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UK CanSat Competition Progress Report 3

GWC CanSat

George Watson's College

February 2019

1 Progress Statement

1.1 Mechanical Development

- Several parachute prototypes have been made varying in size and shape in order to determine the design best suited for our CanSat. Our final design (one that is small yet maximises drag) has been tested multiple times ensuring that the CanSat will fall at the correct velocity, and the parachute will be able to withstand the force of being deployed.

1.2 Electrical Development

- All the sensors have been tested in competition-like conditions and are receiving data properly.
- Our custom-designed PCB, which will allow us to connect all the modules and sensors in a way that greatly decreases the likelihood of malfunctions occurring, is currently being shipped. It is expected to arrive within the next 2-3 days. This was kindly offered to us free of charge by one of our sponsors - TecBridge.
- The Hacker RF receiver has been replaced by another HC-12 module because, after multiple tests, it was discovered that latency could be significantly decreased without a decrease in range if it were replaced with another HC-12.

1.3 Software Development

- The code for the proposed base station design (displaying information collected by the sensors in an easy to understand yet detailed way) is being finalised leading up to the competition.

1.4 Outreach Development

- Our new and improved website has been released and now displays information about the team, our design, ideas and much more.
- We now post twice a week on both Instagram and Twitter and these posts have remained at a high quality and standard.
- Our first YouTube video has been released showing the progress we’ve made over the course of the competition. Our second video is in production and will be released in the weeks following the Regional competition.

1.5 Other News

- Unfortunately, a crucial member of our team, Kristy, has left the team in order to allocate more time to her own solo STEM-related projects.

2 Introduction

2.1 Team Organisation and Roles

Harold - Team Leader, Secondary Mission Coordinator, Mechanical, Outreach
Abhijith - Team Co-leader, Software, Outreach
~~Kristy - Secondary Mission Coordinator, Mechanical~~
Alexander – Electrical
Nikolai - Electrical, Mechanical
Neil – Outreach
Fraser - Electrical, Software

2.1.1 Mission Objectives

This year, the team is proposing a technology that will display information about the CanSat as it is descending towards the ground. This technology will be able to provide detailed information about the CanSat's acceleration, gyroscopic position and the impact of magnetic forces on the CanSat. The unification of these measures will also allow for 3-axis space orientation permitting the displaying of the orientation of the CanSat as it is falling.

Primary Mission:

The primary mission proposes the measuring of both air pressure and air temperature. The chosen sensors will also have the capabilities of measuring air humidity and VOC (volatile organic compound) gas.

Secondary Mission:

The aim of our secondary mission this year is to display the 3-axis orientation of the CanSat as it descends. By utilising the accelerometer, gyroscope and magnetometer capabilities of the 9-DOF sensor, the team will be able to create a frequently updated digital display of a 3D model of the CanSat showing its orientation as it descends. This will allow us to determine how the CanSat will land and, in later designs, use this information to alter the way in which the CanSat is landing for optimal landing conditions. We will also attach a camera to the base (as long as it does not cause the CanSat to exceed the maximum mass) of the CanSat to show the quality of the terrain below, which will determine whether these conditions are suitable for a controlled landing.

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	Show the relative position of the CanSat in the air	Using the Adafruit 2479
Temperature, barometric pressure	To fulfil the requirements of the Primary Mission and display other measurements about the CanSat's surroundings	Measured using the BME680 from Pimoroni
Acceleration, gyroscopic position	Unification of these readings used to display the 3-axis orientation of the CanSat	Using the Adafruit 9-DOF with IMU fusion breakout - BNO055
Quality of terrain below the CanSat	Used to determine whether the conditions of the terrain are suitable for a safe and controlled landing	Measured using the Raspberry Pi Zero Camera Module
The strength of magnetic forces	Show the magnetic forces the CanSat is experiencing from the surrounds and if these will interfere with other electrical components	Measured using the Adafruit 9-DOF and IMU fusion breakout - BNO055
Humidity, VOC gas content	Additional measurements to accompany the primary mission and display other meteorological elements in the vicinity of the CanSat	Using the BME680 from Pimoroni

3 CanSat Description

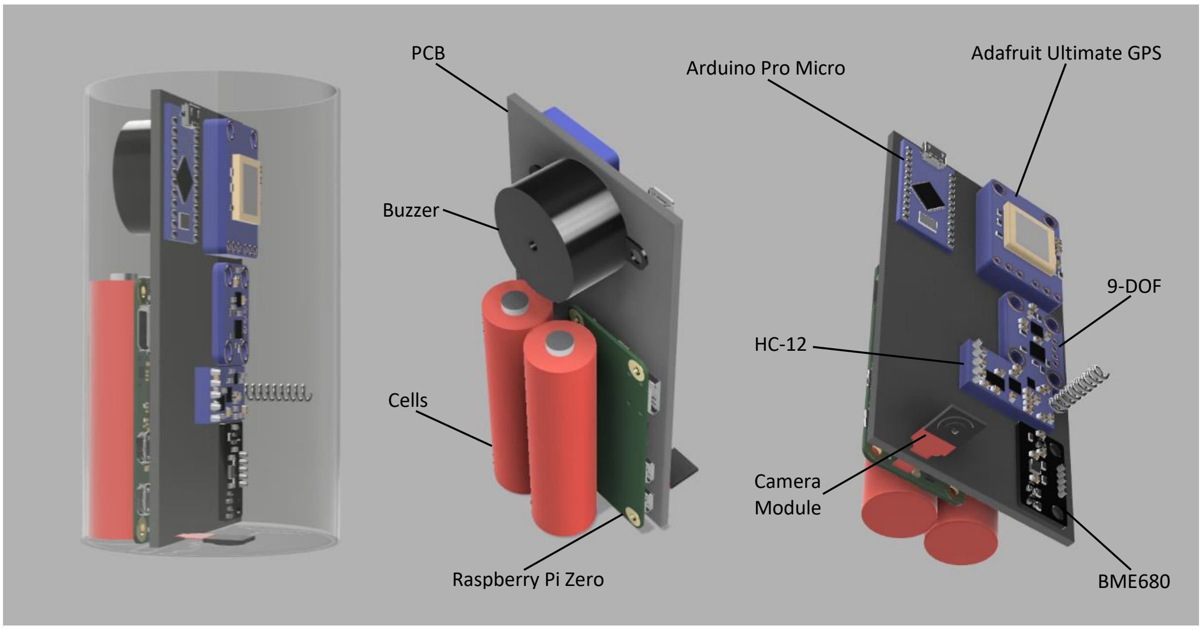
3.1 Overview

This year, we aim to focus on producing a frequently updated display of a 3D model of the CanSat as it descends. We have designed the CanSat with a focus on technical and scientific accuracy and have achieved this by ensuring that the electrical components function properly and with precision. We have verified this by testing both the individual components and when all the components are functioning together in a launch day setting. The CanSat will also be entirely assembled in-house, with none of the construction being outsourced – other than our PCB.

3.2 Mechanical design

Although we initially planned to use a layered design for the internals of the CanSat, upon testing and experimenting with other configurations we are instead arranging the components side-by-side in order to maximise space efficiency. The cells are located next to Raspberry Pi Zero which is positioned beside the PCB. The sensors, HC-12, buzzer and Raspberry Pi are all mounted onto the PCB, with the Raspberry Pi Zero Camera Module located on the base of the CanSat (as shown in the CAD model below). Because of the ample amount of space due to the low profile of our sensors, we can incorporate our initial idea of positioning the sensors in a way that enables them to not overheat or interfere with each other. Moreover, mounting the sensors directly onto the PCB using pin headers rather than soldering the components, significantly decreases the likelihood of soldering errors or short circuiting to occur. This also means that the sensors can be more easily removed and changed if necessary.

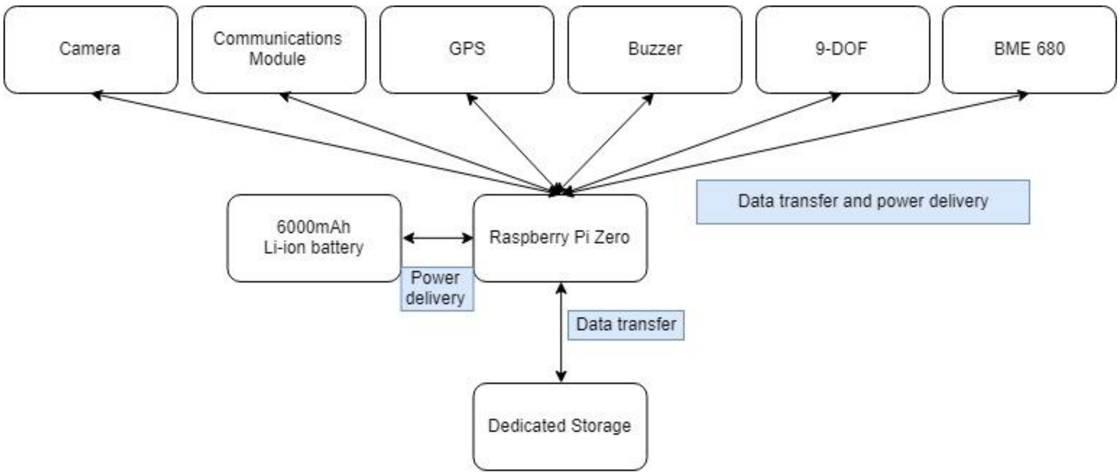
By taking advantage of the reusable design of last year's CanSat, we intend on using the same external shell. This has been shown to withstand the impact of the fall from not only numerous tests but by its performance during the actual competition. This external shell is composed of a lightweight 3D printed plastic, preventing the components on the interior from being damaged on impact. This external shell will absorb the shock sustained from the landing and if it were to shatter (although unlikely), the internals would remain protected. The parachute will be mounted to the external shell as well, as to prevent the stress of the parachute affecting the internal setup and potentially damaging it



(Fig.3.1, 3D CAD Model of the internals of the CanSat)

3.3 Electrical design

In order to power the CanSat we are using two Samsung 30Q 3000mAh 18650 cells connected in parallel, delivering 3.7V to a 5V step-up regulator to then power the MEMS components at 5V, with the Raspberry Pi Zero providing power to the other components as well. The built-in power management circuitry of the Raspberry Pi Zero manages the power delivered to other sub-systems in the CanSat, allowing for dynamic power delivery. The components are all connected via female headers on a single common custom-built PCB board – provided by one of our sponsors - to facilitate simple connection and easy replacement should any components require it.



In preparation for launch day, the team calculated the estimated battery life of the CanSat based off the power output of the cells and the power consumption of the Raspberry Pi Zero:

$$\text{nominal 18650 cell capacity} = 3000\text{mAh}$$
$$\text{2x nominal 18650 cell capacity} = 6000\text{mAh}$$

$$\text{Wh capacity} = 3.7 * 6 = 22.2\text{Wh}$$

$$\text{Raspberry Pi Zero power draw (max.)} = 1.2\text{A @ 5V} = 6\text{W}$$

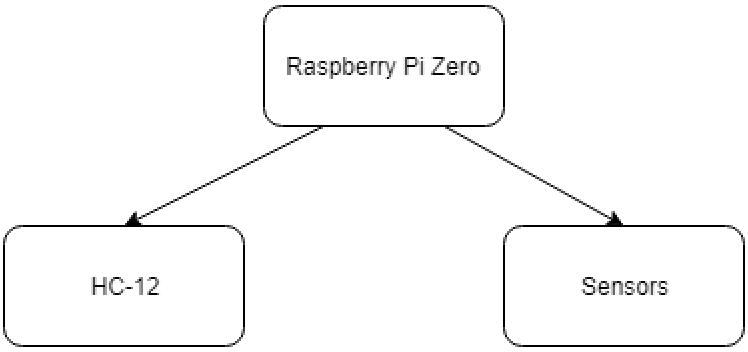
$$\text{Time available} = (22.2*0.8\ (80\%\ \text{efficiency}))/6 = 2.96\ \text{hours (at Pi max power draw)}$$

As shown in the above calculations, the team have considered the power draw of all the sensors, as well as how their power draw has a negligible impact on the resulting battery life.

3.4 Software design

The Raspberry PI Zero will run a custom written Python script that gathers data from all the sensors (BME680, Adafruit Ultimate GPS, 9-DOF) 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 signal to the base-station the details, so we might attempt to fix it.

Initially, this data would then be sent via USART to the Zigbee transmission module - transmitting the data to the base-station on the ground. Due to sizing issues and difficulty integrating with it, we are instead using the HC-12. However, this resulted another issue. When using the HC-12, a UART pin is required to integrate with it, but the only UART pin on the Raspberry Pi Zero was already occupied by the GPS module (the Zigbee Waveshare was connected via USART and therefore a UART pin was not required). In order to resolve this issue, we salvaged an Arduino Pro Micro which will be connected to the GPS module instead. The Pro Micro is then connected to the Raspberry Pi via SPI, and the HC-12 will be connected directly onto the Raspberry Pi via its dedicated UART pin.



3.5 Landing and recovery system

We plan to use a simple drag parachute made of Ripstop Nylon to regulate the CanSat's descent speed. On landing, the CanSat's external shell will absorb most of the impact and protect the internals. Our CanSat will also use a communications module to transmit sensory data and the camera footage to the base station.

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

$$\mathrm{m} = 0.35\ \mathrm{kg} \quad \mathrm{W} = 3.43\ \mathrm{N} \quad \mathrm{v} \geq 10 \quad \mathrm{u} = 0$$

$$D = \frac{\mathrm{C\ d\ r\ v}^2 A}{2}$$

$$A = \frac{2\mathrm{W}}{\mathrm{C\ d\ r\ v}^2}$$

$$A = \frac{2 \text{ x } 3.43}{1.75 \text{ x } 1.229 \text{ x } 10^2}$$

$$A = 0.0318 \ldots m^2$$

$$A = 319\ cm^2$$

$$A = \pi r^2$$

$$r = \sqrt{\frac{A}{\pi}}$$

$$r = \sqrt{\frac{319}{\pi}}$$

$$r = 10.076 \ldots\ cm$$

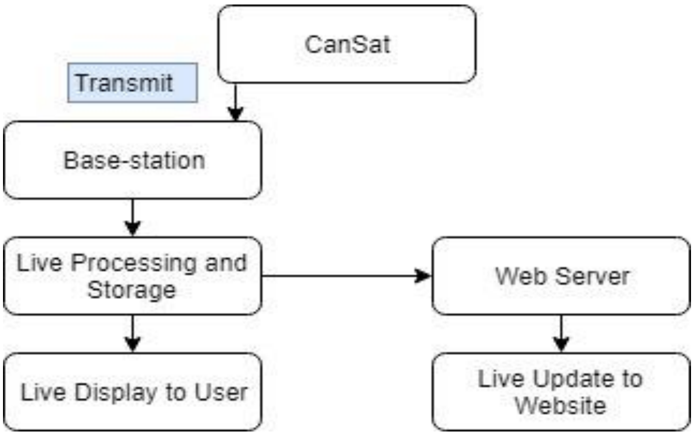
$$r = 10.1\ cm$$

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.

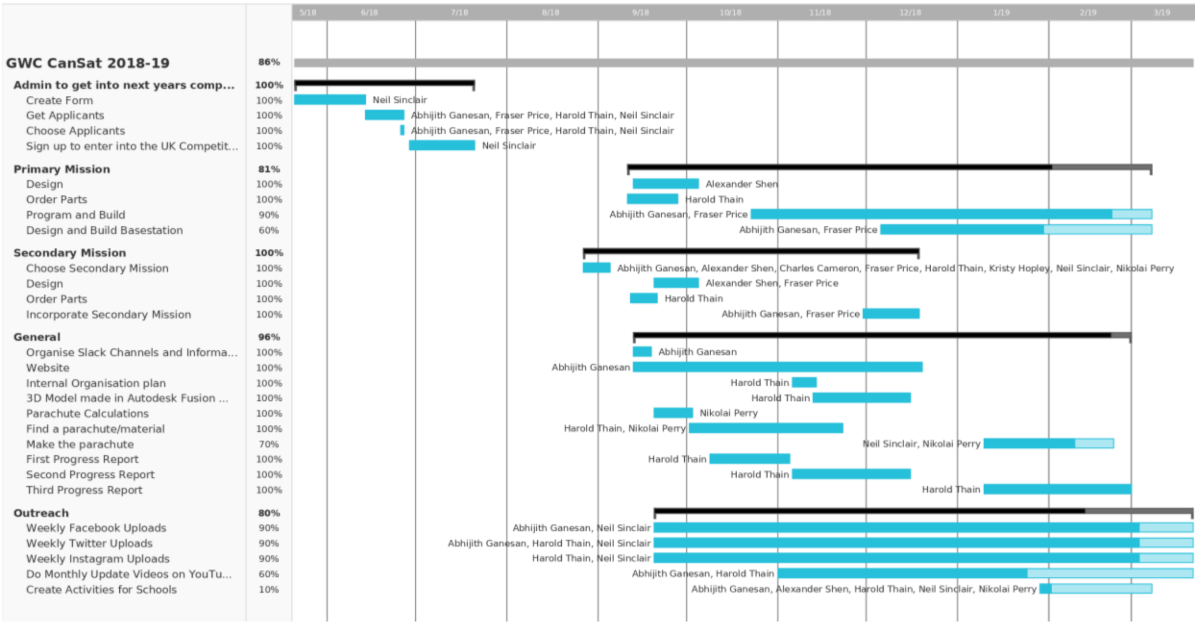
Our base station equipment will likely include:

- Laptop with Wi-Fi connectivity and 1-2 USB Type-A ports
- HC-12 communications module 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 six members each with their own roles relating to the mechanical, electrical and software design of the CanSat. Unlike last year, this year's team members all have clearly defined roles and significant amounts of experience in the field which they have been assigned. Furthermore, we have also communicated with several professionals in relevant industries about further improving the quality of our electronics and mechanical design, as well as our secondary mission.

In terms of funding, we are lucky enough that our school is very onboard with the CanSat project and hence much of our funding is from them. However, due to our sponsors, we have also obtained free software from Team Gantt as well as free PCBs from Tecbridge and Yostar.

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 weights and 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.

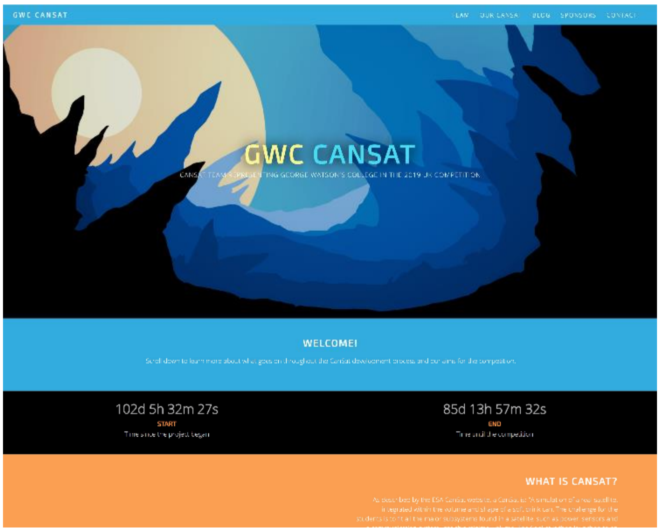
4.4 Test Plan

Feature to test	Method of testing
CanSat parachute	The parachute will be tested by dropping a drink can with the same mass as the CanSat from a height of 100 to 200 metres to accurately represent the height it will be dropped from on launch day.
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 fully powered and comparing this to our predicted results.
Effectiveness of sensors	Ensure that all the sensors are both receiving and recording data by testing the sensors in a variety of conditions (varying in temperature, humidity etc…)
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 we have completely redesigned our website to not only make it easier to navigate on both desktop and mobile versions, but to also make it one of the more suggested websites when searching for the CanSat competition. We are hosting this website at gwccansat.com.

We also host pages on Instagram, Facebook and Twitter which are all updated quite regularly. This year, we have started using YouTube more frequently, making video updates on the progress of our CanSat. Furthermore, in the coming weeks, we will visit several primary schools in the local area to talk about STEM and complete activities - designed to introduce younger children to STEM - with them. Several schools have already expressed an interest in us coming to inform their pupils about STEM as well as the CanSat competition.



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 – Fraser (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 – Harold (30 seconds)

5.2 Post mission checklist

1. Save data received by base-station
2. Retrieve CanSat (made easier by the inclusion of a buzzer)
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 by the base-station. The CanSat's real-time 3D-axis orientation and the footage from the CanSat will be screen recorded by the base-station and stored as well (which will be shown in the final presentation). In order to validate our results, we will compare the measured data to data that was recorded during testing. Although the information collected will be different from what was received during our tests (because of geographic location and differing weather conditions), we will still be able to identify anomalies in the data and determine whether the data is usable whatsoever. Furthermore, if possible (depending on time constraints), we intend on completing a test run at the location of the competition which will also provide us with hopefully very comparable results to what we will obtain during the launch. This will also allow us to determine whether the data we collect from the launch is accurate and usable.