cansats in europe

PlasticMonkeys
Emergency BeaCan CanSat
Preliminary Design Review

Team Name: **Plastic Monkeys**

Country: **Poland**

.pl esero

www.cansat.eu

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1 CHANGELOG

We have decided to modify our secondary mission - we have changed the destination where our CanSat could be used - from high mountains to places where different emergencies occur. (see 2.2.2)

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. Each member of the team spend a few hours of their free time on thinking about potential solutions, calculating data, preparing diagrams, tests and so on. As a result, after school we dedicate approximately 5 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 - meaning a lot of Machine Learning) 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 (which is his favourite programming language these days).

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 (conducts robotic workshops for kids). 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 participates in physics classes at Jagiellonian University and 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 has a lot of different hobbies, including music, sport, science and technology. 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. 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. She is delighted to be involved in this project because of the opportunity to combine multiple of her interests and to gain experience.

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. His greatest successes were a gyroscope-controlled two-wheeled segway, and an autonomous line-follower robot. He is also involved in the school RoboTeam. He has some substantial experience with Python and possesses essential electrical skills and knowledge. 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- Lead Mechanical Designer

Jan is participating in CanSat for the second time. He attends third grade at High School No. 5 in Cracow, learning Physics, maths and computer science on extended level. He has been awarded individual course of teaching, which has allowed him to study physics at the academic level under the supervision of a professor of the Jagiellonian University specialising in Physics. Physics Olympiad has developed his problem solving skills, along with a creative approach to problems. Jan has also proven his management skills by organising “uBot”, a robotic festival.

He loves applying his knowledge in practice, which is his main motivation for participating in CanSat, but also pushed him to assemble a 3D printer. He is an active 3D graphic designer, which makes him familiar with computer design. In his spare time he learns to become a glider pilot, trains triathlon in summer and skis in winter.

Tasks: Jan's design experience will enable him to provide excellent solutions to the mechanical design of our CanSat. His knowledge of numerical algorithms may be helpful during simulations and calculations. He hopes to make a good use of his Physics knowledge while solving encountered issues.

2.2 Mission objectives

2.2.1 Primary mission

Our primary mission is to take measurements of atmospheric temperature and pressure and transmit them to base station at least once per second during the descent of the CanSat. All the gathered data will be both logged to the memory of the Sat and saved at the base station after being transmitted. This is to enable full data recovery in case of a radio communication failure. 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 with GPS recordings, thereby enabling the rescue team to get the exact location of the target. By dropping many of such devices during helicopter searching, rescue team may have found 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. 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,
- After a disaster in hard-to-reach places - thermal camera and heart rate sensor would be helpful in defining preliminarily whether vital signs are stable or not,

- In each situation the rescue team could deliver necessary things (like pills, a syringe of insulin, etc.) to victims using a transport module;

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 embed one or both of these into our CanSat. 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 to accomplish the primary mission
- Each of the attached external modules fulfils their purpose
- reaching two-sided stable radio communication
- building two additional modules (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 w
- No structural damage or electronic failure after landing
- No trouble with localisation of the CanSat after landing due to provided gps readings
- cansat will remain operational for at least 5 hours

2.2.4 Measurements

During our missions the sensors will be used to:

- measure temperature and pressure
- GPS tracking
- measure victim's pulse and oxygen saturation
- display questions on the screen and enable to answer them by pressing buttons
- save thermal imaging photos

2.2.5 Expectations

In our research we want to test the idea of "Emergency BeaCan" and make sure that it would be real help for rescue teams in the future. Moreover, we want to show that the idea of exchangeable modules is realisable concluding in reusability in different environments. We hope the result will prove that our CanSat is ready to accomplish real-life challenges.

3 CANSAT DESCRIPTION

3.1 Mission overview

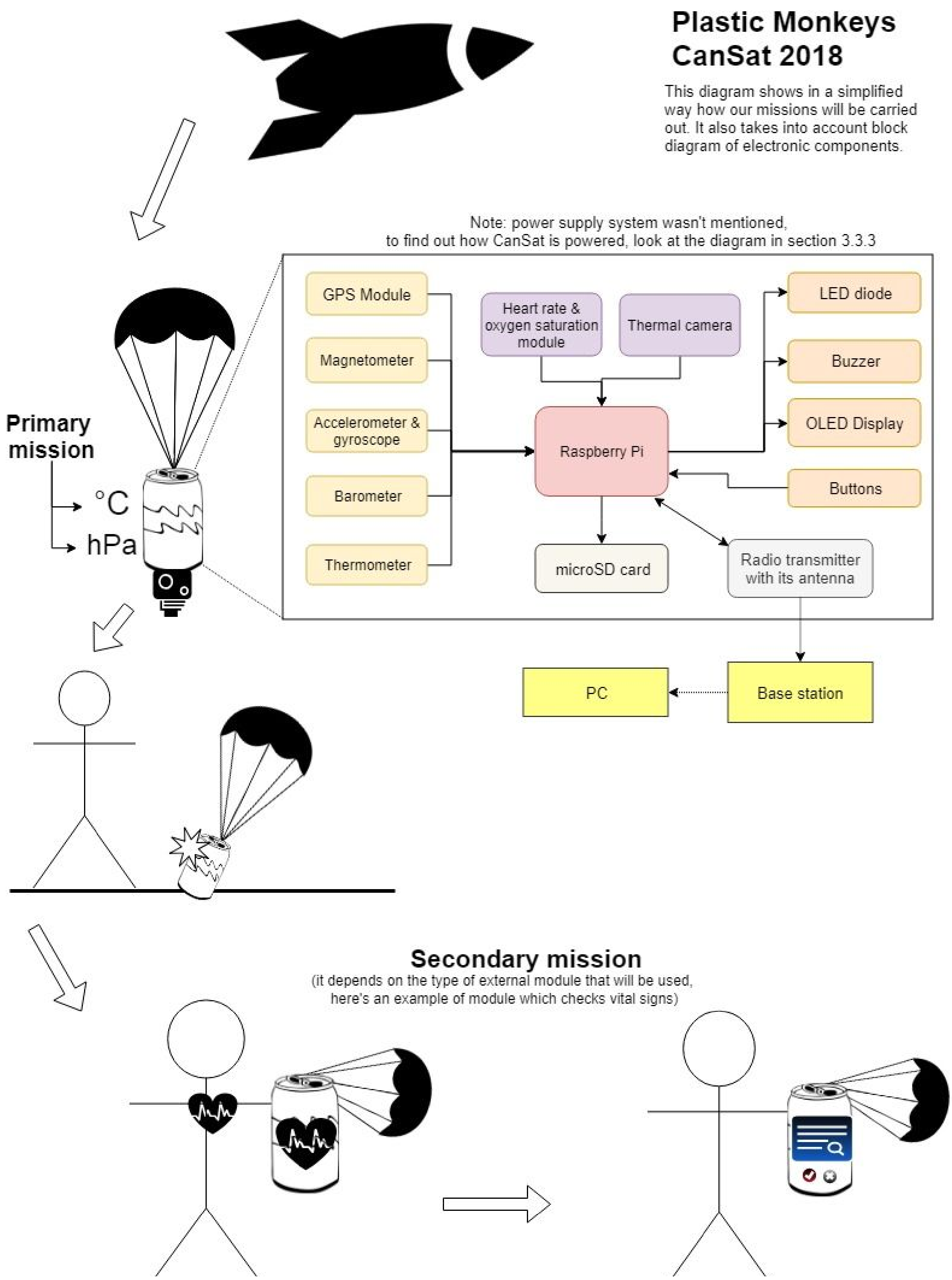
3.1.1 Overview

Before the launch, we will set onboard electronics to standby mode to decrease power consumption, then pack the parachute and prepare base station. After takeoff all sensors will be turned on and then, when CanSats are scattered at an altitude of about 3000 meters, the parachute will unfold. The parameters of parachute are estimated to make our Sat to achieve the target velocity 9m/s during descent. In the time of the flight various measurements will be conducted: temperature, pressure, acceleration, position. Furthermore, every 4 seconds thermal imaging photos will be taken. All the data will be both transmitted to base station and stored on onboard microSD card. To catch attention, we will use the buzzer and the LED that will blink every 5 seconds. Methods mentioned above will enable a potential victim to find the CanSat. Being found, our BeaCan will be used to measure the heart rate and oxygen saturation of the person who will put a finger on the sensor. Moreover, we will send some questions from base station to see whether that person will be able to answer them by pressing the buttons. 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, accelerometer and gyroscope, magnetometer, GPS, radio transmitter with its antenna, screen with buttons, LED diode and buzzer. Additionally, the module that we will use in the secondary mission contains: heart rate and oxygen saturation sensor, thermal camera. Casing and parachute are essential mechanical elements.

3.1.3 Block diagram



3.2 Mechanical/structural design

The internal body of our CanSat will be made out of 3D printed PLA. We are going to design our own 3D model providing compartments for all sensors and electronic components. Also, the monolithic structure will provide durability. Internal 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 silicone or latex 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 print them in 3D and mount them to the main body using screws at the bottom of the device. With such skin our CanSat's overall mass should be between 310-350 grams (mass budget calculation can be found in attachments)

3.3 Electrical design

3.3.1 General architecture

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, virtually unlimited memory and ability to record videos. It will be mounted to one PCB (motherboard) with GPS, accelerometer, gyroscope, barometer and a LoRa module and connected with them over I2C, UART, and SPI protocol. The second PCB board with a temperature sensor, display/buttons interface, a buzzer, and a transistor to drive powerful LED will be connected to the motherboard using ribbon wire as well. Also, we will provide data connection and power supply ribbon from the main board to the external module port, which is in the form of four 2.54 mm pins. Everything is going to be powered by two 3.7V Li-Ion cells connected in parallel, equipped with a kill switch. Voltage will be reduced to 3.3V, which is used by all our components, using a step-down voltage converter and both PCB's will be powered independently.

All connections and the general idea of our electronic design is presented on a block diagram on the following page.

3.3.2 Primary mission devices

As outlined above, the controller of our choice is a Raspberry Pi Zero W. This is because our mission involves using a thermal camera, which requires a lot of processing power. The Pi offers an exaggeration of 512MB of RAM along with a 1GHz processor, a microSD card slot (enables us to store image data without anxiety about exceeding any limits) and most importantly features multithreading (by using operating system), which makes it easier to process data from various sensors independently. Having compared these specs with those of the CanSat Kit and a STM32 family board, we came to the conclusion that Raspberry Pi was the only considered controller capable of handling a thermal camera, thus making it the sole solution to fulfilling the guidelines of our mission.

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 simple DS18B20 thermometer is going to be used. Its upsides are its small size, easy-to-use 1-Wire communication protocol, as well as the supplied temperature range (-55, 125)℃.

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, which was the most compact of the available ones.

3.3.3 Secondary mission devices

<u>BerryGPS-IMU</u>

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

- GPS - In cooperation with the thermal camera 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 thermal images correctly. They will also determine the moment of landing. Furthermore, during the test phase they will give valuable data connected with parachute behavior.

<u>Panasonic AMG8854 Thermal Camera</u>

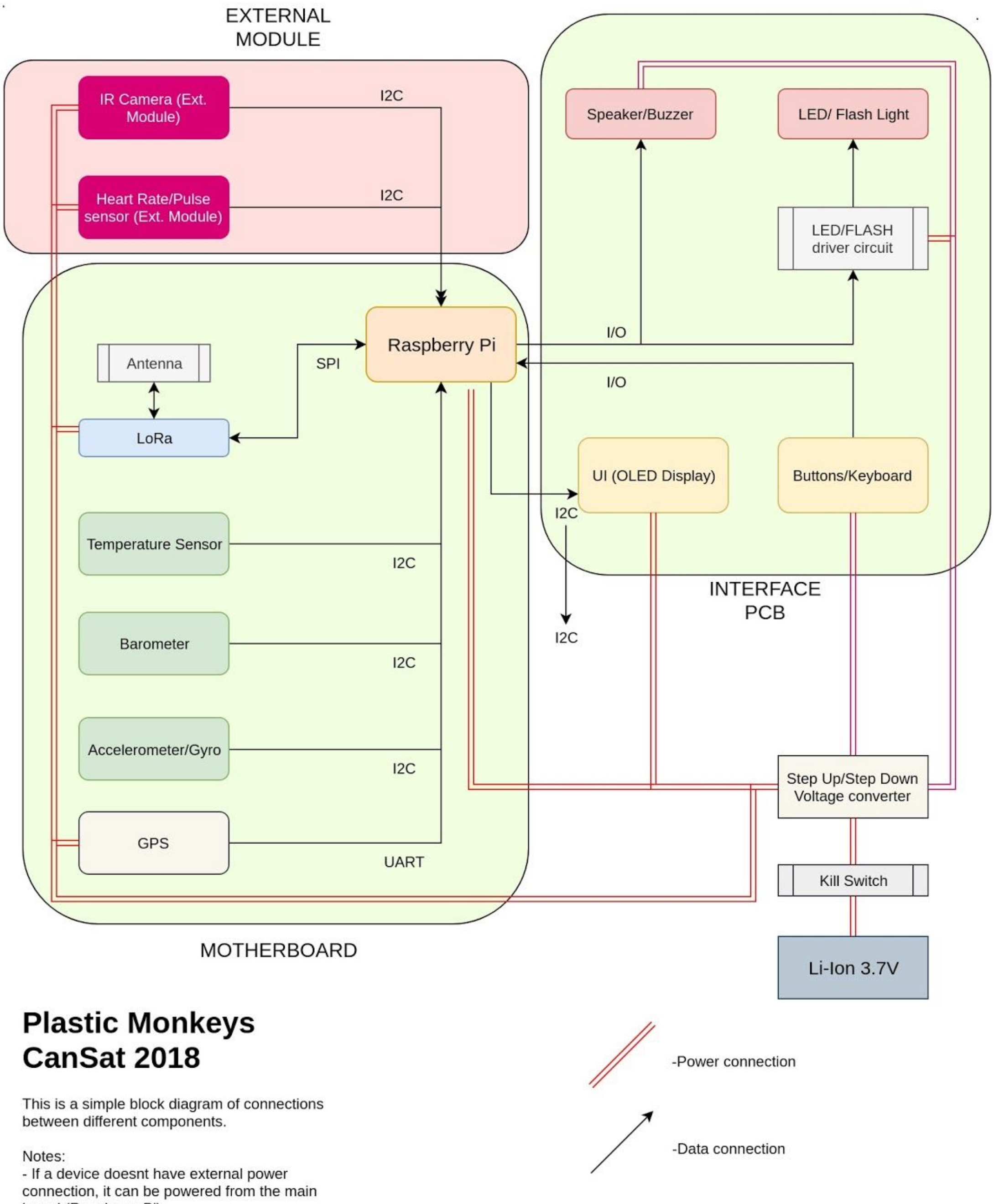
After reaching an appropriate height a series of photos of the ground will be taken. The goal is to determine whether any living entity is in the area. The operating temperature range of (-20, 80℃) satisfies most environments. One of the downsides of the camera is its resolution (8x8px), which does not let us distinguish a potential human from any other heat source.

<u>Star LED and FY248 Buzzer</u>

These are to catch attention of potential targets after landing. Due to the fact that the LED requires a lot of power (810 mA), it will blink for the duration of 0.5s every 5s

<u>MAX30100 Heart rate & O2 saturation sensor</u>

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.



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This is a simple block diagram of connections between different components.

Notes:
- If a device doesnt have external power connection, it can be powered from the main board (Raspberry Pi)
- Red elements (Ext. Module) are in our easily replaceable module. They can be changed just by plugging in other modules

3.3.4 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. The current consumption values provided are based on the datasheets of the sensors unless noted differently.

Component	**Max. Current consumption [mA]**	**Typical current consumption [mA]**	**Remarks**
BerryIMU GPS	31	25	
DS18B20 Temperature Sensor	1,5	1,5	
MAX30100 HR+SpO2 Sensor	1,2	1,2	
AMG-8833 Thermal Camera	4,5	4,5	This seems impossible for a camera, is proven in the datasheet though.
Raspberry Pi Zero W	230	190	The CPU usage of the Pi is probably going to be limited.
LoRa RFM95 or SX1278	120	110	Max Value is pure TX. The two chips share their current consumption specs.
FY248 Buzzer	12	4	Typical for 1s beep every 5s.
Power LED Star 3W	810	81	Typical for 0.5s blink every 5s.
Total	**1210,2**	**417,2**	

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	2:14:00	6:31:00
2x Panasonic 18650 3,6V in parallel	6800	4:29:00	13:02:00
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 six 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 3,9V to even 3,1V when nearly exhausted, so a step-up/down voltage converter is necessary to ensure stable power supply for the sensors and Raspberry Pi (3,3V).

3.3.5 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.

As said before, we decided to embed an AI-Thinker Ra-02 LoRa module into the Cansat. It will be equipped with a 17,3 cm long (quarter wavelength) flexible antenna. The base station will be equipped with a TTGO board which features LoRa transceiver topped with an Arduino-like board and an OLED screen. This could be useful to monitor the performance of the radio link in real time. It will use a Yagi type directional antenna with gain of 15dB.

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. Distributed software structure provides special redundancy - if one sensor stops working, or one program crashes, rest will work without interruption. 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. 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. Also, each log file with raw data can be used as a second, redundant source of data after a mission.

Due to Raspberry Pi usage, 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 * frequency of reading * length of the mission * number of sensors

The result can be seen here:

Max size of one reading (B)	Frequency of reading (Hz)	Operation Time (s)	Number of sensors
80	10	25200	7

Result (MB):	141,12

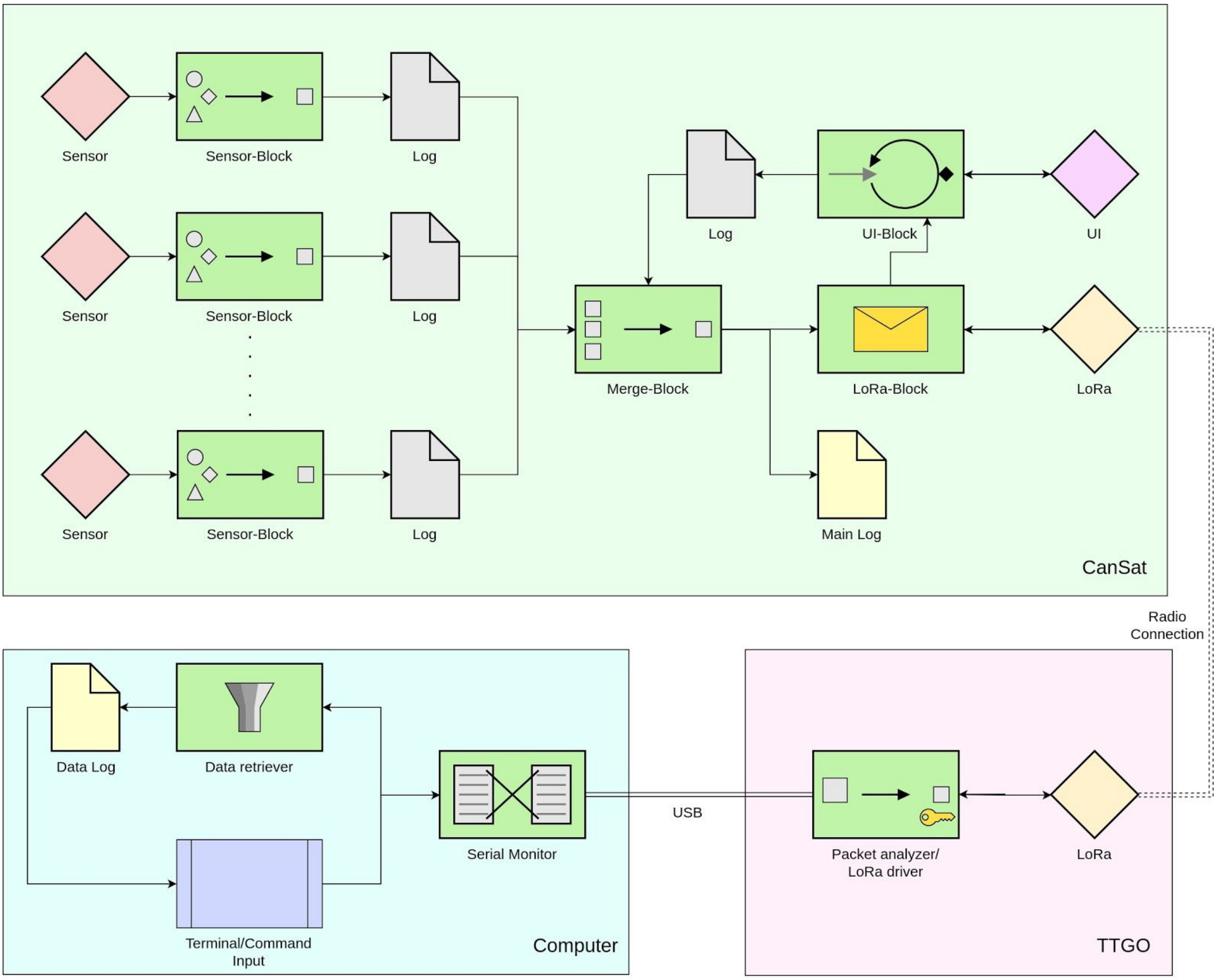
We can see that all logs from 7 sensors during a 7-hour mission will need less than 150MB. Our Raspberry Pi supports micro-sd cards that have much more free space than that. Even after adding extra sensors on our modules, or doubling reading rate, we won't use more than 500MB of storage. We can add to it 5GB occupied by the Raspbian system and our scripts, 2GB of an optional camera recording to see that 8GB SD card would provide enough space for our mission. However, for our safety and ability to add any features later, we are going to use a 16GB+ 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, will have 2 different modes: listening and sending. In the listening mode, it will receive data from LoRa, check their correctness, display them on built-in OLED screen and send them to a computer via USB, where Python script will retrieve serial data and save them on computer's hard drive. In sending mode TTGO will listen for a command from PC, which will be inputted manually, and send it to CanSat using LoRa.

LoRa link efficiency estimation has proven that at minimal Spreading Rate and Coding Factor 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 camera could undergo the following process:

- Pure image is an 8x8 array of values ranging from -20℃ to 80℃ with accuracy of 0,25℃. The first step is to break the data into 8 arrays of 8 values.

- We can narrow the range by excluding ranges which are not important during our mission, and decrease the accuracy to 0,5℃. The range could be then (-15, 48,5)℃
- Adding 15℃ to these values and multiplying them by 2 yields (0, 127). This range corresponds to a 7-bit integer.
- Using MessagePack serialization algorithm, an array of 8 7-bit integers can be written using 9 bytes of data, which will be logged at the Sat and sent to base via radio.



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3.5Recovery system

We would use 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 calculations estimated optimal perpendicular surface of parachute's canopy to be 0,28m^2 (assuming optimal velocity as something close to 10 (more precisely 10,3)) meters per second, (calculated from classical drag force equation). Assuming that we would fall from 3000m and CanSat motion is close to uniform motion estimated flight time is 290 s. Parachute mounting can be seen on the last pages of report.

3.5 Ground support Equipment

Our ground station consists of one notebook equipped with Linux distribution as OS, and TTGO - an arduino compatible development board, with built-in LoRa module and OLED screen (for live data preview) and suitable antenna. 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

So far our test campaign includes sensors' tests mainly. As we advance in our work we are going to extend the test to:

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 we are going to model each component in a 3D software and move them around. Having the design done, we are going to begin prototyping by assembling our CanSat according to the design and by performing tests on the prototype. The tests are going to check: probability of short circuiting, each sensor working, mechanical durability and telecommunications.

4.1.2 External casing

Our external casing is supposed to be made out of silicon or similar material. We expect it to provide water-resistance, absorb part of energy released at impact. We are going to prepare external casing prototypes from different materials and of different thickness. Then put them on a can imitating our probe, with accelerometer inside and check which material has the minimal thickness satisfying our demands for energy absorption. Water-resistance will be checked by replacing accelerometer with hygrometer and submerging it in water or placing it outside, in a wet environment.

4.2 Sensors

4.2.1 Thermometer

We are going to test our temperature measurements by comparing them with a accurate thermometer in different temperatures. High temperatures will be achieved in oven, while low in an insulated box with dry ice.

4.2.2 Barometer

To test our barometer we are going to compare its outputs with the theory of static pressure when moving up and down in an elevator.

4.2.3 Accelerometer & Gyroscope

In order to test accelerometer and gyroscope we are going to use a reliable and precise electric motor, which will allow us to achieve exact angular velocities. Knowing the angular velocity and distance from the axis of rotation we can easily calculate actual acceleration undertaken by sensors and compare it with their outputs.

4.2.4 Magnetometer

We are going to compare this sensor with a compass or a smartphone, whichever turns out to be more accurate.

4.2.5 Thermographic camera

Testing this component of our probe will include measuring temperature of a heat generator (candle, radiator) from different distances and comparing it to the reading from high precision thermometer. This will give us an idea about reading accuracy and operating range.

4.2.6 Pulsometer & Oxygen saturation

To test those medical sensors we are going to use the help from one of our external supporters, a ward administrator in one of local hospitals. Having access to hospital facilities we can compare our sensors with professional equipment, measuring parameters of our bodies. Provided we got a hospitals permission, we will also test it on patients.

4.3 Tests of recovery system

We are going to test recovery system by dropping our sat from places of well-known height - buildings (Alma Tower in Cracow), natural heights (mountains, “Skalki Twardowskiego” in Cracow) or drones. During each test we will calculate what speed our sat achieved, how well it survived.

4.4 Communication system range tests

The aspects of communication system range that need checking are: bidirectionality of the communication, range, performance in motion and how obstacles affect our communication abilities.

First we need to check whether bidirectional communication works while the transceivers are placed next to each other. Then to test it’s range we will be holding antenna on the Kościuszko mound and moving base station further and further. In this case distance is calculated from the pythagorean theorem.

It also might be a good idea to test connection link stability regarding the movement of CanSat with a certain speed (in a car or bike since 10m/s ~ 36km/h which is easily achievable)

4.5 Energy budget tests

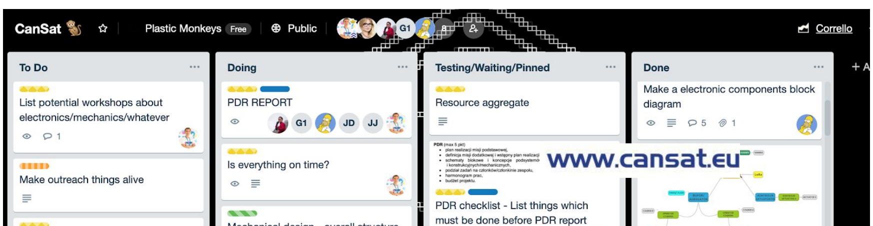
We will evaluate our power source and energy budget by simulating our mission (radio communication, data processing, capturing IR Camera footage), attaching to Sat a multimeter to check energy consumption and actual voltage, and measuring time until it goes off.

5 PROJECT PLANNING

5.1 Time schedule

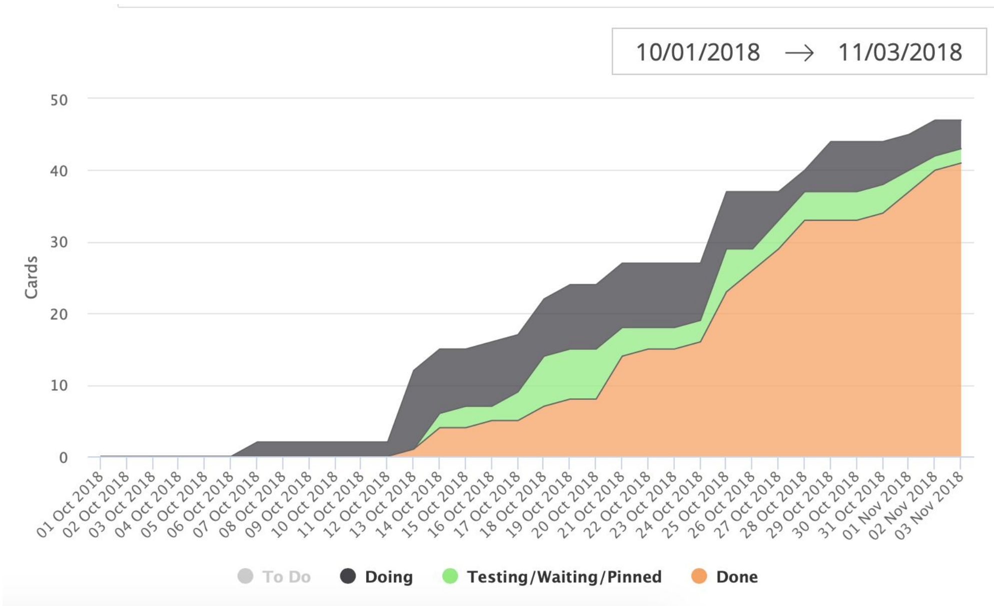
Following the agile framework, we are planning our workloads for every week providing valuable results iteratively, this way our plans evolve on daily basis and we don't follow any specific time schedule. However, project requires us to provide reports every so often, that indicates we are tightly coupled to that dates. As a give-and-take of this situation, we decided that we will provide key intervals for this project to make it on time.

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
November, December 2018	building first prototypes, writing initial software, developing ideas and solutions, starting cooperation with sponsors that will continue over the duration of our project	prototyping
December 2018	testing all the sensors in a way described in "Test campaign"	testing
first half of January 2019	correcting drawbacks	prototyping, testing
13 January 2019	Critical Design Review	Key date
second half of January 2019	constructing CanSat and its additional modules, providing software and mechanical solutions	constructing
February 2019	testing CanSat as a whole, making possible improvements	testing
beginning of March 2019	preparing CanSat to launch	preparation
10 March 2019	Final Design Review	Key date
March 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
4-7 April 2019	Final Competition	Key date



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. To the day of writing this report, we've done 41 tasks with average of 11 tasks per member - which looks like healthy collaboration. From our CDF diagram, it can be easily concluded, that we work in 1 week long sprints, with great results (steep burn-up curve).



5.3 Resource estimation

5.3.1 Budget

Component	Raspberry Pi Zero W	Berry GPS-IMU v2	DS18B20 thermo meter	SX1278 LoRa Module Ra-02	PCB	AMG8833 Thermal camera	Parachute	Power LED diode	FY248 Buzzer
Price	52 PLN	44,5 USD	5 PLN	4,5 USD	85 PLN	34,80 USD	160 PLN	6,50 PLN	2,50 PLN

Component	Tact Switch	SH1106 OLED Display Module	microSD card 16GB	Li-Ion Panasonic NCR18650B Battery x2	Step-up/ step-down voltage converter x2	Liquid rubber - silicone for external case	Filament PLA for Internal Casing	GY-MAX 30100 Heart rate sensor
Price	2 PLN	27 PLN	20 PLN	2 * 24,90 PLN	2 * 35 PLN	35 PLN	45 PLN	4,99 USD

	PLN	USD

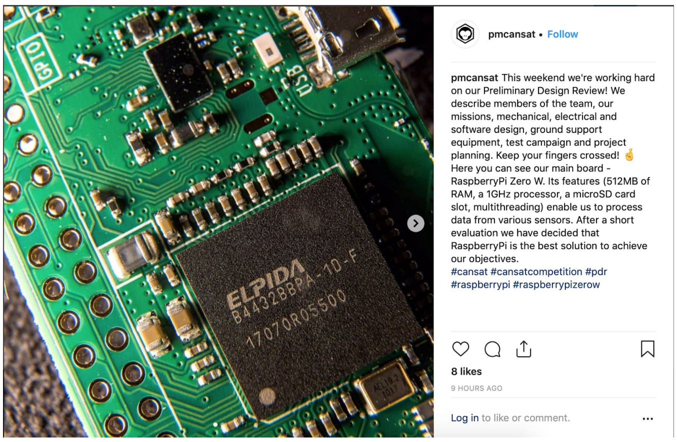
Sum	504,8	88,79
Exchange rate(3.11.2018) to EUR	0,23	0,88
Sum in EUR	116,104	78,135
Total	~195€	

5.3.2 External support

Referring to our time schedule, closer cooperation with sponsors is predicted to November and December. At the moment, we are **waiting for answers from our potential sponsors**. We also count on our school's help. 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**. When it comes to substantive and methodological help, we are getting in touch with **Hackerspace Krk** and **AGH Space Systems**, 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 Facebook and Instagram page (about 110 likes 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 created our own YouTube channel where you can find video that explains our mission[]. Also planned are worklogs, promotion videos and talk about our Sat. 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. Our initiative is also supported by Dreamlab corporation, which offers us their rooms for our meetings. We have been mentioned by them on their official Facebook page.



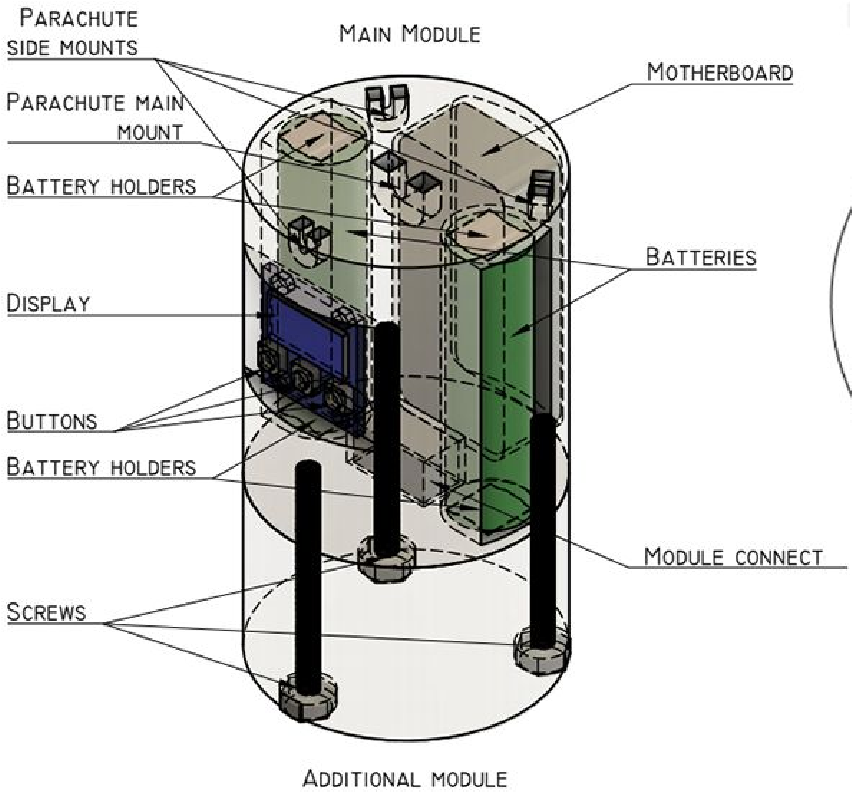
- Our Plastic Monkeys Facebook Page: facebook.com/pmcansat
- Plastic Monkeys YouTube Channel: [PlasticMonkeys Youtube]
- Plastic Monkeys on Instagram: instagram.com/pmcansat/

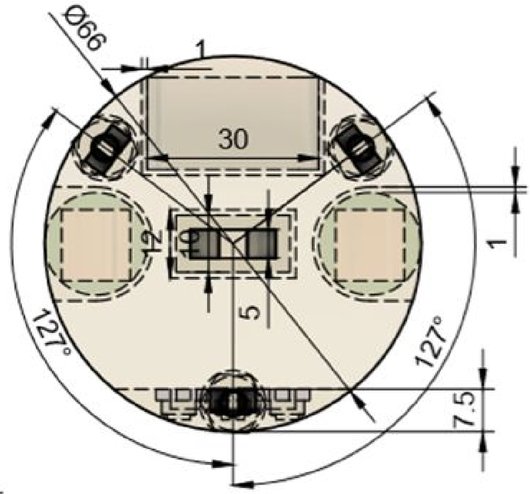
Our outreach plan also assumes: presentations during robotic/maker festivals, having an interview on local radio/tv channel, workshops and show-offs for students in our high school, promoting our posts on Facebook.

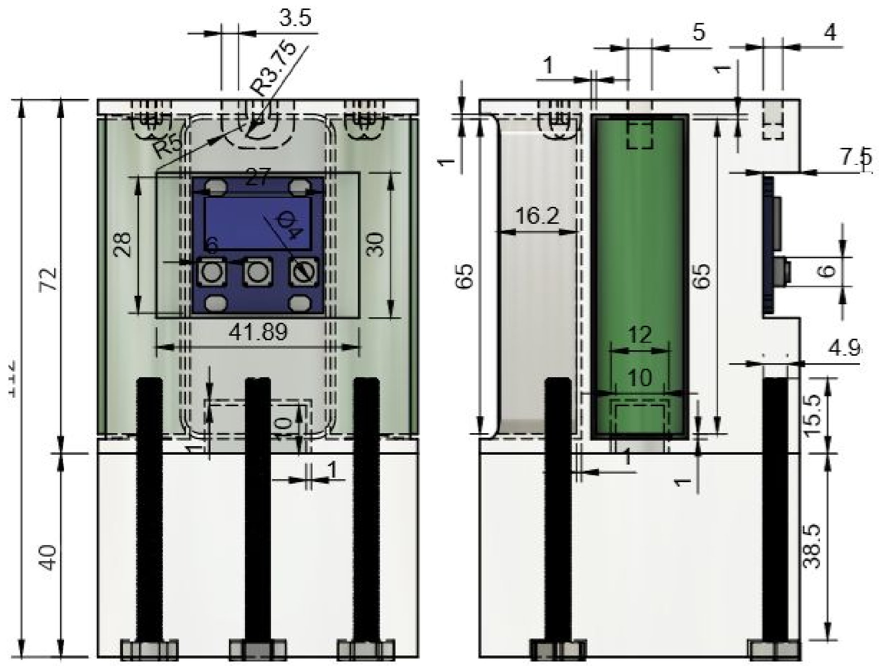
7 CANSAT CHARACTERISTICS

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

Characteristics	**Figure**
Height of the CanSat	112 mm
Diameter of the CanSat	65 mm
Mass of the CanSat	32
Estimated descent rate	7 m/s
Radio transmitter model and frequency band	SX1278, 410-525 MHz
Estimated time on battery	13 hours
Cost of the CanSat	~200€







mass budget:

	A	B	C	D	E
1	część	masa [g]	założona gęstość [g/cm^3]		grubość osłonki
2	silikonowa powłoka	55,46	1,2		0,2
3	obudowa z PLA	100	1,25		
4	spadochron	40			
5	Elektronika przewody, raspi, czujniki etc. (przeszacowane, mocno, w górę)	40			masa baterii:
6	baterie	96			48
7	suma:	331,46			