Cansat UK Progress Report 2

GWC Cansat
George Watson's College

December 2017

Contents

Chapter 1

Progress Statement

We have continued along our current plan, working on each section of the project simultaneously in sub-teams. A summary of our progress is shown below:

Team Administration

- A member of our team has dropped out due to personal reasons. In order to maintain our forward momentum, we have taken on an additional member.
- We have recieved three new sponsorships; two have provided us with extra funding surrounding our project, the third company providing us with free custom PCB manufacturing.
- Having different sub-teams that have responsibilites for different parts of the cansat development was leading to issues with team members not knowing how the overall project was progressing. The team leaders now collaborate to produce an internal report of progress every 2-3 weeks. This has recieved positive feedback within the team.
- We are continuing to maintain our website, hosted on the domain `gwccansat.com`, in addition to having officially launched our video blog ('vlog') programme, showing our progress on a weekly basis, leading up to the competition.
- The team has adopted new graphical designs for its logo and media/website backgrounds in order to give this year's campaign a fresh aesthetic.

Mechanical development

- We continue to work towards having a finalised CAD model. This is dependent upon space requirements of our sensors and custom PCBs, so is still undergoing iterative revisions.
- Additionally, we are still working towards having a modular compartment for our secondary mission, allowing the cansat to be easily reused for other experiments with minimal physical changes made — a simple case of plugging in and programming the new, relevant sensors.

Electronics design

- Our team hit some budgeting issues, leading us to consider other electronics options — primarily in–house assembly, as an alternative to PCB fabrication. This was recently resolved with the addition of our new sponsors, providing us with free PCB fabrication and more funding.
- We also now have an initial schematic design, that is ready to be made into a PCB design, provided that the software team have successfully interfaced and tested all the sensors and the mechanical team have provided ideal locations for the larger components on the PCB.

Software design

- Currently, the project progress is fullcruming off the dependency on testing the sensors from our current design. Hence, we have allocated extra team members and resources to this section.

- We are currently working on testing each individual sensor, to ensure that we are able to interface with them correctly with the current wiring solution and ready to make notes of any required amendments.

Secondary mission

- We continue to strive towards having a diamagnetically stabilised levitation exeriment to harvest vibration energy. We have unfortunately run into several technical problems, so are currently still working on having a functional experiment that produces power.
- We have developed a plan to have multiple experiments ready by the time of the competition, so that we have a backup options in case of failure to prepare the main experiment. It will also allow us to demonstrate the concept of switching the experimental module quickly.
- As a precaution for the secondary mission not working, we have begun brainstorming several other experiments to put in the secondary mission module. This is made easier by our modular experimental compartment in our cansat design.
- Currently, the alternative secondary missions that we are researching further are placing two Geiger-Muller tubes in the cansat to compare changes in cosmic radiation levels between flight, on the ground and other potential places. Another mission being researched is to determine the health of trees, plantations and forests from the levels of various frequencies of electromagnetic radiation being emitted from them.

Chapter 2

Introduction

Several changes have been made to our proposal since report 1, primarily in the secondary mission and team organisation. Changes are shown in blue.

2.1 Team organisation and Roles

Charles Cameron — **Team Leader**, Electrical, Mechanical, Software.

Morven Pennie — **Team Leader**, Electrical, Mechanical, Outreach.

Erin Edmonstone — Mechanical, Secondary Mission Coordinator, ~~Outreach.~~

Harold Thain — Mechanical and Outreach.

Josh Flint — Electrical, Mechanical, Outreach.

~~Jack Hargreaves — Electrical and Software~~ (left due to personal reasons).

Abhijith Ganesan — Electrical and Software (joined the team 16/11/2017).

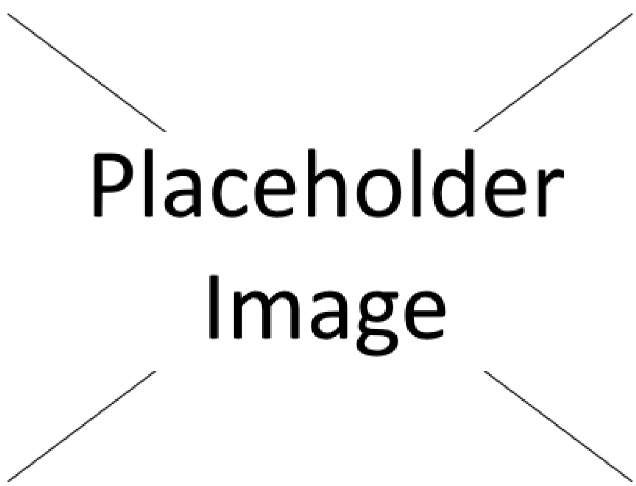

Figure 2.1: 2018 GWC Cansat team

2.2 Mission Overview

2.2.1 Mission Objectives

The team's objectives have remained largely the same, however, we have now put a larger emphasis on creating multiple experimental modules as part of our secondary mission. This is a precaution as explained further in the risk assessment.

Primary Mission

The primary mission commits the parameters of air pressure and air temperature for telemetry. The chosen sensors also measure several other parameters, which have been added as an extension of the primary mission: relative humidity, environmental gasses, acceleration, GPS position and cansat orientation.

Secondary Mission

The team has chosen to incorporate a small, modular, experimental compartment in the cansat. It will be used to house a small diamagnetically stabilised levitating ferromagnet, from which, energy from the vibrations in the cansat may be harvested through use of a tuned inductor coil positioned close to the levitation experiment. The aim is to propose an alternative to traditional space and aircraft power acquisition methods such as solar arrays providing an advantage as it is able to be deployed from launch and allows otherwise wasted energy from other modules to be added back into the system. As a caveat, this method goes largely untested and therefore the primary purpose of the teams experimentation is to test if this is a viable alternative to traditional power sources.

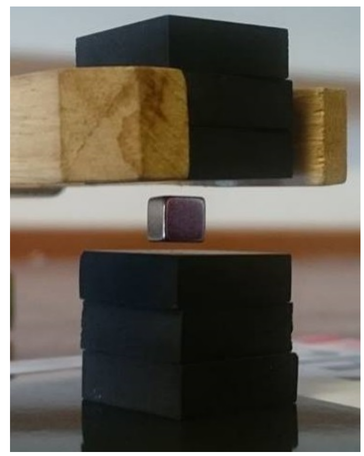

Figure 2.2: A neodymium magnet floating freely in diamagnetically stabilised levitation, unaffected by frictional forces

As a stretch goal, the team is now also looking to make several additional experimental modules, so that the ability to switch experiments may be demonstrated, as well as possibly utilised for a physical launch. One of the experiments currently being researched are researching use of two Geiger–Muller tubes to measure changes in frequency of cosmic showers and collisions.

Another experiment that the team is considering is the use of infrared, visible light and other electromagnetic sensors to determine the health of vegetation, which can be applied to forests, plantations and nature conservation zones, in order to survey overall health of vegetation in these respective areas.

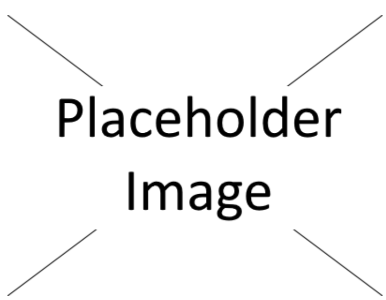

Figure 2.3: Proposed wireframe design of base station live processing graphs and parameter display

2.2.2 What Will be Measured, Why and How

What will be measured	Why is it being measured	How is it being measured
High fps camera footage.	Have a visual record of the secondary mission events.	Using the ArduCam OV5640 camera module.
Barometric pressure, temperature, humidity and environmental gasses.	For telemetry to base station, fulfilling primary mission.	Via a PCB-integrated Bosch BME680.
V_{rms} across secondary mission inductor coils.	For power calculations and analysis from base station.	A MOSFET full-bridge rectifier converts AC to DC without voltage drop. A non-inverting amplifier is used to proportionally increase voltage output. A high resolution linear ADC reads voltage.
GPS coordinates.	To aid cansat tracking.	The MTK3339 GPS is mounted to the main PCB and wired to a dedicated antenna on the side of the cansat.
Rotation, acceleration and relative position.	Additional data to aid primary and secondary mission.	FXOS8700 + FXAS21002 9DOF module soldered to the main PCB.
Vibrations.	Data for secondary mission power generation performance.	Accelerometer from 9DOF package.
I_{rms} generated by secondary mission inductor coils.	For power calculations and analysis from base station.	A MOSFET full-bridge rectifier converts AC to DC without voltage drop. An ACS712ELC in series with the inductor coil measures DC current generated by the setup.

Changes Made

- 3D magnetic field strength is a redundant feature to measure and will not provide relevant data to the secondary mission. Therefore, it has been removed from the cansat design to streamline space, performance, etc.
- Vibrations will be more accurately measured using the accelerometer onboard the cansat, hence, the mechanical vibration sensor has been removed due to redundancy.
- The bridgetek CleO-CAM1 camera module from the former report was overly complex for this application, in addition to being difficult to interface with. This has since been changed to the ArduCam OV5640, which utilises the same optical sensor, but is able to interface via I^2C (so is easily interfacable), has lower power consumption, and is more compact.

Chapter 3

Cansat Description

3.1 Overview

This years entry has taken much more of an emphasis on a scientific experimental module as the secondary mission. Hence, we have designed the cansat with a focus on technical and scientific accuracy. We aim to complete most of the cansat construction in-house. The only part of the cansat that we anticipate outsourcing is the PCB for the cansat, as we do not have access to the materials or machinery for creating our own.

Care was taken to ensure that the electronic sensors used are not negligibly affected by strong and changing magnetic fields, however testing will be required later to confirm that this is not an issue before any launches.

Although our cansat must be technically very accurate to ensure a successful secondary mission, the team also values the cansat's ability to be able to switch out experimental modules with ease, meaning that other experiments can be conducted within quick succession and minimal effort.

3.2 Mechanical Design

The cansat is designed with a modular secondary mission compartment. This will allow the cansat to be used with different experimental apparatus in the future. A rail system will allow experimental apparatus to be set up, then slid into place and secured. Any electrical connections can be easily made with our modified pin-headers that lead to I2C terminals, GPIO and other commonly accessed pins. The experimental module proposed for our entry is held together with a 3D printed frame and assembled by hand, with an adjustable height magnet.

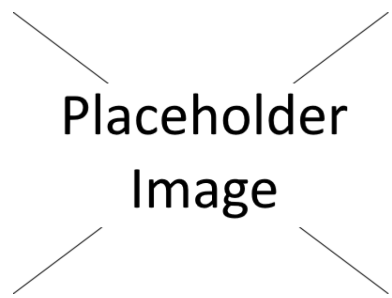

Figure 3.1: Prototype frame for experimental module compartment

The main cansat assembly is also secured with a lightweight 3D printed internal frame, which allows reliable mounting and placement of components and wiring. It is surrounded by a hand-made fiberglass shell, which will flex upon impact serving to absorb and disperse much of the shock of the cansat landing or any other collisions. Plastic plates are used on the top and bottom of the cansat for further protection of the cansat from shock. The $\frac{1}{2}\lambda$ dipole communications antenna is mounted outside the outer shell along the long axis in order to optimise communications.

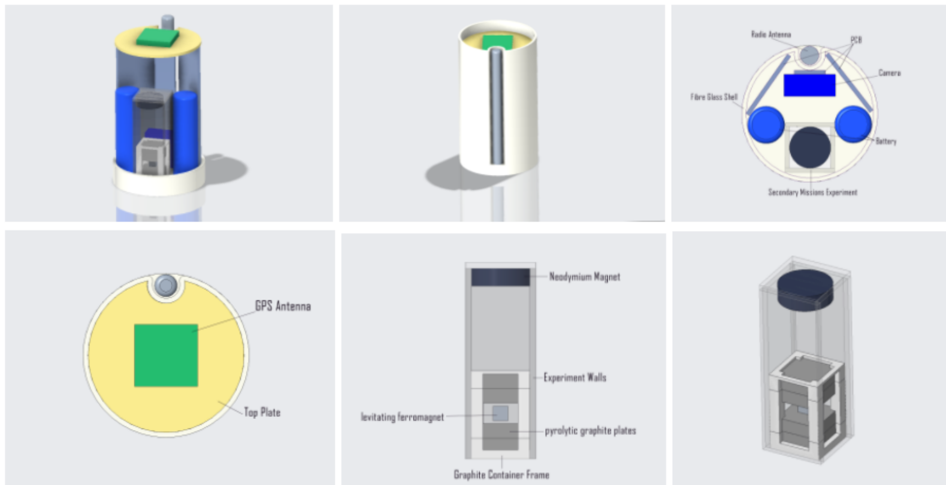

Figure 3.2: Computer–aided design (CAD) renders of the mechanical design

3.3 Electronics Design

Two independent cells are symmetrically distributed in the cansat and connected in series to deliver native 3.7V DC power to the cansat at 4800mAh power to the cansat sub-systems. Built-in IPS (Intelligent Power Select) in the CHIP Pro enables management of the power delivered to the other sub-systems in the cansat, providing flexible control over the battery life of the cansat.

The inductor coil from the secondary mission outputs an AC current, which is converted to a DC rms current via full-bridge rectifier and the output current and voltage read by the industry-standard ACS712 and a high–resolution ADC respectively, since the CHIP Pro built-in ADC does not offer a satisfactory resolution for the experimental precision.

For interfacing purposes, an arduino pro mini has been implemented to the electronics design. This will be used as a hard interface between the CHIP Pro and select sensors, in addition to possibly providing regulated power to some parts of the system. The arduino will not be executing any complex calculations or data aggregation.

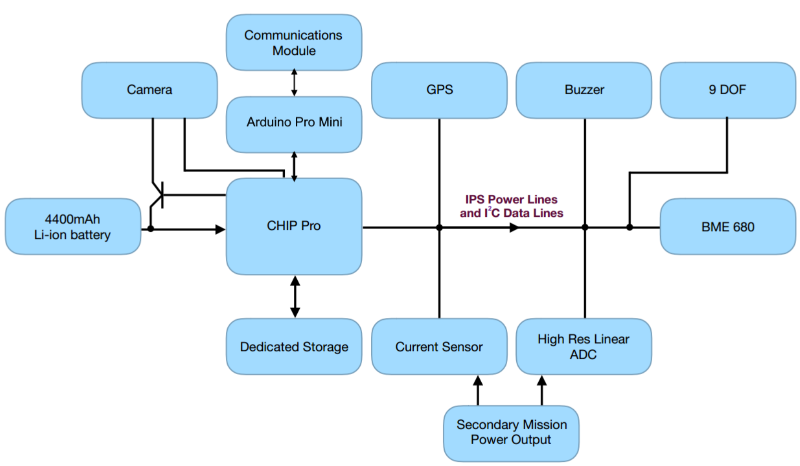

Figure 3.3: Electronics sub-systems diagram

3.4 Software Design

The CHIP reads all incoming sensor data and applies lightweight processing to the values. All raw data is stored in built-in NAND storage on the CHIP or select raw data (larger sets such as camera footage) is stored in an onboard SD card for retrieval from ground crews. The processed data sets are transmitted via 5 channels on a 433MHz frequency at up to 5,000bps baud rate. This allows for dedicated sensor channels in addition to a control channel, giving clean and organised telemetry of packets, as well as being able to pause telemetry of lower priority channels in cases of low connection stability.

The decision to use the CHIP Pro over a typical arduino or Raspberry Pi package was based on the 64–bit ARM–based processor running a native Linux operating system, as well as built-in hardware to handle wireless networking, bluetooth and battery regulation systems.

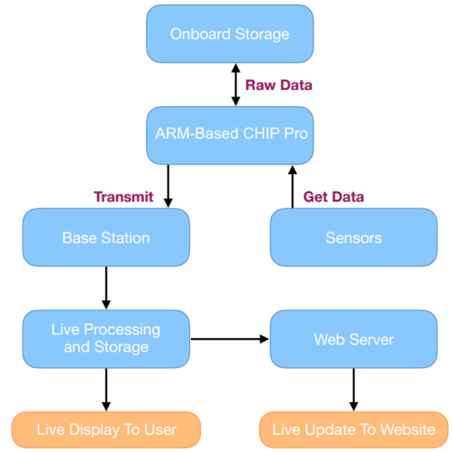

Figure 3.4: Software system architecture diagram

Previous iterations of the system architecture required an Arduino Pro Mini in addition to the CHIP Pro for interfacing purposes. This year, the team aimed to omit this from the system requirements. Unfortunately, given the time and feasibility constraints, this must be deferred until later consideration.

Additionally, the original plan to divide telemetry into 5 channels may be less feasible than first envisaged. In which case, we will take care to organise packets neatly on a lower number of bands.

3.5 Landing and Recovery System

We plan to use a basic drag parachute design to regulate the cansats descent speed. On landing, the fiberglass outer shell will flex, absorbing some of the landing shock. Our cansat will have both a dedicated communications antenna and gps antenna. This means we will have better connection to the base station and a high chance of accurate GPS lock, further assisting the recovery team in locating the cansat.

As an additional measure, foam padding will be added directly underneath the batteries to protect them from extensive damage, which could otherwise risk the battery life of the cansat during the recovery phase of the launch.

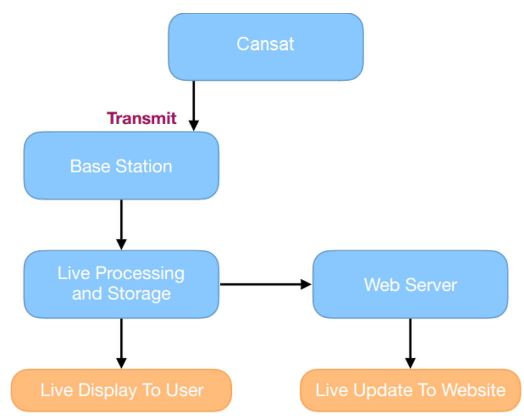

Figure 3.5: Landing and recovery system diagram

A buzzer will also be implemented to the design, which will sound after the cansat enters post-landing mode, which will sound at approximately 90db, which is equatable to the amplitude of a jet from 300m distance.

3.6 Ground Support Equipment

The team is developing a lightweight, robust base station program, which can be executed with very low system requirements. This has inspired a stretch goal to create an all-in-one base station by setting up the base station software on a Raspberry PI package, as well as the communications module and I/O for SMA, display outputs, and USB ports.

Our base station equipment will include:

- Custom made base-station computer with WiFi and bluetooth connectivity and ¿3 USB ports.
- HC-12 communications module and dedicated Yagi antenna
- Battery charging station and 5V supply

Our base station will receive, aggregate and display live data from all the onboard sensors, showing the relevant graphs to our primary and secondary missions, respectively. It will also store all raw and processed data locally, in addition to backing up to an external drive or laptop.

Chapter 4

Project Planning

4.1 Gantt Chart

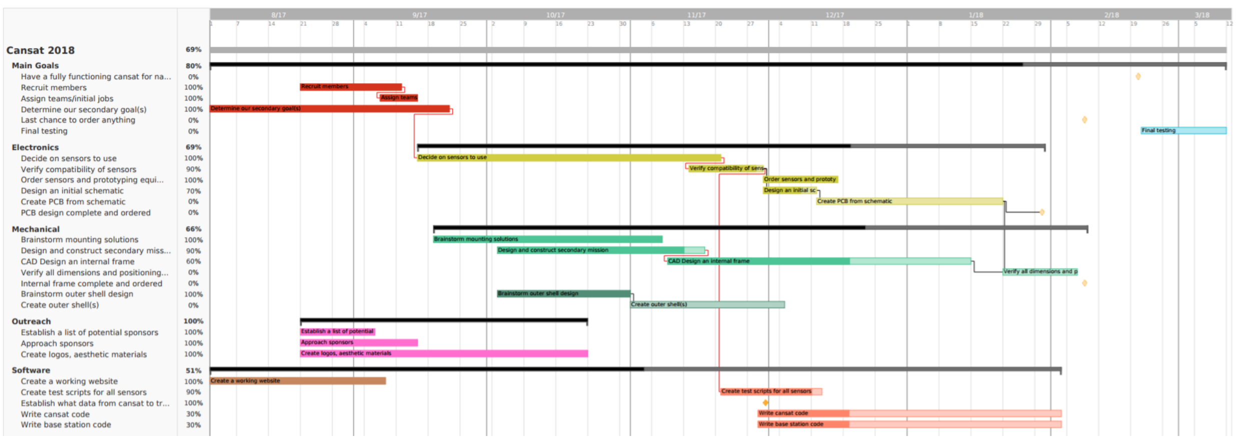

Figure 4.1: Gantt chart as of December 2017. Full resolution chart available at:`https://goo.gl/dDAatf`

4.2 Team and External Support

We currently have five team members with varying levels of experience in mechanical, electronic, and software design. While our team has a good technical background in all aspects required for cansat design, We have now completed a training programme to ensure the team is prepared for the competition with the appropriate skills.

We also continue to arrange occasional meetings and communications with professionals in various relevant industries, thus improving our understanding of how to further improve the quality of our electronics and mechanical design decisions, as well as aiding us in preparing our secondary mission.

4.3 Risk Analysis

Potential Issue	Mitigation Method
Unable to produce fiberglass shell with required durability or tolerances.	Use 63mm PVC tubing instead of fiberglass. We already have a source for the PVC tubing.
Communications modules do not have required range with Yagi antenna.	Use provided radio modules instead of HC-12 radio modules.
Cansat does not meet battery life requirements.	2 more cells will be implemented, giving 9600mAh of battery life (double that of the current design).
Cansat is over budget.	We will remove non-critical systems from the cansat or move to a more conservative design based around the supplied kit.
Cansat is overweight.	We will create an polymer internal frame to replace the current aluminum design.
Cansat is underweight.	We will add 2 more cells, serving to increase battery life in addition to solving weight issues. We also have space for ballast weight on the bottom of the cansat.
Missing internal space necessary to implement all proposed sensors.	Select sensors will be removed to meet size spec.
Diamagnetically stabilised levitation experiment is not working as intended	We are working towards creating multiple alternate experimental modules along with programs for them. This will also allow us to demonstrate the modular abilities of the cansat.
Magnetic fields interfering with electronics or communications.	Iron shielding will be placed between the experiment and electronics, or around the experiment.

4.4 Test Plan

Feature to Test	Testing Method
Radio transmission.	Radio range and transmission tests will be conducted line-of-site in an open field with our final Yagi antenna, as well as forestry and a hill. We have already organised an ideal location for this.
Cansat parachute.	The cansat will be dropped from a drone at heights from 100 to 200 meters in accordance with the cansat guidelines document.
Power consumption and battery life.	Power consumption and battery life will be tested by measuring active battery life under a variety of temperature conditions.
Cansat durability.	The cansat frame will be dropped, with electronics substituted with weights, from a variety of heights to simulate worst-case parachute conditions.
Robustness of cansat and base station code.	All inputs and functions of the programs will be extensively tested to ensure that our software design will perform to a high standard.

Chapter 5

Outreach Programme

In addition to the following, the team has also renewed the graphical designs for this campaign, which will help to give the team a fresh and stand–out aesthetic.

Figure 5.1: New Team Logo

5.1 Media

For this years outreach we have designed, programmed and are hosting our own website at `gwccansat.com`.

We also host pages on Instagram, Facebook and Twitter, giving regular updates on our Team's progress.

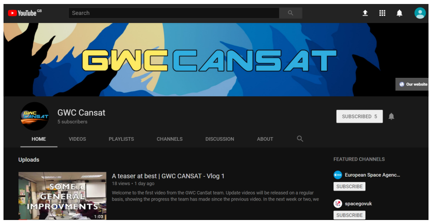

Figure 5.2: Team YouTube channel

The team's YouTube channel now has a fortnightly video blog, where we will be informing viewers of our progress. Several videos have already been released and we look forward to receiving feedback on this aspect of our project. Our channel can be viewed here: `https://goo.gl/YxHHkH` and our first video can be viewed here: `https://youtu.be/tEawegQ2coM`

We aim to livestream much of the development process, such as the electronics PCB design and mechanical CAD modelling. Additionally, we would like to livestream and record elements of the competition experience this year, to show to our sponsors and other interested viewers, as we have received a magnitude of positive engagement and interest in this aspect of the competition.

5.2 Physical Press

Following the success of our booth at the 2017 Edinburgh maker faire, we have signed up to attend as makers again this year. We are aiming to further improve our setup to engage interested parties (particularly children) in the project to a greater extent than previously, including potential interactive programming or engineering challenges.

Additionally, we will continue to participate in engaging younger children from the GWC junior school with STEM education, as we did last year. We believe that in engaging kids with STEM at a young age, we will continue to inspire generations of scientists and engineers to come. We will also research into organising visits to other primary schools around the Edinburgh area.

Figure 5.3: Primary school children getting involved in parachute design

Following the largely successful 2017 campaign, the team featured in the 'Edinburgh Evening News' and aims to feature in other larger scale press releases such as this in future months.