cansats in europe

Team Name: TinX

Country: Poland

.pl esero

www.cansat.eu

1. INTRODUCTION

1.1. Team organisation and roles

Each team member dedicates one hour per week during meetings in school and members are prepared to dedicate needed time in after school time.

- Ms. Anna Pękala (teacher)

  Background:

  Ms. Pękala has a Masters in Economics, and is a certified career counsellor. She has 15 years working experience with students in the fields of basic economics, entrepreneurship and career planning. Ms. Pękala has a number of interests, these include economics, psychology and personal development.

  Field of work within team:

  Ms. Pękala will be responsible for work planning and assignment of tasks. She will also be responsible for helping to motivate team members so that they can deliver their best work on this project. Ms. Pękala will also help members of the team to develop and grow through this process.

  Ms. Pękala will also assist in management of the budget for this project, and assist in fundraising as necessary.

- Mikołaj Data (Team Leader).

  Background:

  Mikołaj Data is a student of Technical High School no. 6 in Rzeszów. He has extensive knowledge in the fields of programming, data analysis, electronics and astronautics. He has 6 years of experience in IT. Languages mainly used by him are C and Python.

Field of work with team:

He will be responsible for work planning, software and electronic development. His duties will also include website and social media managing.

- Przemysław Lib

  Background:
  Przemysław Lib is a 3D designer with many years of experience. Inventing useful devices and mechanisms is his passion. The programs he uses are Fusion 360 and Simplify 3D. He is a student of Technical High School no. 6 in Reszów.
  Field of work with team:

  His main task is to develop a safe recovery system, design CanSat's body. He is also responsible for finding financial support in external sources.

- Filip Różak

  Background:

  Filip Różak has experience in designing and troubleshooting electronic devices from different fields: RF circuitry, SMPS, industrial, production, automation. Furthermore, he develops software for microcontrollers such as AVR, PIC, ARM mainly in C language. He has great interest in creating robust and cheap solutions for everyone. Filip Różak is a student of Technical High School no. 6 in Rzeszów.

  Fields of work with team:

  His main task is to make design decisions about electronics in CanSat, develop schematics, circuit board(s) and write applications for onboard microcontrollers.

- Mateusz Soszyński

  Background:

  He is a full stack developer - has experience in many different aspects of programming - from embedded devices, to mobile apps, to managing Linux servers. He is also a passionate open-source community member, so he will be the most active in managing and maintaining our GitHub repositories.

  Fields of work with team:

  His main task is to take care of handling the data from satellite on the ground - processing and analyzing it on the back-end, and displaying it on the front-end.

1.2. Missions objectives

Primary mission: Measurements of atmospheric pressure and temperature with subsequent data analysis.

Key goals:

- Measurement of pressure and temperature outside the CanSat.
- Radio transmission of measured data in minimal rate one packet per second.
- Calculation of altitude based on atmospheric pressure assisted with geolocalization data.

Secondary mission: Demonstration of CanSat system for rescue operations during natural disasters.

Key goals:

- Design system that meet following requirements:

  - Low cost of design and produce
  - High accuracy and stability
  - Easy access to information about position, altitude, temperature, acceleration
- Take photos from the thermovision and visible range camera - merge them and analyze.
- Mark on photos all obstacles (to protect rescuers) and places where people could possibly be.

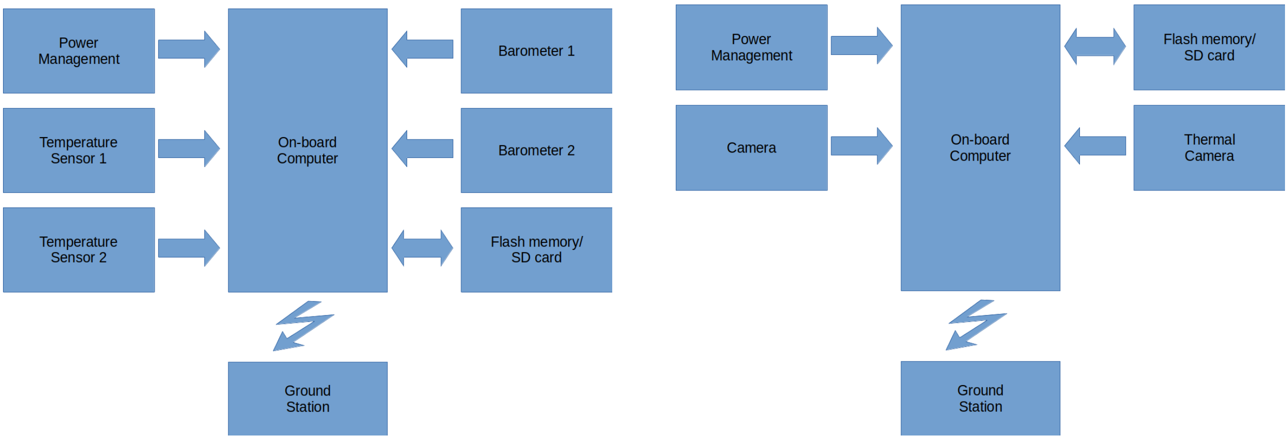
Optional goals:

- Investigate a fire resistant biofiber composite with which body of CanSat will be built, keeping cost as low as possible.
- Pointing geographical coordinates of marked obstacles/humans basing on gyro data.

2. CANSAT DESCRIPTION

2.1. Mission overview

The mission is being developed through a CanSat competition. The organisers of the competition provide a take-out system (rocket or UAV). CanSat on-board computer start is planned for +/- 2 hours before take-off. During take-off the satellite accelerometer will inform the on-board computer about rocket launch, then the primary mission starts. When CanSat will be deployed the secondary mission starts. Landing is predicted 4 minutes after deployment.



Primary and secondary mission diagrams

2.2. Mechanical/structural design

General objectives for the mechanical structure of the CanSat:

1. We will introduce the construction of CanSat inertial dampers to protect sensitive electronics, such as cameras, against vibrations and high acceleration stresses.
2. The internal frame with electronics will be covered in a semi-fireproof shell made of fibers and ceramics.
3. The internal frame will be printed with 3D technology, using nylon or materials with similar properties.
4. Sensors will be placed in the external shell and will be connected by flexible wires to the main board.

The inertial dampers will be 3D printed using flexible material with properties similar to hard rubber. Such a solution will protect our main board and cameras against high acceleration while being lifted by rocket and will protect physical data storage in case of parachute failure on landing.

The fireproof case will be made with some cheap bio fiber like paper or flax, glued in the shape of a cylinder. Next, the cylinder will be soaked with a sodium silicate water solution (water glass) which will make it hard, fireproof and waterproof.

The internal frame will be connected with inertial dampers to the external shell. The main board, power supply system and other electronic parts will be attached to it. We expect to make it with nylon, because that material has high impact strength and is insensitive to heat up to 170 degrees Celsius.

Sensors will be placed in the external shell to let them make reliable measurements. Connecting them to the main board by using flexible wires will allow internal frame movement in the field of inertial dampers without breaking connection with the sensors.

2.3. Electrical design

General architecture

Primary requirements for electronics in Cansat:

1. Usage of double/triple redundancy for each physical component to improve fail-safe operation and robustness.
2. Accurate measurement of several electrical parameters inside the system in order to provide information about possible failures and their sources.
3. Usage of low-cost widely available, off-the-shelf components to allow for decreased budget on electronics part and make it more affordable.
4. Physically robust construction of PCB.

To answer all needs a versatile digital control is required. Acquisition and interpretation of different kinds of data requires speed and plenty of memory. Modern Uc's with 32 bit cores are extremely low-cost, fast and have a lot of useful pheripherials. This leads to the use of a STM32F103RG as main controller.

Reliability and redundancy, used widely in self-driving cars, are main challenges to deal with, while keeping cost as low as possible. To improve MTBF (mean time between failures) all parts of the system will have hardware support for self-testing.

Data Acquired from all sensors/cameras are stored in Flash memory (external physical chip), due to simplicity to use, high speed (SD card needs file system initialization and handling). Data can be protected from corruption using CRC calculation and checking, usage of two separate physical chips increases reliability. When the mission is complete, data will be transferred to the micro SD card (easy to use for operator).

Primary mission devices:

Usage of sensors combined in one physical device usually leads to lower accuracy and reliability. Thus sensor systems have to be constructed from individual probes and digitalization circuits.

Some of the environmental sensors need exact airflow and/or protection against atmospheric conditions. This creates a need for their physical alignment.

Main task of primary mission devices is to acquire required data with as high as possible accuracy and reliability, to simplify processing of the results.

Temperature measurement has to be very linear, because predicted temperature variations will be relatively small. Absolute error can be easily reduced by implementing a calibration procedure.

To measure temperature several probes can fulfill its task:

1. Thermocouple - needs high accuracy, low drift and low offset voltage amplifier

2. Resistive sensor - needs nonlinearity compensation and stable reference

3. Off-the-shelf digital sensor - needs high price for high accuracy, however simple to implement

Further tests have to be done to distinguish which one(s) to use.

Measuring atmospheric pressure is used to calculate altitude together with the geolocation system, thus is very important. Development of own pressure probe and indirect measurements (eg. through frequency) using it are tricky and might not provide linear results. In this case using industry standard sensors (eg. BMP-280 from Bosch Sensortec) improves reliability and performance. Due to the high importance of pressure measurement redundancy is required here. Stable reference voltages and/or current sources are required for stable measurements across the whole ranges. Also, there could be a need of keeping some delicate measurement circuitry under stable conditions (e.g. temperature, humidity).

Secondary mission devices

Accelerometer and gyroscope are needed to provide information about the actual relative position and rotation of the device. Collected data will be used in the ground station, but they also have to be analyzed onboard to recognize mission steps. Those sensors can be embedded in one physical chip - this simplifies layout and allows for physical redundancy, due to reduced size.

To calculate the actual device’s position on the earth, a geolocation data receiver can be used. Support for different geolocation systems (GPS, Glonass, Galileo) makes results more accurate (especially over different continents).

Camera operation requires acquisition, storage and processing of huge amounts of data. Moreover, data has to be fetched extremely fast and simultaneously in both cameras, due to the relatively high falling speed of CanSat. To do that cheaply, a main microcontroller can be used. However if it turns out that it's too slow - external FPGA can also be utilized as camera handling logic. Pcb layout has to be optimized mainly for camera operation, due to high operating frequency, in order keep EMI as low as possible and reduce interference with other components.

Power supply

As there seems to be lack of power management solutions for such projects - own has to be developed and tested. This will further improve control over the system. Moreover, in this kind of low-power application efficiency is required along with low EMI emission to meet electromagnetic compatibility requirements and to not disturb delicate sensors. Battery should have not less capacity to let CanSat inform about it's position for several hours, chemistry has to be chosen during initial tests.

Communication system

Communication going to be performed in two ways:

1. From CanSat to ground station - acquired data, actual state, diagnostics
2. From ground station to CanSat - control commands

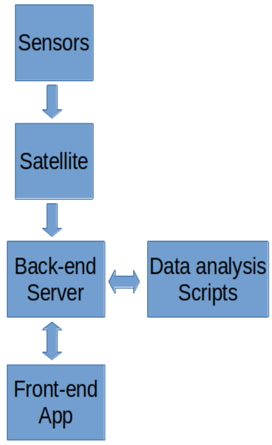
To communicate over a recommended distance of 3kms and meet power requirements, a highly efficient system has to be used. One of approaches to achieve that is to use a modulation technique optimized for low-power long-range transmission. Adequate tests have to be done, but from research can be seen, that LORA standart meets above requirements.

All long range communication systems require tuned antennas, to increase connection budget (tuned antennas have connection budget profit). Possible antenna tuning will be possible with Vector Network Analyzer.

To facilitate finding CanSat after landing, a GSM network can be used to transmit device's localization, however GSM network doesn't have coverage on the whole globe, thus communication cannot rely on this type of communication.

To improve fail-safe operation and communication reliability, different (possibly high power) transmission could be developed if needed.

2.4. Software design



Primary requirements for software in project:

1. Managing peripherals onboard CanSat.
2. Store and transmit data.
3. Analyse data.

To achieve all listed requirements software will be divided into three parts: satellite, ground station and algorithms to image analysis.

Software will be developed under GPLv3 license, so source code will be shared on our Github(https://github.com/TinXsat).

Satellite software design

Satellite will be operating in 4 modes:

1. Before flight - calibration of sensors, low-level self test.
2. Lifting - data collection from accelerometer and possibly environment inside the rising system.
3. Falling - data collection and processing for on-board use. Execution of primary and secondary mission tasks. Maintenance of communication with the base station.
4. On the ground - enter low power mode, transmit recognition packets, possibly also with GSM. Fetch data to removable storage (sd card) for further analysis.

To automatically distinguish between mission phases, state machine can be used. Such a system would take into account several variables: accelerometer reading, pressure (altitude). However, if some parameters would not be as assumed, the base station can send command to change mode.

Onboard data analysis will provide only basic information about the environment, due to limited processing power and speed needed to acquire data. Lack of operating system force usage of interrupts and timing peripherals of the microprocessor to implement multitasking, but also improves real-time operation synchronization.

Acquisition of such an amount of data from environmental sensors requires extensive averaging and filtering. To provide enough data to work with, high speed sampling has to be used. Luckily DMA can be utilized for some of these tasks to unload core and let it perform other operations.

Data communication with different onboard devices has to be solid and fail-save. In order to achieve that, extensive self testing of every funcional block has to be implemented. Software should report failure and (if possible) change/disable faulty block(s) and continue to work - this reduces downtime of the system in the air.

Calibration procedure improves absolute accuracy of onboard sensors and their adaptation to different environmental conditions (atmospheric pressure changes rapidly even within a day).

Ground station software design

Ground station will be responsible for collecting, storing, processing and presenting data received from CanSat. To handle all those tasks we are going to create a back-end server connected with a front-end app.

Back-end server is the program that will collect and process the data received from satellite - will be fully written in Python, because it's one of the fastest to develop, popular and most versatile languages out there.

Data from the radio receiver will be read by USB UART serial, and saved in the database/csv files.

While receiving the data, the server will be able to push it on-the-fly to the front-end app, through http API.

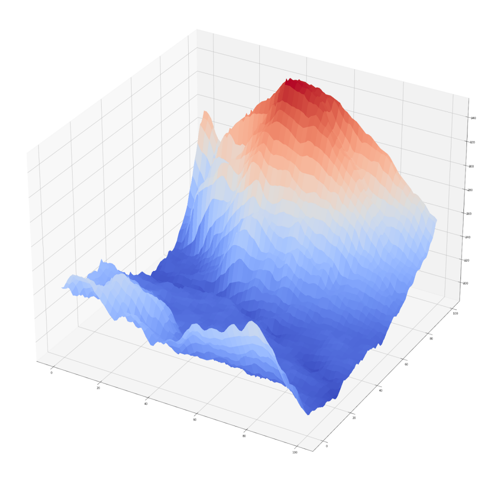
Front-end app that is, everything that end-users interact with when our satellite launches. It will be made with Flutter, because it's cross-platform, fast to develop, and very easy to build good-looking UI.

Thanks to its ability to compile to a web app, it could be served from the same server where the back-end will live - no need to install any extra software for the end user.

All of it's changes (while developing it) will be versioned with the "Git Flow" technique.

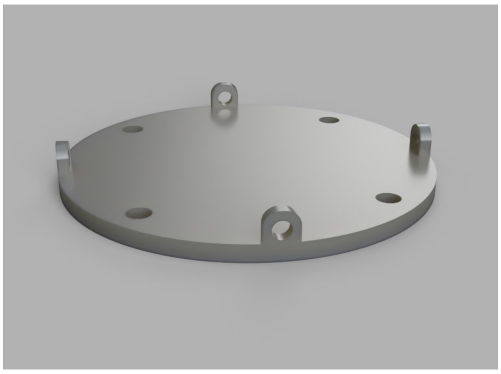
Scripts for data analysis

To make our code more readable, the team decided that we create a special repository only for scripts to data processing. To create them we will use Python and its data science libraries e.g: numpy, pandas, matplotlib.



To provide accurate position of located objects scripts will be based on 3D terrain models (see picture).

2.5. Recovery system



Our recovery system will be based on a parachute. That solution is cheap, safe and reliable. Parachute will be a hexagonal shaped bowl made with light nylon fabric. Its dimensions will be 30x30 cm and were calculated by using a website: descentratecalculator.onlinetesting.net We expect 9.54 m/s free fall velocity. Parachute will be attached to four fasteners on the top of CanSat using paracord strings.

2.6. Ground support equipment

Our ground equipment will contain:

- communication device
- antenna
- data processing unit

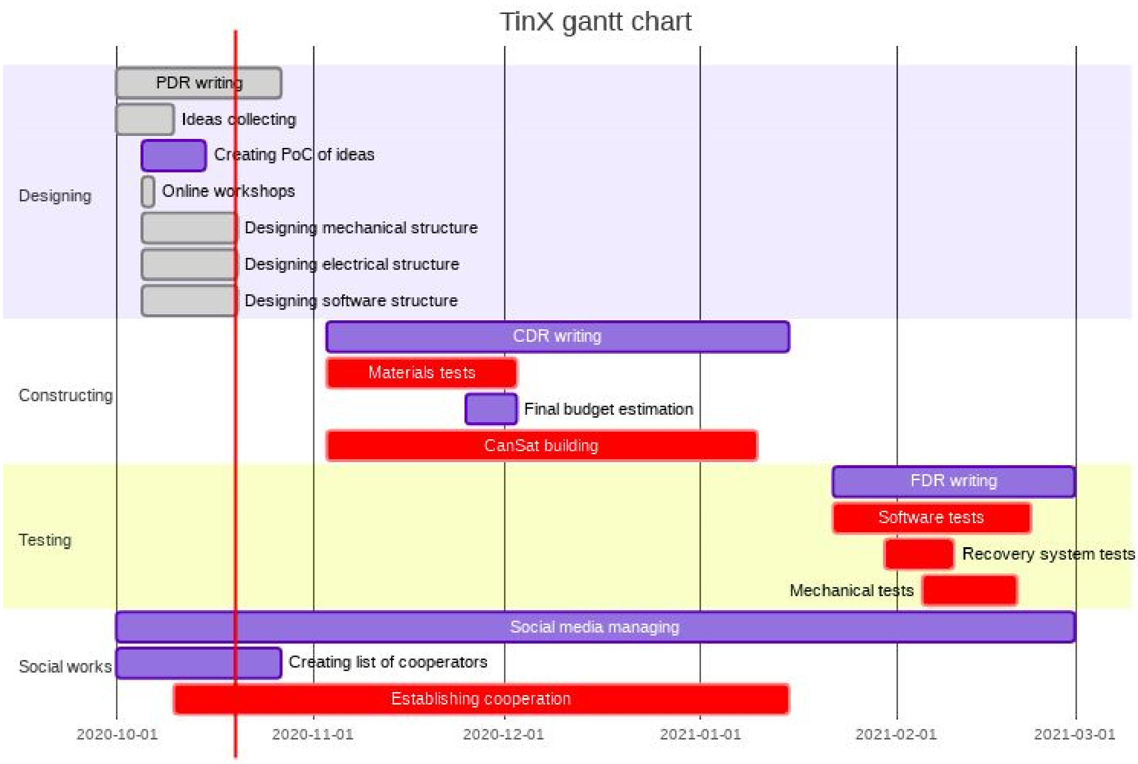
Communication device will be based on the radio receiver module, its task is to receive data from CanSat and pass it to the computer. It will cooperate with the antenna to extend transmission range.

Data processing unit will be a mobile computer with special software that will process data, save them, show in usable shape and share to other devices e.g. team members mobile phones.

3. PROJECT PLANNING

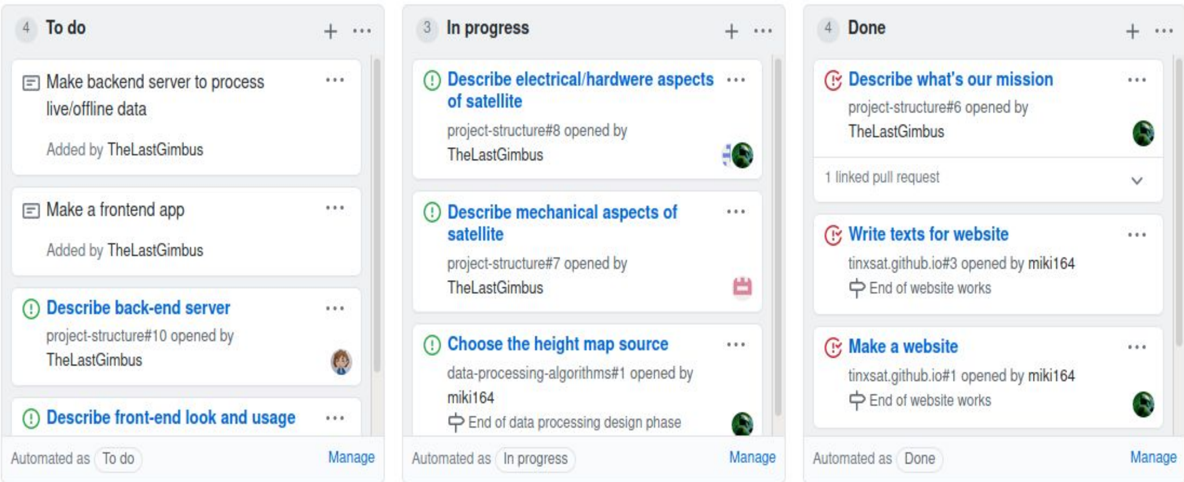
3.1. Time schedule

Time schedule is created using https://github.com/mermaid-js/mermaid



3.2.Task list

Team task list is updated in real time and is shared on Github platform. (https://github.com/orgs/TinXsat/projects/1)



3.3. Budget

In this document we only present our budget forecasts. We are going to provide more accurate budget estimation in next document revision.

No.	Part name	Quantity	Price per piece [EUR]
1.	Microcontroller	1	7
2.	Temperature Sensor	2	2
3.	Camera	1	10
4.	Thermovision camera	1	30
5.	Accelerometer	2	4.5
6.	Barometer	2	4.5

7.	3D printing materials	1 kg	10
8.	PCB board making	3	10
9.	Rest of electronics	-	10
10.	Recovery system	1	7
11.	Battery	1	5
TOTAL:			100

3.4. External support

In order to obtain support, the team established cooperation with:

- Kolegium Nauk Przyrodniczych Uniwersytetu Rzeszowskiego - substantive assistance and rental of research equipment
- Blue Dot Solutions - substantive assistance and team advertising
- Kosmonauta.net - substantive assistance and team advertising
- Aleksy Malawski - graphical design

Now the team is looking for a funding source. Team plans to start cooperation with producers of filament to 3D printing and government agencies.

3.5. Outreach programme

Our team started:

- Website - tinxsat.github.io - addressed to our cooperators or future cooperators
- Fanpage on facebook - fb.com/tinxsat - created to encourage people to programming and creating space projects.

- Github organisation - github.com/tinxsat/ - addressed for programmers, data scientists. It creates opportunity to get more help from open-source developers community
- An email - tinxasat@gmail.com - created to communicate with companies, cooperators and government agencies.

BLUE DOT SOLUTIONS

KOSMONAUTA.net

Uniwersytet Rzeszowski