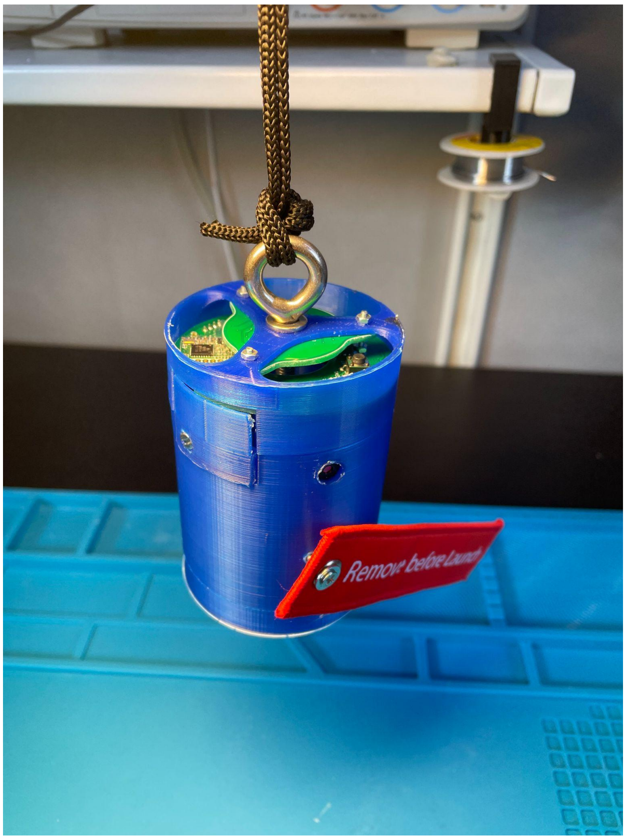
Pre Launch Report

H.O.M.E.S.T.E.A.D



Team name: Homesteaders
Country: Sweden
Date: 09-06-23

1. Introduction

1.1. Mission objectives

Our two missions examine certain qualities of the planet the probe lands on, which are crucial to whether humans could live on the planet. The purpose of the mission and the probe is to make a rough first measurement of some of the factors that cannot be investigated with certainty, easily, or at all from a distance with various observations. The secondary mission measures water vapour in the atmosphere, the UV radiation level, the magnetic flux density and the altitude of the probe. These are secondary factors that determine whether humans can be on a planet for longer periods, not as critical as the primary mission, as they can be bypassed/avoided for shorter periods, but not in the case of permanent residence.

2. CanSat description

2.1. Mission outline

The CanSat will be launched from a rocket to an altitude of around 1000 meters where it will subsequently be separated from the rocket and be subject to freefall. The CanSat is planned to descend with a vertical speed of around 10 meters per second after deployment of the parachute, which will occur nearly directly after separation. While in the controlled descent, the CanSat will store and transmit data from a temperature sensor, pressure sensor, humidity sensor, UV-sensor, magnetic field sensor and an inertial measurement unit. Once the CanSat has landed it will lower the polling rate of the scientific sensors and transmission of the data, to instead prioritize recovery systems.

2.2. Mechanical design

The mechanical design of our CanSat focuses on three main objectives: strength, airflow, and ease of access. The CanSat structure, made from 3D printed PLA plastic, has been carefully designed to meet these objectives.

Strength

To withstand the strong forces generated during parachute deployment and the landing phase, the CanSat structure is designed with robustness in mind. A strong closed-loop screw is used to secure the parachute, which is attached to both a 3D printed lid and directly to the circuit boards. This ensures that the CanSat structure can withstand the sudden jerks caused by the parachute catching the air and the tension on the line. Additionally, the structure is built to withstand the anticipated landing speeds of 8 to 11 meters per second.

Airflow

To ensure accurate measurement of atmospheric properties, it is crucial that the airflow within the CanSat is optimised. The structure incorporates a large central air duct that runs vertically through the entire CanSat, terminating at the sensor board. This design enables a constant flow of fresh air from below, representing the atmospheric conditions at the altitude of the CanSat. The incoming air spreads evenly across the sensor board before exiting through side vents at the top.

Ease of Access

Considering the frequent need to access components for debugging and demonstration purposes, the CanSat structure has been designed with easy access in mind. A particular focus has been placed on providing convenient access to the programming port and power switch, which have dedicated openings. This design allows easy access to all components without the need to disassemble the entire structure.

The diagram in appendix A illustrates the CanSat structure and the placement of major components. The main board, sensors, transmitter, and battery are mounted on the structure using three long threaded rods that run along the vertical axis, securely holding the PCBs and different parts together.

2.3. Electrical design

2.3.1 Main circuit board

The main circuit board could be said to be the brain of the probe. Its job is to connect and control all the other parts. The most important component of the main circuit board is the microcontroller. The choice of microcontroller was SAMD21E18A. This is because it meets the requirements for pins for communication with the external chips and sensors needed. But also because there are plenty of resources online that use microcontrollers from the same family, which makes both hardware and software development easier. Then there is plenty of experience designing circuits based around this microcontroller within the team, so we could feel confident that it would work well for our purposes. Another important part of the main circuit board is the flash memory. This is a W25Q128JV flash chip from Winbond that holds 128 megabits of data accessed via SPI communication. This is expected to hold all the data from the entire mission. Unlike many other CanSat designs that use an SD card for data storage, we decided to save data directly on a flash chip, this reduces sources of error such as SD cards losing contact during the strong vibrations that can occur during launch. It also saves space as no SD card holder is needed. However, after the national qualifying competition we learned that having a simple way to get the data out after the flight is important. Therefore, a USB connector has been added to the main circuit board. A mode switch was also added that allows you to easily switch the CanSat between data acquisition mode, which is used during launch, and data output mode which causes the CanSat to output all the data stored on the flash memory via USB to a computer. The main circuit board also holds a buzzer that makes noise. This is used, among other things, to easily signal status. But also to make it easier to find after launch as it can emit a strong sound signal. For the same purpose, there is also an LED light on board that flashes to signal different statuses. The rest of the circuit board consists mainly of connectors for the remaining modules, but also components such as power regulation and battery status measurement.

2.3.2 Sensor circuit board

The sensor circuit board connects to the main circuit board and makes it easy to replace if the scientific purpose changes and other sensors are needed. To achieve the primary

mission, a BME 680 from Bosch was chosen. It measures air pressure accurately in the range of 300 to 1100 hPa, which is the range relevant to the scientific purpose. The sensor also measures temperature in the range of -40 degrees C to 85 degrees C which includes the areas relevant to the scientific purpose. The sensor also measures humidity which leads us to the secondary mission.
To measure UV radiation, a Si 1133 from Silicon Labs is used. To measure the magnetic flux density, a BNO 085 from CEVA Hillcrest Laboratories is used which measures the magnetic flux density in the three Cartesian axes. The sensor also measures three axes of acceleration and three axes of angular velocity (gyro) which, thanks to the sensor's on-board processor, can be used together with the CEVA Motion Engine™ sensor fusion software to estimate the height at which the probe fell.

2.3.3 Power supply

The power source used is a 1200 mah LiPo battery. A rocket pull pin switch with a remove before launch pin has also been designed to make it easy to start the power supply and CanSat on the launch pad.

2.3.4 Radio link

For radio communication between the CanSat and the ground, LoRa radio technology is used which is well suited for long range, low power and low bandwidth. The CanSat uses an RFM95W LoRa module that transmits on the open ISM radio band 433MHz. A 433MHz radio antenna is also connected to this module. For the choice of radio antenna, 4 different variants were tested based on the characteristics of size and the range we can reach with it. Finally, the choice fell on a so-called flexible antenna from Molex. This is because it takes up virtually no space with its completely flat design that can be bent around and attached to the wall of the CanSat without reducing the range significantly.

2.3.5 GPS

To make it easier to find the probe again when it has landed, it was decided to include a GPS module. Grove GPS Air 530 was chosen for this as it is easy to use, has good contact with GPS satellites and draws little power. This plugs directly into the main circuit board where it quickly starts up and gives us GPS coordinates to the CanSat.

2.3.6 Secondary electronics system

This system consists of an esp32-cam module that offers a connector for an OV 2640 camera along with a sd card to save images from the trip on. This system also serves as a backup system as it also has a BME280 sensor attached to it that measures air pressure and temperature and saves the data to the SD card. This is to ensure that the primary mission is actually carried out.

2.4. Software design

The software design of our CanSat focuses on gathering data from various sensors, relaying it to a ground station in real-time, and storing it on a flash memory chip for retrieval. The primary goal of the software is to ensure accurate data collection and efficient communication with the ground segment.
Hardware Interaction

The software interacts with a range of hardware components, including temperature, pressure, UV, magnetometer, IMU, and humidity sensors. Additionally, the CanSat incorporates a GPS module, camera, and radio module. The software utilizes the I2C and SPI protocols for communication with these sensors and modules.

Data Handling

Data from the sensors is collected by the software and processed without any preprocessing or filtering on-board. The software directly relays the collected data to the ground segment in real-time via a radio module. As a backup, the data is also saved to a 128 megabit flash memory chip for retrieval after the mission.

Software Modes

The software operates in three distinct modes: Pad, Launch, and Recovery. In the Pad mode, the software initializes the sensors, performs calibration, and verifies all systems before launch. During the Launch mode, the software prioritizes the collection of sensor data and real-time transmission to the ground station. Finally, the Recovery mode focuses on GPS data to aid finding the CanSat.

Data Storage and Transfer

The CanSat utilizes a 128 megabit flash memory chip for on-board data storage. The software ensures that the collected data is continuously saved to the flash memory chip, acting as a backup in case of any transmission issues. Additionally, real-time data is transmitted to the ground segment over radio communication for immediate analysis and monitoring.

Programming Language and Development Environment

The software is developed using C++ programming language to take advantage of its robust support for the selected microcontrollers. The development process is facilitated by using the PlatformIO ecosystem and the Arduino Framework, providing a comprehensive set of libraries and tools for efficient software development and integration.

2.5. Recovery system

The canopy consists of 8 gores, shaped so that when they are sewn together, they make a hemisphere parachute. The material used is called ripstop, a very strong and lightweight fabric with low permeability. If you get a tear or hole in the fabric, it will not spread. The parachute has a spill-hole to increase its stability. It will have a descent rate of 10 m/s.

2.6. Ground support equipment

To receive the data that the CanSat transmits over the radio, a receiver station was also developed. It uses a so-called quarter wave antenna connected to an LNA (Low Noise Amplifier) connected to a bandpass filter and then to a TTGO LoRa32 card that has a built-in lora receiver, oled screen and bluetooth and wifi. This LoRa 32 card is used to receive the radio signals, show some statistics about how good the contact is and then send the data to a computer. The computer runs a program we developed in python that receives the data, saves it to a file and streams it via websockets to a website. We have developed the website using react.js that shows live updated graphs of the data to easily see that everything is going well.

3. Budget

Our final budget was 92.25€, which by a margin stays within the budget that ESA set at 500€. List of components can be found in appendix B.

4. Testing

The radio has been tested by walking away with the CanSat while monitoring the reception strength on the ground station. The test was done over a distance of one kilometre with obstructions in between without noticing a larger loss in signal strength

The parachute connection has been tested to withstand atleast a 50N of force by lifting a 7 kg weight tied to the connection. See image C in the appendix.

The CanSat has been tested to withstand a high acceleration by mounting the probe on a bicycle rim at a distance of 29 cm from the centre and spinning the wheel at 435 rpm creating a centripetal acceleration of about 60g. A slow motion video was recorded to confirm the rotational speed and can be viewed here at https://youtube.com/shorts/jRJPu95M83E.

5. Outreach programme

We have an Instagram account @cansat_homestead where we have posted our progress throughout building the CanSat and designed a logo for it which can be seen in appendix D. Additionally, we received a scholarship from "Adelbergska stipendiefonden" for our project. We also had a presentation in front of our class where we told them about our project and the National Competition.

6. Requirements

6.1. Characteristics

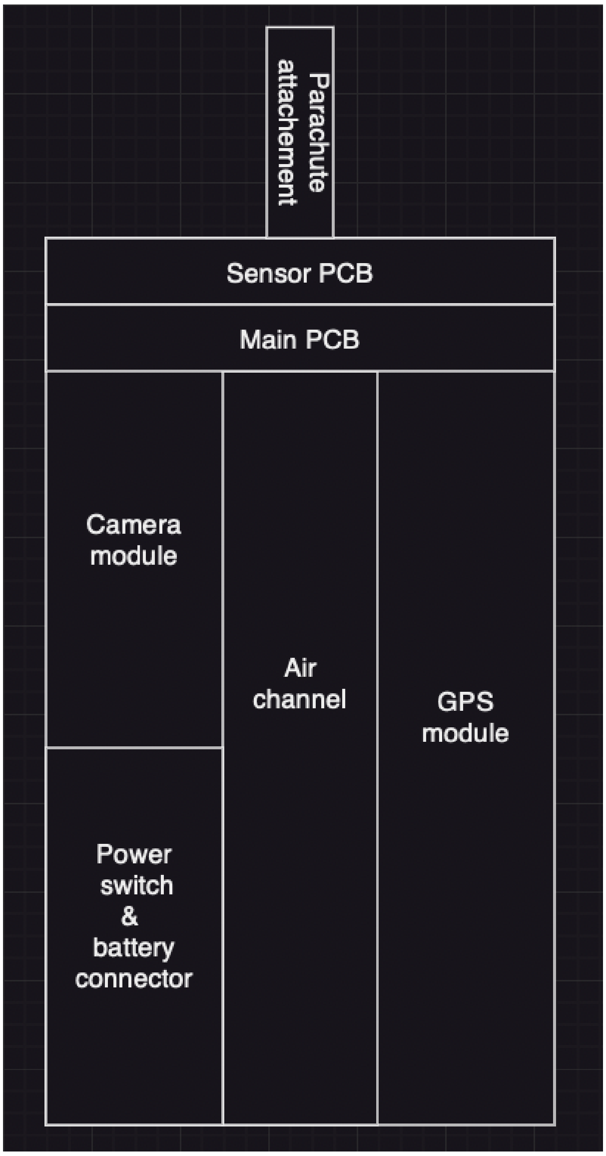
See appendix E for CanSat characteristics

6.2. Power budget

The power consumption has been calculated and measured to an average of 825mW while in the high frequency flight mode. Using the 1200mA battery this would give us about 4.5 hours of runtime. However most of the time the CanSat will be in either pad mode or recovery mode with much lower power consumption giving us many more hours of runtime. See appendix F for breakdown of the power budget.

Appendix

A - Physical layout



B - List of components and prices

Component	Price [€]
Radio module RFM95w	13.5

Antenna	5.63
Esp32 camera module	10
Grove GPS (Air530)	10.7
Battery	9.5
Printed Circuit Board	1.4
Sensors	18.79
Microcontroller	3.85
Other integrated circuit (Power memory)	2.46
Connectors	4.94
Passive components (resistors, capacitors, etc)	3.48
Parachute materials	7
Parachute attachment screw	1
Total cost	92.25 euro

C - Parachute connection test

D - Logo

E - Characteristics

Characteristics	
Height of the CanSat	95 mm
Mass of the CanSat	310 g
Diameter of the CanSat	66 mm
Additional length of external elements (along axial dimension)	21 mm
Flight time scheduled	100 s
Calculated descent rate	10 m/s
Radio frequency used	434 mhz
Power consumption	825mW
Total cost	92.25€

F - Power budget

Device	Voltage (V)	Current (mA)	Power (mW)
Radio module	3.3	50	165
Camera module	3.3	120	396
GPS module	3.3	40	132
PCB components (including microcontroller & sensors)	3.3	40	132
Total	3.3	250	825