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UK CanSat Competition Progress Report 2

GWC CanSat

George Watson’s College

January 2020

1 Progress Statement

1.1 Mechanical Development

- The new and improved parachute has been designed and a prototype was tested. This year, the emphasis on using a strong material for both the parachute and its wires was greater and the result is well worth the attention to detail.
- This year's external shell was modelled using Fusion 360 (CAD software) with the integration of a dual-access system as the core focus. Although it was a challenge, by utilising the threading found in screws and bottle caps, a secure and reliable seal has been ensured. A prototype has also been printed.

1.2 Electrical Development

- All the electrical components including the cameras, PCB and sensors have been tested to ensure that they are all in proper working order.
- Since the components have been tested and we can confirm that they function properly they have been attached to the custom-printed PCB provided to us by our sponsor TecBridge.

1.3 Software Development

- The code for processing and displaying the video data has been written.
- The code for retrieving the data from the other sensors has also been written.
- The GUI that will display both the video footage and sensor data in an ergonomic layout has been designed.

1.4 Outreach Development

- The website has been updated with this year's mission objectives, our new team members, and our sponsors.
- Our first post was released on Instagram/Facebook/Twitter.
- We have spoken to a number of local primary schools about potentially speaking to their students and hosting a STEM-related workshop.

2 Introduction

2.1 Team Organisation and Roles

Team Leader - Harold
Vice Team Leader – Abhijith
Head Programmer - Fraser
Head of Electronics – Alex
Head of Outreach – Neil
Head of Aeronautics – Harry
Design Coordinator – Thomas
Secondary Mission Coordinator – Neasa
Head of Finances and Administration – Iain

2.1.1 Mission Objectives

Using an array of sensors, this year's mission is to survey the surroundings of the CanSat and determine whether a chosen landing location is a safe and appropriate one. The CanSat will feature two cameras, recording its descent and the terrain of the landing site. Prior to landing, the CanSat will deploy three tripod-like legs from its base which will elevate it to a better position for collecting visual data. Alongside this, the design will include a heads-up display which will be cast on top of the footage from the CanSat - showing the primary mission data as well as other parameters in real-time. This data will also be used to determine the habitability of a planet, which is heavily influenced by whether there is a presence of water, the concentration of CO_2 in the air, and the UV index of a chosen site – all of which the other sensors can measure.

Primary Mission:

The primary mission proposes the measuring of both air pressure and air temperature. The chosen sensors will also have the capability to measure air humidity and detect the presence of Volatile Organic Compounds (VOC) and equivalent carbon dioxide (eCO_2) in the surrounding environment.

Secondary Mission:

The aim of the secondary mission is to utilise the footage from the cameras inside the CanSat to gain a better perspective of the surrounding environment. Being able to visually assess the vicinity of a satellite is essential in identifying potential hazards that other sensors are unable to detect. This may include large rock formations, the presence of ice, or unstable terrain that may affect the CanSat's ability to land on a hypothetical planet. Furthermore, having a visual representation of a planet helps us gain a better understanding of its environment and others like it.

2.1.2 What will you measure, why and how?

Table of the sensors required for both the primary and secondary missions along with their measurements.

What will be measured?	Why is it measured?	How is it measured?
GPS coordinates	To determine the geographical position of the CanSat.	MTK3339 GPS Chipset (via Adafruit Ultimate GPS Breakout)
Barometric pressure, air temperature and relative humidity	To fulfil the requirements of the primary mission and display other measurements about the CanSat's surroundings.	LPS22HB chip (via Arduino Nano 33 BLE Sense)
Acceleration, gyroscopic position, magnetic field strength	Acceleration and gyroscopic data, as well as the presence of planetary magnetic fields to dictate whether survival is possible.	LSM9DS1 IMU (via Arduino Nano 33 BLE Sense)
Atmospheric and ground environment	To investigate the environment around the CanSat and determine whether a safe landing is feasible.	2x ArduCAM Mini 5MP OV5642
Total VOC gas concentration, eCO2	Additional measurements about the meteorological elements in the vicinity of the CanSat.	Adafruit CCS811 Air Quality Sensor Breakout
UVA, UVB, UV Index	To determine the UV Index (strength of UV radiation) of the local planetary atmosphere.	Adafruit VEML6075 UVA, UVB and UV Index Sensor Breakout

3 CanSat Description

3.1 Overview

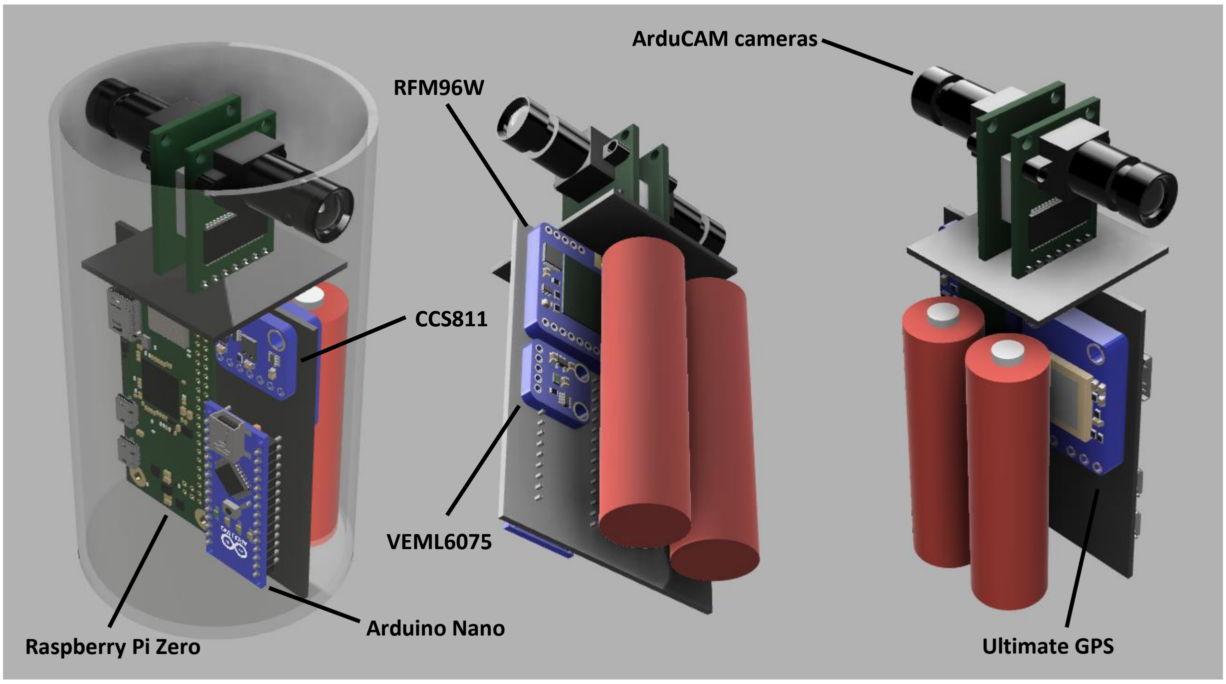
This year, the aim is to construct a CanSat with the ability to capture images and footage of a potential planet and use this information to gain an insight into the geographic properties of its surface. This data, along with the data from the other sensors, will be used to determine the habitability of a planet and whether landing on said planet is possible.

3.2 Mechanical design

The design consists of three major parts: the cameras, the PCB and sensors, and the landing gear. The two ArduCAM cameras are isolated in the upper section of the CanSat for the best vantage point, and to prevent interference with other sensors. The cameras will be fitted to a designated PCB which is connected in series to the larger one in the section below. The larger PCB is responsible for the power delivery and data transfer to/from all the other sensors. Moreover, like last year, the sensors themselves will be mounted directly onto the PCB using pin headers rather than with solder, as this significantly decreases the likelihood of soldering errors and short-circuiting. This also means that the sensors can be more easily removed and changed if necessary.

This year, A new and improved external shell will be 3D printed for the CanSat. The new design will incorporate a dual-access system whereby the components inside the CanSat can be removed and/or implemented from either end. This will ensure a more careful and logical arrangement of the components and prevent issues with packing from arising. In terms of the external shell itself, it will be printed using ABS filament. ABS is low cost, tough, durable and able to withstand a wide range of temperatures; meeting the requirements of the mission. In order to meet the requirements of a system such as this, the lids will be secured using threading on both the lid itself and inside of the shell (like an inverted bottle cap) so that they can be easily screwed on and off.

Finally, the landing gear will likely be machined out of a low-cost metal such as a steel alloy. The legs will be deployed via a series of springs - drawing inspiration from the mechanisms found inside ballpoint pens. The mechanisms themselves are contained in columns that are integrated into the shell itself. The legs will take most of the immediate impact from the landing and distribute it evenly across the entire structure. The parachute will be mounted to the external shell, as to prevent unnecessary stress from being applied to the internal setup and potentially damaging it.

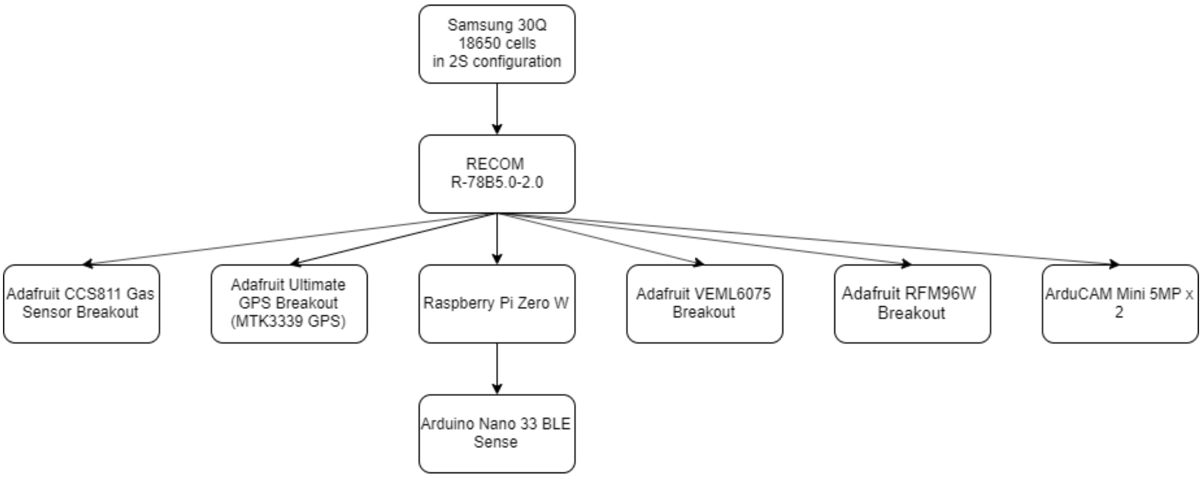


(Fig.3.1, labelled CAD Model of the internals of the CanSat)

3.3 Electrical design

To power the CanSat this year, two Samsung 30Q 3000mAh 18650 Lithium-ion cells connected in series will be used, delivering 7.4V to a switching (linear regulator replacement) converter. This will power the electronic components at 5V, with the Raspberry Pi Zero W also providing power via its 3V3 rail to other components at 3.3V. The built-in power management circuitry of the Raspberry Pi Zero W manages the power delivered to other sub-systems of the CanSat, allowing for dynamic power delivery. The components are all connected with a single custom PCB to facilitate facile connection and simple replacement.

Power delivery is as below:



Data flow is as follows:

<u>Bi-directional data flow between Raspberry Pi Zero and the following:</u>

Software Serial:	Arduino Nano 33 BLE Sense
UART:	Adafruit Ultimate GPS Breakout
SPI and I2C:	ArduCAM Mini x2

<u>Bi-directional data flow between Arduino Nano 33 BLE Sense and the following:</u>

UART:	Adafruit RFM96W LoRa Radio Transceiver
I2C:	Adafruit VEML6075 Breakout
	Adafruit CCS811 Breakout

The estimated battery life of the CanSat is as below, considering the power draw of all components:

Minimal voltage - 2x 18650 Samsung 30Q Li-ion batteries = 6000mAh @ 7.4V
2x 18650 Samsung 30Q Li-ion batteries = 44.4Wh

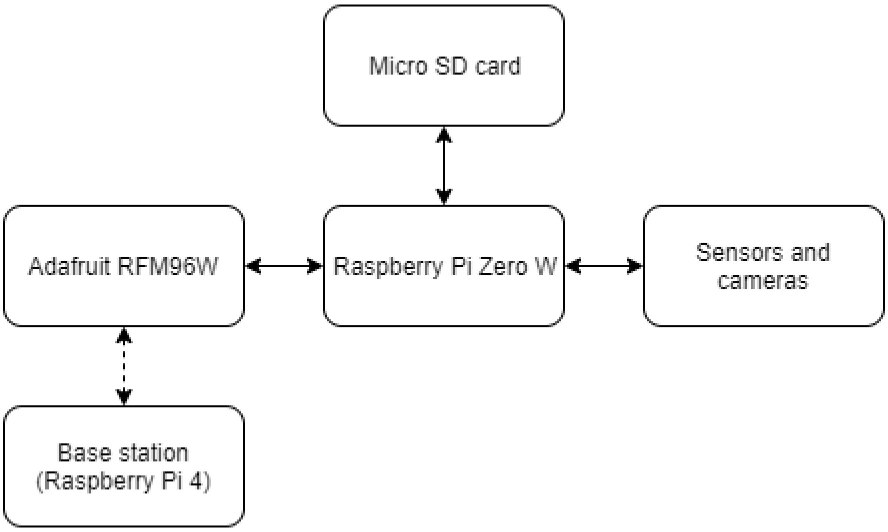
Estimated maximum power draw = 963mA @ 5V and 200mA @ 3.3V = 10.285W

Therefore, minimum estimated time of operation is 44.4 / 10.285 = 4.3 hours

3.4 Software design

The Raspberry Pi Zero W will run a custom-written Python script that gathers data from all the sensors (Arduino Nano BLE Sense, Adafruit Ultimate GPS, CCS811 and VEML6075) and cameras, and then processes it into a form the base station software can understand. The code is designed in such a way that even if one of the sensors were to fail, it would recover itself and send the details to the base station, so that it can be repaired remotely.

This data would then be sent via SPI to the Adafruit RFM96W transmission module - transmitting the data to the base station on the ground.



3.5 Landing and recovery system

A simple decagonal drag parachute made of Ripstop Nylon will be used to regulate the CanSat's descent speed. On landing, the CanSat's landing gear and external shell will absorb the impact.

To determine the size of the parachute, the team made some calculations which consider the CanSat's mass, the velocity it is required to fall at, as well as other variables:

$$\text{Air pressure} = 1.04\text{ bar; Temperature} = 15°\text{C; Humidity} = 75\%\text{; Air density} = 1.25\text{ kgm}^{-3}$$

$$F_d = 0.5\, C_w\, \rho\, v^2 A$$

$$A = \frac{mg}{0.5\, C_w\, \rho\, v^2}$$

$$A = \frac{3.43}{0.5 \text{ x } 0.24 \text{ x } 1.25 \text{ x } 8^2}$$

$$A = 0.36\, m^2$$

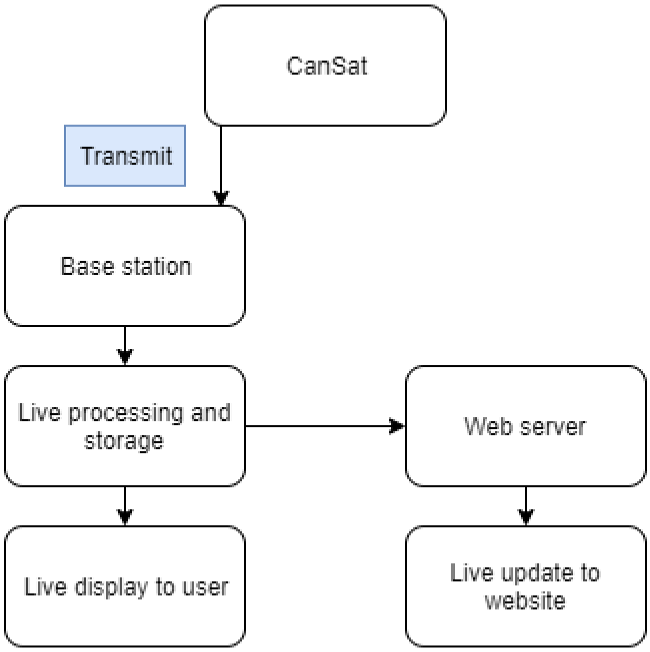
$$\therefore r = 0.33\, m$$

3.6 Ground support equipment

The team's software developers are developing a fast, complete and robust base station program, which can be executed with low system requirements. The software will run on a Windows or Linux based laptop and will only require a USB connection to receive data.

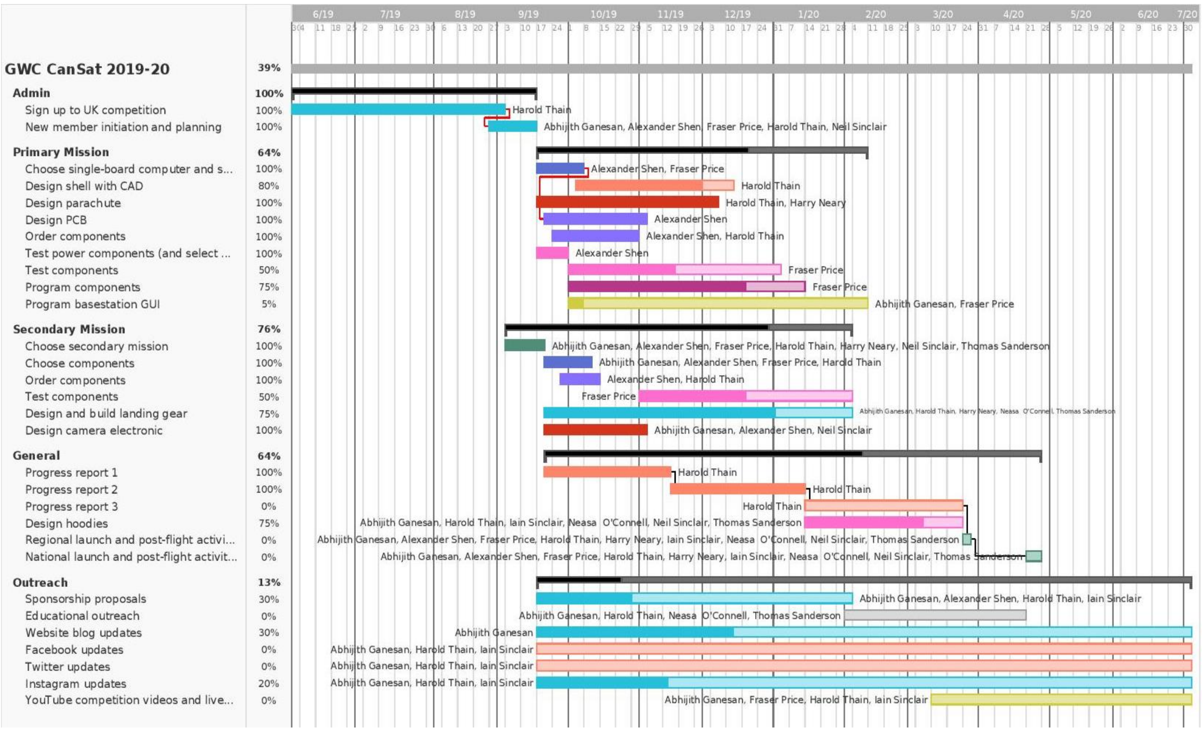
The base station equipment will include:

- Laptop with Wi-Fi connectivity and 2 USB Type-A ports
- RFM96W communications module connected to a Raspberry Pi 4 to act as the receiver
- Battery charging station with the ability to charge cells used in CanSat



4 Project Planning

4.1 Gantt Chart



4.2 Team and External Support

Currently the team is comprised of nine members each with their own skillsets and specialities relating to every aspect of the CanSat's design. This year, the team also features specialists in outreach, graphic design and aeronautics alongside the pre-existing members. With these new-found members we intend on increasing the output and quality of our outreach program, as well as developing a more stable and reliable parachute.

In terms of funding, our school has very kindly agreed to offer us a baseline amount after we presented the CanSat project pitch to the school principal. The remainder of our funding comes from our sponsors TeamGantt, Sketchfab and Tecbridge, who aside from providing us with adequate funding for our more ambitious ideas, have also given us free software and electrical components.

4.3 Risk Analysis

Potential Issue	Solution
CanSat is over budget	Remove non-essential systems from the CanSat or resort to a less expensive, more conservative design.
CanSat is underweight	Add ballast and/or cushioning to the base of the CanSat to not only increase mass but act as padding to further protect the CanSat upon landing.
CanSat is overweight	Resort to less heavy components which can easily be replaced such as the buzzer or cells.

Lacks transmission range	Incorporate a range amplifier into the design.
Lack of internal space in the CanSat	Alter organisation setup inside the CanSat to maximise space.

3.4 Test Plan

Feature to test	**Method of testing**
CanSat parachute	The parachute will be tested by dropping a can with the same mass as the CanSat from a height of 100 to 200 metres to accurately represent how it will perform on the day of the launch.
Radio transmission range	The range of the transmission will be tested line-of-site in an open field.
Battery life	Battery life tests will be conducted by measuring the length of time the CanSat can stay powered and comparing that to our calculations.
Effectiveness of sensors	Ensure that all the sensors are both receiving and recording data by testing the sensors in a variety of conditions.
Base station information display	Complete a test run of how the CanSat should perform on launch day and verify that the base station is receiving data and displaying it in the appropriate format.

5 Outreach programme

This year, with the help of designated outreach specialists, we have redesigned our use of social media. Our use of Facebook and Twitter will remain primarily the same (regular updates), however Instagram – as it has the greatest following and the most traction – will use a new-and-improved theme/colour scheme for each post to create a more recognisable and consistent brand. In addition, we will continue to host our state-of-the-art website at gwccansat.com.

Unlike last year, we intend on focusing more of our attention on outreach at schools and events. Over the course of the year, we will visit several primary schools in the local area to talk about STEM and introduce younger students to the widely interesting opportunities that lie ahead of them if they decide to pursue a career in science, technology, engineering or mathematics. Several schools have already expressed an interest in our visiting. We will also attend events such as the Edinburgh Maker Faire to network and hopefully spark the interest of other young engineers.

5. Launch Day Preparation

5.1 Launch checklist/countdown

Checklist of tasks to complete when preparing the CanSat for launch:

- Turn CanSat on and ensure it is transmitting data – Alex (2:00 minutes)
- Start up the base station – Abhijith (2:00 minutes)
- Turn on the receiver – Fraser (30 seconds)
- Ensure that the parachute is secured to the CanSat – Harry (30 seconds)

5.2 Post mission checklist

1. Save data received by base station
2. Retrieve CanSat
3. Turn CanSat off
4. Briefly inspect for any damages to the exterior of the CanSat

5.3 Results analysis procedure

The primary and secondary mission data transmitted from the CanSat will be displayed and stored in the base station. The footage from the CanSat will be recorded by the base station and a physical copy will also be stored on the CanSat itself. In order to validate the results from our array of sensors, the collected data will be compared to that of the preliminary test done on the ground prior to the launch. Although the data from the launch will differ slightly to that of the test, we will still be able to identify anomalies in it and determine whether it is usable.