Guidelines for the Critical Design Report

Team: ROSPIN

January 22, 2024

Contents

1 Progress report

1.1. New progress statement for the team profile

1.2. Tasks list

1.3. Detailed project status

2 Introduction

2.1. Purpose of the mission

Overall goal is to help businesses pick a strategic placing for their entities, and to revolutionize GPS services with faster and more precise data.

2.2. Team organisation and roles

- **Team Name:** ShuttleSat - shuttle is spaceship + sat is satellite, and we brought them together.
- **Team Composition:**
  - Rares: Previous Experience $\rightarrow$ Hardware&Embedded Google course | Background $\rightarrow$ pure sciences and maths | Interests $\rightarrow$ physics and mechanical engineering | Field of work within team $\rightarrow$ pick satellite's components, build the satellites, keeps track of available components, take care of components integrity, research and plan on physical components | Expected hours dedicated $\rightarrow$ 20-30.
  - David: Background $\rightarrow$ electronics, signals and devices | Interests $\rightarrow$ electronic engineering | Field of work within team $\rightarrow$ R&D, expertise in mission's area, data collect/analysis, timeline of data results, find and compare technical solutions, aerospace and electrical expertise | Expected hours dedicated $\rightarrow$ 20-30.
  - Alex: Previous Experience $\rightarrow$ Project managing Innovation Labs mentorship | Background $\rightarrow$ analytical thinking and logical reasoning | Interests $\rightarrow$ team management and software engineering | Field of work within team $\rightarrow$ pick technologies, design and develop the software, meetings, initial ideas/information to start from maintain a developing plan, keep track of project directions, design/develop communication system | Expected hours dedicated $\rightarrow$ 20-30.

- **Team's Activity:** Half meetings are online and half are physical, based on the expected length and progress review or the intended planification volume of the meet.

2.3. Mission objectives

1. **Traffic measurement and mapping, for known congested areas, either entities identified as cars or humans.** Secondary mission objective is to achieve an infrastructure capable of monitoring human and cars traffic. The infrastructure should be based on a single satellite that covers a single area at a time. We are looking forward to collect data such as: the number of entities inside the area and the flux of entities relative to time.
2. **Proving that the concept can be applied at a larger scale, such as a network of orbital satellites doing traffic measurements, is the target objective to call the launch successful.** Main target is to successful capture stable and high quality pictures

of the designated area. Smaller targets are to transmit this data to ground controller, and develop an innovative algorithm and AI in order to obtain 2 main variables: number of entities and their flux, within an area.

3. **We are expecting to find: majority of challenges, data to simulate actual implementation, costs and impact, infrastructure improvements.** We are looking further to understand and list the majority of challenges that are faced when designing and building an orbiting satellite for current mission objective. Obtain the necessary data to run simulations of the cost to build and maintain a satellite network that measures and maps traffic, as well as it's impact and benefits. A flawless data transfer infrastructure is expected to be built trough the overcame challenges. Nonetheless we expect to improve our current skills and develop new ones, necessary for satellites development and engineering.
4. **Measure the values of CH_4, CO_2 and N_2 and the quantity of entities inside a designated area.** We are seeking to identify the % of CH_4, CO_2 and N_2 from the air with a precision of up to 98 at any altitude% and the quantity of entities, in a targeted area with a precision of around 50% at 300-700m for cars and 100-300m for humans. Also we are looking to test the transmission of this data, its capabilities and limitations, to the ground controller, continuously, until we fall under 100m of altitude. But the most important test will be the satellite as a whole, that every system work as expected and what improvements can be done for a successful infrastructure.

3 CanSat description / Payload description

3.1. Mission overview

3.2. Mechanical / structural design

1. **Mechanical Design:** The CanSat is made of carbon fiber/ aluminum alloy because of their mechanical properties such as low weight, high durability and high tolerances in thermal expansion. The structure was designed to maintain a certain position while mid-air and to withstand the stress of launch and landing. It comes with a removable top and bottom to facilitate access inside. The components are attached to the structure with screws, nuts and mounts to assure stability during the mission.

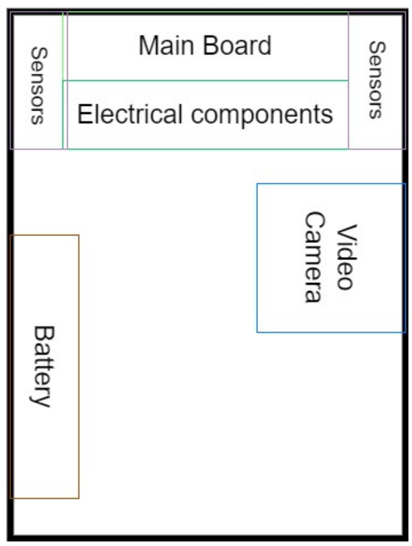
2. **Components:** Components used for building the CanSat include: a main board, sensors, a video camera, a battery and a GPS module. The main board contains the microcontroller which collects the data from the sensors and sends it to the ground station via it's communication module. The sensors include: a temperature sensor, a CH_4 sensor, a N_2 sensor, a CO_2 sensor and an altimeter which measures both pressure and altitude. The GPS module registers the current position of the CanSat. The video camera takes frames of the surface below to be processed afterwards at the ground station. The battery provides power to the CanSat during flight. The list of components stands as it follows:

   - **Microcontroller:** Raspberry PI Zero
   - **Temperature sensor:** sensor DS18B20
   - **CH_4 sensor:** sensor MQ-4
   - **N_2 sensor:** sensor MiCS-5524
   - **CO_2 sensor:** sensor MQ-9
   - **Altimeter:** sensor BMP-388
   - **GPS Module:** GPS GY-NEO6MV2 module

- **Communication module:** already integrated in main board
- **Gyroscope:** sensor MPU6050
- **Video Camera:** OV5647 video camera
- **Rechargable battery:** portable power bank

3. **Placement:** The main board is attached to the top of the CanSat structure with the sensors located adjacent to it. The battery is attached to a side of the CanSat while the camera is attached to the opposite side of it. The structure was designed to maintain balance during flight, to minimize the weight and to provide space for the components and for further human intervention.

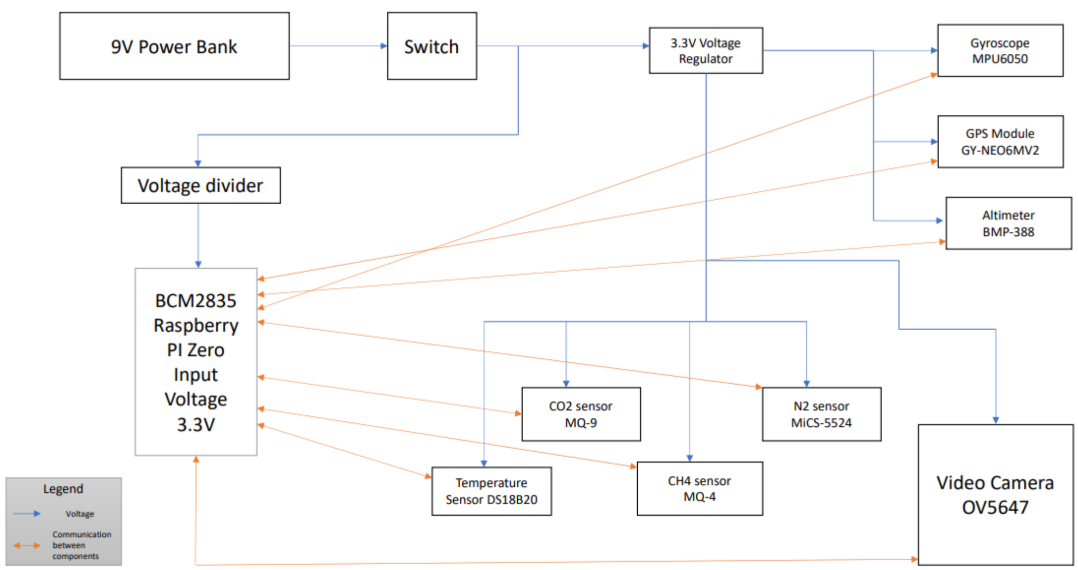
4. **Drawings:** This is a mechanical drawing of the CanSat structure in which we have emphasized on the placement of the major components.



5. **Explanation:** The main board, Raspberry PI Zero acts as the data collector for the sensors and the camera, aswell as the data transmitter for the ground station. The sensor DS18B20 offers an accurate and fast measurement of the atmospheric temperature. MQ-4, MiCS-5524 and MQ-9 accomplish the main mission of the Payload, measurement of the quantity of atmospheric gasses. They all have a small power consumption and a very small error margin. Even though the BMP-388 is a Barometric Pressure sensor it can be used as a altimeter with a precision of $\pm$ 0.5 m. The GPS module GY-NEO6MV2 comes with an antenna which helps it receive the current position from the satellites and the MPU6050 sensor can be used as a 3 axis gyroscope. The OV5647 video camera is a standard Raspberry PI Camera with a small power consumption and a resoultion of 1080p which will be used to accomplish the secondary mission of the Payload, traffic measurement and mapping.

3.3. Electrical design

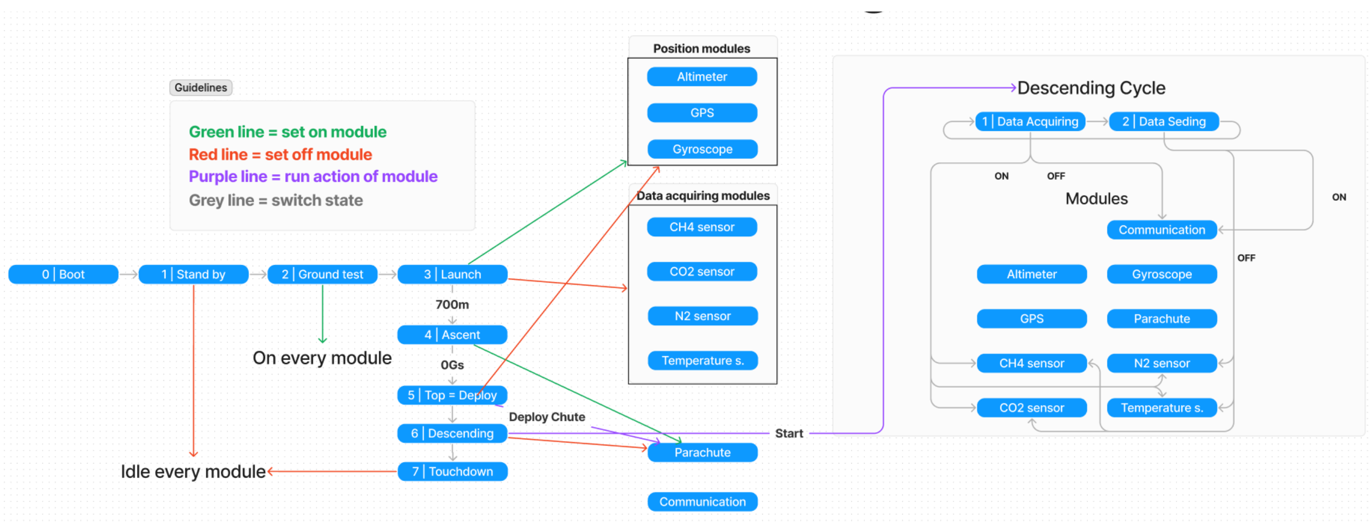
1. **Electrical Interface:**
2. **RF Link:**
3. **Power Budget:**
4. **Power Consumption and Duration:**
5. **Battery:**



3.4. Software design

1. **Introduction:** The CanSat's robust software architecture is designed to seamlessly manage three key systems: the flying system, data acquisition, and data transmission. Powered by the Raspberry Pi Zero/Pico, our custom software ensures optimal energy efficiency and high-speed processing for precise control of the CanSat's mission.
2. **Software flow overview:** The software operates in predefined states, allowing the CanSat to adapt to various mission phases. In the event of any mid-flight issues, the system intelligently resumes from the last known state. For a detailed representation, refer to the Software Flow Diagram (SFD) atached below.
3. **State based controls:** Initiating from the boot phase, where the system verifies state integrity, the software progresses to standby, where all modules are idling. The subsequent ground test phase activates all modules at full power, testing their connections and integrity. The second phase commences with the launch, maintaining only the position modules, followed by ascent, where the parachute deployment system is engaged. The final stage, 'top/deploy,' marks the deployment of the chute. In the third phase, the position modules transition to idle, initiating the descending cycle. The last state, touchdown, signals the return of all modules to idle.

4. **Data Handling:** We anticipate a data volume ranging from 2Mb to 7Mb for images and over 10kb for sensor data per flight. The Raspberry Pi's non-volatile memory efficiently stores this data, ensuring data integrity throughout the mission. Real-time transmission to the ground station is facilitated through the communication system.
5. **Programming Languages:** C/C++ is employed for image data management, optimizing efficiency for handling larger datasets. Python, chosen for its versatility, manages sensor data efficiently, considering the smaller dataset size and lower processing requirements.
6. **Conclusion:** In conclusion, our software flow design not only ensures the reliability and adaptability of the CanSat but also facilitates efficient data management and transmission. This sophisticated architecture, coupled with the power of Raspberry Pi, positions our CanSat project for success in the upcoming challenge.



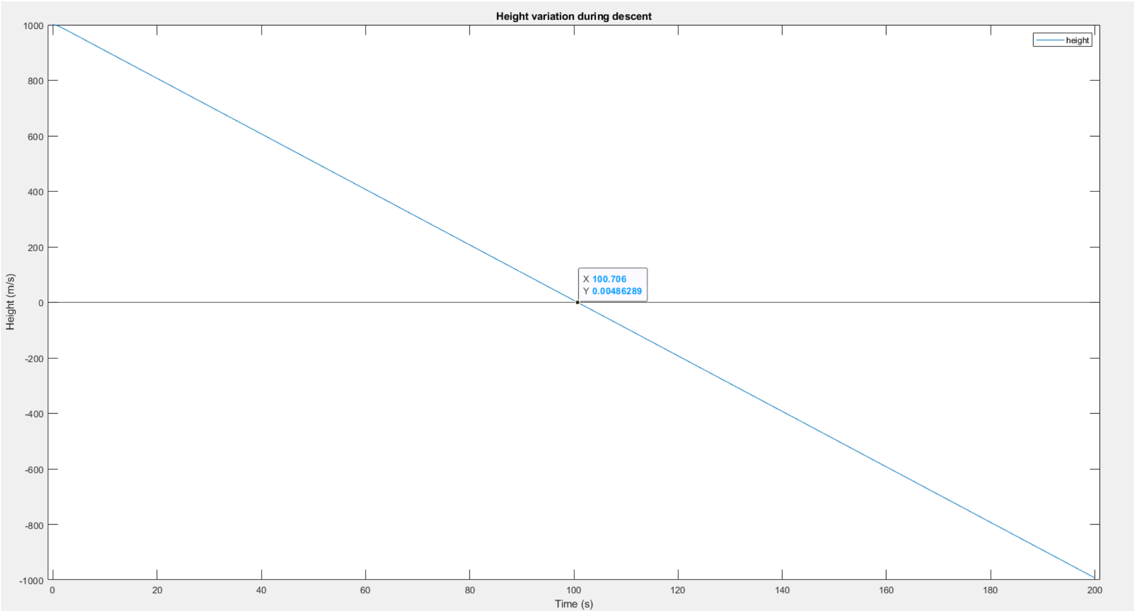
S.F.D.

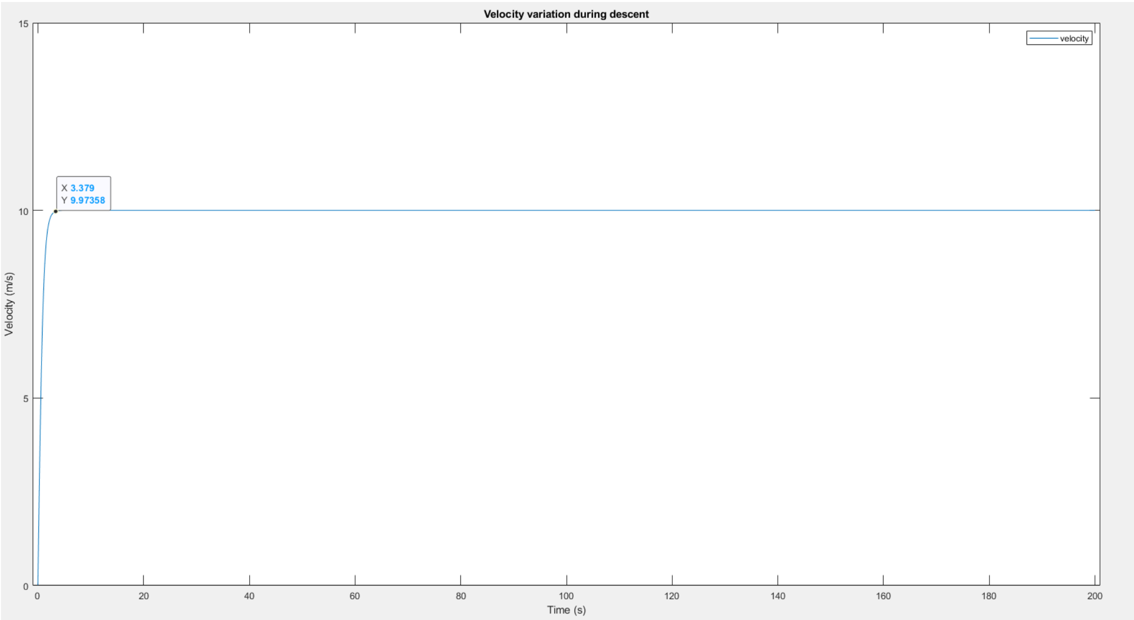
3.5. Recovery system

1. **Description:** The Recovery System of the CanSat is designed in order to be easy to make and to ensure a safe and controlled descent back to the ground station. It consists of a flat parachute with a drag coefficent of 0.77 and an area of 0.06 m^2, made with rip-stop fabric and attached to the CanSat via nylon cords. The parachute is deployed as soon as the CanSat is released from the rocket.

2. **Method of attachment:** The parachute is attached to the CanSat structure using a harness that is made of nylon fibres. The harness is connected to the structure itself with screws and PVC collars providing a stable attachment for the recovery system

3. **Picture:** Here is an indicative picture of how the parachute will look during the descent
4. **Expected flight time:** The CanSat's estimated flight time is around 10 minutes in which it reaches its maximum altitude and returns back to the ground station. After a short simulation, taking in consideration the characteristics of the parachute and of the Payload, the time for the descent is 100.7 seconds in perfect weather conditions and it reaches its maximum velocity of 10 m/s in 10 seconds. Here are the altitude and velocity variation graphs:


Height variation during descent
height
Height (m/s)
Time (s)
X 100.706
Y 0.00486289
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
0
20
40
60
80
100
120
140
160
180
200


Velocity variation during descent
velocity
Velocity (m/s)
Time (s)
X 3.379
Y 9.97358
15
10
5
0
0
20
40
60
80
100
120
140
160
180
200

3.6. Ground support equipment

1. **Introduction:** Ground Support Equipment (GSE) consists of three main components: a laptop, an antenna, and a radio receiver. This system is vital for receiving and processing data transmitted by the CanSat during its mission.
2. **Ground software design:** The ground software design is segmented into two crucial parts. The backend is responsible for processing and storing data using advanced tools, including algorithms for image clarification and AI for comprehensive data analysis. Simple algorithms are also employed to process sensor data efficiently. On the other hand, the frontend is dedicated to presenting the processed data in a clear and human-understandable format, such as intuitive indicators like 'high level of traffic' or 'low level of traffic'.
3. **Data handling and storage:** All received and transmitted data are stored in binary format throughout the entire flight process. While binary data is utilized during the flight, a localized decoding process may be applied at the ground station for user experience and interface purposes.
4. **Transmitter and data transmission:** The transmitter, integral to the Raspberry Pi, facilitates data transmission and reception. Operating on the existing 4G network within the 600MHz to 2.5GHz band width, our system minimizes interference with common signals in densely populated cities, such as Bucharest.
5. **User friendly interface:** The computer in our GSE will offer a user friendly interface, enabling operators to control various actions. This includes managing the 'descending cycle,' determining the focus of data gathering, toggling modules on/off, and additional functionalities designed to enhance mission control capabilities and reduce limitations.
6. **Conclusion:** In conclusion, our Ground Support Equipment is meticulously designed to receive, process, and interpret data from the CanSat during its mission, as well as send commands to the satellite and monitor every module and process by telemetry. The integration of advanced algorithms, binary data handling, and a user-friendly interface ensures the efficiency and effectiveness of our GSE in mission control.

4 Project planning

4.1. Time schedule of the project preparation

4.2. Resource estimation

4.2.1. Budget

Component	Cost(RON)
Microcontroller	100
Temperature Sensor	12
CH4 Sensor	11
N2 Sensor	80
CO2 Sensor	15
Altimeter	70
GPS Module	50
Gyroscope	17
Video Camera	80
Rechargable Battery	100
Structure	200
Additional materials	250
Personnel	200
Launch site fees	200
Total Budget	1385

4.2.2. External support

Our CanSat project, ShuttleSat, receives support just from the following departments:

- **University Politehnica Bucharest:**
  - Professors from the Electronics and Telecomunications department are providing useful informations for the electric diagrams and components configurations
  - Professors from the Computer Science department are offering advices in the choice of components and development of software

At the moment, the team lacks financial support for the purchase of components and also lacks support in the area of aerodynamics testing

4.3. Test plan

4.4. Time management

5 Data analysis and outreach

5.1. Data Analysis Plan

The data analysis plan for the CanSat is designed to assure a clear understanding of the data it collects during the primary and secondary missions:

- **Primary Mission:** Measurement of the quantities of atmospheric gasses: CH4, CO2 and N2 by using specific sensors mentioned above at different altitudes is the CanSat's primary

mission. The data gathered by them will be directly sent to the microcontroller which further sends them to the ground station, then it will be analised and visually represented in a database.
- **Secondary Mission:** As it was stated above, our CanSat's secondary mission is traffic measurement and mapping and finding a corellation between the traffic in a certain area and the density of the atmospheric gasses measured. The data gathered will consist of photos taken by the CanSat at different altitudes used for counting the entities at the ground such as cars and people.

In order for the data to be processed so it will offer us a great value, the following software will be used:

- **Data acquisition software:** The Microcontroller uses a Unix interface which allows installing of different packages specific for each sensor to allow it to get the data from them. Also, the Microcontroller comes with a specific module for the video camera which allows it to get the image file obtained by the camera.
- **Data processing software:** The computer at the ground station will be using an algorithm for compressing the image and searching for key points of interest, especially for entities present in the image. Also, the data collected by the CanSat will be sent to a server in order to be downloaded in the ground station computer.
- **Data visualisation software:** The data obtained will be represented visually in a program such as Matlab to quickly understand it and identify patterns and trends, especially in the case of traffic analysis and mapping which are key components of our secondary mission.
- **Statistical analysis software:** The data obtained will be analised in a program such as Matlab to visualise if there is a connection between the density of the atmospheric gasses at different levels of altitude and the traffic in a certain area. It will consist in different types of charts, like cluster charts or regression charts that will help us determine if there truly is a corellation.

5.2. Outreach Program

1. **Introduction:** We embark on our CanSat challenge with a holistic outreach program aimed at building a thriving community around our project. Starting with a foundation on social media, we plan to engage and educate our audience through entertaining and informative content.
2. **Social media strategy:** As we progress and develop our first prototype, our social media presence will evolve from a '3 students hobby' to a platform for organic growth. We'll share behind-the-scenes moments, funny and documentary clips, fostering a connection with our audience.
3. **Events and conferences:** Participation in events and conferences will be a key element. These platforms will serve as avenues to showcase our prototype to potential investors, clients, and sponsors. Simultaneously, we'll leverage these opportunities to educate the community, sharing insights into the challenges we face and our innovative problem-solving approaches.
4. **Demonstrations:** To create a buzz and increase awareness, we'll organize engaging demonstrations, while redoing key tests. Leveraging various channels like flyers, posters, our students league (LSAC), and social media, we'll promote these events with a touch of entertainment, ensuring they become memorable ('Falling satellite at 3:00PM from the rectory building – watch out for your head').

5. **Hosting events:** As we grow, hosting events will become a reality. This opens doors for collaborations and sponsorship opportunities. Social media channels will transition into platforms for event promotion, sharing event-based photos, and connecting with our community.
6. **Website utilization:** The website will be a central hub for technical updates, showcasing our accomplishments and outlining our future goals. Real-time data from our satellite, live camera feeds, and effective SEO strategies will enhance the site's value.
7. **Financial resources and team development:** Further we are looking to access financial resources which will be the turning point. We'll invest in team development, providing training for current members and welcoming new talents. This infusion of funds will elevate our social media, marketing, and event strategies, positioning us as a new contender in the industry.
8. **Conclusion:** In summary, our outreach program is designed to create a dynamic and engaged community around our CanSat project. From social media to events, collaborations, and a robust website, we aim to not only excel in the CanSat challenge but also leave a lasting impact on our community and industry partners.

6 Conclusion

6.1. Summary of the CDR

6.2. Recommendations for next steps