WARWICK CANSAT
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CanSat Competition
UNITED KINGDOM

CanSat Competition
UNITED KINGDOM

2018/19 Design Review

Warwick University CanSat

1009

v01: 1st February 2019

Outline

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Team Organisation

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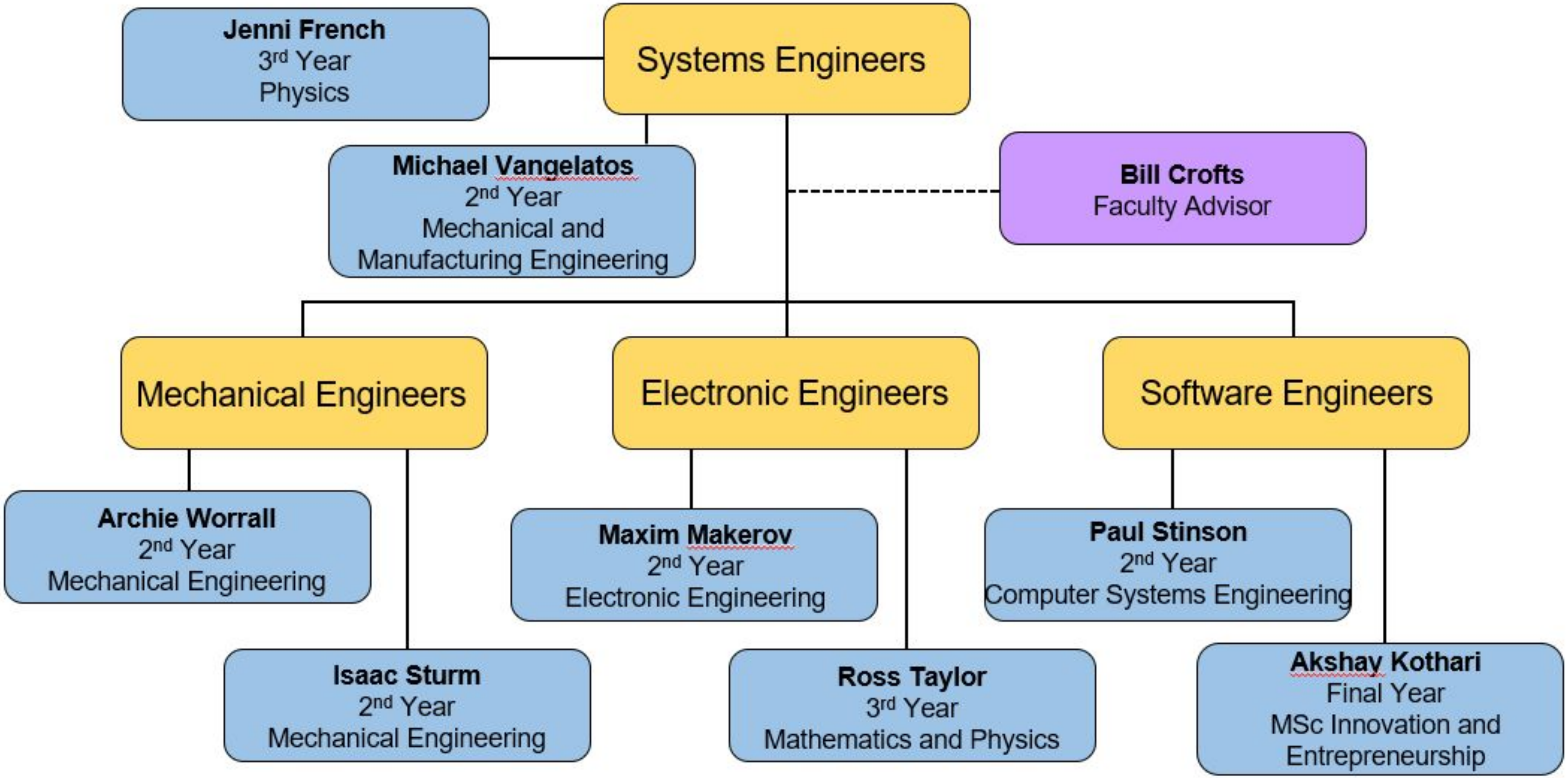

Acronyms

A	Analysis
I	Inspection
T	Testing
D	Demonstration
I & T	Integration and Testing
GUI	Graphical User Interface
FSW	Flight Software
DCS	Descent Control System
CDH	Communications and Data Handling
EPS	Electrical Power System
GCS	Ground Control Station
LED	Light Emitting Diode
HD	High Definition

RF	Radio Frequency
RTC	Real Time Clock
WUSAT	University of Warwick Satellite Programme
PLA	Polylactic Acid
SD	Secure Digital
I2C	Inter-Integrated Circuit
SPI	Serial Peripheral Interface
SRAM	Static Random Access Memory
IDE	Integrated Development Environment
IO	Input/Output
USB	Universal Serial Bus

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Systems Overview

Mission Summary

Broad Mission Objectives:

1. Build a CanSat with an atmospheric-sampling sensor and a parachute.
2. Launch CanSat from QbCan Releaser at an altitude of 100-150 metres.
3. Immediately after drop, the CanSat shall deploy the parachute.
4. The CanSat shall collect and transmit atmospheric data, battery voltage and altitude to a Ground Control Station in real-time throughout its descent phase.
5. The CanSat shall land intact, after which it will continuously operate an audio beacon for location.
6. The Ground Control Station shall receive and display CanSat data.

Mission Summary

External Objectives:

- Obtain sponsorships.
- Minimise production costs.
- Develop webpage and social media presence to promote UK CanSat competition and team sponsors.
- Promote Warwick Aerospace and WUSAT to a wider audience.
- Publish regular updates of progress on webpage and social media.

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System Requirements Summary

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Requirement #	Description	A	I	T	D
1	Total mass of the CanSat will be below 350g.		X		X
2	The dimensions of the CanSat will not exceed a cylindrical envelope of 66mm diameter x 115mm height with 45mm extra height for the external parachute.		X		X
3	There will be no sharp edges to the CanSat that could get caught in the QbCan Deployer.		X		X
4	The QbCan Deployer will not be used as part of the CanSat operation.	X			X
5	The CanSat will deploy from the QbCan Deployer payload area.	X			X
6	The Descent Control System (parachute) will be deployed immediately after release from the QbCan Deployer.	X		X	X
7	The descent rate of the CanSat will be between 5-10 ms^{-1}.	X		X	X
8	All electronics will be hard mounted or glued using hard adhesives.		X		X
9	The structure of the CanSat will accommodate all electronics.		X		X
10	All electronics will be enclosed within the structure of the CanSat and shielded from the environment, with the exception of sensors.	X		X	X
11	The CanSat will collect air pressure, outside temperature and battery voltage once a second during the descent.	X	X	X	X
12	The CanSat will determine altitude with respect to ground level based on pressure and temperature readings.	X		X	X
13	Each sensor data packet will be tagged with the time and packet count.			X	X

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System Requirements Summary

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Requirement #	Description	A	I	T	D
14	The sensor data packet will follow this structure: packet count, mission time, pressure, temperature, altitude, battery voltage, soft state.				X
15	The CanSat will store all data packets onboard.		X		X
16	The CanSat will transmit all sensor data packets to the Ground Control Station during the flight.			X	X
17	The CanSat will include an LED as a power indicator, which will indicate when the CanSat is operational.		X	X	X
18	The audio beacon will operate continuously after landing.		X	X	X
19	The audio beacon will indicate if any electronic component in the CanSat is not functioning.		X	X	X
20	The battery source will not be lithium polymer or lithium ion.		X	X	X
21	The battery source will be easy to remove and replace.	X	X		X
22	The microcontroller will be accessible with a USB plug without having to completely disassemble the CanSat.	X	X		X
23	Each team will build their own Ground Control Station.				X
24	All received data packets will be displayed in real time and SI units.		X	X	X

Bonus Requirements Summary

Requirement #	Description	Justification	A	I	T	D
Bonus 1	LED will light to indicate successful run of setup sequence.	Availability of parts required and team electronics experience.		X	X	X
Bonus 2	HD camera will be included in the CanSat to capture the descent. The camera will fit entirely inside the structure of the CanSat.	Team experience from previous projects that involve small HD cameras.		X	X	X

System Level CanSat Overview

Screw cap

Parachute mounting holes

Inner sled

Foam cushioning

Rounded corners

Arduino MKR Zero

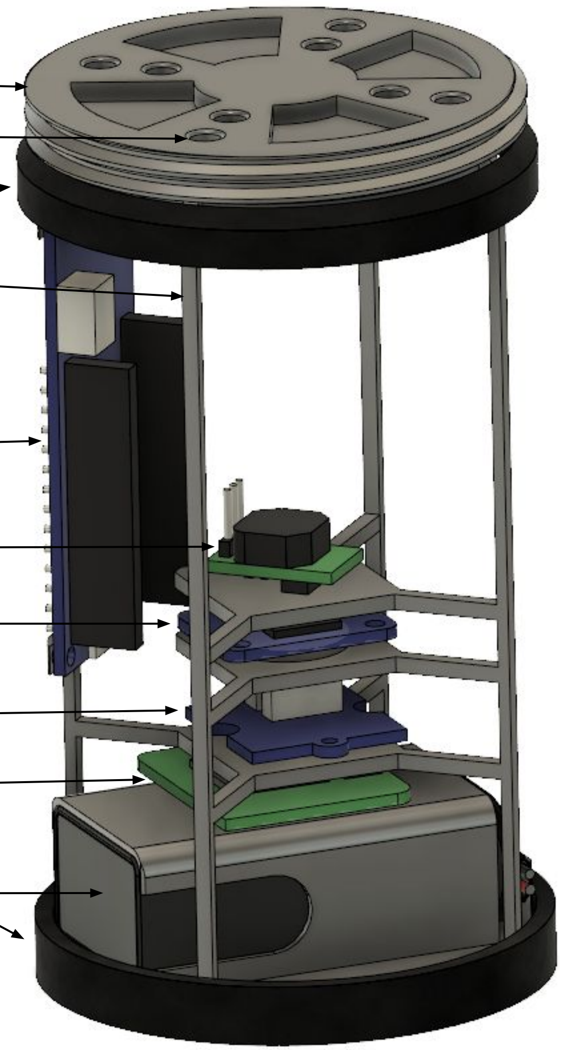
Power regulator

Precision RTC

Barometric Pressure Sensor, Temperature Sensor

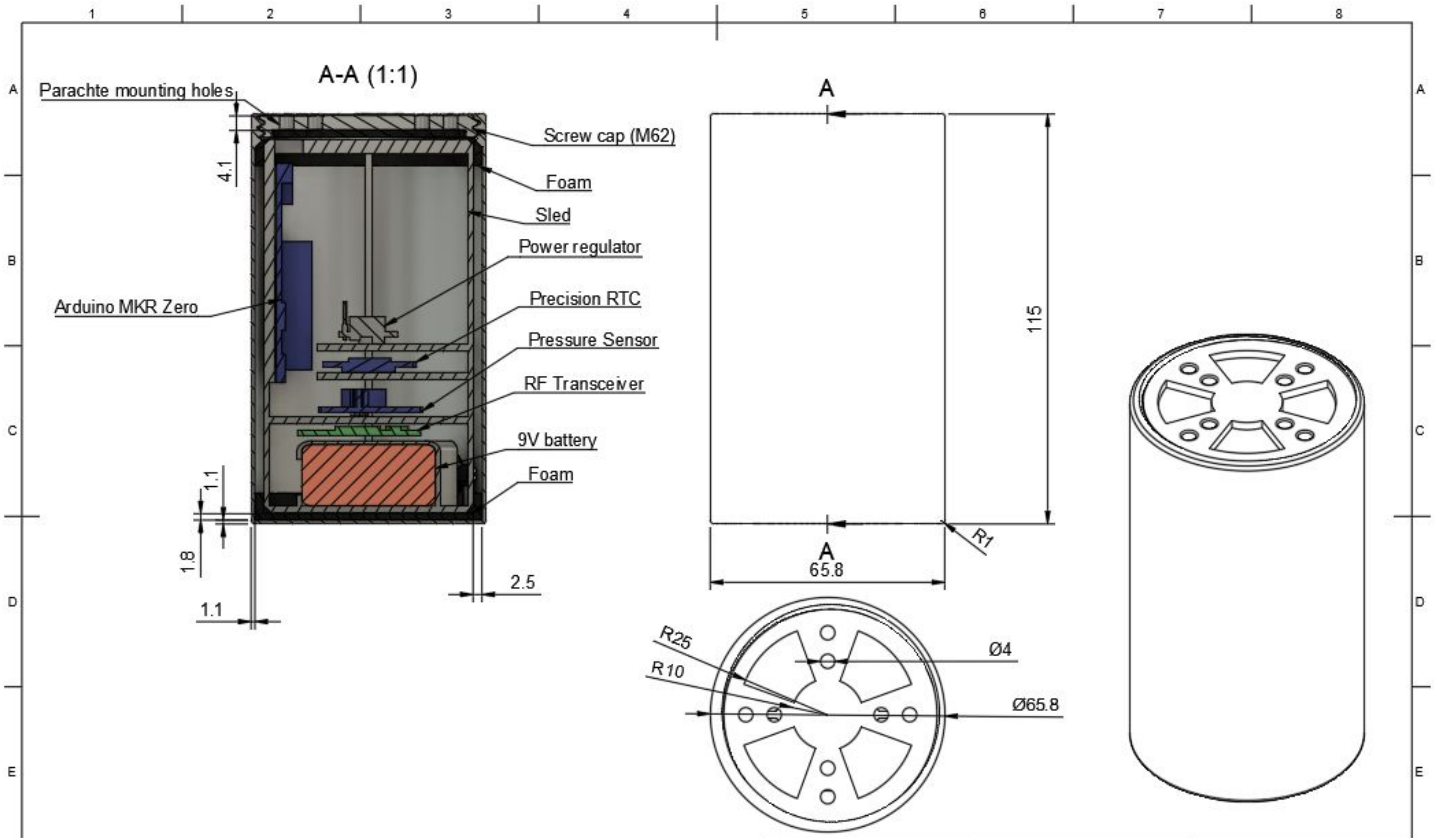
RF Transceiver

9V battery



CAD model without outer shell

System Level CanSat Overview



CAD drawings of CanSat (not to scale)

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System Level CanSat Overview

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- Screw cap for easy access.
- Parachute attached at 4 points in top of the screw cap so it can be replaced easily.
- Sled inside so all components can be removed and inspected/repaired/mounted easily and the battery can be replaced.
- Sled mounted in foam to ensure secure fit and increase impact resistant.
- 3D printed case and mounting sled out of clear PLA.
- Sled can be removed easily so that usb plug and SD card can be accessed.
- Led indicator can be seen through translucent plastic.
- Modular outer design so that if any part breaks it can easily be reprinted and replaced.
- Single ripstop nylon parachute aiming for 7 m/s.
- Combined temperature and air pressure sensor with altitude calculated from these values.
- Microcontroller board with built in micro SD card slot, allows for logging of data packets to SD card.
- 433MHz packet radio module, transmitting data to a matching module on the ground
- All electronics powered from a single 9V PP3 battery.

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System Level CanSat Configuration

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Battery replaced as required and CanSat powered on

↓

Confirm CanSat is powered with power indicator light and that the beacon is not sounding to indicate an initialisation error

↓

Load CanSat into launch vehicle and wait while it is carried to drop height

↓

Send mission start command to begin data recording, then give clear to drop

↓

Track CanSat visually as it descends

↓

After touchdown send mission stop command to end data recording and activate audio beacon

↓

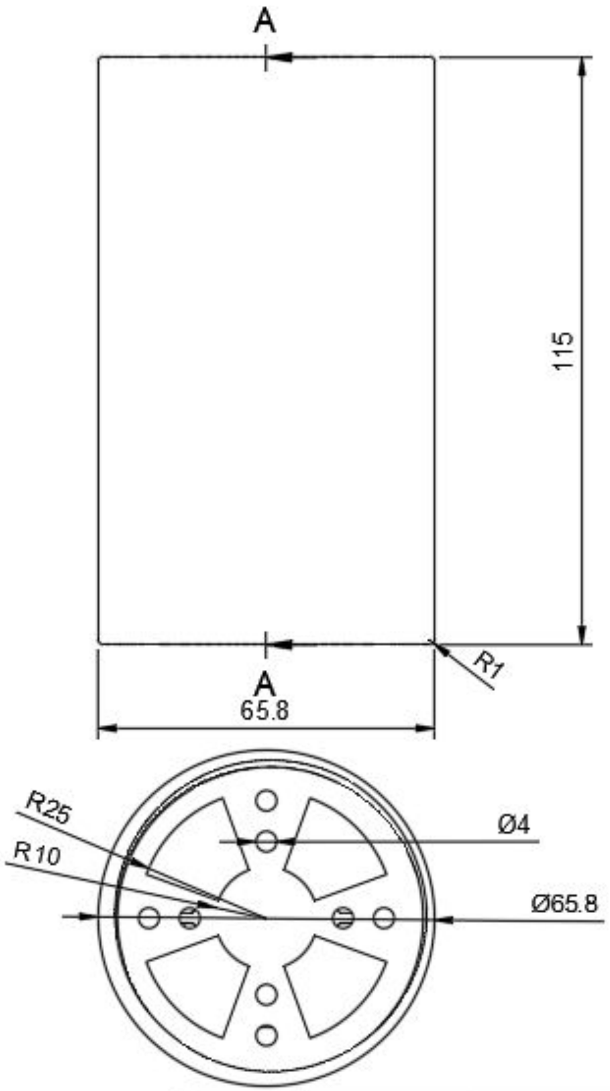
Locate and recover CanSat, powering it down once retrieved

↓

Remove SD card and connect to computer to download data for analysis

Launch Vehicle Compatibility

- 0.2mm in diameter smaller than Maximum specifications- allo for clearance assuming launch vessel has standard tolerances i place for 3d printing (approx 0.2mm), this will allow for a smoo exit from the launch vehicle.
- Screw cap slightly recessed to avoid chance of being over heig limit.
- No sharp protrusions on edge or top of module.
- Maximum height cansat as parachute will not take up full space.
- Loosely packed parachute will fill the useable 45mm height in a sponge like manner.
- Rounded corners to reduce chance of catching in launch tube and to allow for easier loading.



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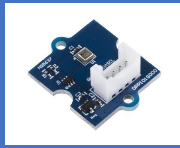
Sub-Systems Overview

Sensors Overview

Temperature + Pressure Sensor – For collecting data

Picture	Name	Accuracy and Resolution	Communication Interfaces	Ease of use	Power Inputs	Dimensions and Weight
	TE Connectivity MS5637 Breakout	Calculated Altitude: 2m Accuracy 0.13m Res. Pressure: 200 Pa Accuracy 1.6 Pa Min. Res. Temperature 1.0ºC Accuracy 0.01° C Res.	I2C	Arduino Library Available	5/3.3V Input	20.6x20.6 mm Weight Unknown

Sensors Overview

Reasons for sensor choice:

- The MS5637 sensor can measure pressure and temperature, which can then be used to calculate pressure. This means all of the required data can be measured/calculated with only one sensor, minimising weight and space requirements.
- The sensor uses I2C to communicate readings to the microcontroller, this is slower then SPI in most cases but is still more then fast enough for the 1Hz readings specified for the CanSat competition. However, it uses fewer wires then SPI and so reduces wiring complexity.
- It is compatible with the 3.3V logic levels used by the microcontroller.
- The sensor is reasonably accurate in both its temperature and pressure measurements.
- It is “fully factory calibrated”.

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CDH Overview

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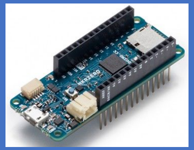
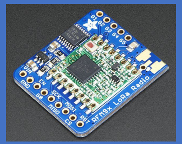
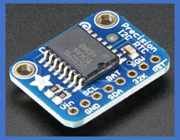
Microcontroller – For overall control of flight systems

Picture	Name	MCU Model and Frequency	Communication Interfaces	Memory	Power Inputs	Dimensions and Weight
	Arduino MKR Zero	ATSAMD21G18 @48MHz	1xI2C 1xSerial 1xSPI	256KB Flash 32KB SRAM No EEPROM	5V USB Micro 5V Vin Pin LIPO Battery	61.5x25 mm 20g (including packaging)

Radio Transceiver – For transmitting data back to ground station

Picture	Name	Frequency	Communication Interfaces	Advertised Range	Power Inputs	Dimensions and Weight
	Adafruit RFM96W LoRa Breakout	433MHz	SPI	“2 Km line of sight using simple wire antennas”	5/3.3V Input	29x25 mm 3.1g

Real Time Clock – For keeping track of time when unpowered

Picture	Name	Accuracy and Resolution	Communication Interfaces	Memory	Power	Dimensions and Weight
	Adafruit DS3231 Breakout	Possible Few Sec/Month Drift 1 Second Res.	I2C	None	5/3.3V Input 840nA battery-backup current	23x17.6mm 2.1g

CDH Overview

Reasons for microcontroller choice:

- Small dimensions and light weight. Weight of the board alone will be confirmed once it is on hand but is expected to be similar to Adafruit feather boards, which are in the range of 5-6g.
- It also features a built in SD card slot, which means a separate module for this function is not necessary. This will save space, weight and additional wiring.
- The microcontroller used on the board, the SAMD21G18, has a higher clock frequency then the standard Arduino Uno and more flash and SRAM. This will allow for more flexibility during the development of the FSW, as computation will be faster and running out of memory is less likely.

Reasons for radio choice:

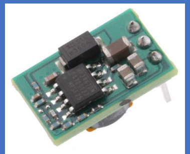
- Small and lightweight.
- Allows for identification of packets so they're only received by other radios with the correct ID.
- Advertised range should be sufficient for mission requirements.
- Arduino library and examples available.

Reasons for real time clock choice:

- More accurate then other modules (temperature compensated for reduced drift).
- Simple I2C interface, with library available for Arduino.

Power Overview

5V Regulator – For powering onboard systems from batteries

Picture	Name	Output Voltage	Input Voltage Range	Output Current	Efficiency	Dimensions and Weight
	Murata Power Solutions Switching Regulator	5V	7-36V	1.5A	90.5%	16.5x10.4mm 2g

Battery – For powering CanSat

Picture	Name	Nominal Voltage	Chemistry	Typical Capacity	Connector	Dimensions and Weight
	9V PP3 Battery	9V	Alkaline	~600mAh at 25mA ~400mAh at 100mA	Industry Standard 9V PP3 Connector	48.5x26.5x17.5mm 45g

Power Overview

Reasons for regulator choice:
- Small size and lightweight.
- High maximum output current (more than necessary for CanSat design by a good margin).
- High efficiency.
- No heatsink required.
- Short circuit protection.

Reasons for battery choice:
- Standard size, easy for mechanical design.
- Easy to source.
- Compact.
- Voltage within regulator input range.
- One battery, less time consuming to replace than pack of multiple batteries.
- Should provide multiple hour runtime, suitable for mission requirements.

FSW Overview

Chosen programming language: Arduino C/C++ variant

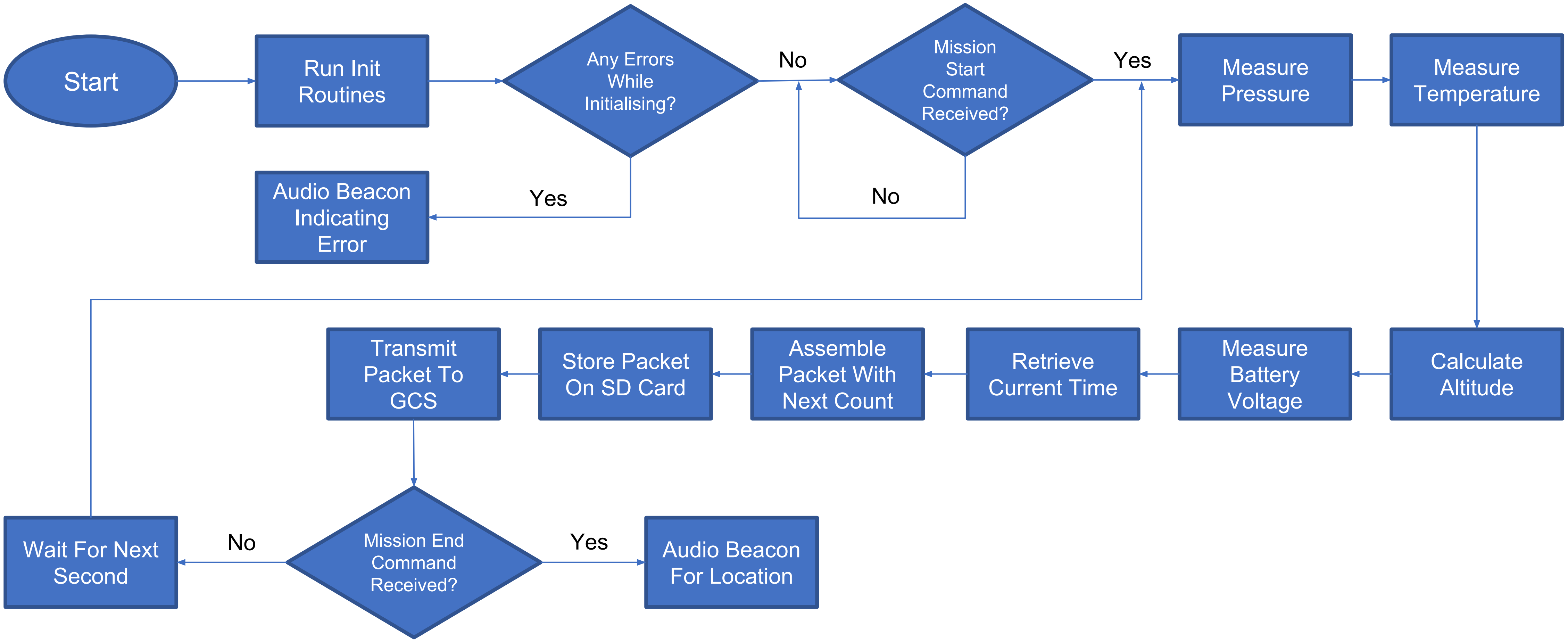
Reason for selection: Past experience, ease of use, large number of libraries and examples to provide guidance.

Chosen development environment: Arduino IDE (considering moving to platformIO)

Reason for selection: Built in support for Arduino boards and language. Easy to add additional libraries. (May move to platformIO for a more advanced features like code completion and linter)

Current stage of development: Several components have been tested individually, but work on the complete FSW has not begun in earnest.

FSW Overview



GCS Overview

The GCS will use a matching radio module to the one used on the CanSat, connected to a suitable microcontroller. Using the radio, the microcontroller can receive packets transmitted by the CanSat before passing them to the GCS GUI program running a computer. The microcontroller will communicate with the computer using serial over USB.

The following software will be used to develop the GCS GUI:

- Python 3.7 – Base programming language
- Tkinter – For GUI elements
- Matplotlib – For Graph plotting
- pySerial – For USB serial connection to ground station hardware
- Numpy – For mathematical functions

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GCS Overview

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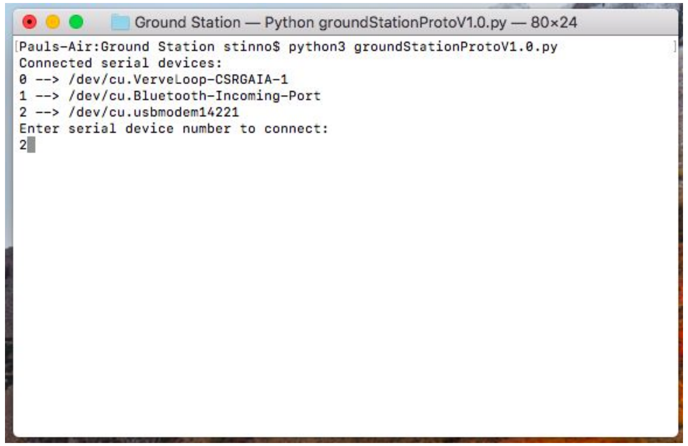
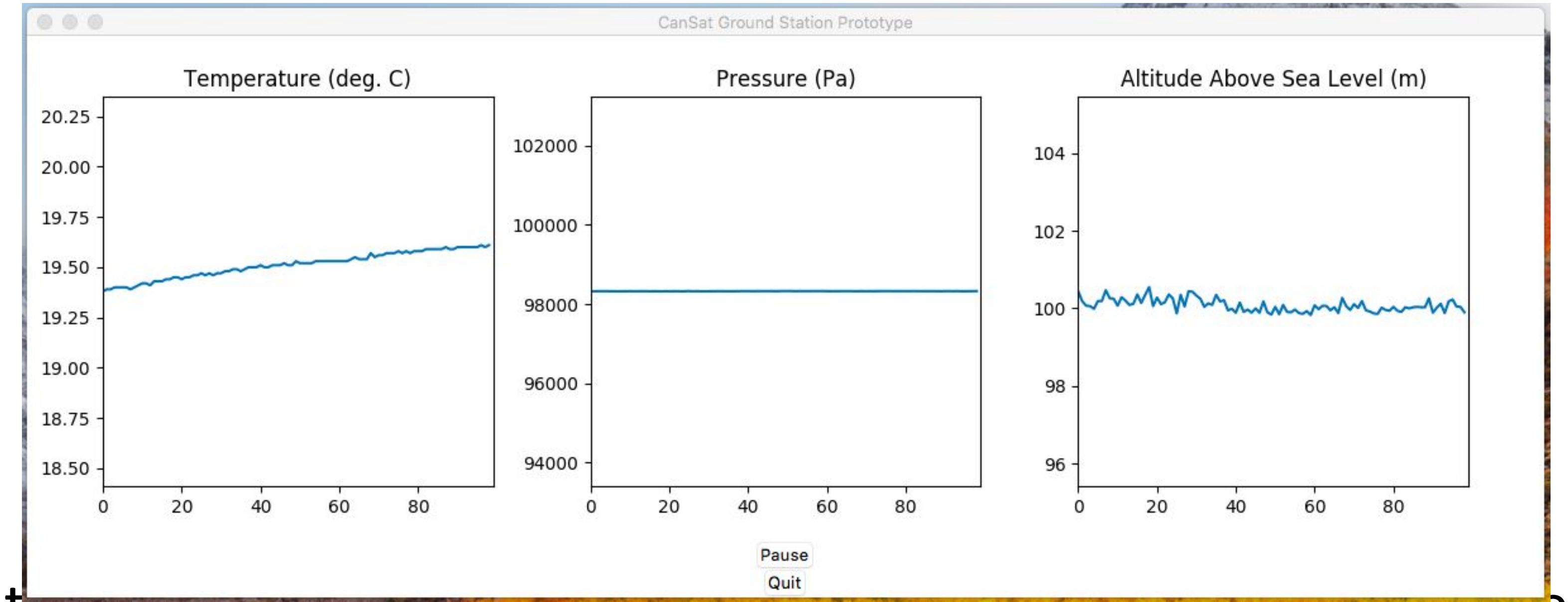
The following images are screenshots of the current GUI prototype:

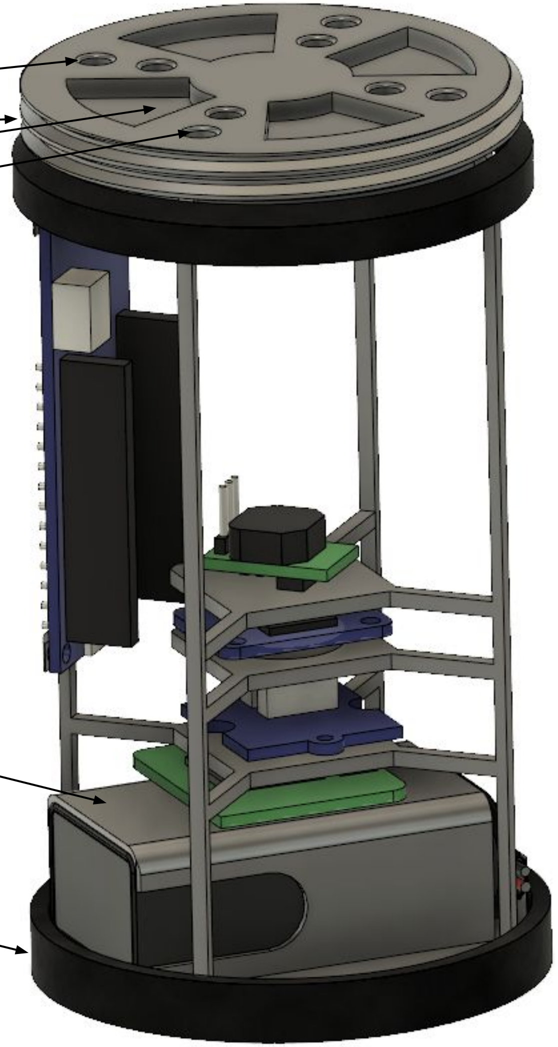




This version allows connecting to a microcontroller with USB serial (currently port is selected in command line on start). The microcontroller sends pressure, temperature and calculated altitude values once per second. When new values are received the graphs are updated live. The pause button suspends graph updates and quit exits the GUI.

Mechanical Overview

- Parachute attached at 4 points on top of screw cap.
- M62 thread.
- Indents for grip-easy turn on/off.
- Parachute mounting holes.
- Components mounted with a mixture of bolts and hard epoxy (final placements will depend on wiring requirements).
- Modular outer design so that if any part breaks it can easily be reprinted and replaced.
- Battery holder with slots cut for easy replacement.
- Foam cushioning at top and bottom.



CAD model without outer shell

Mechanical Overview

- Screw cap for easy access.
- Sled inside so all components can be removed and inspected/repaired/mounted easily and the battery can be replaced.
- Inner sled easily removable via thumb holes.
- Hole in top of sled for usb plug to be easily accessed.
- Sled mounted in impact resistant foam to ensure secure fit .
- 3D printed out of clear PLA.
- Single ripstop nylon parachute diameter 0.5m attached onto screw top lid.
- LED indicator can be seen through translucent plastic.

CAD model without upper lid

Descent Control Overview

- In order to safely control descent we decided to use a singular ripstop nylon parachute that makes the speed of descent approximately 7m/s (in the middle of the 5-10m/s desired range to allow for uncertainty).
- We tested the possibility of using 3 smaller parachutes to aid stability but found them to be unreliable.
- Using the calculations shown on the next slide we determined the optimal diameter(lain flat) of a single parachute would be 0.5m when using maximum allowable weight.
- The parachute will have a spill hole in the centre of approximately 3% of the projected area in order to aid stability by allowing air to flow smoothly rather than cause turbulence.
- The parachute will be loosely packed above the CanSat as this will allow for immediate and reliable deployment.
- The parachute will be tied onto the removable lid so that backup chutes are quick to exchange.
- The parachute will ideally be bright to aid recapture.

Pre-launch	Launch	Operation	Recovery	Post-operation
Parachute will be packed into allowable space above the CanSat.	The parachute will immediately deploy once released.	The parachute will slow the cansat to 7m/s.	The parachute will aid in recovery as it will be a large item to see.	The parachute will be untangled and repacked.

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Descent Control Overview

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Total Mass(Kg)	0.35	Weight (N)	3.4335	ρ(kg/M^3)=	1.229	projected /actual ratio	0.65
coefficient of drag*		1.5					

Fdrag = ½ r Cd A v^2

single parachute-vary diameter to find terminal velocity

Diameter(m)	Projected Diameter	Area (m^2)	Area-3%	Cd*	Vt (m/s)
0.6	0.39	0.119459060	0.1158752	1.5	5.669784
0.55	0.3575	0.100378794	0.0903409	1.5	6.421251
0.5	0.325	0.082957681	0.0746619	1.5	7.063377
0.45	0.2925	0.067195721	0.0604761	1.5	7.848196
0.4	0.26	0.053092915	0.0477836	1.5	8.829221
0.35	0.2275	0.040649263	0.0365843	1.5	10.09053
0.3	0.195	0.029864765	0.0268782	1.5	11.77229
0.25	0.1625	0.020739420	0.0186654	1.5	14.12675

*= estimate 0.8-1.8?? From nasa website

V = sqrt ((2 * W) / (Cd * ρ* A))

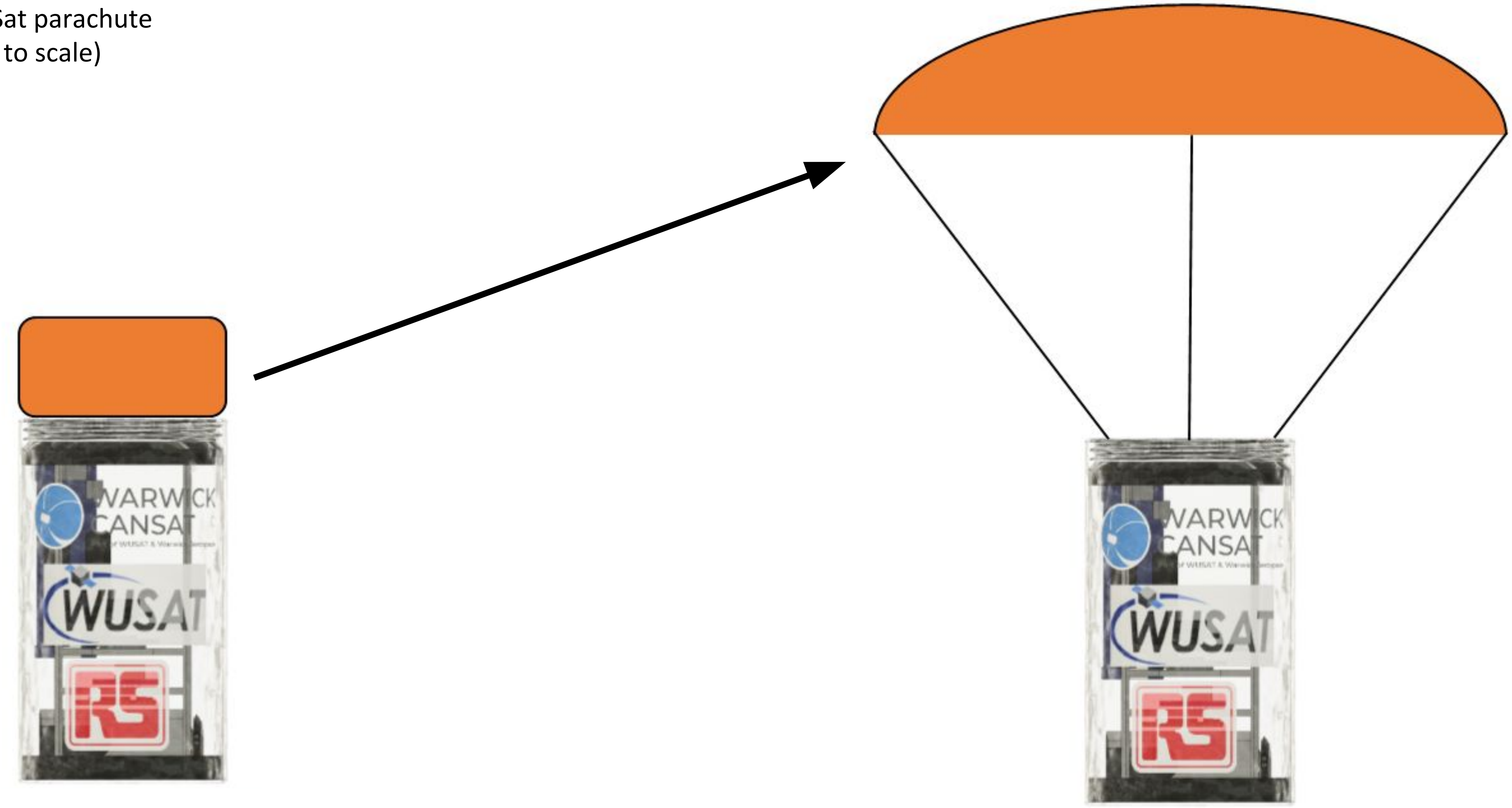
spill hole area= 3% because of hole in top roughly needs to be 3% of parachute

Diameter	projected Diameter	area	3%area	spillhole diameter
0.5	0.325	0.08295768101	0.002488	0.05629165125
0.35	0.2275	0.04064926369	0.001219	0.03940415587
0.3	0.195	0.02986476516	0.000895	0.03377499075

- Above is the calculations used to determine the desired diameter of a parachute.
- Most formulae and constants were taken from a NASA website [1]
- Spill hole area of 3% is common among manufacturers.
- The area of the parachute when laid flat cannot be used in equations as it does not accurately represent the area that causes drag as the edges are almost parallel with air flow direction.
- Projected (useful) area of a flat shute is approximately 65% of flat area.

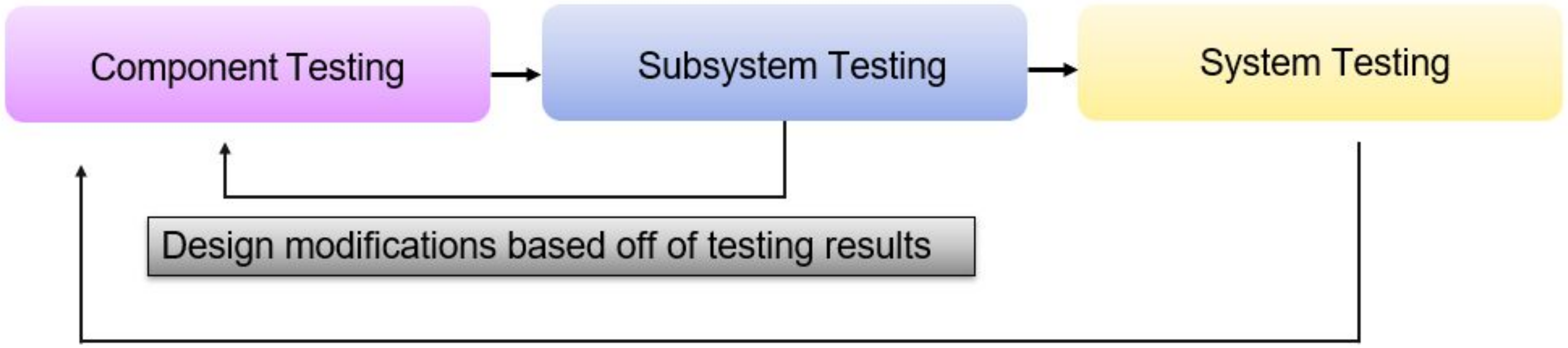
Descent Control Overview

Drawings of CanSat parachute deployment (not to scale)



I&T Overview

- Testing of the CanSat and its components and subsystems will follow the structure below



such as DCS and CDH, and then the system can be tested as a whole.

- Tests will verify that components, subsystems and systems function as expected, and complete the required objectives.
- The results of testing and potential failures/improvements will result in design modifications as necessary, and testing will restart from the component level.

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Integration and Testing Overview

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- Key areas for failure and how they can be mitigated are presented below.

Subsystem	Potential Failure	How to mitigate
Electrical Power System	All power comes from a single battery. If this fails, there is no power to any sensors or electronics, and key objectives will not be able to be completed.	Battery chosen such that it is sufficient to support the electronics and sensors used. This will also be tested, and a new battery will be used on flight day.
Communications and Data Handling	Transmission of flight data is performed by a single microcontroller. A combined sensor is used, so if this does not work, key objectives will not be able to be completed.	Testing of the CanSat will ensure that the microcontroller functions as expected and transmits to the Ground Control station. Testing plan will ensure sensor works correctly, including when it is integrated into the system.
Mechanical	Components become dislodged during launch, flight, or landing.	Components will be hard mounted within the CanSat and tests will be carried out to ensure the strength of these mounts is sufficient.
Descent Control	Parachute fails to deploy. This will mean the descent rate is uncontrolled and the CanSat will crash.	Parachute deployment will be rigorously tested, including modelling the release of the CanSat from the QbCan Deployer.

- Environmental tests will also occur at each testing level for factors such as shock, acceleration and temperature.

Mass Budget

Electronic Parts:

Part	Stock Number [RS]	Mass (g)	Cost
Barometric Pressure Sensor, Temperature Sensor Development Board	146-8208	2.5	£7.84
Transceiver Breakout Board	124-5502	3.1	£13.95 x 2 (1 ground, 1 sat)
Arduino MKR Zero	169-7584	20 (shipping mass so actually much lighter)	£19.59
Switching Regulator	796-2138	2	£3.18
9V PP3 Battery	914-5051	45	£1.59
RTC Board	[Non-RS] Part ID: DS3231	2.1	£13.00

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Mass Budget

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Mechanical Parts:

Part	Specifics	Mass (g)	Cost
Shell	3D-printed by Warwick CanSat Transparent PLA (sold in reels).	82.5 (based on PLA density of 1.25 g/cm3)	£12-15 (Reel not completely used up)
Impact Resistant Foam	Stratocell (light, cheap, strong and durable) or similar alternative foam.	6.28 (based on density of roughly 0.0721 g/cm^3)	£9.43 (Quote: £7.99 + £1.44 VAT) (Free delivery)
Parachute	Size determined by weight of chute and descent rate. (roughly $0.196 m^2$)	9.42 ($48 g/m^2$ according to ripstop nylon provider) 11.0 (with strings)	Min. £10.50 Max. £24.95
Parts fastening	Epoxy resin (RS supplies)	11 (overestimate of volume of epoxy)	£3.22

Mass Budget

Total Electronics Mass:	72.7 g (underestimate)
Total Mechanical Mass:	109.2 g
TOTAL PRELIMINARY MASS:	181.9 g

This mass is calculated without wiring and without added features like the HD camera.
It currently makes up 51% of the maximum mass. This leaves ample room for design changes to make the CanSat more robust or more complex in the realisation of extra objectives.

Price Budget:
With current sponsorship from RS Components, our costs are estimated to reach £51.50.
If sponsorships are obtained for parachute and protective foam parts, costs may be reduced to £16.75.

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Conclusions

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Major Accomplishments
Most parts ordered and delivered.
Sponsorship obtained from RS.
Parachute mount prototype completed.

Main Unfinished Work
CanSat Assembly
CanSat testing.

Justification to Progress
Sponsorship obtained.
Thus far, are on schedule with progress.

References

[1] https://www.grc.nasa.gov/www/k-12/VirtualAero/BottleRocket/airplane/rktvrecv.html