cansats in europe

PlasticMonkeys
CHIMP CanSat
Final Design Review

Team Name: **Plastic Monkeys**

Country: **Poland**

.pl esero

www.cansat.eu

Table of Contents

1 CHANGELOG
2 INTRODUCTION
2.1 Team organisation and roles
2.2 Mission objectives
2.2.1 Primary mission
2.2.2 Secondary mission
2.2.3 Objectives
2.2.4 Measurements
2.2.5 Expectations
3 CANSAT DESCRIPTION
3.1 Mission overview
3.1.1 Overview
3.1.2 Key elements
3.2 Mechanical/structural design
3.2.1 Body
3.2.2 Safety pin
3.2.3 Battery placement
3.3 Electrical design
3.3.1 General architecture
3.3.2 Primary mission devices
3.3.3 Secondary mission devices
3.3.4 Hardware Platform Interface
3.3.5 Power Supply
3.3.6 Communication system
3.3.7 Failsafe and failover mechanisms
3.4 Software design
3.5 Recovery system
3.6 Ground support Equipment
4 TEST CAMPAIGN
4.1 Mechanics
4.1.1 Hardware alignment
4.1.2 External casing
4.2 Sensors
4.2.1 Thermometer
4.2.2 Barometer
4.2.3 Thermographic camera
4.2.4 Raspberry Pi Camera
4.2.5 GPS
4.3 Tests of recovery system
4.4 Communication system range tests
4.5 Energy budget tests
5 PROJECT PLANNING
5.1 Time schedule
5.2 Task list
5.3 Resource estimation
5.3.1 Budget
5.3.2 External support
6 OUTREACH PROGRAMME
7 CANSAT CHARACTERISTICS

1 CHANGELOG

1. We performed “takeoff readiness assessment”
2. More additional tests we conducted (see chapter 4):
    a. next parachute descents from tall buildings
    b. drone drops - parachute and radio communication tests
    c. sending photos via radio - field tests
    d. TPU durability - field tests
3. Electronic design:
    a. we developed all electronic boards
    b. we created our ribbon based connections
    c. all electronics working together
4. Software design:
    a. written code for photos serialization/deserialization
    b. written code to send our data through LoRa
    c. written code to deserialize packets on PC
5. We’ve successfully finished all of our 5 sponsorship deals
6. We learned that systematic work based on team effort is necessary to achieve intended purposes.
7. We managed following outreach gigs:
    a. active promotion on Facebook and Instagram fanpage (continuation)
    b. taking part in Pykonik’s meetup with our presentation about the CanSat and its Python code
    c. presentation about CanSats for high schools’ students
8. Project budget has been updated (again)
9. We came to the conclusion that one of the modules we planned to develop (the module with cameras) in the framework of our secondary mission is far more interesting and challenging than the other one (with oximeter only). For this reason we decided to focus on that one module with cameras (because it will be used during the rocket drop), but to emphasise that our idea of interchangeable modules is completely applicable, we are going to develop entirely the module with oximeter for the drone drop during finals. (see 2.2.2)
10. We took part in webinar with the Jury so that we gained some useful informations.
11. Due to other activities and duties, Jan Derlatka (Lead Mechanical Designer) has left the team

Flight readiness assessment - we are ready to take-off!

Element	Is it tested?	Is it ready?	Is it doable between FDR and start campaign?
Durable CanSat 3d printed body	✔	✔	
CanSat external shell	✔	✔	
Parachute setting descent speed between 8 and 11m/s	✔	✔	
Cansat weight lays between 300 and 350g	✔	✔	
CanSat dimensions do not exceed soda can size	✔	✔	
Primary mission sensors	✔	✔	
Primary mission software	✔	💡 (tightly coupled with secondary mission software)	✔
Stable lora radio link for long range (5km)	✔	✔	
Secondary mission equipment	✔	✔/💡 PCBs v1 proved working, PCBs v2 yet to be confirmed	✔
Secondary mission software	✔	💡 (core ready to be deployed, some parts need to be tweaked)	✔
Ground station electronics	✔	✔	
Ground station software	✔	✔	

2 INTRODUCTION

2.1 Team organisation and roles

At school we can gain knowledge in the fields of maths, physics, IT and biology that is crucial when constructing our CanSat. Not all issues are directly connected with ours, but we estimate that 2 hours of schoolwork per week are linked with the project. Moreover, we meet once a week, discuss the work progress and make plans for further growth, that's additional 3 hours. To work on our tasks, after school we dedicate approximately 5 hours of contribution weekly per person. It wraps around 10 hours weekly per person.

Our team comprises the following members:

Patryk Gałczyński - Project Manager, Tech-lead, Supervisor

Patryk is a fifth year Computer Science (major in Systems Modelling and Data Analysis) student at the AGH University of Science and Technology. He founded and runs RoboTeam science club in our high school, where we know him from. He made a couple of autonomous mobile robots called mini-sumo and line-followers. He works as PaaS layer cloud platform developer in Dreamlab, which means lots of DevOps challenges and writing tons of code in Python **Tasks:** Patryk is acting as our project manager, tech-lead and supervisor. That means, he provides us with tools to work efficiently (like Trello or Git repository), organises our work by planning meetings, and pushing us to work hard every day. He also is our inexhaustible source of knowledge about electronics, Unix systems and software engineering and a helping hand when it comes to tough architectural decisions.

Jakub Podolak- Team Leader, Lead Software developer

Kuba - second year student of V High School in Cracow, member of school RoboTeam. Experienced in building different robots such as mini sumo, robotic arms and drones. In his free time he also codes in C++ and Python - mainly programmes for Arduino and Raspberry Pi. He is familiar with power tools, PCB making, soldering and 3D printing, participant of many robotic competitions such as Robotic Arena, Robomaticon. Besides he is sociable, likes meeting new people and taking on new challenges . Also skilled in vlog making and promoting. Enthusiastic about every new task, having great fun while working in team.

Tasks: Kuba's enthusiasm and charisma is going to spread in the whole team and keep it motivated - he is ready to be the team leader, help each member in case of any trouble. Kuba will also be responsible for YouTube worklogs and vlogs (promotion of

CanSat). With his experience in programming, Unix systems, electronics and mechanics he is a versatile executor of tasks and problem solver.

Grzegorz Żmija - Lead Physicist

Grzesiek is in second grade at V High School in Cracow. He is mainly interested in physics and maths, but he has various hobbies including music, chemistry, martial arts and origami. He is familiar with soldering iron and other hardware tools. He also likes working under pressure and has experience in dealing with hopeless situations. His

greatest successes in robotics were second place in Line Follower category at uBot (cooperation with Bartek) and some other minor robots.He is sociable, likes meeting new people, especially with similar interests, and taking on new challenges.

Tasks: His physics knowledge and hardware skills will definitely come in useful in the creation of a reliable CanSat. He will also be responsible for physical calculations during the project. On top of that, he is ready to give the team a hand in making hardware. His cold blood and ability to quick solve unexpected problems might be useful if something goes horribly wrong. He also hopes to learn some software design principles from his more experienced colleagues.

Julia Jakieła - Lead Outreach Officer

Julka is in second grade at V High School in Cracow. Although she attends biology and chemistry class, she is interested in electronics and programming and this is why she decided to broaden her knowledge in these areas. As the result, she learnt the basics of Python and Java, made some Arduino projects and built few simple robots. In love with different types of manual work - she pays great attention to details what is useful when soldering, drilling or making PCB. Recently she got familiar with PCB designing in Eagle. She is a kind of perfectionist with the belief that hard work is a key to success. Ready for all challenges and new dose of knowledge.

Tasks: Her social skills would be useful in order to increase public interest in our project. Julka will be responsible for outreach and promotion. She will also contribute in areas such as electronics and mechanics. On standby for cooperating with other members of the team to realize all our plans before deadlines. She also hopes to share some essential information in the field of biology while accomplishing our secondary mission.

Bartek Słupik - Lead Data Processing Engineer

Bartek is a student in his second year of high school. In his free time, except for various forms of physical exercise, he undertakes diverse Arduino projects. He has some substantial experience with Python and possesses essential electrical skills and knowledge. Furthermore, during our project Bartek has learned to develop 3D Models and make them real. He prefers hands-on doings over pure theory, which was the deciding factor for him to participate in the Cansat project.

Tasks: Bartek's experience with microcontrollers makes it possible for him to develop basic software efficiently. He is also ready to give the team a hand in the area of data analysis and processing and all kinds of necessary research. Moreover, due to the fact, that one of his hobbies is hiking in remote areas, he is well versed in rescue technology and equipment - his task will also be to see to it, that the Cansat fulfills the guidelines of the mission.

Jan Derlatka

Because of the A Levels approaching and participating in Physics Olympiad he realized that he wouldn't be able to take so many responsibilities so after having prepared some CAD models for Plastic Monkeys he decided to leave our group.

2.2 Mission objectives

2.2.1 Primary mission

Our primary mission is to take measurements of temperature outside of cansat casing and atmospheric pressure, then transmit them to base station at least once a second. All the gathered data will be both logged to the memory of the Sat and saved at the base station after being received via LoRa link. Furthermore, all data will be uploaded to an online time-series database. This won't just enable full data recovery in case of a radio communication failure, but also allow us to analyze data during the descent. Basing on the recordings, the data analysis will be conducted and the correlation between the measurements will be presented.

2.2.2 Secondary mission

Our original idea for the secondary mission was finding people who got lost in the mountains. This was to be achieved by combining thermal images and regular images with GPS recordings, thereby enabling the rescue team to get the exact location of the target. By dropping many of such devices during a helicopter flight, the rescue team would be able to find the injured person faster. In order to ensure that we are making something really useful (not only in theory), we consulted our idea with the experts from Mountain Rescue Service (GOPR/TOPR). They indicated some drawbacks: 1) In high mountains people use down jackets to keep the heat - that would unable our thermal camera to identify them, 2) Helicopters aren't used as frequently as we thought so there could be a problem while scattering CanSats, 3) Such devices should be: numerous, produced at a low cost, prepared for different weather conditions.

So we came to the conclusion that we should modify our secondary mission. Although it might not be the best suit for mountain areas, we think that our developed solution may be useful in other cases, hence we'd like to adapt our CanSat to prepare it for different emergencies. To accomplish that, the CanSat will consist of one basic module that will ensure two-sided communication between the victim and a rescue team. The injured person will communicate with base station by pressing buttons in answer to questions displayed on a small screen. The main unit is extendable with additional modules attached at its bottom by defined hardware platform interface. This allows the Cansat to be adapted to the purposes of a particular operation or its environment. The following list contains several module ideas proposed by us, although this spare room could be used in numerous other ways:

- When an earthquake occurs – an earthquake sensor could be used to measure seismic activity after landing - providing real on-site data,
- When there is a tsunami – adding to set mentioned above waterproof casing that could even drift on water,
- During volcanic exhalation - gas sensors would give some information about the eruption,
- In each situation the rescue team could deliver necessary things (like pills, a syringe of insulin, etc.) to victims using a transport module;
- Scanning the terrain in order to find lost or injured people - comparing the images from a camera and IR array we would be able to define the victim's localization
- After a disaster in hard-to-reach places - heart rate sensor and oximeter would be helpful in defining preliminarily whether vital signs are stable or not,

On the grounds that the last two of the depicted modules are the most versatile ones and their application is closely bound to saving people's lives, we decided to develop both of them for the finals. Because we can fit only one in our Sat, we've decided to use Double-Camera module in our main descent so in this report we focus on that module.

Both thermal and color images will be sent to base to enable immediate investigation of the area of flight. The analysis of those can aid in determination of victim's localisation and save precious minutes during a rescue action or just be helpful in scanning the terrain.

For their part, heart rate sensor and oximeter enable us to gain substantial information about victim's health status. But these data isn't sufficient. For this reason we will send some questions that will be displayed on a can's OLED. In that way we will complete initial medical interview which, alongside the measurements form sensors, will be helpful for rescuers and doctors. Planning a full interview in advance is really hindered due to the fact that human body is an incredibly complicated mechanism and there are numbers of different cases of being injured. Though, we have prepared a scheme (attachment #1) showing how we will conduct the interview, allowing the victim to reply only by pressing YES/NO/I DON'T KNOW Buttons. We will send our questions as Strings from our base station, and listen for an answer.

The main idea emerged because by carrying out our project we want to succor rescue actions. Maybe it will contribute to minimize the number of deaths in emergencies. Such mission would tackle the real problem.

2.2.3 Objectives

We will consider the CanSat launch as successful under the following conditions:

- measuring all parameters and transmitting them to base to accomplish the primary mission
- after the descent, successful transmission of requested photos from different moments of flight (rocket drop)
- after the descent successful reading of victims vitals (drone drop)
- reaching stable two-sided radio communication
- building an additional module (because of the limited space in a rocket probably only one module will be attached on board) - our aim is to receive all essential data from the module.
- No structural damage or electronic failure after landing
- No trouble with localisation of the CanSat after landing due to provided gps readings and attention drawing elements
- Cansat will remain operational for at least 5 hours

2.2.4 Measurements

During our missions the sensors will be used to:

- measure temperature, pressure and humidity
- GPS tracking
- measure altitude
- measure victim's pulse and oxygen saturation (drone drop)
- display questions on the screen and enable to answer them by pressing buttons (drone drop)
- save thermal photos (rocket drop)
- save color photos (rocket drop)

2.2.5 Expectations

In our research we want to evaluate how our "CHIMP", equipped with adequate sensors, works as a rescue device and make sure that it would be a real help for rescue teams in the future. First and foremost, we can provide victim location to the rescue team in no time. What is more, thanks to the user interface display provided on our CanSat, we could ask some crucial questions from the base station and gain information about the person who would be responding. Moreover, we want to show that the idea of exchangeable modules is realisable concluding in reusability in different environments. To prove that the concept of designing different modules is innovative, we are planning to use both modules that we are creating on finals day - the vital signs measurement one during the drone drop, and the camera module while scattering CanSats from the rocket. This is also due to the fact, that on the rocket flight no interaction with the device is allowed, which is definitely not the case during the camera module operation. The results will emphasise that our CanSat can be adjusted to various environmental conditions, and the modules are easy to change and customize. We hope the performance during finals will show that our CanSat is ready to accomplish real-life challenges.

3 CANSAT DESCRIPTION

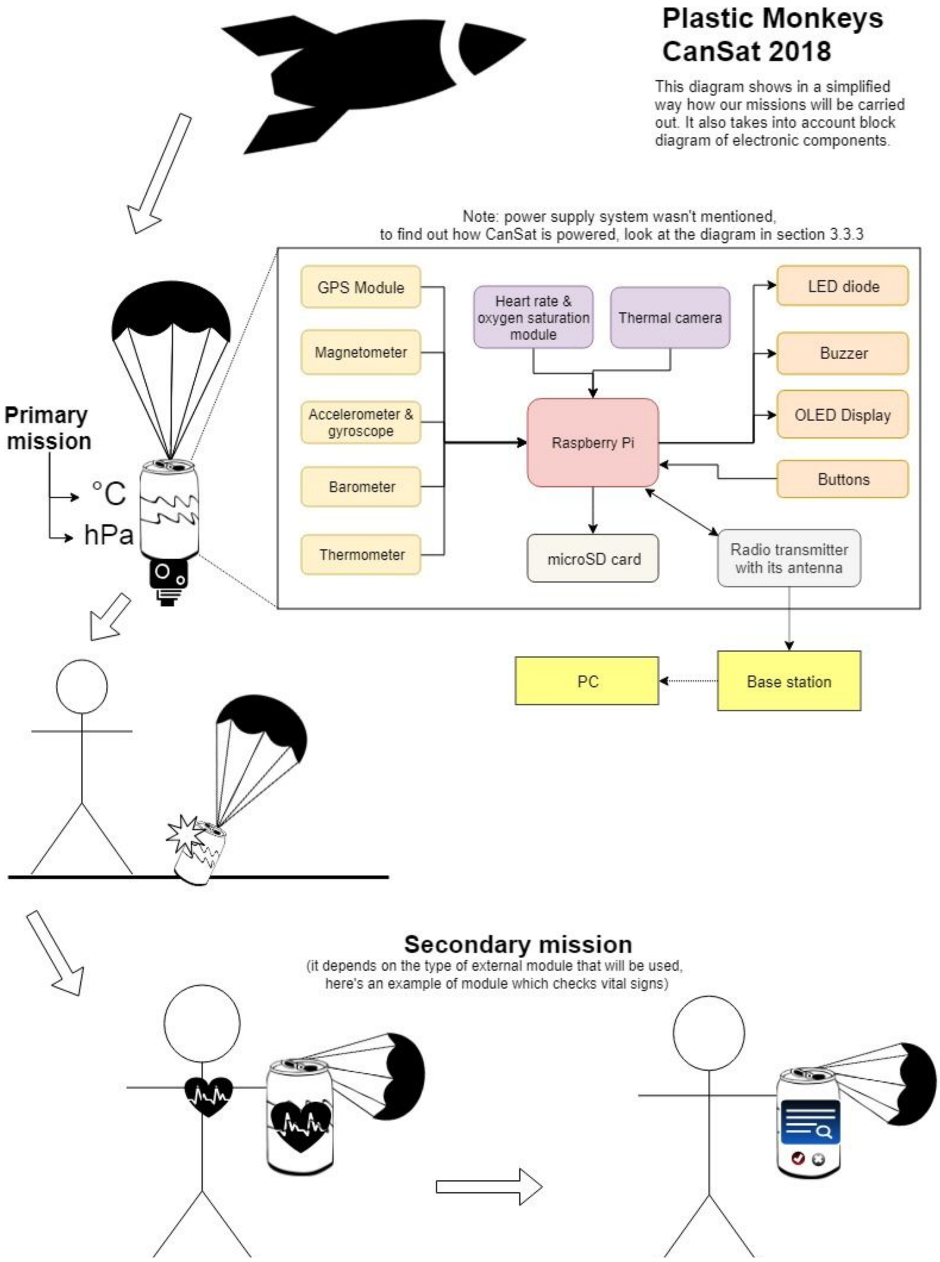
3.1 Mission overview

3.1.1 Overview

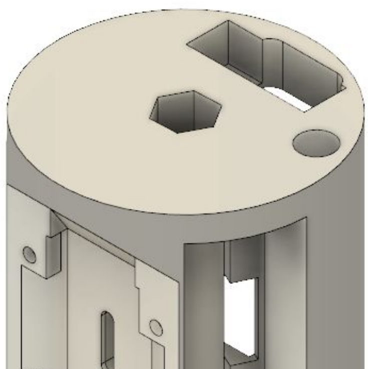
Before the launch, we will set onboard electronics to standby mode to decrease power consumption, then pack the parachute and prepare base station. Having reached the altitude of about 3 km, the parachute will unfold after the cansats will have been scattered. Its parameters are estimated to make our Sat achieve the target velocity of 9m/s during descent. In the time of the flight various measurements will be conducted: temperature, pressure, position, GPS logs, IMU readings. All data will be stored in log files on the SD card, and the key results such as thermometer, barometer and GPS readings will be transmitted to base. Furthermore, every 5 seconds, color images and thermal camera readings will be taken. These pictures will be stored in relevant directories on the SD Card, and be ready for transmission to the base station after a request. This will also happen once during the flight as after touchdown in rough terrain the radio link may break. To catch attention, we will use a buzzer and a LED that will blink every several seconds. Methods mentioned above will enable a potential victim to find the CanSat. After being found, our Chimp will be used to measure the heart rate and oxygen saturation of the person who puts their finger on the sensor. Moreover, we will send rescue-related questions and some recommendations based on the victim's situation. After receiving our CanSat, we will check its condition and analyze saved data.

3.1.2 Key elements

Onboard electronics includes: main computer, thermometer, barometer, an IMU unit, GPS, radio transceiver with its antenna, an OLED screen with buttons, high-power LED, buzzer and a kill switch. Additionally, the secondary mission modules: heart rate sensor in the first one, thermal sensor array and a camera in the other one. Casing and parachute are essential mechanical elements.

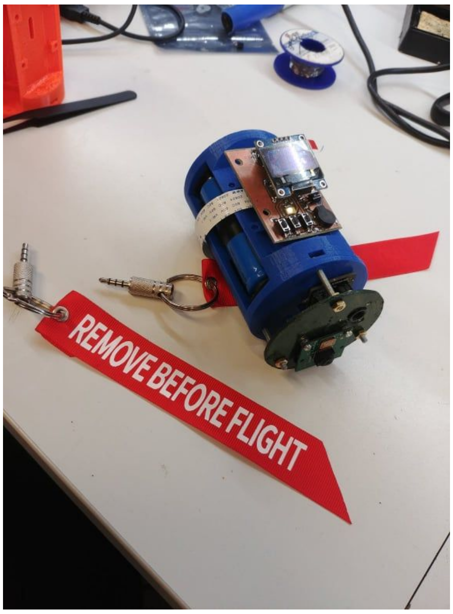


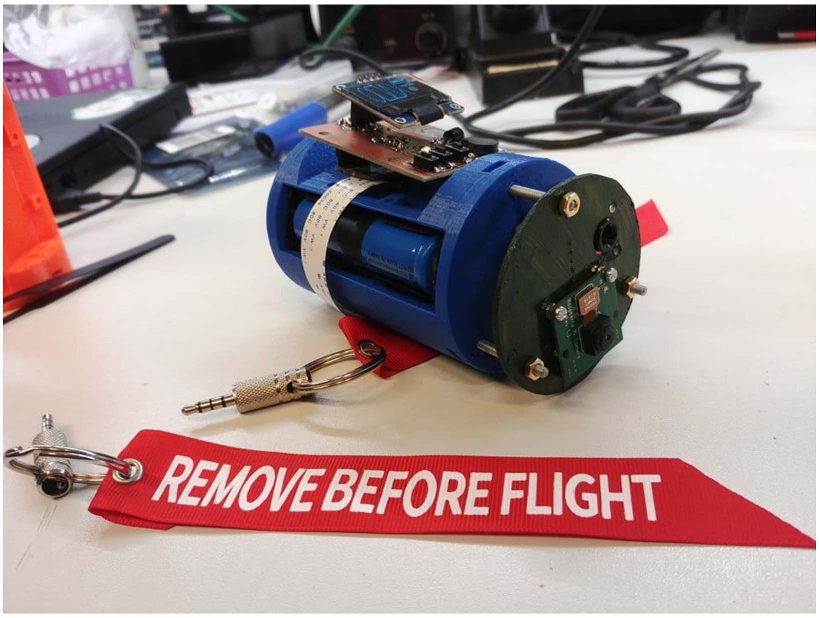
3.2 Mechanical/structural design



3.2.1 Body

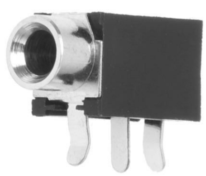
The internal body of our CanSat is made out of 3D printed PLA. We have designed our own 3D model (available in our [github repo](), attachment #2) providing compartments for all sensors and electronic components. It also features place for a threaded rod, which is placed in the center and provides mounting point for parachute. Also, the monolithic structure seems durable - more about that in tests section. Internal electronic components are mainly soldered to the motherboard, which is screwed to the body. Temperature sensor, OLED display, buttons and a LED driver will be soldered to the second PCB board, that will be screwed in place as well. External casing in the form of flexible skin will be cast from TPU/silicone in a form of elastic tube, that our CanSat will tightly fit in. This makes our Sat more shockproof, and dust/waterproof. We will provide a special cutout in it for the display and buttons. Also, our project assumes creating interchangeable modules - we will mount them to the main body using screws at the bottom of the device. With such skin the overall mass of the CanSat is 312g.





3.2.2 Safety pin

One of main CanSat requirements is having main kill switch accessible and easy to use. We were considering a push button with a cap, which pushed turns our CanSat off, and after removing this cap our Sat turns on, however this solution turned out to be not satisfying. Mechanical parts inside were shaking and the cansat was rebooting after we put the safety pin on a vibrating drill.



Our current approach is to use a 3,5 mm audio jack, connected to a power converter. When inserted, it switches the converter to sleep mode (shorts shdn pin to ground). Before the flight we are removing the jack plug - converter exits sleep mode and starts to work. This approach is great for our CanSat -

lack of moving parts excludes vibration concerns, also there is no possibility to enable sleep mode without our jack jumper-key - push button wouldn't give us these pros.

Several conducted tests ensured us, that our solution is generally safe. Even after them, we decided to add a small jack-cap - male jack connector without any wires or connections. We will close our safety pin with this cap after turning CanSat on, making any kind of shortage virtually impossible.

In order to turn the CanSat off, one needs to **insert the safety pin into the jack port**, located at the top of the body.

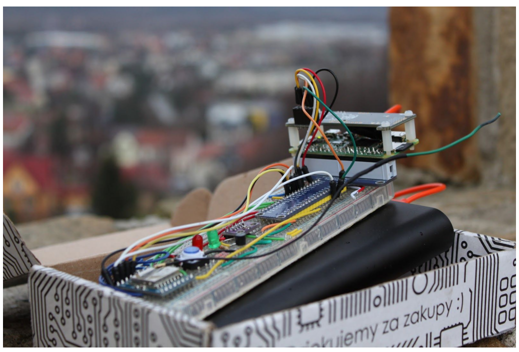
3.2.3 Battery placement

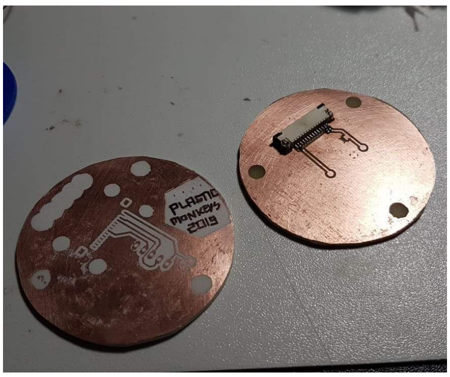
We have designed our CanSat internal body to meet the requirement of easy battery replacement on demand. It features two single 18650 battery holders exposed on two opposing sides of our can pointing upright. They will be covered by TPU external casing, which can be easily removed when needed. Although during tests we confirmed that our CanSat can work even with one functioning battery, we don't want to risk on finals so we decided to solder additional battery springs to prevent the reboot during the descent that could be caused by single-springs' bending.

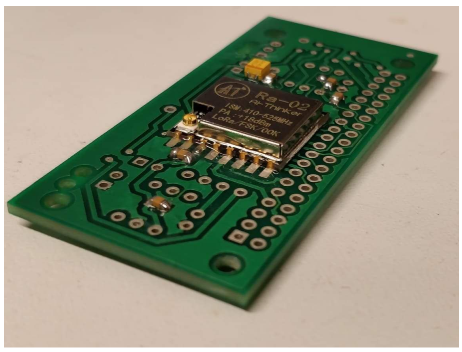
3.3 Electrical design

3.3.1 General architecture

First prototypes were made on breadboards to see if everything worked fine. We could easily change the sensors used and check all connections before preparing PCBs. After having spent a few hours on the Eagle projects, we decided to prepare home-made boards before ordering them from the factory. Printed boards that we received worked fine but it came out that we can still increase their functionality and correct some routes, hence we have just prepared the project for second PCBs iteration.

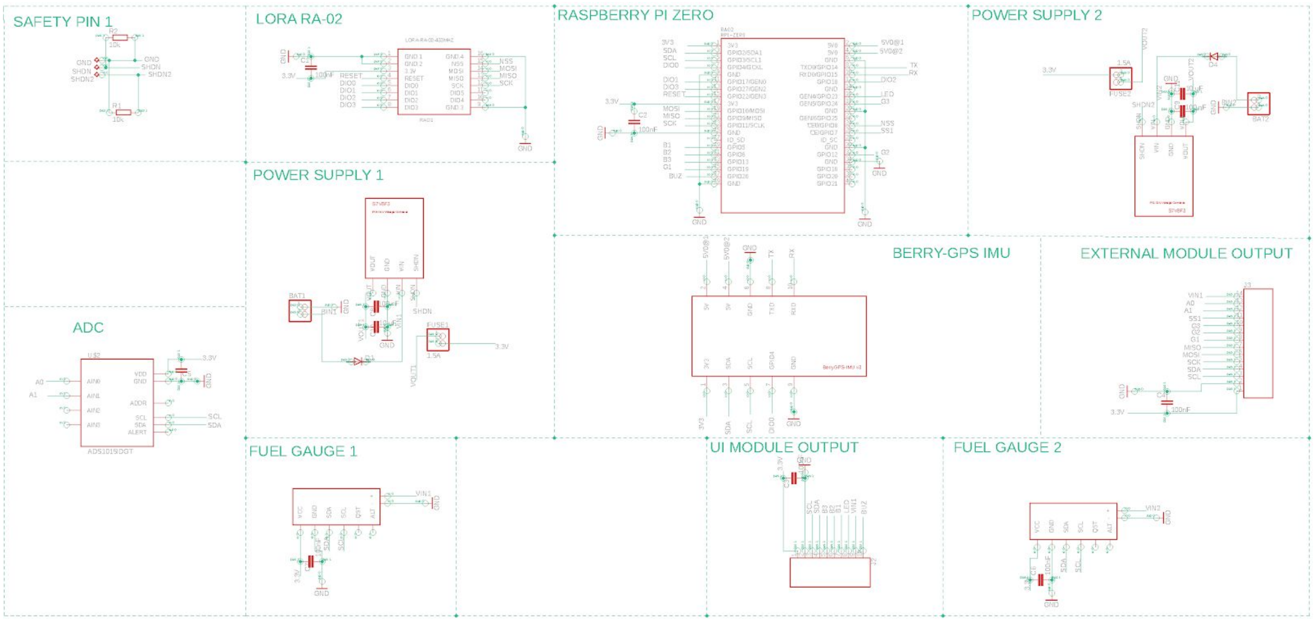






As the heart of our CanSat, we have chosen a Raspberry Pi 0W - it combines its small size with a powerful CPU which offers us multithreading, relatively huge amounts of memory (in comparison to microcontrollers) and possibility to record videos. It is soldered to one PCB (motherboard) with GPS, accelerometer, gyroscope, barometer (BerryGPS-IMU), two voltage regulators, place for fuses and a LoRa RA-02 module with SX1278 chip (it’s the same chip that is used in CanSat kit). Everything is connected with Raspberry Pi over I2C, UART, SPI protocols and GPIO pins. The second PCB board with a temperature and pressure sensor, display/buttons interface, buzzer and LED driven by a transistor is connected to the motherboard using an unpluggable (zif) ribbon cable as well. Also, we provide data connection and power supply through a ribbon cable to the external module. Everything is powered by two 3.7V Li-Ion cells in parallel through step-up/down voltage regulators (one for each), fuses and a kill switch.

All *Connections and the general idea of our electronic design is presented on a block diagram on the following pages. (for full page render, please find it under attachment #4)*



3.3.2 Primary mission devices

The Pi is going to be topped with a BerryGPS-IMU shield designed to fit Pi zero pinout. This board has both temperature and barometric sensors embedded into it. The BMP280 (which is part of BerryGPS-IMU) offers a satisfying accuracy of +/- 1 hPa in a broad spectrum of pressure and ambient temperature, which makes it a superb candidate for missions conducted in harsh environments.

Due to the fact that the temperature is to be measured outside the CanSat, we are not able to use the sensor within the said shield. Instead, a BME680 sensor, mounted to the front PCB, is going to be used. It’s upsides are its small size and the ability to measure not only temperature but also humidity and pressure, what allows us to compare readings from outside and inside of CanSat and make use of the backup sensor in case of failure of one of them.

The gathered data will be serialised and then sent to base via LoRa radio. A couple of modules have been considered, although all of them used either a SX1278 or a RFM98 chip. The specifications of these do not depict any considerable differences though, so the general criterion of choice was in this case the breakout board. We decided to opt for an Ai-Thinker Ra-02 module **(bases on SX1278 chip)**, which was the most compact of the available ones.

3.3.3 Secondary mission devices

BerryGPS-IMU

A Raspberry Pi Zero shield featuring various sensors which will help us realise the secondary mission:

- GPS - In cooperation with the cameras enables locating of the target
- Accelerometer, Gyroscope, Magnetometer - All three are going to be used to determine vertical axis roll, which is necessary to interpret images correctly. They will also determine the moment of landing.

Pimoroni MLX90640 Thermal Camera

After reaching an appropriate height, it will start to take thermal pictures. They will be taken each second, in pair with color photos from picamera. While descending, a GET command can be sent from base to download the photo. It is a part of our first external module.

Raspberry Pi Camera - picamera

Classic Raspberry Pi Camera module recording in HD resolution. Photos are going to be taken each second, and stored in memory with thermal camera photos. Color photos can be used to analyze the area from any altitude, which can be used to identify the potential victim(s) and/or damage caused by a natural disaster.

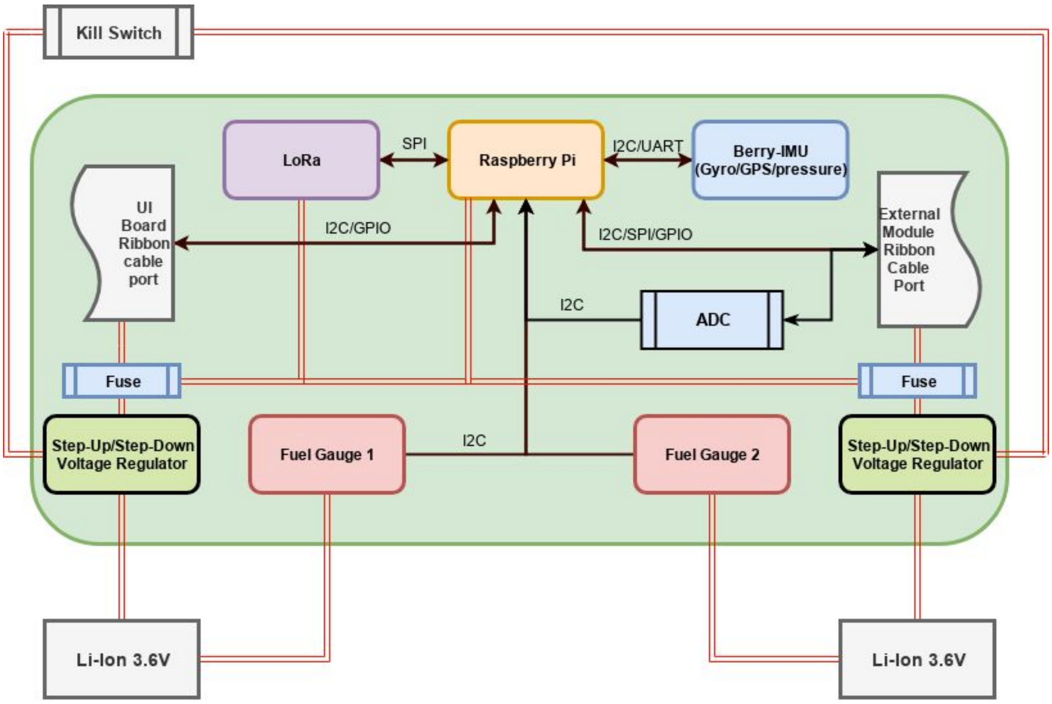
Luxeon Rebel High Power LED (LXM3-PW61) and Redbot Buzzer (CCV-084B16)
These are to catch the attention of potential targets after landing. Due to the fact that the LED requires a lot of power (600 mA), it will blink for the duration of 0.5s every 5s. Both buzzer and LED will be ran by a 2N2222 Transistor, which combines its small size with the ability to control 1A drag.

Pulse sensor with APDS-9008

This is to measure the vitals of the target. Basing on this data the rescue team could be able to prepare themselves appropriately in advance. Because of the fact that we decided to use Double-Camera module during the rocket drop, we haven't fully developed module with this sensor, but thanks to FPC used, connecting this sensor to main board wouldn't be a problem.

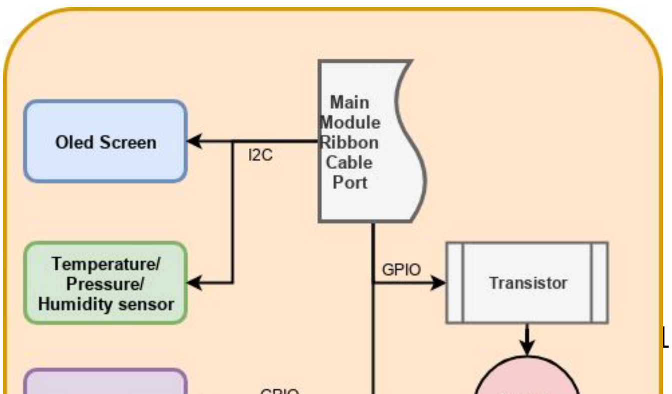
SSD1306 OLED Display

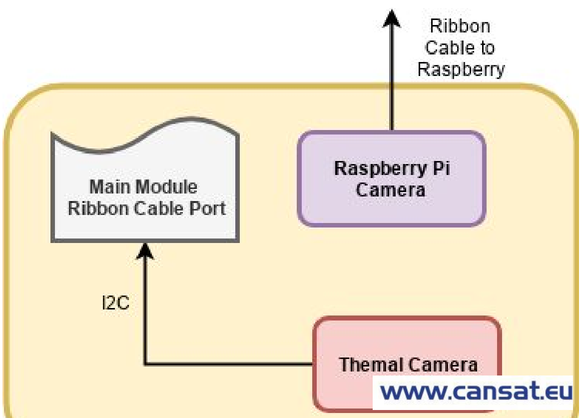
The screen will be used to print questions requested by base and to ensure an easy-to-use two way communication user interface. Its resolution and size are big enough to fit simple sentences.



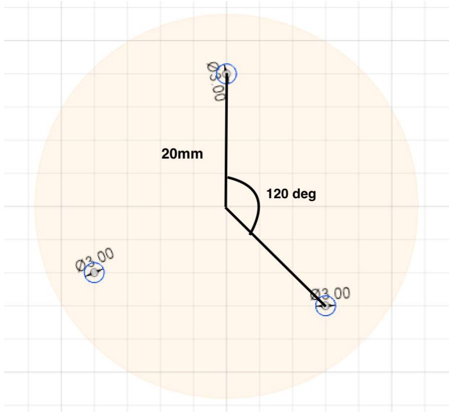
Main Board

Plastic Monkeys 2019



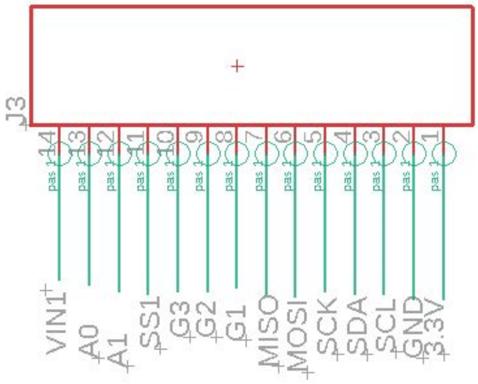


3.3.4 Hardware Platform Interface



Our solution offers generic way of hooking up different modules to our can, which is guaranteed to work if it meets the following specification:

- 16 pin 1mm ZIF connector, both sides
- may use i2c, spi with two chip selects, 3 gpio
- may use two devices with analog output (0-3.3V)
- its average current draw does not exceed 300mA
- provides 3x3mm mounting holes in place depicted below
- does not exceed 20mm height
- does not exceed 60mm in diameter



3.3.5 Power supply

An approximation of power budget has been made in order to derive how many energy sources of which capacity need to be taken into account. It is depicted in the following table.

Component	**Max. Current consumption [mA]**	**Typical current consumption [mA]**	**Remarks**
BerryIMU GPS	31	25	
MAX30100 HR+SpO2 Sensor	1,2	1,2	
BMP680 Temp, pressure, humidity	12	7	
MLX-90640 Thermal Camera	4,5	4,5	Although this seems impossible for a camera, it is proven in the datasheet. It has been confirmed in the test campaign
Raspberry Pi Camera	250	200	Will be turned off after landing
Raspberry Pi Zero W	230	230	
LoRa SX1278	120	30	Max Value is pure TX. The two chips share their current consumption specs. Typical value based on tests.
SSD1306 OLED screen	15	10	
Buzzer	12	4	Typical for 1s beep every 5s.
HP LED	310	60	Typical for 0.5s blink every 5s.
Total	**987,2**	**573,2 (343,2)**	

Based on these results, a set of possible solutions has been presented. It is shown in the next table. When deriving uptimes, an 80% efficiency factor of the voltage regulator has been taken into consideration.

Solution	Total Capacity [mAh]	Uptime @Max. Consumption	Uptime @Typical Consumption
Panasonic 18650 3,6V	3400	2:49:00	7:25:00
2x Panasonic 18650 3,6V in parallel	6800	5:38:00	15:39:00
Prologium Li-Cer 3.7V	To match a single 18650 (3400mAh), a 32x32cm sheet is required		
	To match two 18650s (6800mAh), a 42x42cm sheet is required		

The considered solutions feature two standard 18650 sets as well as a pioneer bendable solid state Lithium-ceramic battery provided by ProLogium. Although these are cut-proof, bendable and safe on the whole, a hefty 32x32cm sheet would be necessary to match its alternatives, which was the reason of excluding this solution. Over fifteen hours of uptime is a satisfying amount, nevertheless this result does not consider voltage falloff and ambient temperature (which is proven to drastically influence battery life) and therefore is surely overestimated. On these grounds the decision has been made to opt for a **double 3400mAh Panasonic 18650 set**. It provides voltages ranging from 4,2V to even 3,1V when nearly exhausted, so a step-up/down voltage converter (Pololu S7V8F3 3.3V 1A) is necessary to ensure stable power supply for the sensors and Raspberry Pi (3,3V). This setup has been thoroughly tested (see 4.5)

3.3.6 Communication system

The mission assumes two-way communication between the Base and the CanSat. To achieve this, one could set up synchronized clocks on both devices and assign specific time intervals for each station. Nevertheless such configurations tend to desynchronize, which would lead to global communication failure. To overcome this problem, we propose the following master-slave protocol:

The principle is that the slave listens most of the time and the master may transmit at any time. Slave transmissions are only allowed as response to the messages received from the master. After transmitting a message, the master listens for the slave for a predefined time window. Let CanSat be the master node, and the base - the slave. The reason for this is that the slave always needs to be listening for packets - thus using energy. Furthermore, more data will be sent from CanSat to Base than the other way, which enables the Slave TX Interval to be shorter.

The Frame (the period of two way communication) looks as follows:
First, the Master sends one packet of data. After the slave receives it, an ACK (acknowledgement) is sent back to the Master. It is then followed by a brief time period of specified length, when the Slave transmits their data. The base station can issue commands to the Can, which involve shutdown or activation of sensors, data transmission requests and system management.

On the grounds that our mission involves image transmission, after an Image GET command is received by the can the protocol changes slightly. The Can ceases all ongoing transmissions and sends the image file. During this time the slave response period is reduced significantly to increase the throughput, thus no upload is possible. After the whole image is transmitted, the protocol changes back to a standard two-way communication.

As said before, we decided to embed an AI-Thinker Ra-02 LoRa module into the Cansat. It is equipped with a 17,3 cm long (quarter wavelength) flexible antenna. The base station is equipped with a TTGO board which features LoRa transceiver topped with an Arduino-like board and an OLED screen. This is useful to monitor the performance of the radio link in real time. It uses a Yagi type directional antenna with gain of 15dB. Moreover, we are considering the usage of a second laptop-TTGO-Yagi set in the base station with higher gains on the antenna (narrower angle of amplification) to increase the chances of a stable link after touchdown.

3.3.7 Failsafe and failover mechanisms

Power

We are aware, that errors occur all the time during such complicated system development, hence we are preparing our hardware for such circumstances. We have implemented redundant power supply systems, with two step-up step-down voltage converters operating totally independent. Moreover, both voltage converters are protected from battery reverse voltage with schottky diodes. Next, we have incorporated over voltage protection at voltage converter output with zener diode and resettable fuses. Last but not least, we position both circuits on two opposite sides of the board, to make it impossible to short both of them with the same wire.

Sensors

For our primary mission we have incorporated redundant sensors, bme280 and bme680 which can override one another in case of emergency.

3.4 Software design

Linux-based operating systems available for Raspberry Pi, which we are using in our Sat, support multithreading, so we can apply distributed software. We will call each program in our design a “block”. Each sensor is going to have its own individual block and individual log file. Merge-Block will merge obtained data with attached timestamp and send it to the main buffer, which will be regularly (partly) emptied by LoRa transmitter block. Buffer will mainly work in prioritet FIFO manner, if not else specified. Priority specification gives us option to request some specific data (photos for example). Distributed software structure provides special redundancy - if one sensor stops working, or one program crashes, the rest will work uninterrupted. What is more, Raspbian provides us with daemons and systemd units that should keep our blocks up and running. Flow diagram of our software can be found at the end of Software Design part.

Communication between all blocks is based on writing and reading from log files. Each block will write to its own log file creating a stack of data, from which
Merge-Block can easily obtain most recent readings (most recent line). This solution has many advantages over direct data transmission between two blocks - different scripts aren’t connected in any way, a crash of one of them does not affect others, Merge-Block doesn’t have to ask for a reading and wait for it (all tasks are done asynchronously) - the data in the log file is always ready to take. Furthermore, if we want to launch another block, that has turned off before, it doesn’t have to look for a connection to the Merge-Block, it just writes to one specified file as if nothing happened. Our Merge-Block is highly customizable - it reads it’s settings, paths to logs from config file, where we can edit them, add new devices, thus supporting our modular approach. Also, each log file with raw data can be used as a second, redundant source of data after a mission.

The only thing that is going to run in a slightly different way is Camera Block. The images will be taken every 5 seconds and stored in appropriate folder. They will also be immediately resized to 4 different sizes and compressed to JPG using PIL. Their names are a combination of a timestamp and quality signature. The Image GET command can pass both of them from base to CanSat, thus enabling us to optimize the search for the interesting ones. During the transmission of the photo, all other transmissions are halted and the protocol changes as specified in 3.3.6.
Due to the usage of Raspberry Pi, and experience of our members in this language, we decided to write our code in Python with additional various Bash scripts.

To calculate the storage that will be used by all logs we came up with a formula:

Used storage = ((size of one reading (S) * number of sensors (N) * read frequency (f1)) + (color image size (I) + thermal image size (T)) * imaging frequency (f2)) * operation time (t) The result can be seen here:

S [B]	N	f1 [Hz]	I [B]	T [B]	f2 [Hz]	t [s]
40	10	4	900000	12000	1	25200
Total:	**23022,7 MB**					

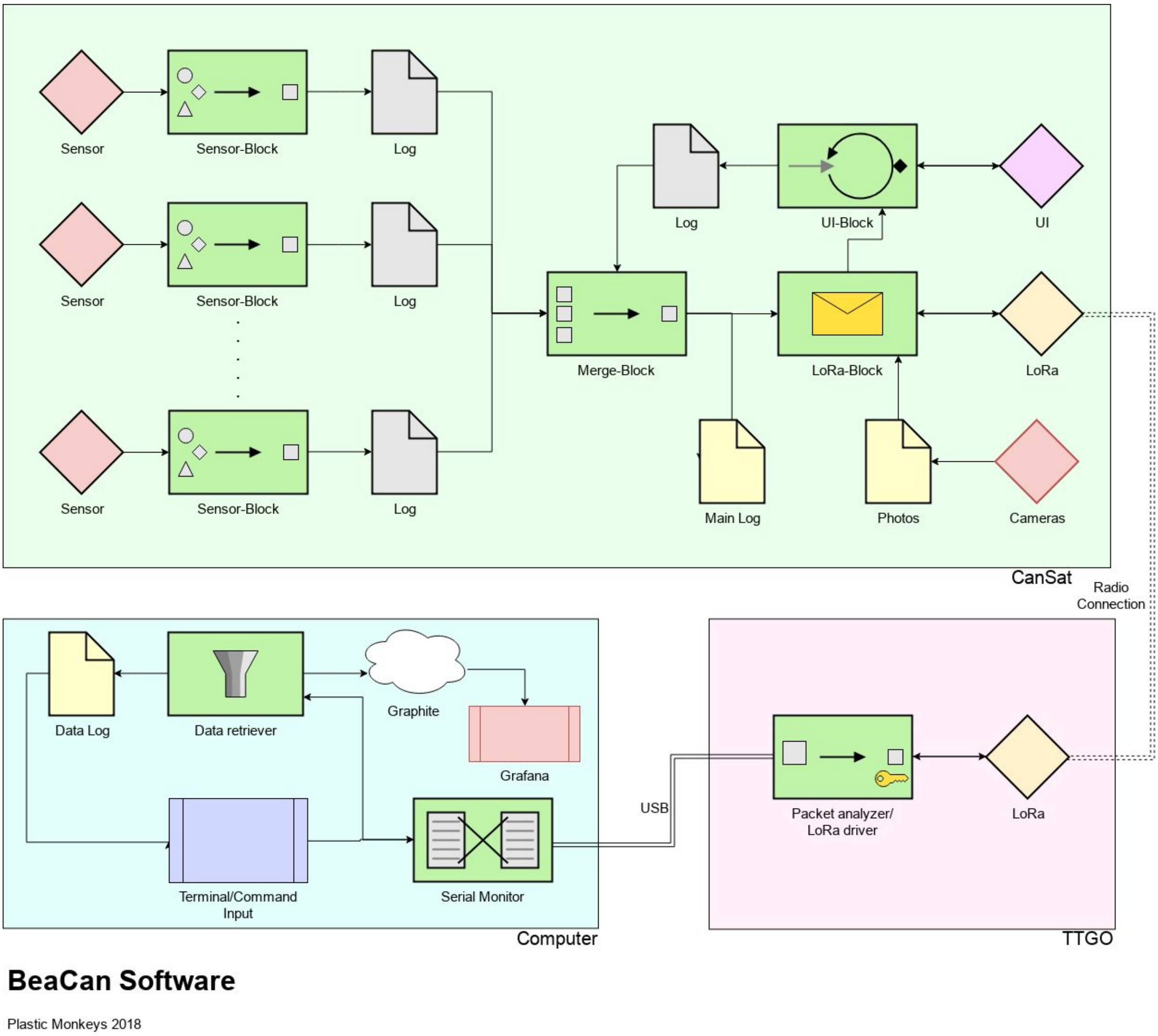
We can see that all logs from 10 sensors and photos from two cameras (thermal and regular) during a 7-hour mission will need 23GB, even though all givens have been significantly overestimated.. Our Raspberry Pi supports micro-sd cards that have much more free space than that. We can add to it 5GB occupied by the Raspbian system and our scripts, 2GB of an optional camera recording to see that 32GB SD card would provide more than enough space for our mission. However, for our safety, ability to add any features later or double or triple the photo/reading rate, we are going to use a 64GB card.

Our base station setup has to be written in two languages and for two devices - TTGO LoRa module and notebook with Linux. TTGO, programmed in Arduino C, has the said radio protocol implemented and communicates with the PC via USB, where a Python script will retrieve the serial data and save them on computer's hard drive. Furthermore, all readings will be automatically sent to our own Graphite (time series) database using python scripting. This gives us even more redundancy and ability to plot data live using Grafana Software. In sending mode TTGO will listen for a command from PC, which will be inputted manually, and send it to CanSat using LoRa.

To send the data via LoRa, we decided to use MessagePack. It is a binary serialization format thanks to which we will be able to pack the sensors' readings. As this protocol does not increase the size of the readings significantly, we are able to send them over LoRa safely and check their correctness later.

LoRa link efficiency estimation has proven that at minimal Spreading Factor and Coding Rate necessary for the transceivers to stay in touch it is possible to send about 1500 bits of pure payload per second. To make maximum use of this low bitrate, the data is compressed and serialized in an appropriate way. For instance, the readings from the temperature sensor undergo the following process:

- The raw value is a float in range of around (-20, 40 degrees)
- If we assume the boundary range of (-20, 43,5) and decrease the accuracy to 0,5 degrees, we can use the following operations to fit the value into seven bits (format which MessagePack likes):
- floor((Raw temperature value + 20) * 2) converts the range into (0, 127)

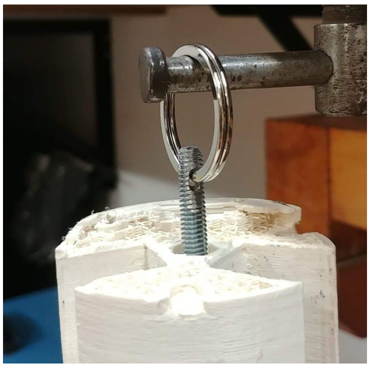


3.5 Recovery System

We are going to use a parachute to land safely, however at the first stage of planning we evaluated the idea of landing using spherical airbag, but it turned out to be way too risky and time-consuming. Our first calculations estimated optimal perpendicular surface of parachute’s canopy to be 0,14m^2 (assuming optimal velocity as something close to 10) meters per second, calculated from classical drag force equation:

$$S = 2mg/v^2C\rho$$

However, during tests we learned that parachutes canopy behaves differently than expected from our simple calculations (the material was very stiff and significantly overstated assumed in the calculations drag coefficients), so we decided on a series of tests with different sizes of parachutes, between which we gradually increased the size of centrally located cutout until we have reached the speed that falls within the norms or until we found out that broadening the hole even more seems a bad idea since the parachute might curl out. (see 4.3) Assuming that we would fall from 3000m and CanSat motion is close to uniform motion estimated flight time is 320s. Parachute mounting is done by binding all 6 (3 pairs) of its strings to metallic circle that is dragged through the hole in threaded rod in internal casing. To test its durability, we hung on it equivalent of about 80 kg and it endured! Parachute is made of durable, waterproof and tear resistant material. Several test drops have been conducted. Tests performed led us to the conclusion that the best choice for our mission is parachute with outside diameter of 35cm and centrally located cutout with diameter of 4cm (see 4.3). Such solution ensures descent descending stability regardless of the weather and corresponds to the falling speed of about 9,3 m/s.



3.6 Ground support Equipment

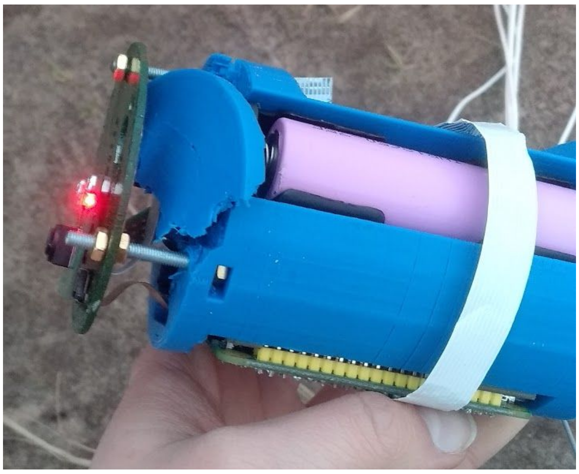
Our ground station consists of one notebook equipped with Linux distribution as OS, and TTGO and suitable Yagi antenna. TTGO is equipped with LoRa module thanks to which we can sustain radio communication with our can. It has also its own display that enables us to have live data preview. It will be paired with our radio module in

CanSat, and constantly listen for packets from it. Packets will be sent to the computer through USB-cable where they are going to be aggregated, arranged, analyzed and stored. Also, we want to send commands and text to our sat - they will be loaded on laptop, sent to our board through USB Serial and then released to Sat.

4 TEST CAMPAIGN

4.1 Mechanics

4.1.1 Hardware alignment



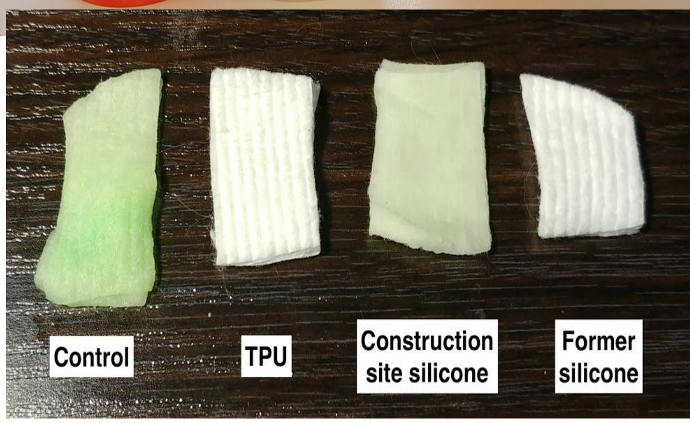
We consider space saving a very important factor of our design, since less space taken by necessary components leaves more space for modules. To align our hardware optimally modeled each component in a 3D software and moved them around. We printed the models and conducted some tests which showed that we had to make some improvements. Fortunately only one model was destroyed during tests (photo below), then we printed the last and most durable version of the model.

4.1.2 External casing

We have made 3 different outer shell prototypes to test their durability and water resistance. They were made from:

- Former silicone (easy to make good forms, not so easy to work with)
- Construction site silicone (easy to get, not so easy to model)
- 3d printed TPU (easy to model, not so easy to print)

We carried out water resistance test by placing tissue between shell and internal casing, and partially submerging them in mixture of water and ink for 20 minutes. Construction site did not pass this test due to its multiple defects. TPU and Former silicone went fine.

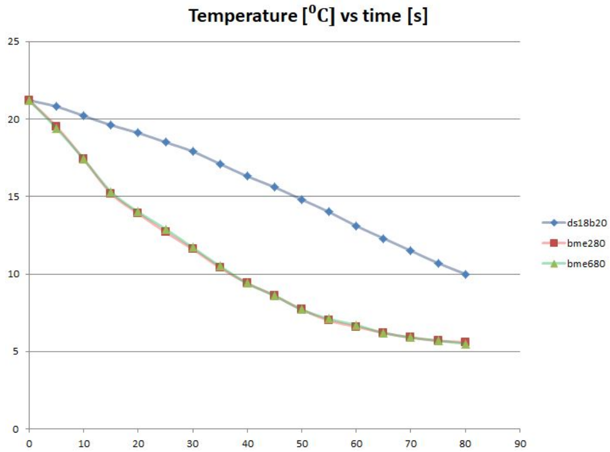


Conducted durability tests showed that since we can not control former silicone thickness (unlike TPU where we just set its thickness in 3d cad software) it is easily breakable. Therefore we opted for TPU.

After several drone drops it came out the external casing was intact and it protected all electronics inside.

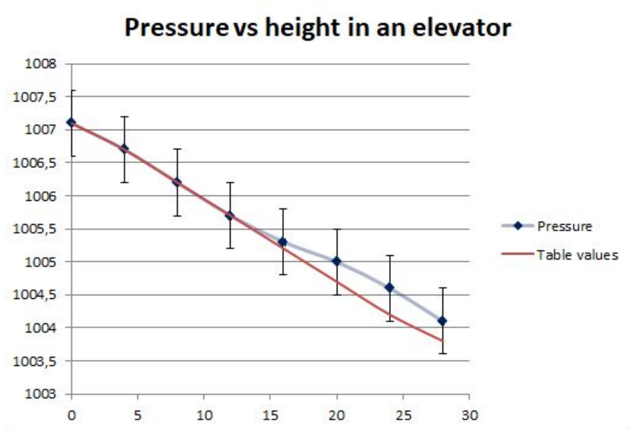
4.2 Sensors

4.2.1 Thermometer



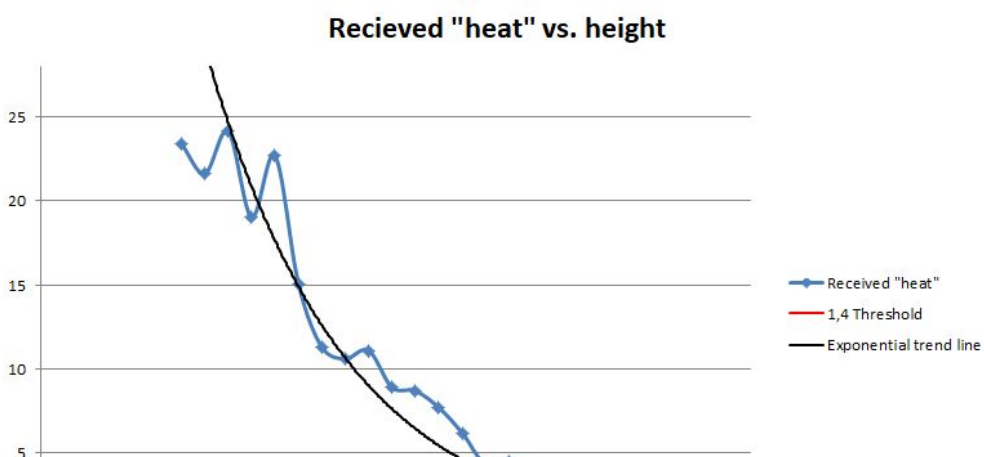
Three different thermometers (DS18B20, BMP280, BME680) have been evaluated and tested. The devices were put into a fridge (ca. 5oC measured with an alcohol thermometer). It is noteworthy, that the DS18B20 reacts to temperature changes much slower than its counterparts. Moreover, it takes over 0,5 seconds to get a sample of data. Because of that we opted for the BME680, as it is the newer version of BMP280 and has some additional features.

4.2.2 Barometer



The BMP680's pressure sensor has also been thoroughly tested. During an elevator ascent, it has shown accurate readings which changed appropriately every floor. They have been compared to calculated table values. The sensor has also been taken to a highland region, and the read pressure has been compared with the table value for such height showing no offset. This proves its reliability and enables us to embed it into the CanSat.

4.2.3 Thermographic camera

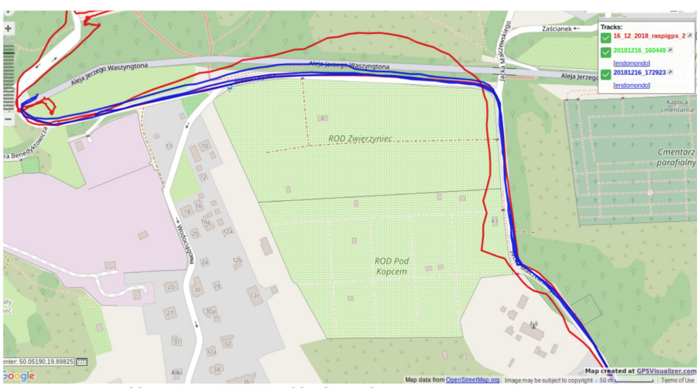


The goal of the thermal camera test was to measure the boundary height, from which we can detect various objects using this sensor. To achieve this, a drone flight over a bonfire has been conducted. A series of images at altitudes varying between 20 and 200m have been taken and analyzed. An automatic algorithm has been used to determine important areas on the image (we don't want to transmit the whole raw readings). It works as follows: First, the average temperature of all pixels is calculated. Then all pixels, the temperature of which is greater than this average + a given threshold are returned as the result. The diagram depicts the relationship between the drone's altitude and the "received heat", which is the sum of values of the chosen pixels. During additional pre-tests an optimal threshold value of 1,4 has been determined, which successfully removes background noise and is shown by the red line. Basing on the gathered data a conclusion is to be drawn, that from the altitude of 170 meters one can doubtlessly detect a small bonfire (40x40cm). That implies that an area of 140x140 meters on the ground can be successfully scanned for such objects. It appears that in situations where a heat-emitting object is to be found, the thermal array actually gives more data then color images, hence it is doubtlessly useful in our mission.

4.2.4 Raspberry Pi Camera

During the same flight the color camera has been tested. The full-quality images enabled us to find the said bonfire from about 170m, which is comparable to the possibilities of the thermal sensor array. However, in order to send them to base they need to be significantly compressed, thus losing sharpness. As the result the maximum height from where we were able to detect the 40x40cm target was about 80m. After some calculations, this implies that a 3x3m tent would be recognizable form the height of 340m out of a 400x300m area.

4.2.5 GPS

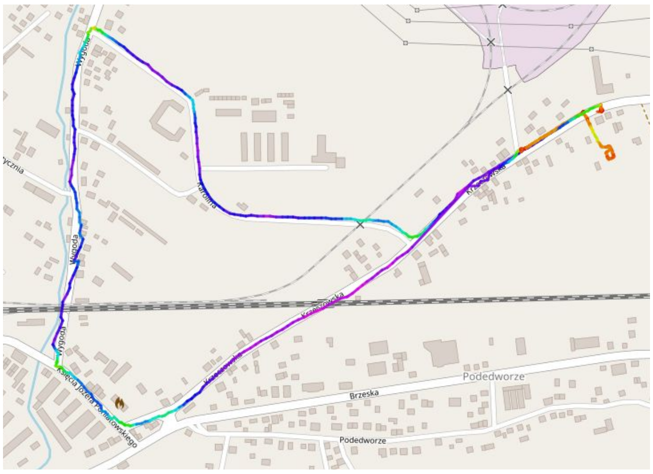


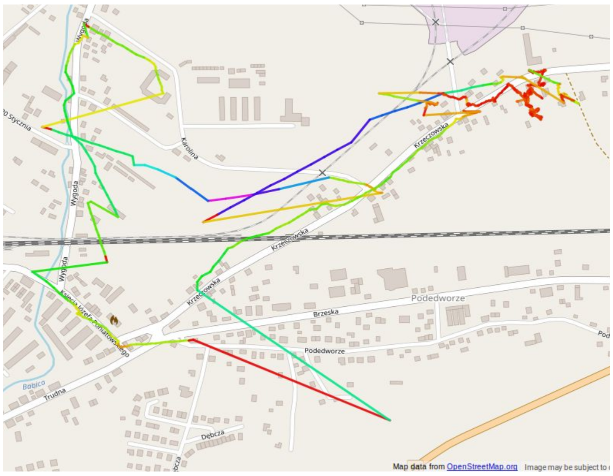
red line – BerryGPS-IMU, blue line - phone

As a GPS module we are using BerryGPS-IMU v3. We have tested its accuracy by moving with different velocity (walking and driving a car) and comparing the logs with the very precise phone's GPS. After having found GPS fix, the track designated by Berry IMU was almost the same as the

track appointed by phone. But when Berry loses contact with some satellites, its readings start to differ from reality. During our test, the biggest measurement error was equal to around 50 m and it was noted when our module was inside a car and its velocity started to grow. After a while the number of available satellites increased so consequently the measurements became more precise again.
Although sometimes BerryGPS IMU has some problems with indicating the proper route, we assume that those differences aren't really significant . Taking into account all situations when we used this module and compared its readings to another source, we were always satisfied. We are thus ready to confide in BerryGPS's measurements.

We have also tested how does BerryGPS perform without external antenna. Being in a car, there were a lot of problems with obtaining a fix – measurements were really deformed. But getting out of the car didn't help much. There is only one conclusion: without external antenna the measurements are not accurate.





4.3 Tests of recovery system

During first tests we have dropped a payload, connected to the parachute with 8 strings (65cm each), from various heights. A bowl measuring 80 cm in diameter, with a 40 cm hole in its middle. This is to ensure a stable descent.

The first drop was from a 11 floor of Kapitol dormitory building (50 meters in total, 40m from 11 floor, during neglectable wind. Although the flight was stable and controlled, the descent rate was as low as 4,6 m/s (calculation based on video taken, which is available as attachment to this document). In order to reach speeds closer to the desired ones we have broadened the hole in our parachute from 40 cm to 50 cm.

It still wasn't enough to fall within the norms and it was very vulnerable to the weather
so we ordered a smaller parachute. During the next test we have decided to use a drone to lift the payload to exact 100m in order to evalute our new, smaller parachute (55 cm in diameter, 6 strings). However, drone had a strict mass limitation of 100g, so we didn't use the full payload. The analysis of gathered data has proven though, that even with 300g of load and 23 cm diameter cutout the speed would be about 6-7 m/s. On these grounds we have ordered a smaller parachutes (35 cm in diameter, 6 strings), the parameters of which seem to rise the descent rate to 10m/s. During final examination of parachute we have conducted several new test using new drone with a higher lifting capacity and 320g payload. Several discharges from 50 and 100 m were carried out during which the average speed was about 9.3 m/s. During tests we have learned a lot about parachute geometry and its connections with drag coefficient. Some of us also had the opportunity to learn the basics of drone operating.

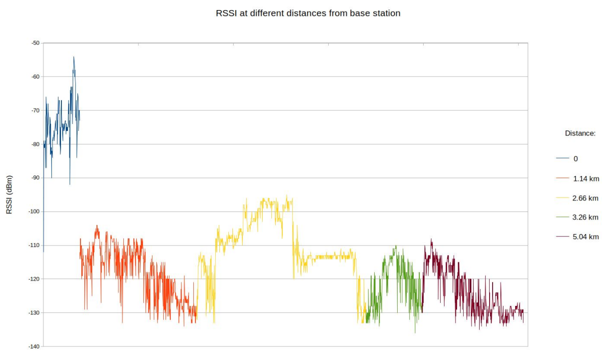
4.4 Communication system range tests

Our first environmental radio test was conducted in Blonia Park Krakow and it focused on the measurements of throughput during an about one kilometer long walk. All further tests were conveyed with 20dBm = 100mW of power setting.

Length of the packet	Delay between sending packet (ms)	Approximate distance from base station (m)	Packets per second	Percentage of received packets	Average RSSI (dBm)
30	300	0-250	3.28	98.27%	-96
20	300	250-300	3.26	99.40%	-97
20	500	300	2.03	100%	-97
10	500	300	1.99	97.30%	-99

10	800	300	1.33	81.08%	-100
10	300	300-850	2.81	85.48%	-117

In order to measure maximum range of our radio and the link reliability, we set off to Dobczyce Lake. The base station was situated on top of a 10m observation deck. The transmitter attached to a car and driven to four measurement sites at distances of 1.14km, 2.66km, 3.26km and 5.04km from base station. The results are shown in the table below:



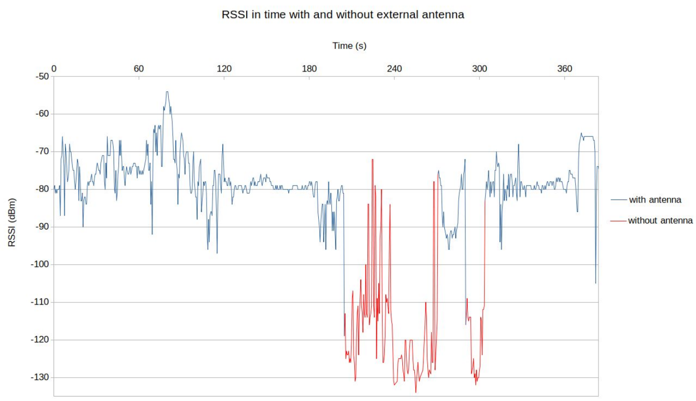
Dist-ance	Altitude	Received packets	Packets per second	Average RSSI	Radius of the 1. Fresnel zone	Comments
1.14 km	316 m	91.25 %	1.82	-118 dBm	14.05 m	Due to the fact that the transmitter wasn't so far from the base station, we expected that the signal strength would be better. However we should take into account that when we were holding our can, we were surrounded by trees that could cause some distortions.
2.66 km	290 m	87.55 %	1.74	-110 dBm	21.46 m	Although the results were quite good, most of the lost packets were sent in the last minute of this attempt. We we were heading back to the car then so when we were in a some kind of ravine surrounded by trees, radio communication was hindered. Assuming that we take into consideration the time without last minute (so when we weren't moving through trees), the percentage of received packets is getting up to 97.35%, that gives us 1.94 packets per second!
3.26 km	338 m	72.35 %	1.44	-121 dBm	23.75 m	Low percentage of received packets was probably caused by limited amount of

						time we spent doing this try– all indications are that if we had stayed there longer, the results would have been better.
5.04 km	268 m	73.59 %	1.46	-124 dBm	29.53 m	Thanks to reduced amount of distortions in Fresnel zone, communication between transmitter and receiver was possible even though the distance was substantial.

The conducted ground radio tests have proven a reliable communication over distances exceeding 4 kilometers - thus ensuring uninterrupted transmission during the flight. Moreover, the link was also stable when the transmitter was moving attached to a car (over 15 m/s, which is more than the descent speed of the CanSat). In spite of heavy rain and many terrain obstacles on the way, 75% of 20-byte packets have been successfully received (the checksum matched) . It has also appeared, that settings such as Spreading Factor of 7, Coding Rate of ⅘ and TX Power of 20dBm are sufficient to achieve the said goal safely. This enables us to achieve 80 bytes per second per side throughput which can probably be further increased by optimising software. Such efficiency lets us transmit images of satisfying quality quickly which has been proven in several tests.

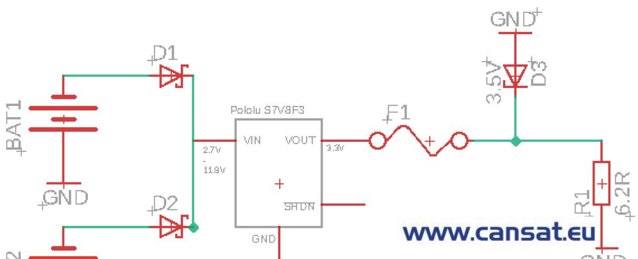
The photo on the left is a 160x120 JPG file of size of about 3kb. Using our most efficient protocol we managed to transmit it during the flight within 25 seconds at 125B/s throughput after sending a request.

In addition to that, we conducted tests regarding available antennas. The Yagi came up trumps, as it boosted the RSSI by over 20. The chart below shows how RSSI was changing in time when we were changing the quarter-wavelength antennas and even though the differences are not really visible, one of them seemed to have the best signal strength.

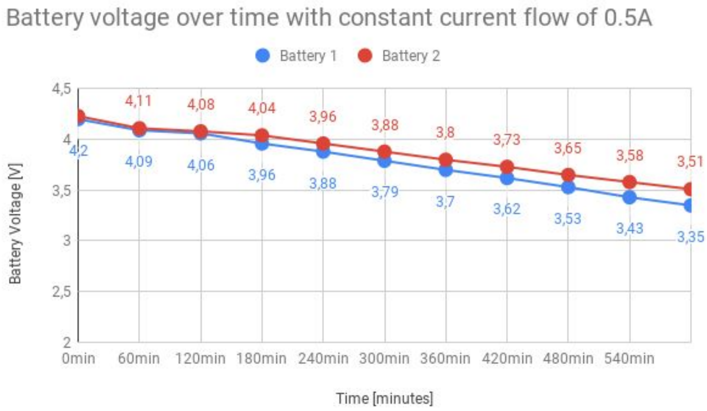


4.5 Energy budget tests

To estimate the maximum battery uptime during the mission, the measurement



of current consumption has been taken. A current of 520 mA was drawn during the usage of the camera, while 300mA were the peak values while this device was turned off. These values correspond to preliminary predictions. To confirm our calculations we carried out battery discharge tests. We took our whole power supply system (that includes two 18650 batteries, couple of schottky and zener diodes (failsafe mechanisms), fuses and 3.3 step-up/step-down power converter) for a fairly long trial (10 hours in total). We have constructed the following circuit, using 6.2 Ohm resistor resulted in constant current load of 0.5A which is a good approximation of real current consumption our sat will draw. Battery voltage drop over time can be seen at chart provided on the left. This test confirms that our sat will be able to work constantly for over 10 hours without any doubt.



4.6 Primary Mission tests

In order to claim the readiness of our primary mission, a drop simulation has been conducted. While the CanSat was descending from a drone at the altitude of 100m, readings of temperature and pressure have been received in base station approximately 4 times a second. Moreover, both of them comply to independently measured values in then present environmental conditions. On these grounds we can safely say, that **our primary mission is fully operational.**

4.7 Secondary Mission tests

During the said flight, the secondary mission has also been thoroughly tested. The cameras turned out to work flawlessly. We also managed to successfully download several color images from the can, although, due to software failure, no thermal image has been sent. While working on a fix, we can safely claim that the partial readiness of the main secondary mission assumptions is **sufficient to bring the awaited results**

Those two tests proves that our solution is working in environment, the closest we could get, simulation real mission during start campaign. With that being said, we are pretty confident, that **we are ready to take-off!**

5 PROJECT PLANNING

5.1 Time schedule

Following the agile framework, we are planning our workloads for every week providing valuable results in iterations, this way we deliver basic solutions first and improve them over time. This approach has led us to decent (good enough) solutions in specified time frame.

Date	Action	Phase
September, October 2018	Making decisions about missions, electronics and mechanics, evaluating ideas, testing basic key concepts, starting activity on social media that will develop along with our project	design
4 November 2018	Preliminary Design Review	Key date
8 November 2018	organisational meeting with our agile coach to draw some conclusions wha we should change before the second report to enhance our performance	organisation
15 November 2018	Preparing first external case prototype	prototyping
17 November 2018	Comparing and testing each of 3 thermometers we had	testing
22 November 2018	Creating some silicone molds	prototyping
26 November 2018	Establishing radio communication and initial test with stock antennas	testing
27 November 2018	receiving essential parts from OzzMaker	organisation
29 November 2018	Barometer tests	testing
4 December 2018	First descent - parachute test	testing
11 December 2018	Participating in PCB designing workshops	organisation
16 December 2018	Environmental radio test with yagi antenna focusing on the throughput measurements and, at the same time, GPS accuracy tests	testing
18 December 2018	Receiving new components from Pimoroni	organisation
20 December 2018	First test of the thermal camera	testing
22 December 2018	Final environmental radio test with yagi antenna focusing on the range measurements	testing
27 December 2018	Water and dust resistance of the silicone mold	testing

2 January 2019	Establishing two-way radio communication and sending first photo via LoRa module	testing
5 January 2019	First safety pin prototype	prototyping
9 January 2019	Batteries' lifetime test	testing
11 January 2019	LED and buzzer performance	testing
12 January 2019	Final tests of IR array, picamera and parachute	testing
13 January 2019	Critical Design Review	Key date
15 January 2019	team meeting to discuss the working plan	organisation
29 January 2019	parachute tests	testing
1 February 2019	discussion about the code written, debugging	coding, organisation
5 February 2019	home made PCB boards (module and UI)	prototyping
15 February 2019	final CAD models	constructing
20 February 2019	first iteration of PCBs	prototyping
22 February 2019	discussion about the code written, debugging	coding, organisation
25 February 2019	preparing Graphite environment	preparation
28 February 2019	presentation at Pykonik's meetup	promotion
6 March 2019	drone drop (thank you, SobieskiSat) - parachute test	testing
10 March 2019	webinar with Jury	organisation
12 March 2019	receiving new parachute and making some calculations regard to it	calculations
19 March 2019	ending up sponsoring-deal	organisation
20 March 2019	electronics and parachute field tests (drone drop)	testing
21 March 2019	presentation for high schools' students	promotion
21 March 2019	sending photos via LoRa - field tests (drone drop)	testing
Generally, in the meantime we were working on the software, improving the performance of the sensors that we were testing before the CDR. Apart from that, we conducted a lot of different types of tests - only some key dates are included. Moreover, the time between CDR and FDR was dedicated to fix all the problems with electronics and mechanical design that had shown up.		
22 March 2019	Final Design Review	Key date
March 2019	develop one more module to confirm that our idea of changing modules is totally applicable	constructing
April 2019	thinking how to optimize the work of CanSat, possible changes will be executed but only when supported by tests, making sure that Sat is ready to be launched	preparation, possibly constructing and testing

5.2 Task list

We carry out task tracking with Trello's Kanban table, which is publicly available at https://trello.com/b/yPotoGbC/cansat-🐒 (please note that there is an emoji in the url). Since we divide our workload into many small tasks, there is no point into placing all of them here, as stated before, the full list can be found in our trello table. Every task is properly labeled according to its subject and has a team member assigned to it, hence we can track whether knowledge sharing process is taking place and if workload is evenly distributed. One thing we learned about ongoing workflow, is that that the fully agile approach is not adequate for this project since we have no way to manipulate time limits. Hence, we opted for modified Kanban approach with fixed due dates. From the day of last report, every task had its own deadline according of team members declaration. To the day of writing this report, we've done **117 tasks** with average of **23 tasks per member** - which still looks like **healthy collaboration**. Due to presented modification we increased number of tasks done on time. From our CDF diagram, it can be easily concluded, that we work in 1 week long sprints, with great results (steep burn-up curve).

To better build up team spirit, after PDR submission, we have organised so called retrospective meeting, with our Agile coach, to look back at our workflow from distance and propose some improvements. We came up with several conclusions, where most of them were applied during work between PDR and CDR. These are:

- doing tasks in pairs results in better quality of delivered values and keeps us motivated
- we should consult ideas with each other
- good communication between team members is a key value
- doing tasks from same category all the time decreases morale, now we do tasks with different labels for better knowledge propagation

5.3 Resource Estimation

5.3.1 Budget Sat cost

Component	Raspberry Pi Zero W	BerryGPS-IMU v2	BME680 thermometer	SX1278 LoRa Module Ra-02	PCB	IR Array Breakout MLX90640 (Qwiic)	Parachutes	Power LED diode	Buzzer
Price	52 PLN	44,5 USD	22,5 USD	4,5 USD	300 PLN	34,80 USD	250 PLN	6,50 PLN	2,50 PLN
Status	✓	✓	✓	✓	✓	✓	✓	✓	✓

Component	Tact Switch *3	SH1106 OLED Display Module	microSD card 32GB	Li-Ion Panasonic NCR1865 B Battery *2	Step-up/ step-down voltage converter *2	Liquid rubber - silicone for external case	Filament PLA for Internal Casing	Pulse sensor	Fuel Gauge * 2	picamera
Price	3 * 2 PLN	27 PLN	19,95 USD	2 * 24,90 PLN	2 * 35 PLN	35 PLN	45 PLN	24,95 USD	2 * 10,95 USD	29,95 USD
Status	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

	total
PLN	843,8
USD	203,05
sum (EUR)	196.25+47.23=**243.48**

5.3.2 External support

It comes out that our project is considered as pretty interesting one because of the fact that a number of organizations have decided to help us. At the moment we are collaborating with worldwide known companies such as **Pimoroni** (United Kingdom), **Sparkfun** (United States of America) and **OzzMaker** (Australia) - they sent us necessary parts. Additionally, the **Krakowski Park Technologiczny** (KPT) (Poland) which is the most complete one-stop-shop for business operating in Poland offered us financial support. Listing other backers we mention **DreamLab** [Ringier Axel Springer Polska sp.z.o.o.] that provides us with access to their **conference rooms** and **agile coaching** when needed - **Aleksandra Kendziora**. We have consulted our ideas with professional **TOPR rescue team member - Jacek Bąkowski** and we also gain some **medical advice** form **Katarzyna Szpak** - befriended doctor. Thanks to **Paweł Błach** we were able to test our parachute and cameras using his drone. When it comes to substantive and methodological help, we had confronted our ideas and prototypes with multiple **Hackerspace Krk** (rapid prototyping, electronic circuit design) , **Klub** Turystyczno-**Radiowo**-Astronomiczny **Ryjek** (regarding radio uplink, antenas, two sided communication and so on) and **AGH Space Systems** (mechanical design, parachute choosing etc.) members. We have been granted with access to **3d printer in our highschool**. Last but not least, we are actively consulting our ideas and decisions with **former CanSat builder - Jan Dziedzic** - to learn from others mistakes.

6 OUTREACH PROGRAMME

Our team is betting on various publicizing methods. Currently, Plastic Monkeys have their own simple web page (plastic-monkeys.space), Facebook and Instagram fan pages (about 370 followers in total), where our work progress is shown to our followers. These mediums of communication are the most versatile and popular among young people, who we are targeting. Also, we have our own YouTube channel where you can find videos explaining various aspects of our project. Furthermore, we have designed our own logo, graphics, and wallpapers that are used by all team members. Our page and description of CanSat competition were spread among students and teachers in our high school using facebook school group. We have been mentioned by them on their official Facebook page.

- Our Plastic Monkeys Facebook Page: facebook.com/pmcansat
- Our Plastic Monkeys Website: plastic-monkeys.space
- Plastic Monkeys YouTube Channel: PlasticMonkeys Youtube
- Plastic Monkeys on Instagram: instagram.com/pmcansat/

We have boosted our posts on Facebook which resulted in broaden the outreach up to 10 thousands users!

In addition, we conducted a presentation regarding CanSats for alongside the physics workshops for the local high schools' students. We were encouraging them to take up the challenge and build their own CanSats next year. They were very interested in whole project and gave us a lot of valuable feedback.

Moreover, we presented our team and project during one of the local meetups - Pykonik Tech Talks. We could discuss our project with Python-lovers.

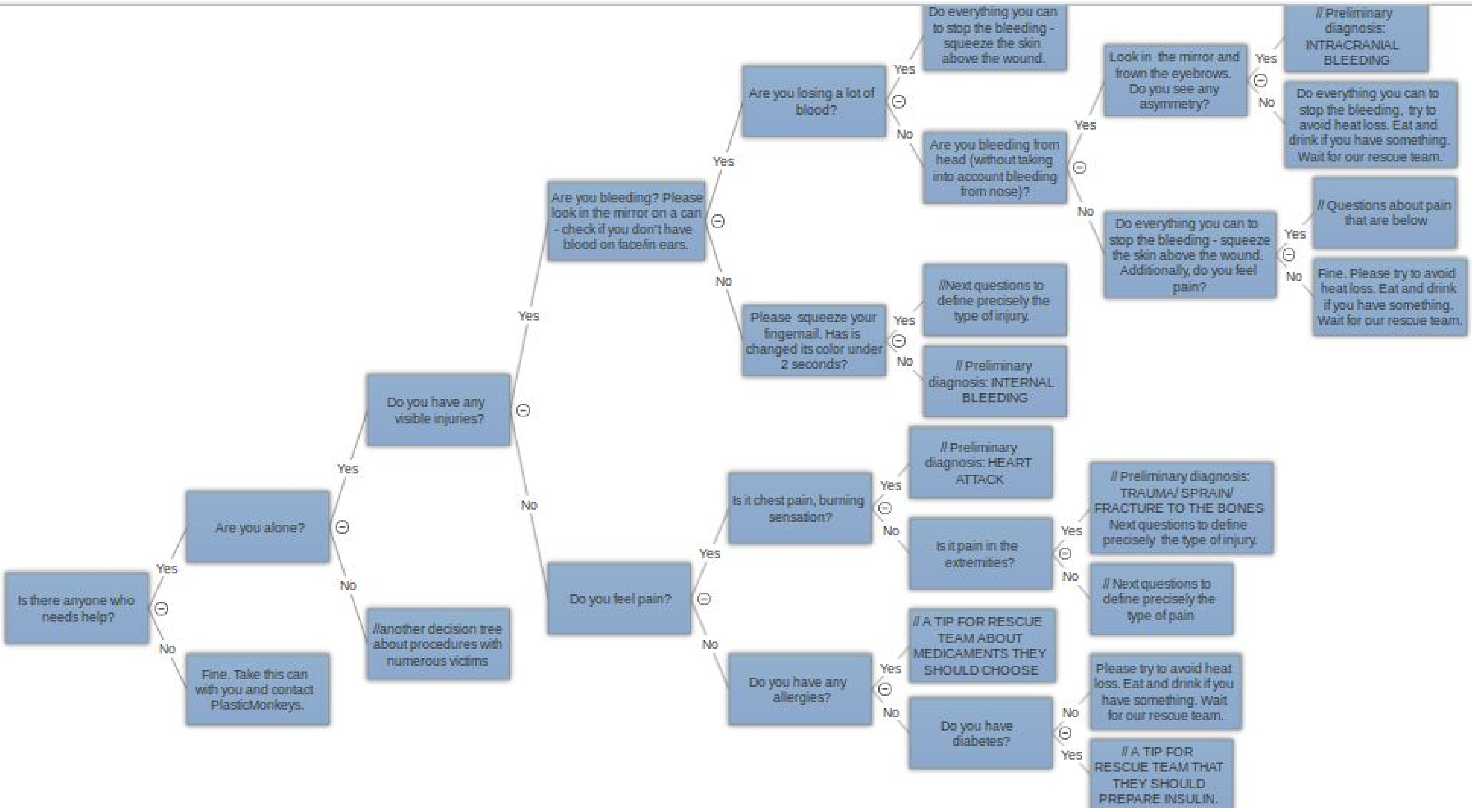
CANSAT CHARACTERISTICS

Notes: Diameter of the CanSat is bigger than the one shown on the last page because of extra skin.

Characteristics	Figure
Height of the CanSat	113 mm
Diameter of the CanSat	64 mm
Mass of the CanSat	311 g
Estimated descent rate	9.3 m/s
Radio transmitter model and frequency band	SX1278, 410-525 MHz
Estimated time on battery	13 hours
Cost of the CanSat	~280€

Attachments:

#1 Interview scheme



#2 github repository link: https://github.com/evemorgen/PlasticMonkeysCansat

#3 mass budget table

część	masa [g]	założona gęstość [g/cm^3]		grubość osłonki
silikonowa powłoka	40.00	1.2		0.2
obudowa z PLA	62.5	1.25		
spadochron	40			
Elektronika przewody, raspi, czujniki etc. (przeszacowane, mocno, w góre)	40			masa baterii:
baterie	96			48
mocowanie spadochronu (pręt)	40			
elementy konstrukcji i bezpiecznego uruchomienia	20			
Suma:	338.50			

#4 main board electric schematic