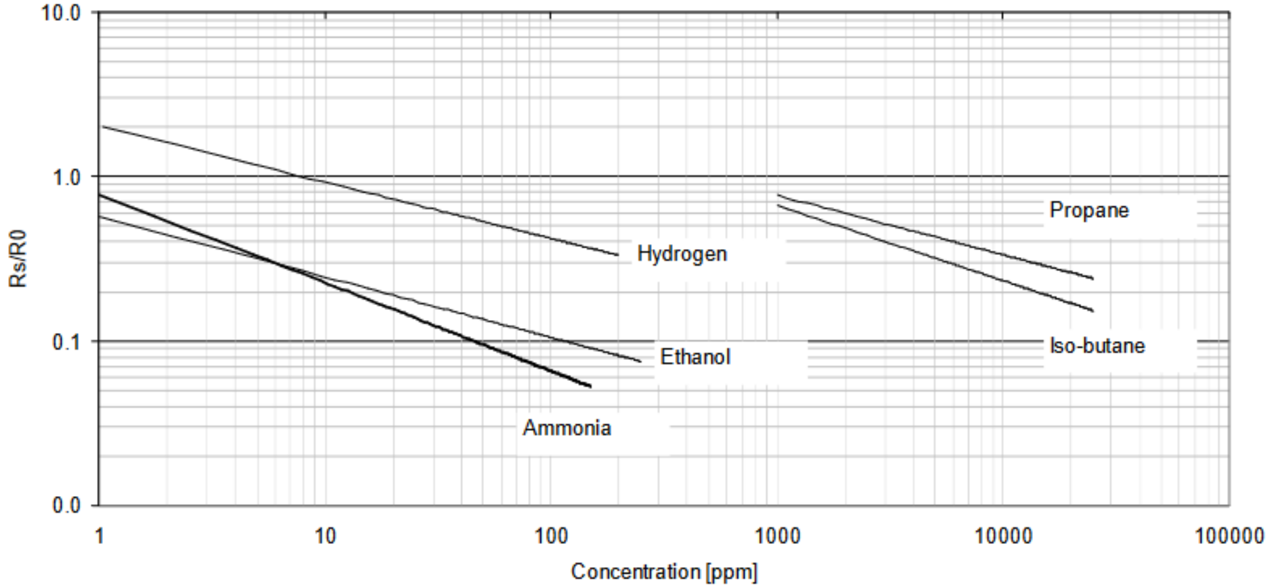
Air pollution - MICS6814

The MiCS-6814 is a compact MOS sensor with three fully independent sensing elements in one package.

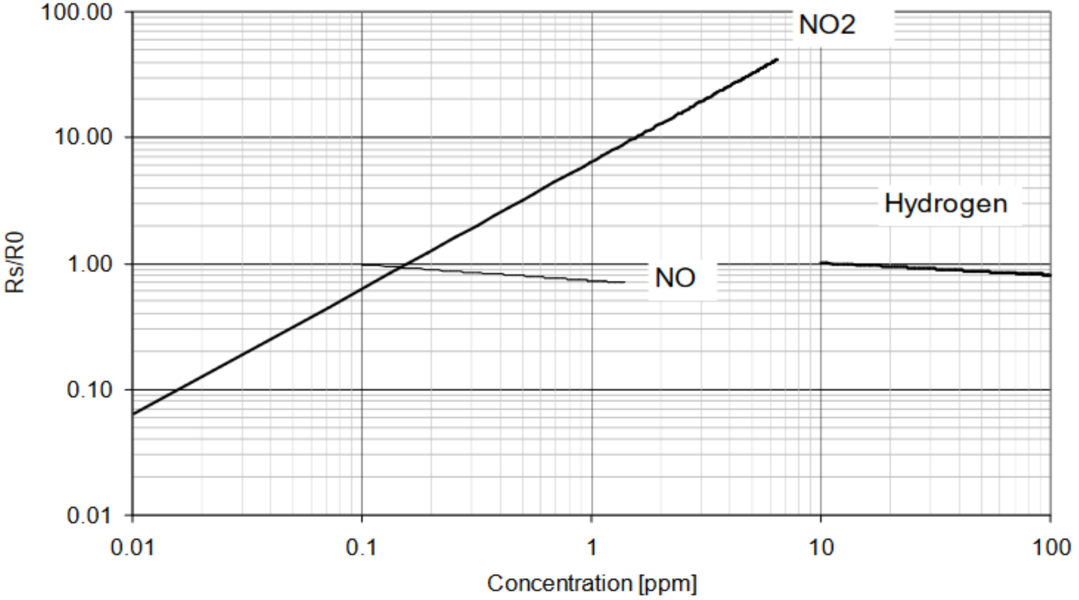
The three sensing elements are sensitive to different group of gasses: REDucing, OXidizers and ammonia



RED sensor, continuous power ON, 25°C, 50% RH



NH3 sensor, continuous power ON, 25°C, 50% RH



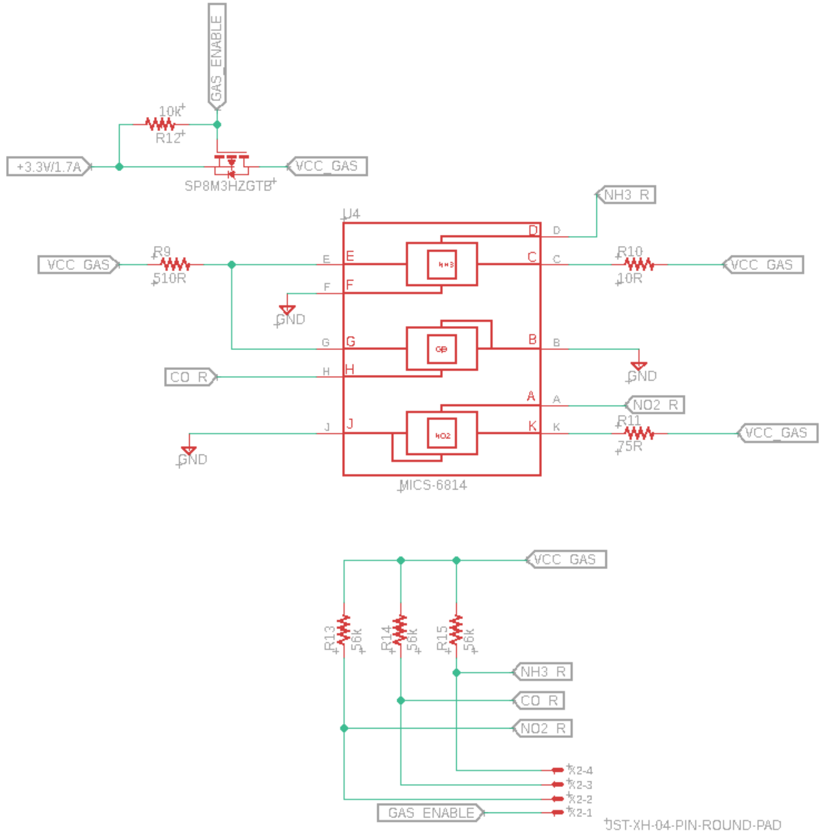
OX sensor, continuous power ON, 25°C, 50% RH

Air pollution - MICS6814

MOS sensor elements changes their resistance with the gas concentration.
Simplest way to measure: resistive voltage partitor and microcontroller ADC

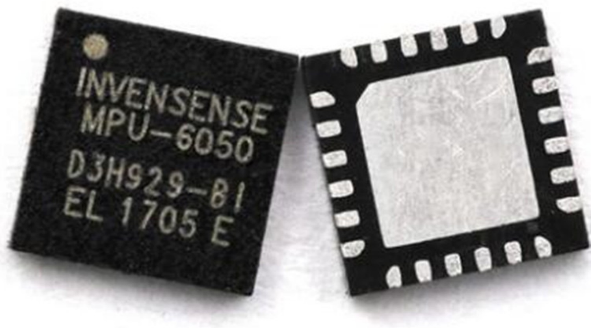
Heating elements are power hungry

Added a mosfet to cut the power supply when the sensor is not used



Other sensors

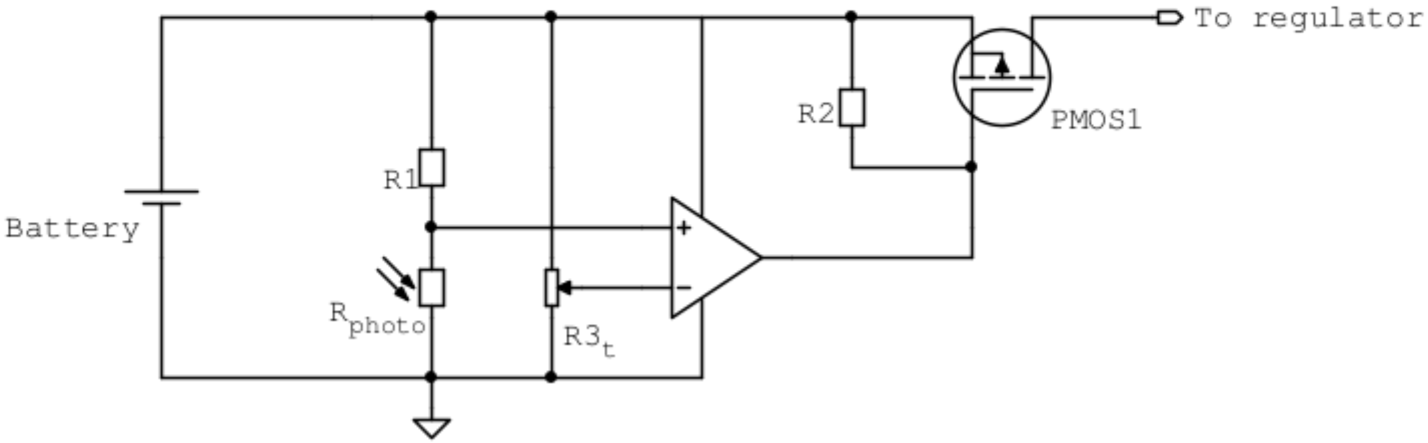
GPS NEO-6M



Accelerometer/Gyroscope MPU-6050

Power ON circuit

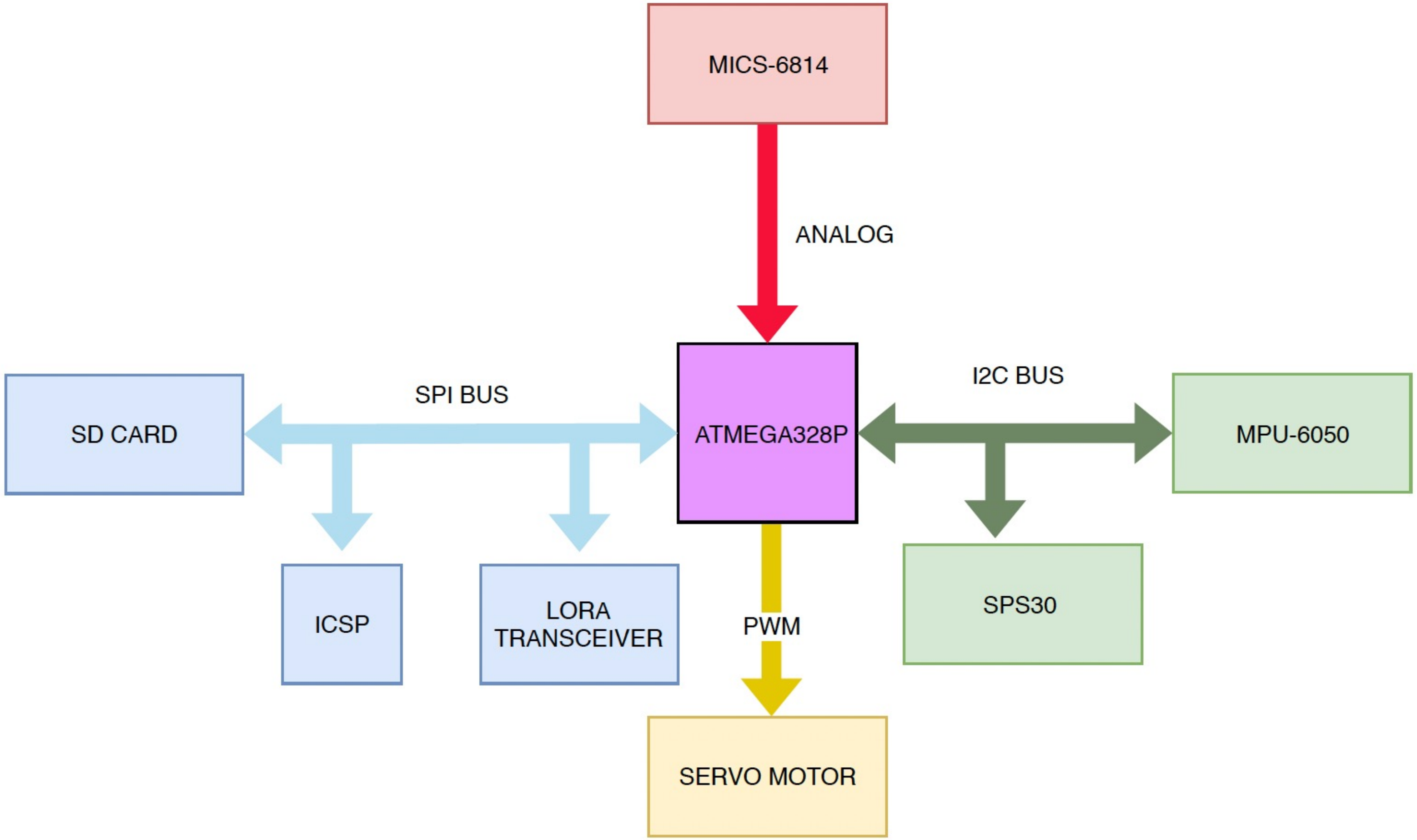
Voltage on photoresistor compared with a fixed threshold



Output of the comparator is high when light is low. PMOS is low-gate active

Entire system is unpowered inside the dark rocket

System architecture



LoRa communication

Primary mission: transmission at least every two seconds

↓

European regulations: 36s available for communication time on air

↓

Limited packet dimension 1800 packets in an hour

COMMISSION IMPLEMENTING DECISION (EU) 2019/1345

of 2 August 2019

amending Decision 2006/771/EC updating harmonised technical conditions in the area of radio spectrum use for short-range devices

(notified under document C(2019) 5660)

(Text with EEA relevance)

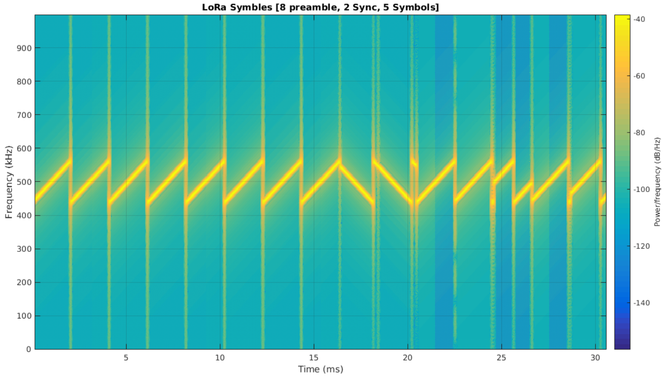
Band no	Frequency band	Category of short-range devices	Transmit power limit/field strength limit/power density limit	Additional parameters (channelling and/or channel access and occupation rules)	Other usage restrictions	Implementation deadline
48	868-868,6 MHz	Non-specific short-range devices	25 mW e.r.p.	Requirements on techniques to access spectrum and mitigate interference apply [7]. Alternatively a duty cycle limit of 1 % may also be used.		1 January 2020

For the purposes of this Annex, the following **duty cycle** definition applies:

"**duty cycle**" means the ratio, expressed as a percentage, of Σ(Ton)/(Tobs) where Ton is the "on" time of a single transmitter device and Tobs is the observation period. Ton is measured in an observation frequency band (Fobs). Unless otherwise specified in this technical annex, Tobs is a continuous one hour period and Fobs is the applicable frequency band in this technical annex. Less restrictive conditions within the meaning of Article 3(3), mean that Member States may allow a higher value for "duty cycle".

Chirp Spread Spectrum Modulation

every symbol can encode 2^SF values



Frequency: 868 MHz
Bandwidth: 500 KHz
Preamble: 6 symbols
Header: 1 Byte
CR: 1 (redundancy, added 1 symbol every 4)
CRC: 1 Byte

$$Npayload = 8 + ceil\left((PayloadSize_{byte} - 4 * SF + 8 + 16 * CRC) * \frac{CR + 4}{4 * SF}\right)$$

$$Tsymbol = \frac{2^{SF}}{BW} \qquad Tpayload = Npayload * Tsymbol$$

$$Tpacket = Tpreamble + Tpayload$$

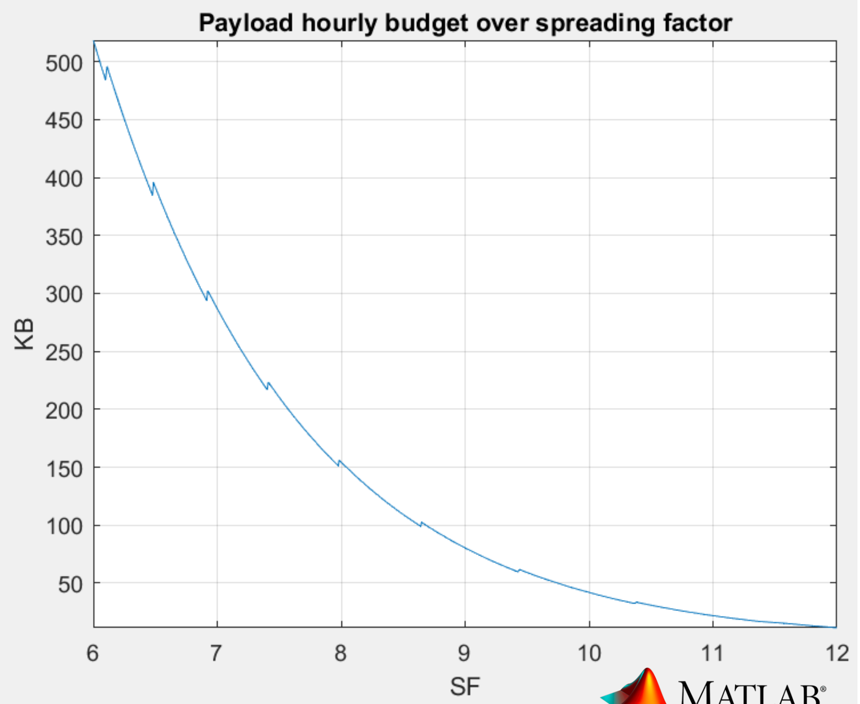
Payload length: 59 Byte

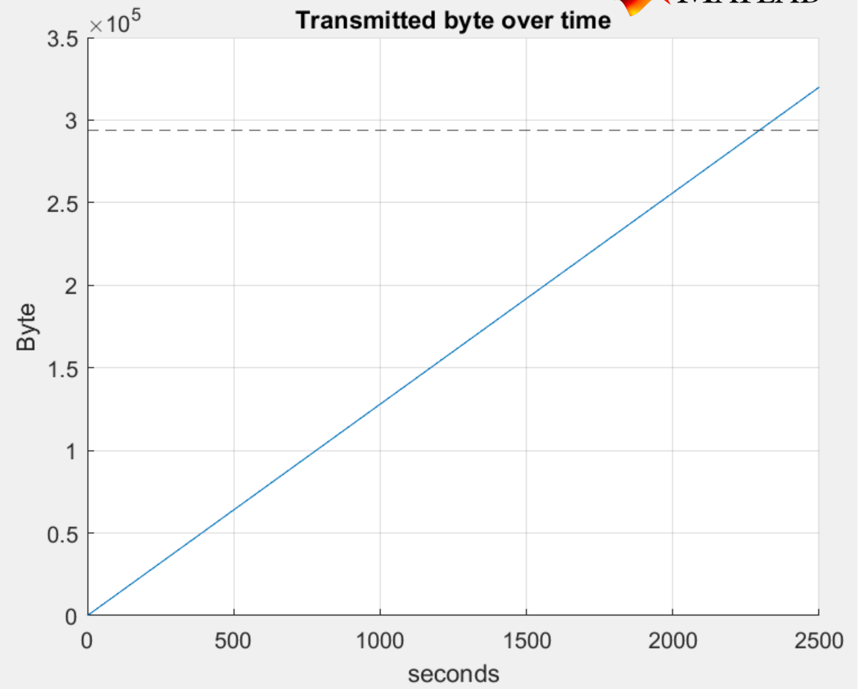
Hourly budget: 287 KByte

Budget reached after 2300s (38 minutes)

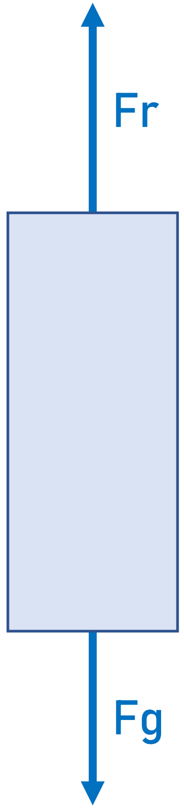
PREAMBLE	HEADER	PAYLOAD	CRC

#PKT	TIMESTAMP	GPS	GAS	PM	TEMP	PRES
1 Byte	4 Byte	12 Byte	12 Byte	20 Byte	4 Byte	4 Byte





Parachutes design



SUPPOSITION: the Resistance force is proportional to the square of the velocity

$$\vec{F} = m \cdot \vec{a}$$

$$mv' = m \cdot g - \gamma \cdot v^2$$

$$v(t) = \frac{1 + \frac{v_o - v_\infty}{v_o + v_\infty} e^{-\frac{t}{\tau}}}{1 - \frac{v_o - v_\infty}{v_o + v_\infty} e^{-\frac{t}{\tau}}}$$

$$v_\infty = \sqrt{\frac{mg}{\gamma}}$$ Terminal velocity

$$\tau = \frac{1}{2}\sqrt{\frac{m}{g\gamma}}$$

Fall after the parachute opening

Short Cylinder →	1.15

https://en.wikipedia.org/wiki/Drag_coefficient

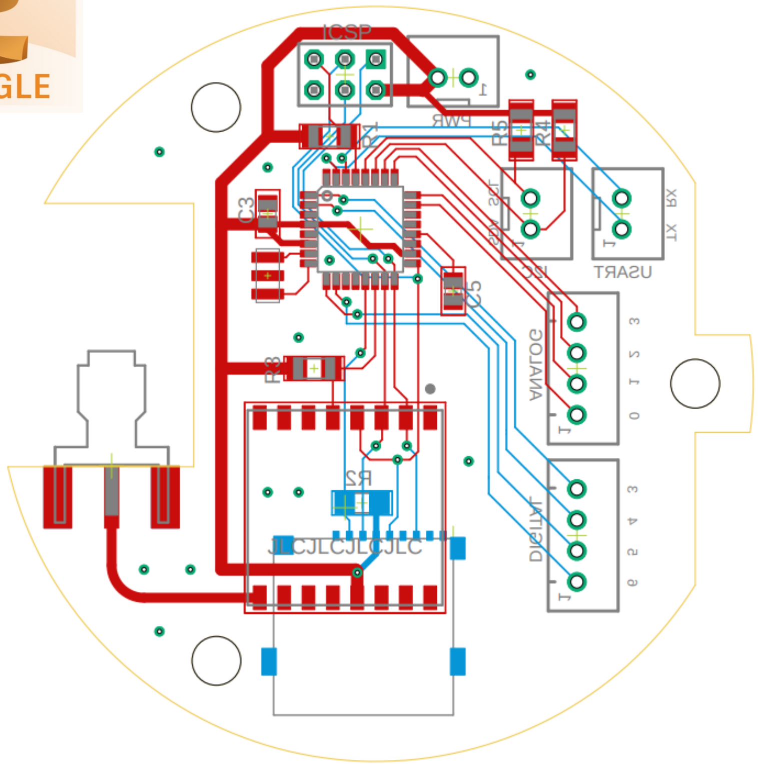
Fall after the parachute opening

Type of body	Reference area	Condition	Drag coefficient C_D
Hollow hemisphere	$S = \pi D^2 / 4$	$Re > 10^4$	→ 0.38 ← 1.42
Parachute	$S = \pi D^2 / 4$		1.4

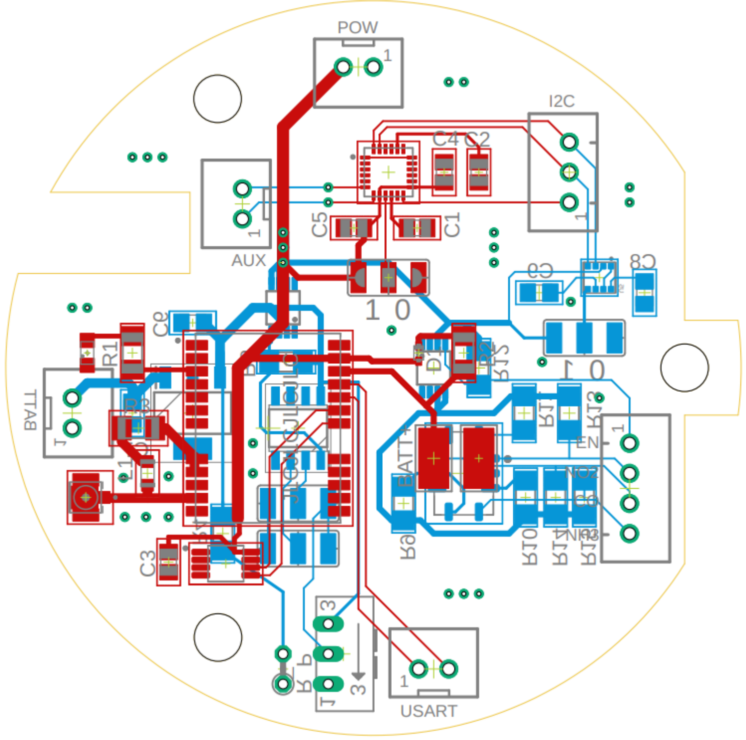
Aziz, Elsayed & Esche, Sven & Chassapis, C.. (2008). Online Wind Tunnel Laboratory. 10.18260/1-2--3402.

https://www.researchgate.net/publication/273771608_Online_Wind_Tunnel_Laboratory

PCBs



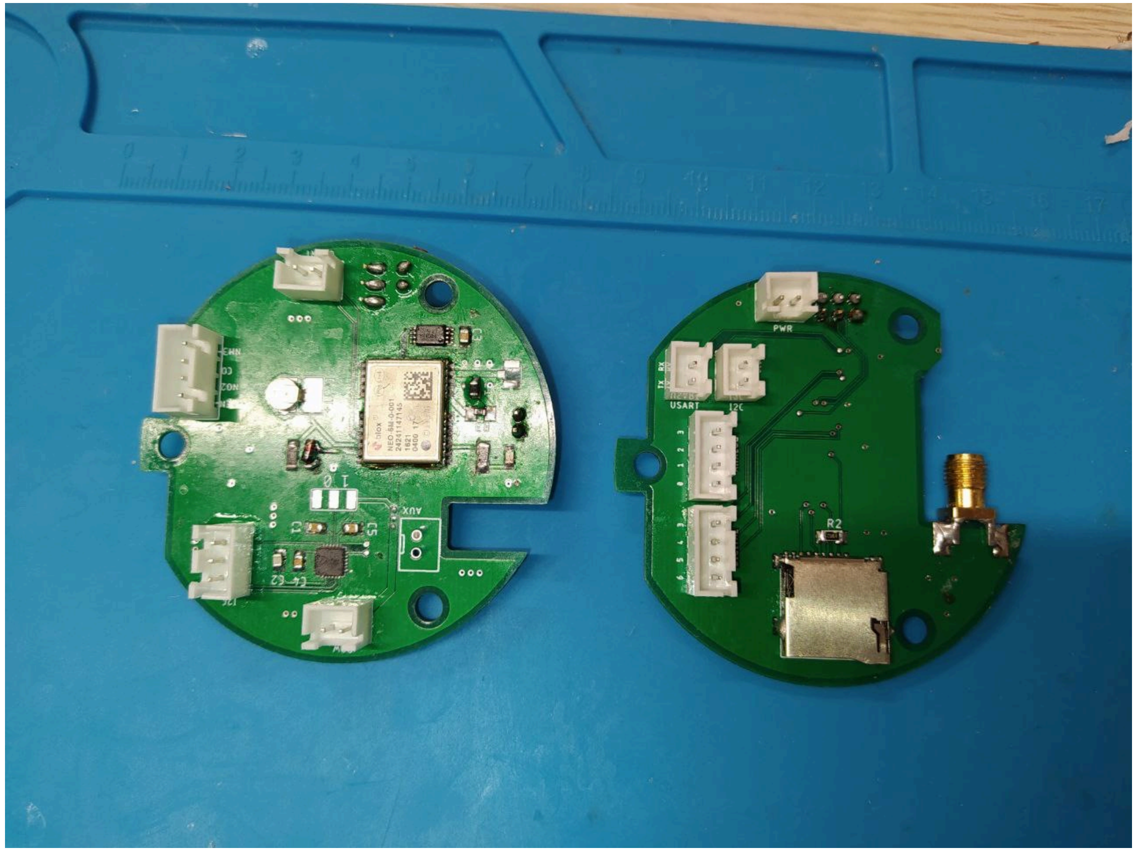
Modularity, new mission
new sensor board



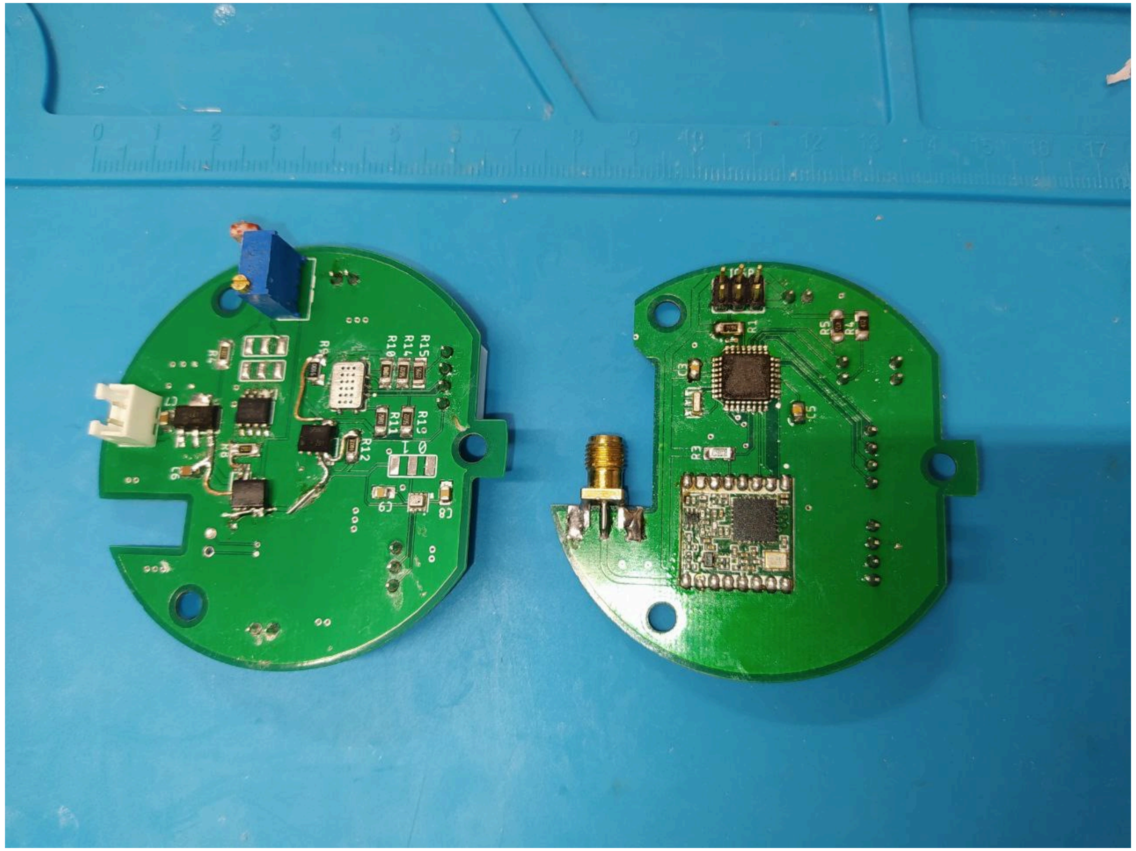
Main board:
Microcontroller
LoRa transceiver
MicroSD

Sensor board:
Power
GPS, inertial unit
Gas Sensor

First critical considerations



JST connectors:
Pro: can be placed anywhere
Cons: occupy too much space and are difficult to wire properly



Double check the packages before ordering!
SMA connector for antenna is too heavy

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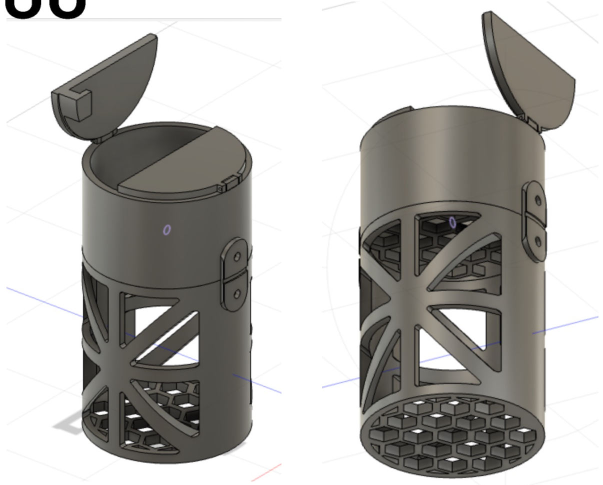
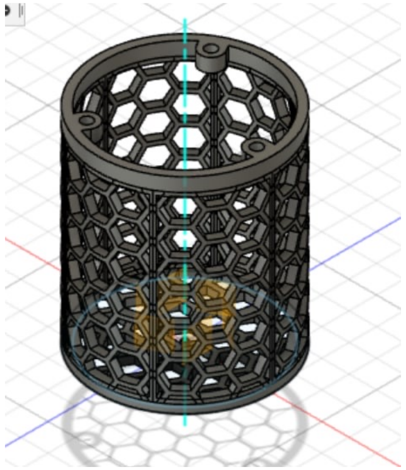
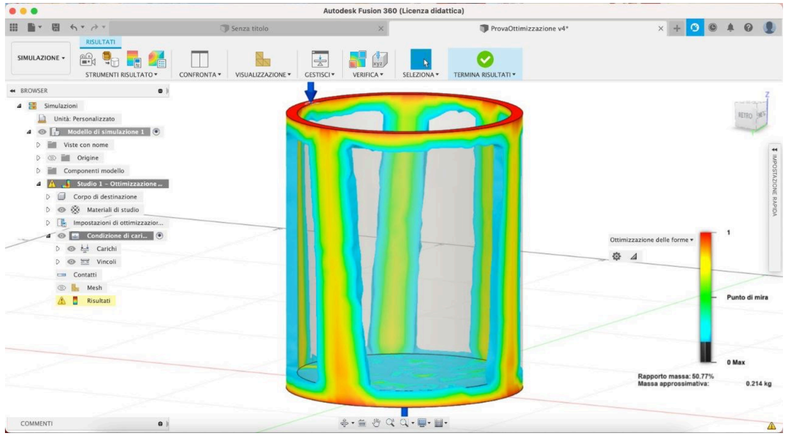
Chassis

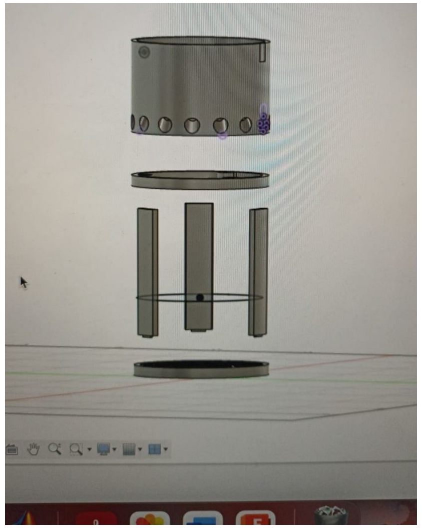


Galileo Primo v1



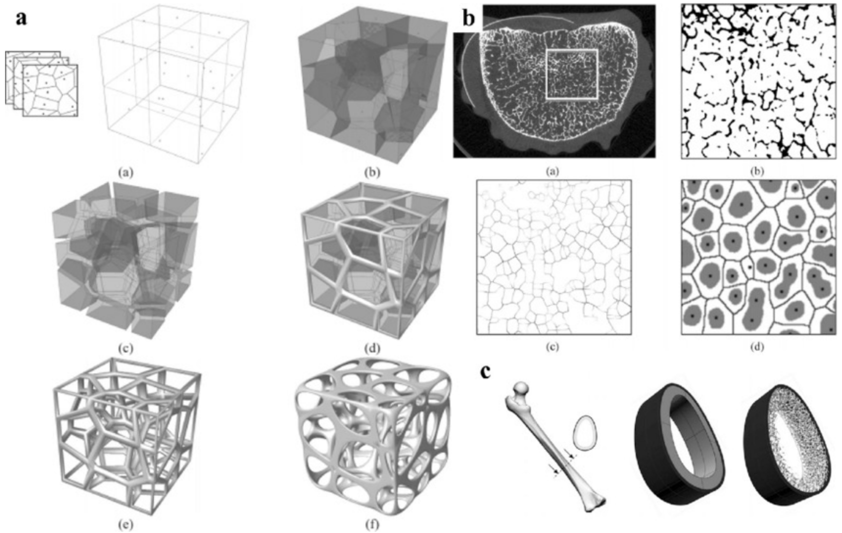
Galileo Primo v2

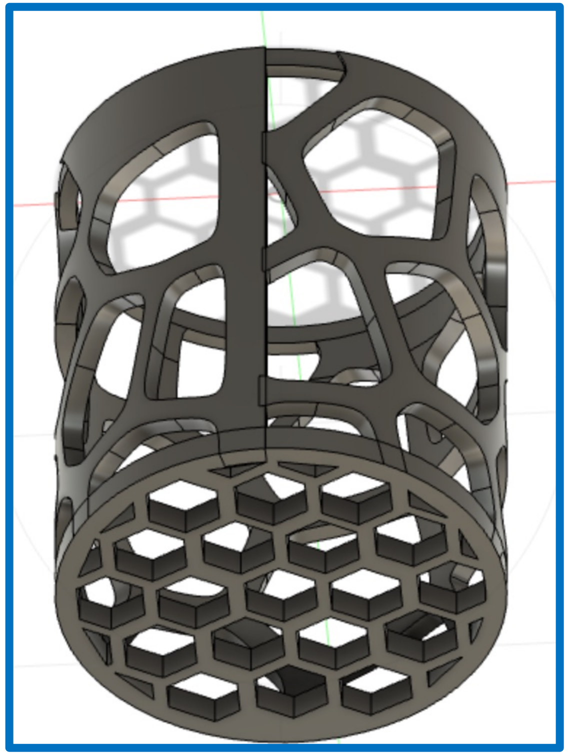




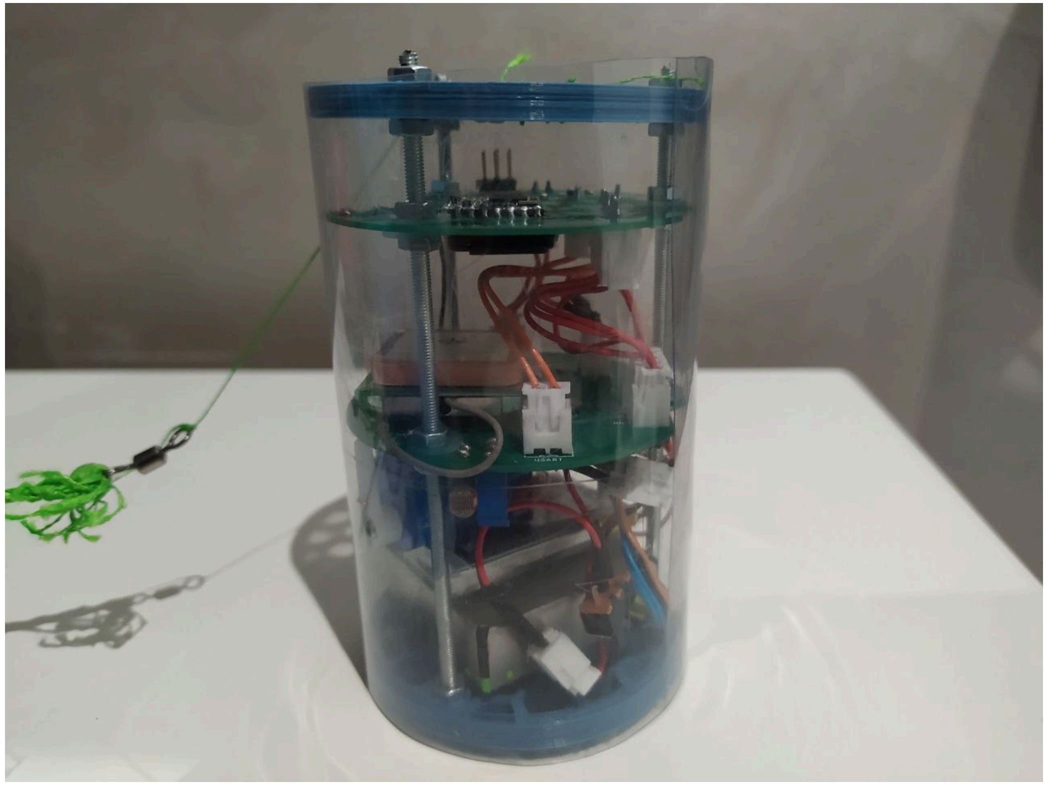
Galileo Primo v3

Chassis – Voronoi Patter





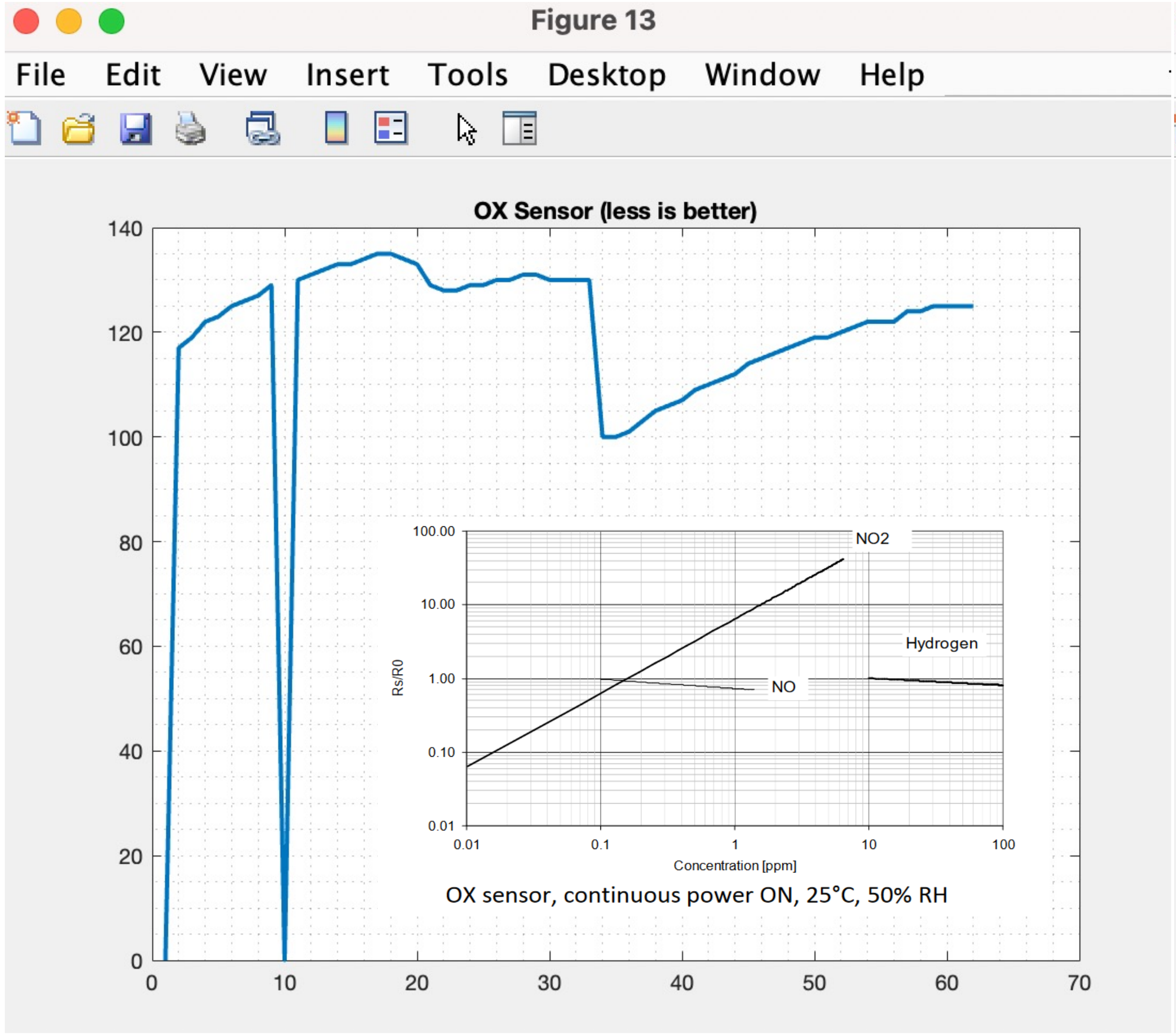
Final chassis



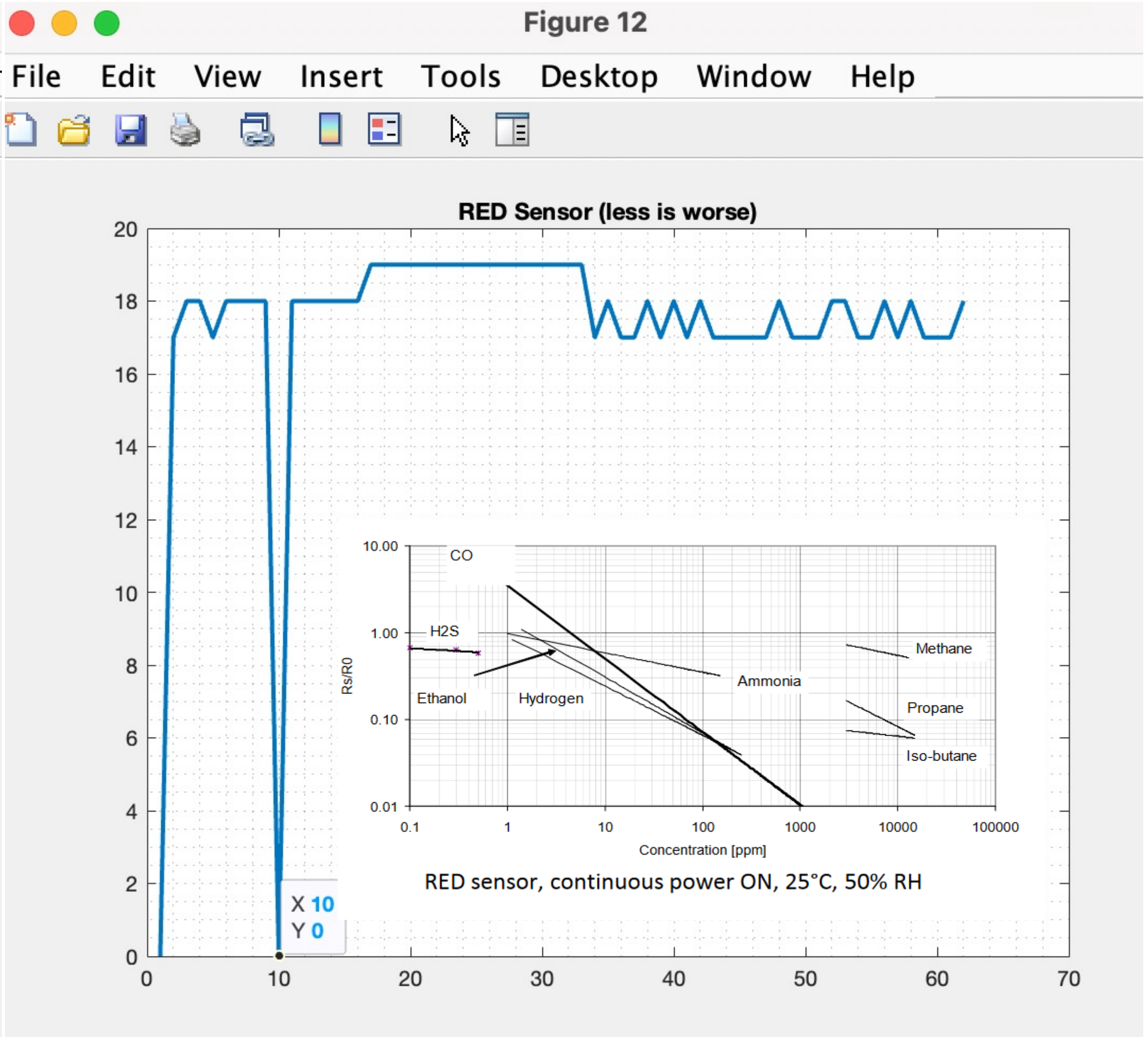
Problem faced – Plan the delivery time

PCBs and discrete components arrived 5 days before the departure
Most of the sensors didn’t work because of careless last minute soldering

DATA



Less is better



More is better

Secondary mission

Deploy of a secondary parachute with a servo motor mechanism

Price

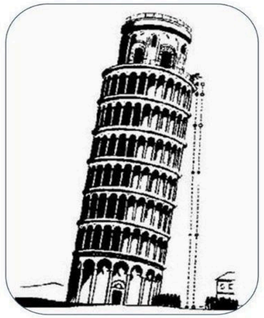
COMPONENT	PRICE (EUROS)
Sensirion SPS30	38,92
CO/NO2/NH3 Sensor	31,99
GPS	9,99
MicroSD reader + SD CARD	7,00
Parachutes and wire	30,00
6 axis IMU	5,00
ATMEGA328P	3,00
LoRa Modules	9,00
3D Printing	24,00
Various components (Voltage regulators, MOSFETs, resistors, capacitors, connectors)	20,00
Servo motor	3,00
Temperature and pressure sensor	7,39
TOTAL	189,29

GALILEO PRIMO

HERE WE HAVE ONE OF THE FATHERS OF MODERN SCIENCE, GALILEO GALILEI (1564-1642)

AMONG ALL OF HIS WORK, WE WILL REMEMBER HIS EXPERIMENT ON THE LEANING TOWER OF PISA

THROWING TWO SPHERES WITH DIFFERENT WEIGTH, GALILEO WANTED TO SHOW THAT THE TWO BODIES WOULD FALL AT THE SAME RATE, REGARDLESS OF THEIR MASS



IN THIS PROJECT WE HAD TO DESIGN A PARACHUTE, IN ORDER TO SLOW DOWN THE FALL OF THE CANSAT BUT, BEFORE THE OPENING OF THE PARACHUTES, THE CANSAT IS IN A FREE FALL

SINCE GALILEO MADE HIS CONTRIBUTION TO THE STUDY OF FALLING BODIES, WE DECIDED TO NAME OUR CANSAT AFTER HIM

THE WORD "PRIMO" IN ITALIAN MEANS "FIRST", SINCE THIS IS THE FIRST VERSION OF OUR CANSAT

IN THE LOGO WE USED A MINIMAL VERSION OF GALILEO'S SKETCHES OF THE MOON, WHICH HE DREW JUST BY LOOKING AT HER THROUGH A TELESCOPE