TEAM NAME: SATX TECHNOLOGIES

COUNTRY: NORWAY

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1 Introduction

SatX Technologies is a Norwegian based CanSat project consisting of five high school students all enrolled in a STEM specific program at Horten High School. The project started the summer of 2020 and the goal since has been to reduce climate change with the use of modern technology. SatX Technologies is representing Norway in the European CanSat Competition 2021 hosted by ESA with their CanSat named Tropos and prerequisite technologies.

1.1 Team organisation and roles

Each team member is listed below with contact information in addition to an overview of their personal responsibility within the project. The two supervising science professors who helped guide us through the project are listed below as well.

Each team member has a special interest within the STEM subjects and the field of technology. During the project, the team paid attention to each personal interest as well as knowledge within that specific field. Tasks were assigned thereafter. This report will not specify this further, however more information can be found at our website and Instagram page (6.2 Attachments).

1.1.1 Team members

Didrik Wiig–Andersen

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1.3 Team Workload

Expected workload within the team is estimated to be around 3 hours per week during the subject Technology and Science at Horten High School. The project lasted 17 weeks in total, meaning that the project was worked on 51 hours in total during school time.

Hours dedicated before and after school is estimated to be around 280 working hours for the entire team. Project leader Didrik Wiig – Andersen and Data Analyst, Mikael Thorvaldsen dedicated the most time outside of school to work on the SatX Tropos design, the final report and further develop the various SatX Softwares.

1.4 Mission Objectives

The key objective of our secondary CanSat mission is to monitor and reduce climate change with the use of modern technology. During summer 2020, countries such as Australia and states like California were severely impacted by several major wildfires. The results of the fires were devastating and had major implications on the climate, the animal life as well as the people exposed to the fires. The SatX team decided to target this sector. Our main purpose of our scientific investigation was to build a CanSat that could monitor and warn the users of our data whether a wildfire may be significant in the area or not. By building various technical tools, an app, and a webpage, the CanSat information can be used to improve awareness, collect relevant information, and potentially prevent the loss of human lives.

2 CanSat Description

2.1 Mission outline

The requirements to complete the primary mission was to design, build and launch a CanSat with mandatory functions determined by ESA (ESA, 2021). The GY-91 sensor and NTC resistor were the two components necessary to fulfil the primary mission. It was also required that the CanSat had working radio equipment that transmitted data back to the ground while in air. SatX Tropos fulfils all requirements for the primary mission. This will further be described in *3.3 Test Plan.*

As a part of the secondary mission, we equipped the CanSat with a GPS, a humidity sensor, an ultraviolet radiation sensor, one extra temperature sensor and a camera. The goal during flight was to save all data from the CanSat on two separate SD cards, one for the data retrieved from the sensors as well as one for the footage from the camera. In addition, the CanSat was also programmed to transmit everything, except the photos back to the ground station. When turned on, the CanSat will perform a general test of the sensors and will be put in GPS – search mode. When GPS is found the CanSat will alert the user with three consecutive sounds from the on – board piezo. While in air, the CanSat retrieves humidity, pressure, temperature, UV radiation, GPS coordinates, camera footage as well as gyrometer and barometer data from the GY-91 sensor.

The Tropos has been developed as the main part of a bigger puzzle. The main goal of the Tropos is to reduce climate change with the use of modern technology. In correlation with this, three different programs have been developed to further improve the use cases of Tropos. These programs are all part of the secondary mission of alerting wildfires and serves as a further implementation of the project.

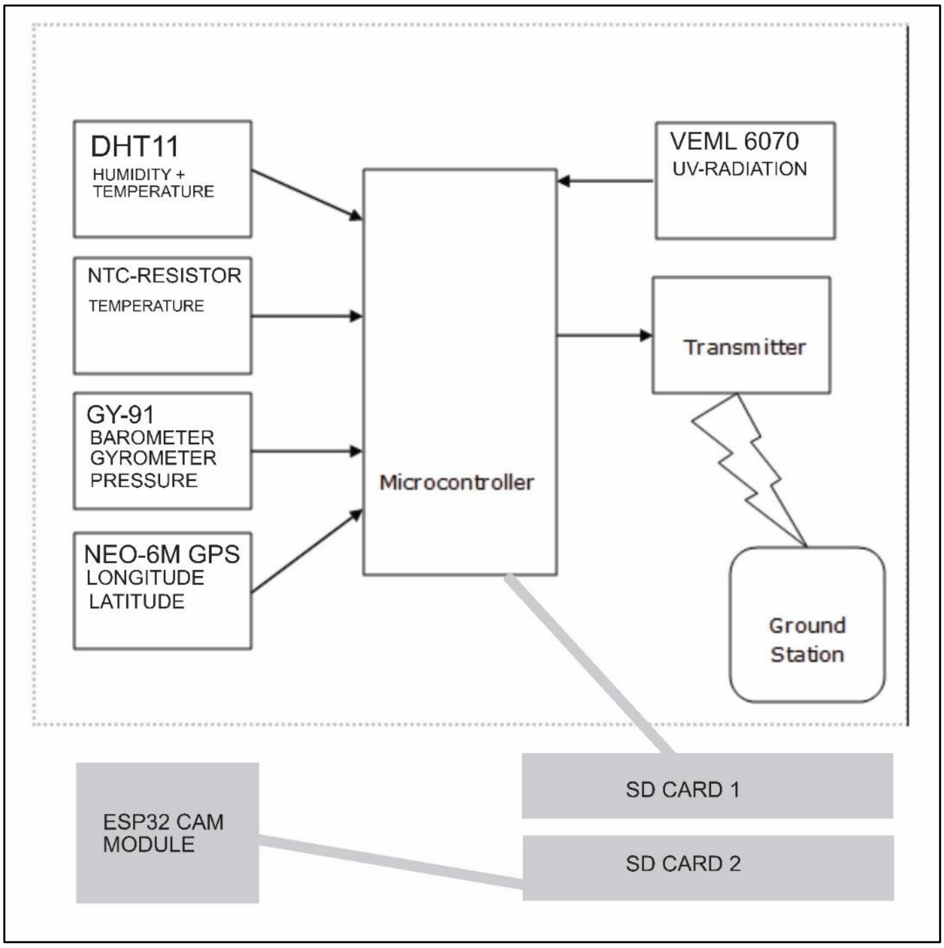


Figure 1: Block diagram of the CanSat functionality.

2.2 Software development

2.2.1 SatX fire

The core program for determining the risk of wildfire using data from launch. Takes temperature, humidity, and recent rainfall as input and returns a value between one and four, indicating the risk of wildfire. Fire is written in C++ using the Visual Studio Code IDE.

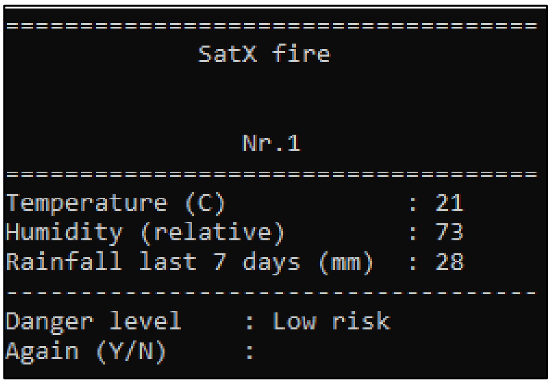


Figure 2: A picture of the SatX fire program running as an EXE file.

(Thorvaldsen, 2021)

2.2.2 SatX Haptic

SatX Haptic is a further implementation of Fire. Using regression and machine learning, the program calculates data for a specific height using previously retrieved data. This means that the person or team using Tropos can launch the CanSat at a height of 40 meters above ground and calculate temperature, humidity, GPS – coordinates and more at for example, 100 meters above ground level. The program automatically detects files within its repository and reads the data from the files. It takes a user–determined height as input and outputs the calculated data. In addition, the program also writes the calculated data into a separate .txt file. SatX Haptic can be implemented together with SatX Fire to calculate approximate wildfire risk. The program is written in python using the Visual Studio Code IDE.

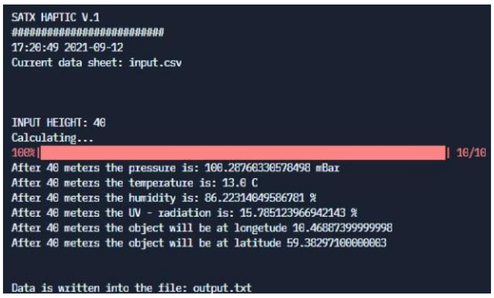


Figure 3: A picture of the terminal when running the SatX Haptic software. The data used for the demonstration is the data from Tropos 1st launch.

(Andersen, 2021)

2.2.3 SatX Plot

SatX Plot is a program which makes it easy to display data quickly. The program detects files within its repository and automatically reads the data off the file. The user specifies which type of data he or she wants to display. Further, the program creates a graph of the data as displayed in the picture to the right. In addition, the graph can be downloaded as a .JPG file. The program is written in python using the Visual Studio Code IDE.

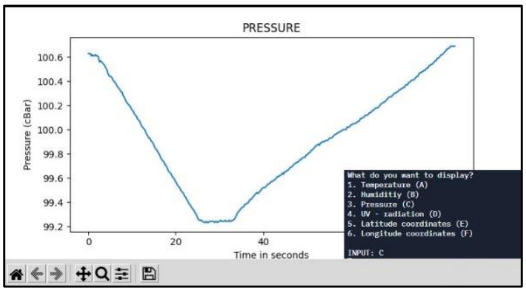


Figure 4: The figure shows how the SatX Plot software works. In this example the pressure data from the Tropos 1st launch is visualized.

(Andersen, 2021)

2.2.4 SatX Cloud

Cloud is an application which makes it easy for anyone to access and share specialised data. As of today, Cloud works as the Facebook for CanSat data sharing and is as of September 5th undergoing evaluation at Google Play.

The user of the app can search for launches or places and access an overview page as displayed in the image above. From here the user can download data published by SatX or other CanSat teams approved by SatX. The goal of the application is to create a community of data-sharing within the field of specialised data

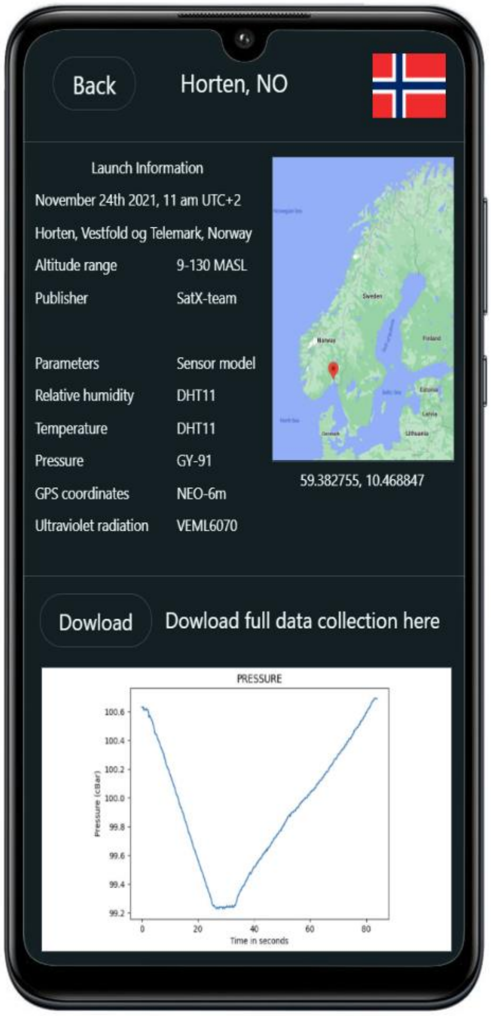


Figure 5: The figure shows how the SatX Cloud application looks like on a smartphone. The bottom part of the window is a slideshow of visualized data from the launch.

(Andersen, 2021)

2.3 Mechanical/structural design.

The SatX Tropos is designed to look futuristic yet be practical enough to house the l components for the primary and secondary mission as well as two batteries. The CanSat consists of two separate shells, both 3D – printed using PLA (Polylactic Acid). The inner shell is used for mounting the components and consists of a vertical mounting plate for the main board. The main board is mounted using four screws onto the vertical mounting plate (see top-left figure below). The GPS module is mounted vertically facing outwards and is part of the outside of the inner shell (see square outline on top-left figure). Further, the humidity and UV – sensor is mounted the same way, whereas the UV – sensor is mounted besides the GPS module (see right for the GPS module mounting on the top-left figure), while the humidity sensor is mounted on the back side of the inner shell. (See top-right figure). In addition, the camera module is mounted such as the lens is facing towards ground. The camera body is mounted below the main board. (See figure at the bottom right). The temperature sensor is mounted facing towards ground as well and is mounted besides the camera module (See figure at the bottom right). Two additional holes in the bottom plate (see bottom right figure) has been designed to make room for the antenna in which is mounted to the main plate. The second hole is for a USB Micro – C cable, which is used for uploading software to the main board if needed. Further, the two batteries powering the system are mounted in a battery housing situated on the back side of the vertical mounting plate in which the main board is mounted (see top left figure). For practical reasons, cables for the components have been stripped together.

The outer shell of the Tropos is meant for protecting the components within the inner shell. To make it easy to replace both components and batteries, the outer shell has a slide on – off mechanism which makes it easy to remove in case user needs to quickly reach components or batteries. The outer shell has been designed to ensure optimal data quality. Holes in the shell ensures for better air flow and increased data accuracy.

The parachute used for recovery is mounted to the inner shell using a carabine hook. The hole on top of the vertical mounting plate on the figure on the top left of the image above is the hook for mounting the parachute.

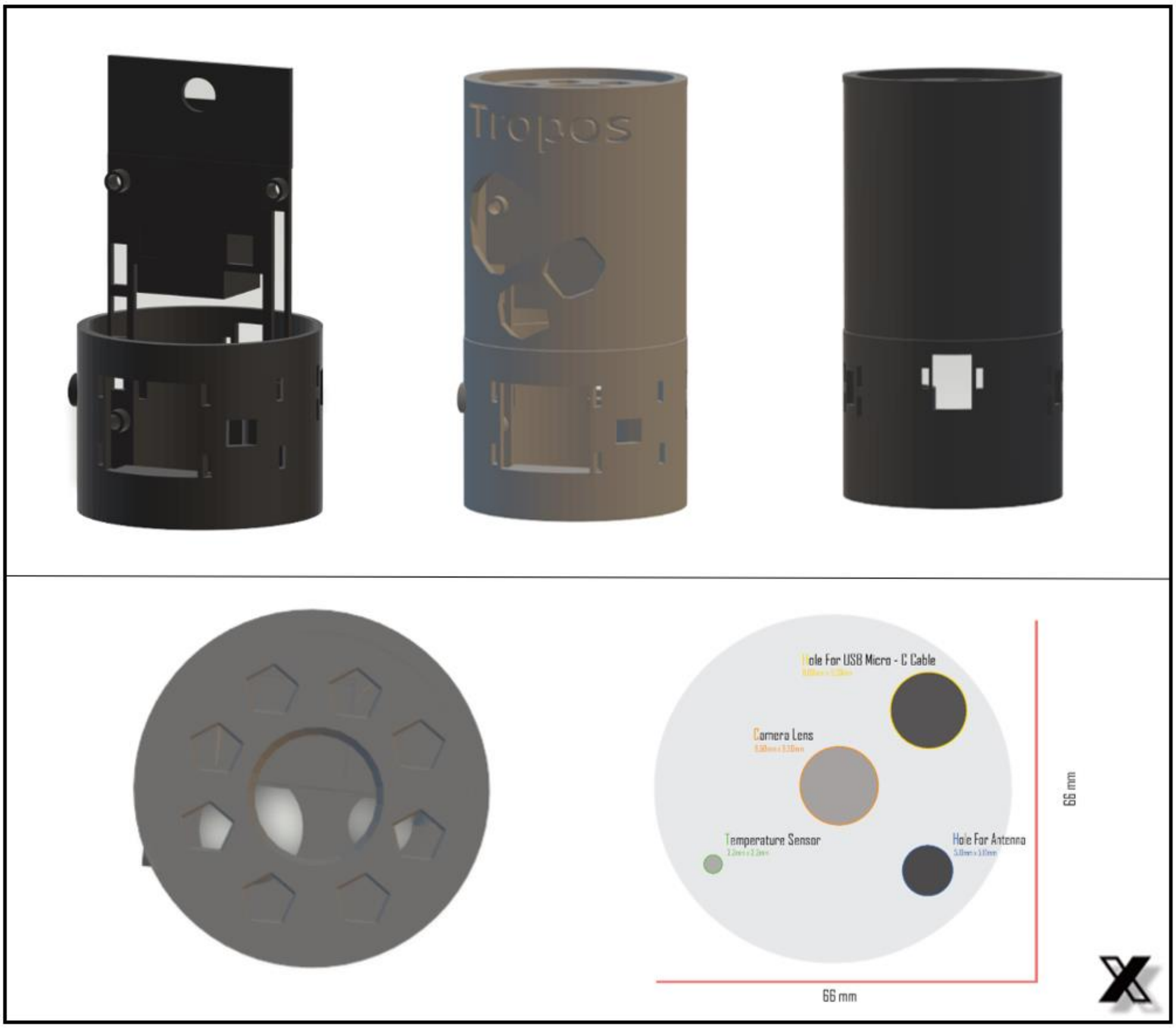


Figure 6: The figure shows the design of the Tropos from different angles. From the top left to right is the inner shell from the front, the inner and outer shell together from the front, both shells from the behind. At the bottom left, is a view of the top plate, and at the bottom right there's an overview of the bottom plate of the Tropos.

(Thorvaldsen & Andersen, 2021)

Table 1: Below is a table of the major components used within the CanSat. For further details about the components see 5 Requirements.

Component	Usage
DHT 11 Sensor	Measures humidity and temperature
NTC Resistor	Measures temperature
VEML 6070 Sensor	Measures UV – radiation
GY-91	Measures pressure, barometric and gyrometer data
NEO–6M GPS Module	Retrieves longitude and latitude data
ESP-32 Camera Module	Retrieves camera footage

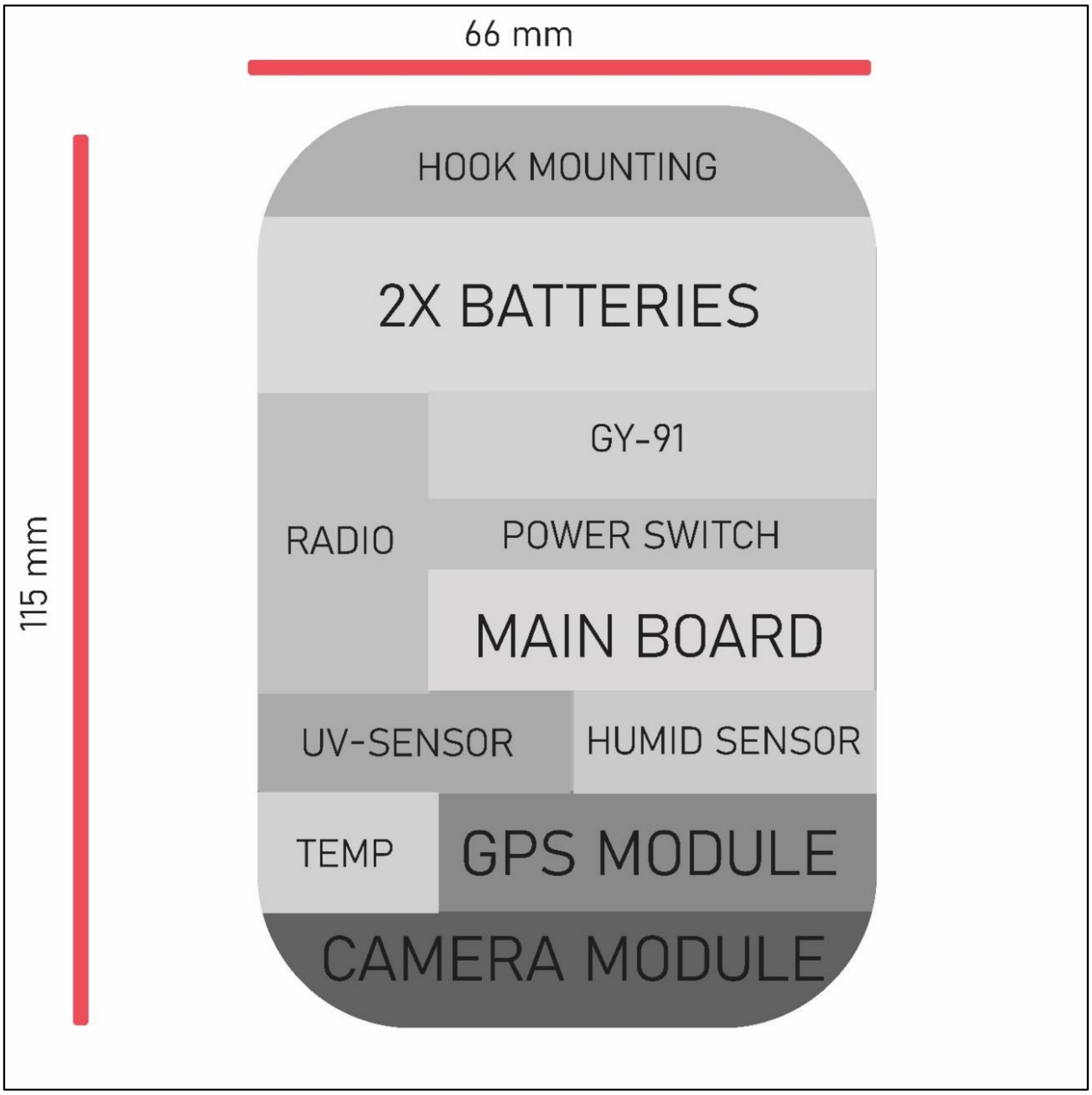


Figure 7: The figure shows how to CanSat is structured when all components and batteries are mounted to it.

(Andersen, 2021)

2.4 Electrical design

The teensy 3.5 is the on – board microcontroller which stores and processes uploaded code. Every component is mounted onto the teensy or main board as displayed on the image to the left. Below is a table of the components and the pins where they are mounted onto the teensy 3.5

Figure 8: The picture is of the CanSat development board from NAROM.

(Stausland, et al., 2018)

Table 2: An overview of the components and their pins.

COMPONENT	PIN
DHT11	7
NEO-6M GPS	0, 1
VEML6070	A4, A5

The NTC – resistor was soldered to a the specific NTC port on the CANSAT main board. The same accounts for the piezo, GY-91 and the radio module as seen on the image above.

2.5 Software design

The software for the CanSat is written in C++ using the Arduino IDE. To begin with, during the setup, variables and libraries are initialized and the CanSat does a system check. During system check, the CanSat takes a single measure from each sensor and write it onto the SD – card in addition to sending it to the ground station as a confirmation of system compliance. The GPS – module searches for GPS signal as the first thing in the loop. While GPS – signal, the further code runs. Here sensor data is retrieved from all sensors and camera footage captured. Height and speed of CanSat is calculated and written into a CSV – string together with the rest of the data. The data is then written onto a SD – card and sent to ground station over radio at a specific radio frequency specified in the code. For each loop run, the on – board piezo makes a sound to confirm that the data has been sent.

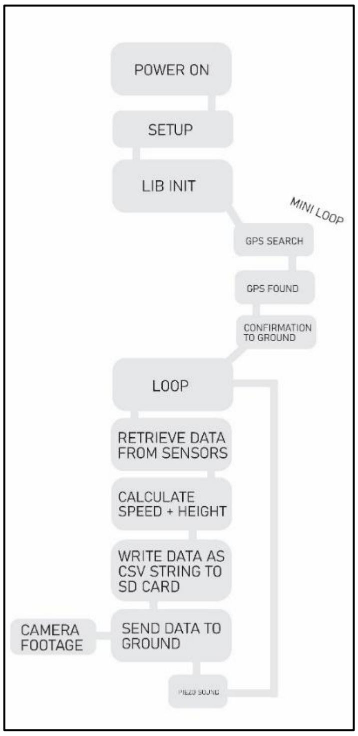


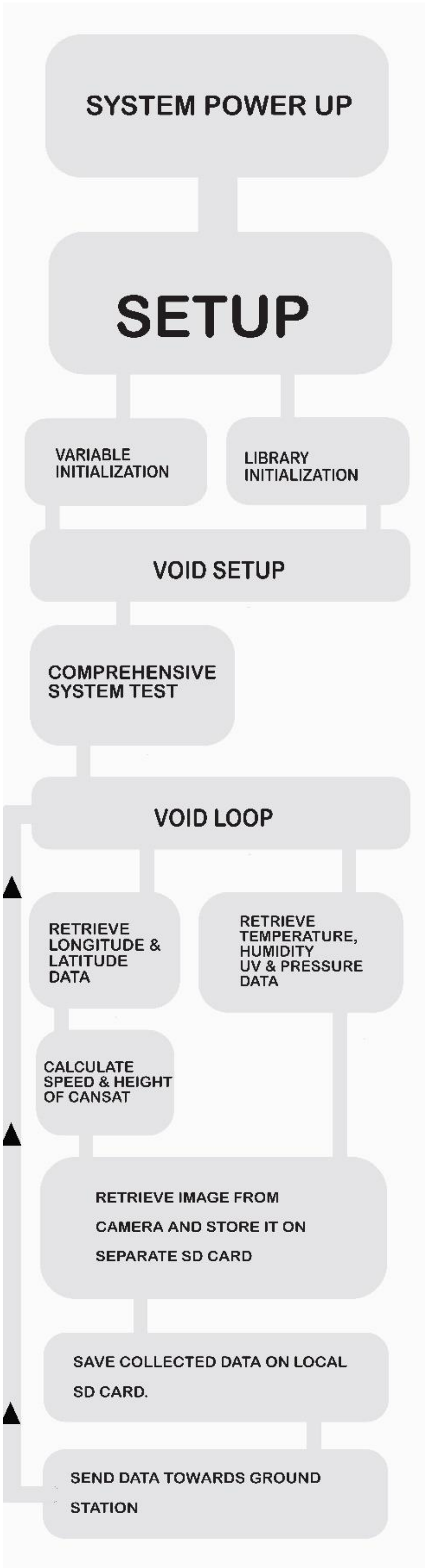
Figure 9: The figure shows the electrical interface of the CanSat.

(Andersen, 2021)

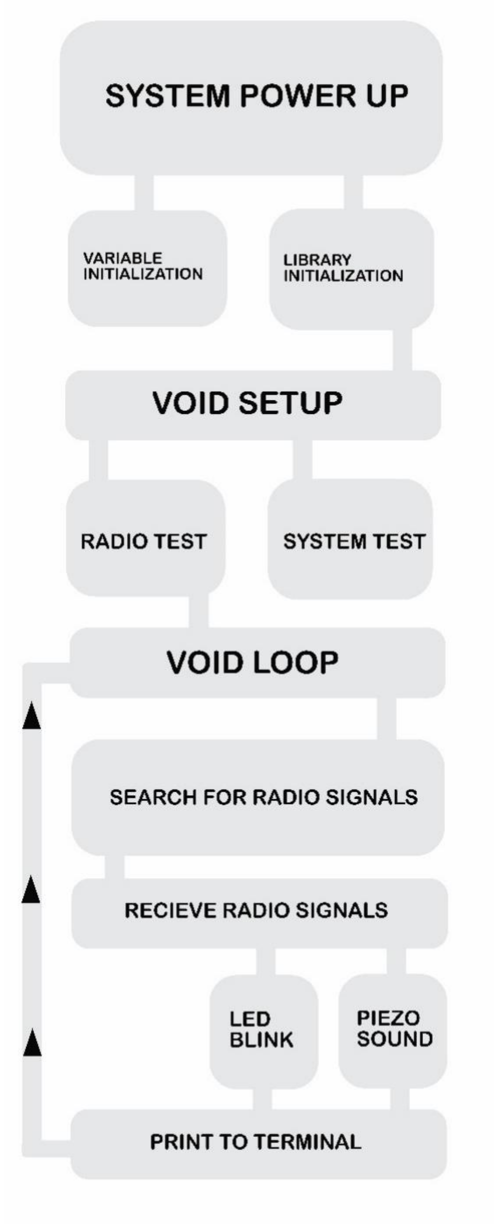
The software for the ground module is similarly written in C++ using the Arduino IDE. During setup, variables and libraries are initialized. During loop, the ground module will search for radio signals within a specific frequency specified in the code. The ground module will, once received data, print the data into the terminal and start the loop over again. Similarly, the on – board piezo will make a sound for each loop run to confirm that data has been received.

There are two main codes for the CanSat. Version 1 retrieves data only if the GPS has GPS-signal, while version 2 retrieves data even though the GPS is lacking signal.

2.5.1 On-board data handling



2.5.2 Ground station data handling



2.5.3 The amount of data retrieved

The SatX Tropos uses 0.23 seconds to retrieve, store and send data to ground station, meaning that it retrieves around 4 sets of data per second. Tropos stores the data in CSV strings on a SD – card. Since each character of a string is allocated 8 bites, we can calculate the approximate size of data retrieved during different lengths of flight. One set of data is 74 characters.

Table 3: The table shows how much data the CanSat produces depending on how long the launch lasts.

Time (Seconds)	Memory (kB)
45	3,1
60	4,1
120	8,4

2.6 Recovery system

2.6.1 Calculating the decent velocity & parachute size

The CanSat guidelines required the CanSat to decent with a speed within the 5-12 m/s range, whereas 8-11m/s was recommended (ESA 2020). The weight of the CanSat, which was 334g, had to been know before the parachute was made as it would impact the equation. Calculating the size of the parachute was based on the formula provided by Tim V. Milligan in his book "Model rocket design and construction", 2nd edition (Milligan, 2008)

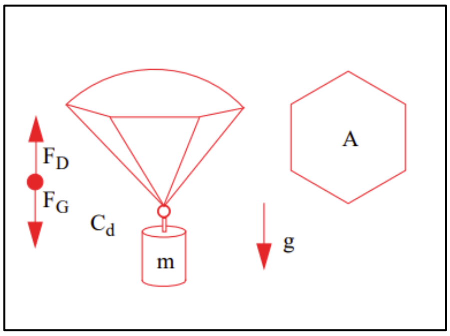


Figure 10: The illustration displays the factors that determine the decent velocity of the parachute.

(Stausland, et al., 2018)

$$A_p = \frac{2gm}{pC_d V^2} \Rightarrow V = \sqrt{\frac{2gm}{pC_d A_p}}$$

- g = the acceleration due to gravity, which is $9.81 m/s^2$ at sea level.
- m = the mass of the payload in grams.
- p = the density of air at sea level, normally $1225 g/m^3$.
- C_d = the coefficient of drag of the parachute, which is estimated to be 0.75 for a round canopy.
- V = the decent velocity of the payload.
- A_p = area of the parachute in square meters.

When the parachute was made, it was designed to decent with the velocity of 3m/s. This was a preferable velocity at the time as the CanSat would record a higher quantity of in-air data, while complying with the guidelines in the national competition. Given that the weight of the CanSat was 334g and the targeted decent velocity was 3m/s, the diameter of the parachute had to be 106cm. In the end the original parachute turned out to have a diameter of 100cm and deliver a decent velocity of 3.6m/s.

Before the European competition, the original parachute was resized and sown again to fit into the 5-12m/s decent velocity requirement. The final parachute was calculated to be descending at 9m/s with the diameter of 31cm. This change was made to the parachute in August of 2021.

Figure 11: The picture was taken during the testing of the original parachute.

(Ndikumana, 2020)

2.6.2 Parachute testing

The parachute was tested twice with a similar payload to the CanSat to make sure it functioned properly and that it would return the CanSat safely to the ground. During the test, the parachute was attached to a 33ml soda can filled with enough gravel to weigh around 334g, the same as the Tropos. Then the soda can with the parachute attached was flown to an approximately height of 40 meters before dropped. The velocity was estimated to be around 3.2 m/s.

2.7 Ground support equipment

Ground support consisted of an identical mainboard as in the CanSat itself, built using a teensy 3.5 and a radio receiver. In addition, there were mounted a piezo and a LED to indicate whether the receiver received signal from the CanSat. During flight, the board was connected to a computer. The board wrote the received data onto the terminal on the computer to display the data for user.

3 Project planning

3.1 Time schedule of the CanSat project

Table 4: The step-by-step project plan with deadlines. Deadlines set by the supervising professors are marked in blue. All the other tasks with deadlines were set by the team.

Task or event	Deadline
Start of project	15.08.2020
Determining secondary mission	19.08.2020
Testing the components	26.08.2020
Soldering the ground module development board	04.09.2020
Soldering the CanSat development board	16.09.2020
Testing the radio equipment & data transferal	20.09.2020
Developing the CanSat 3D model	24.09.2020
Assembling the CanSat	27.09.2020
Making the parachute	03.10.2020
Testing the parachute	06.10.2020
Developing & launching the SatX website	10.10.2020
Developing SatX fire	18.10.2020

Developing SatX Plot	24.10.2020
Developing SatX Haptic	30.10.2020
Developing SatX Cloud	10.11.2020
Upload code to SatX GitHub	20.11.2020
Final testing of the CanSat	22.11.2020
Launch day at Borrehaugene park, Horten	24.11.2020
Analysing the data from the launch	02.12.2020
Publish launch data to SatX Cloud	06.12.2020
Delivering final report (school)	10.12.2020

3.2 Resource estimation

3.2.1 Budget

The project was successfully carried out without exceeding the maximum budget limit of 500€, determined by the CanSat competition guidelines from ESA (ESA 2020). In total the SatX project cost was calculated to be 248€, accounting for all hardware components, cables and special tools required, the parachute and all platform expenses related to the SatX Cloud app, and the SatX website. Although the cost was calculated to be 248€, almost all components for the project were already available in the school's inventory.

The budget is calculated primarily with prices from elfadistrelec.no, an online electronics store in Norway.

The budget includes all hardware components used, except for 2psc CanSat soldering board and 1psc GY-91 module. These items are exclusively produced by NAROM, the educational branch of Andøya space centre, the primary Norwegian space centre. These components are not accounted for in the budget.

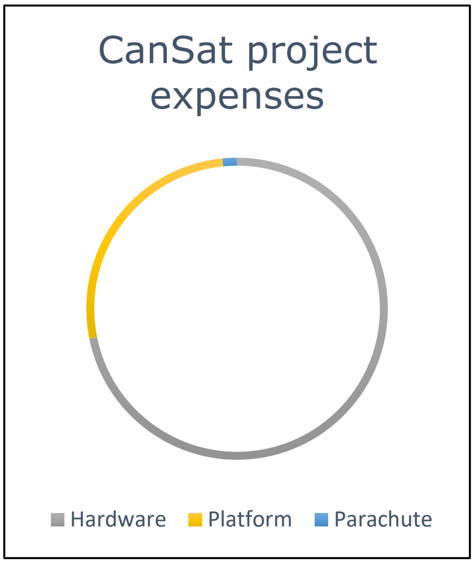


Figure 12: A diagram showing how the total cost of the CanSat project were distributed throughout the different main categories. All the categories combined make up 248€.

(Thorvaldsen, 2021)

Tools from the workshop in which the CanSat and its parachute was produced are not accounted for in the budget. These essential tools are for example: a soldering iron and soldering equipment, a sewing machine, different pliers and similar tools and last but not least a 3D printer. The only tools that are included in the budget are 1pcs USB A to micro-USB cable and 1pcs Battery charging cable USB to micro-USB. These two cables served a very specific purpose in the project, as they gave us the opportunity to upload sketches to the teensy and recharge the Li-Po battery.

28% of the budget is made up by platform expenses. By platform it is referred to the cost related to the development, publishing and upkeep of both the SatX cloud app and the SatX website. When the website was launched, there were a 21€ cost to purchase the domain, and a 7€ yearly server rental fee. The budget includes one year of server rental. Publishing the SatX Cloud app to google store required one-time 21€ to get a google play developer's account.

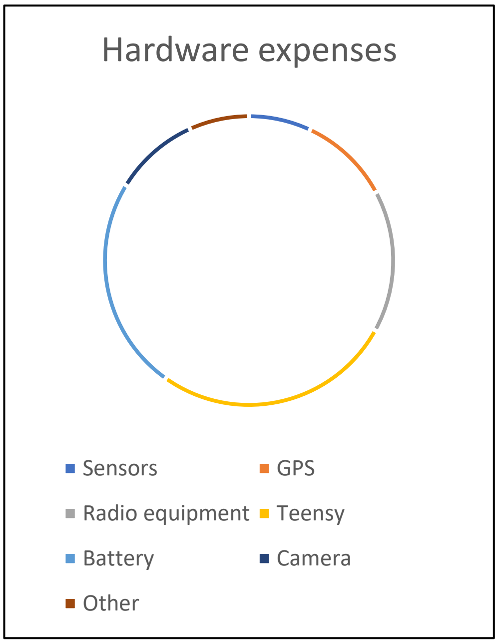


Figure 13: The diagram shows what the total hardware budget of 149€ consists of in detail.

(Thorvaldsen, 2021)

3.2.2 External support

Kongsberg Norspace

SatX is sponsored by Kongsberg Norspace, the space division within the Kongsberg Group. SatX has not received any sort of financial support from Kongsberg. SatX has however, gotten technical advice and the permission to use their logo, in addition to some tee – shirts.

3.3 Test plan

The official test launch was done at Borrehaugene, Horten 24.11.2020. In prior to this, minor tests had been performed, but they were executed rather to test the parachute and radio equipment. As of the official test at Borrehaugene the CanSat was tested twice. Both times the CanSat retrieved all data expected in addition to camera footage. The CanSat also wrote the data to the on

Figure 14: The picture shows the CanSats protectory during the launch from two angles.

(Thorvaldsen, 2021)

– board SD – card and sent the data to ground station. It was concluded after the launch that both primary and secondary mission was successfully carried out.

The data retrieved can be accessed throughout our application or at *Attachments 6.2.* Camera test during flight at Borrehaugene (YouTube Video): https://www.yo-utube.com/watch?v=ia21qHD7TWI

3.4 Takeaways from the national competition

As a result of COVID-19, the national competition in Norway was held fully digital. The competition was completed by having each team perform an online presentation about their project. This meant that SatX never got to formally launch their CanSat else of the two consecutive test launches at Borrehaugene. With this said however, the CanSat worked as expected during both launches.

Still, one complication which we faced during test launch was long waiting times for the on – board GPS to get GPS-signal. As a result of this we decided to mount the GPS so that nothing covers the antenna during flight, whereas the antenna is mounted as a part of the inner shell (2.2 Mechanical and Structural Design). When tested, the waiting time was greatly improved.

4 Outreach

4.1 SatX website

The SatX Website is a site in which in the beginning was used for sharing data and files. As SatX Cloud was developed the website was redesigned into a page used to inform about the project, team, news, and technologies. The site also has a contact section in case readers have questions about our project. The goal of the site is to raise awareness about CanSat technology and the CanSat competition.

The site can be reached through this URL: https://satxnorway.com/

4.2 SatX GitHub account

Through the SatX GitHub account code such as Haptic, Fire and Plot can be downloaded. The code is open – source and publicly available.

4.3 SatX Technologies in the local newspaper

SatX Technologies was featured in the local newspaper the spring of 2021, to raise awareness of the national CanSat competition.

4.4 SatX Instagram account

Through the SatX Instagram account relevant news about the team's progress is shared, in addition to relevant international news from the space sector. The goal of the account is to raise awareness and interest within the space and CanSat subject. The account has 51 followers as of September 5th.

Account name: satx_norway

4.5 SatX Cloud

Cloud is an important tool to raise awareness of the project. Through the app, people can download our data and request sharing their own data.

4.6 School presentation

The SatX Team presented the project at Horten High School to raise awareness of the competition before the national finals.

5 Requirements

5.1 Characteristics

Table 5: The table displays essential characteristics of the SatX Tropos CanSat.

Characteristics	Value (unit)
Mass of the CanSat	334 (g)
Height of the CanSat	155 (mm)
Diameter of the CanSat	66 (mm)
Decent velocity	9 (m/s)
Radio transition frequency	433,5 (MHz)
Length of CanSat's antenna	17,3 (cm)
Power consumption main circuit	169 (mA)
Power consumption camera module	80 (mA)
Total power consumption	249 (mA)
Total cost	237 (€)

Figure 15: Directly translated from Norwegian to English: *These 17–year–olds create adventurous technology: Floating soda can alert forest fire danger.*

(Sætre, 2021)

5.2 Power budget

The Tropos CanSat consists of two separate circuits. The main circuit consists of the teensy 3.5 and all the prerequisite components except from the camera module. The main circuit is powered by a 9V battery with a capacity of 500mAh. The second circuit consist of the camera module only and is powered by LiPo rechargeable battery with a capacity of 1.32 Ah. The two systems have one common power switch.

5.2.1 Camera module power sheet

Table 6: The camera module power budget.

Device	Voltage(V)	Current(mA)	Power(mW)
Camera (ESP 32)	3.3	80	264

The battery life for the camera module is the total drawn current of 80mA divided by the battery capacity of 500mAh, which is over 6 hours.

5.2.2 Main circuit power budget

Table 7: The table shows all power consumption data of the components making up the CanSat's main circuit.

Device	Voltage(V)	Current(mA)	Power(mW)
Radio module	3.3	120	100
GPS module (NEO-6M)	3.3	45	111
Temperature sensor (NTC)	3.3	0.06	1.0
Humidity & temperature sensor (DHT11)	3.3	0.30	1.0
UV sensor (VEML 6070)	3.3	0.25	0.8
Pressure sensor (GY–91)	3.3	3.70	11
Total	3.3	169	214

Expected battery life in the main circuit is battery capacity divided by total drawn current. Not taking account for discharge safety, the expected battery life is almost 8 hours.

On behalf of the team, I confirm that our CanSat complies with all the requirements established for the 2021 European CanSat competition in the official Guidelines.

Signature: Didrik Wiig-Andersen *Place: Tønsberg, NO* *Date: 12.09.2021*

Didrik W.Andersen || Tønsberg, NO || 12.09.2021

6 References

6.1 Information & Figures

Refences can be found in this link:
https://drive.google.com/drive/folders/1VrqDbtdB42PFqzD2X3vwnieTD7J3I8IL?usp=sharing (google drive)

6.2 Attachments

CanSat project code collection.
https://drive.google.com/drive/folders/1cLLpHlwetFAma7bBkyBruiy1cuuLgCp_?usp=sharing

Data collection from 1st launch from the SatX Cloud app.
https://drive.google.com/drive/folders/1iD2svH7MxaIzXeG0B6P5ggQNXTziZIgD?usp=sharing

SatX website. https://satxnorway.com/

SatX GitHub profile. https://github.com/satxnorway/