THE UNIVERSITY OF SYDNEY

SCHOOL OF AEROSPACE MECHANICAL AND MECHATRONIC ENGINEERING

AERO3760: SPACE ENGINEERING 2

# SnapSat Preliminary Design Report

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| Name and Email | Role and Responsibility |
|---|---|
| James Allworth \| 312073038<br>jall8741@uni.sydney.edu.au | *Attitude Determination and Control System* |
| Thomas Forbutt \| 312101058<br>tfor8012@uni.sydney.edu.au | |
| Oscar McNulty \| 312106130<br>omcn3220@uni.sydney.edu.au | |
| Penelope Player \| 312106718<br>ppla7388@uni.sydney.edu.au | |
| Nikita Sardesai \| 312088205<br>nsar2497@uni.sydney.edu.au | |

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# 1 Introduction

*Snapsat* is a design solution as a part of the AERO3760: Space Engineering 2 course at the University of Sydney. The project involves specific design specifications as set out by the course administrator and the CubeSat requirements [?]. <to complete!>

# 2 Spacecraft Deign Overview

Summarised in table 7.1 below is the outline of all components in the SnapSat proposed design.

Table 2.1: SnapSat Design Overview

| **Subsystem** | **Description** |
|---|---|
| Structural | |
| ADCS | |
| EPS | |
| OBC / OBDH | |
| TT&C | |
| Thermal | |

## 2.1 Subsystem Design Schematic

The layout of Snapsat, with the interconnects of power and data lines between the subsystems is shown in the figure below. (NOTE: this is only an example for now)

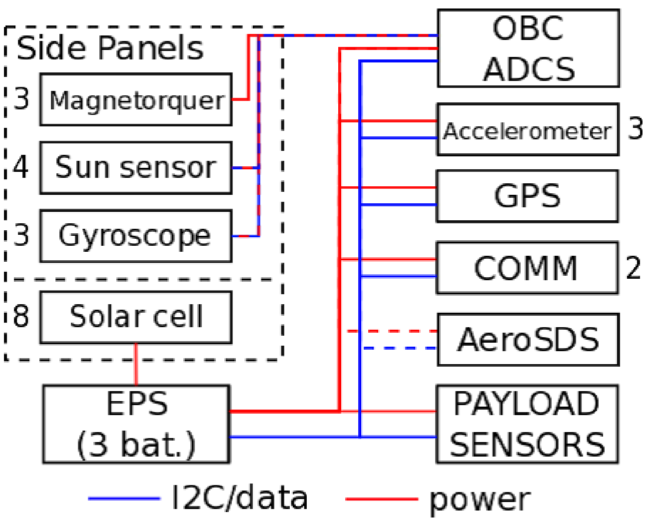



Figure 2.1: Design Schematic

# 3 Payload Design Overview

The CubeSat had been pivotal to the space research and development industry and had generally increased our accessibility to the cosmos. The cubesat platform uniquely offers an extremely low construction and launch cost in comparison to major satellite manufacturers. This has spurred on many educational bodies and small research groups to collect and analyse their own data, especially in developing nations [**?**]. Universities have pioneered the build of the smallest of satellites (nano- and pico-), this has been assisted with the miniaturisation in many technological fields such as electronics, materials ans sensors. These small sizes enable the cubesat to 'piggy-back' on the launch of much larger satellites, because of this they are able to get to very high (and expensive) orbits of a fraction of the price. Many big aerospace companies have also made use of the tiny platform such as Orbital Sciences (2006 [**?**]) and Boeing (2009 [**?**]) along with the United Nations, who have formally recognised the developmental benefits of small satellites [**?**].

Despite the quick growth of this industry in the aerosapce and related academia fields, we are only now seeing the cubesat break into early STEM education. Currently, only science and technology scholars and graduates have the full accessibility to the design of cubesats, our ease of access is not well known amongst the general public. Snapsat hopes to change this, by bringing space to social media via beautiful photographs and Twitter.

Snapsat is a nano-satellite designed for outreach and space accessibility for educational bodies and the general public. In a sun-synchronous orbit at an altitude ot 350km, Snapsat will be in the prime position of Earth observation. Users can send a message to the cubesat, which will take a low resolution image of the Earth and tweet it to the world.

This turns off the

# 4 Spacecraft Modes of Operation

The spacecraft will experience the following modes during its lifetime. A different configuration of system operations and instructions will be executed by *SnapSat* in each case. These are summarised in table 4.1 below.

Table 4.1: SnapSat Modes of Operation

| **Spacecraft Mode** | **Description** |
|---|---|
| Launch Mode | This turns the satellite off for launch to comply with CubeSat Design Specification 2.3.1. During launch the deployment switch is tripped which will turn the satellite on and transfer it into Establish Contact Mode. |
| Safe mode | In this mode, only essential satellite systems are kept ON such as the OBC, power board and VHF receiver. The attitude is not controlled and the transmitter is turned on occasionally for status updates. |
| Recovery/De-tumble mode | This mode is used to de-tumble the spacecraft after deployment into orbit as well as to recover it from any spin states (such as after Safe Mode). All Safe Mode components are ON, as well as the ADCS system. Other devices can be turned ON by ground command. |
| Establish Contact Mode | In this mode the satellite waits 30 seconds before deploying the antenna and attempting to communicate with the ground station. The ACS system works to orient the satellite correctly. |
| Payload Operation Mode | This mode is used only when taking a picture. The camera module is booted up, the camera takes a picture, stores it is RAM/ROM and then the camera is powered town again to conserve power. This mode can be triggered by reaching a preset GPS location or manually via communications. This mode can be entered either by reaching a GPS coordinate or through ground control command. It exists this mode straight into Relay Picture Mode. |
| Relay Picture Mode | This mode is entered after Payload Operation Mode and causes the CubeSat to start sending pictures to the ground station. |
| Relay Picture Mode | In this mode the camera is almost constantly transmitting images taken through the camera. It exists into Telemetry Mode when the picture has been sent. |
| Telemetry Mode | In this mode the CubeSat is idle, just displaying basic telemetry. Attitude controlled. |
| etc. (Other Modes) | |

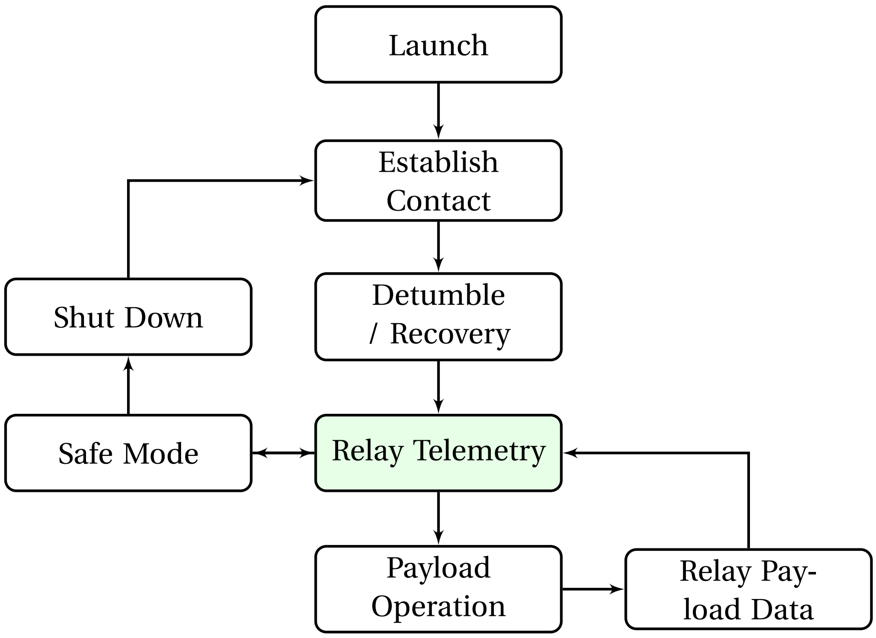


Figure 4.1: Mode Transition Diagram during satellite lifetime

# 5 Structural Design

The proposed one-unit satellite structure will be 3D printed using <???> plastic. This method was chosen in preference of an aluminium chassis primarily because of the ease of access of production.

# 6 System Budgets

This section detail the power and mass budgets of SnapSat. (overview/description)

## 6.1 Mass Budget

The mass budget is shown in table 6.1, it is ensured that *SnapSat* meets the requirement of a maximum weight of 1kg. The component masses were used to determine the center of gravity for the satellie, it is desirable to keep this located close to the geometric centre as the attitude control system (magneto-torques) are placed on the outermost surfaces. Centroid averaging across all three axes was used to calculate this as follows

$$x_{cg} = \frac{\Sigma x_i \cdot m_i}{\Sigma m_i} \qquad y_{cg} = \frac{\Sigma y_i \cdot m_i}{\Sigma m_i} \qquad z_{cg} = \frac{\Sigma z_i \cdot m_i}{\Sigma m_i}$$

The moment of inertia about all three axes is given by

$$I = \int r^2 \, dm$$

The inertial of each individual component was ignored, assuming these were roughly symmetrical. Only the relative locations of the component contributed to the total inertia. Thus, the inertias were given

$$\begin{aligned} I_{xx} &= \frac{1}{\Sigma m_i} \cdot \left( \Sigma \sqrt{(y_i - y_{cg})^2 + (z_i - z_{cg})^2} \cdot m_i \right) && (6.1) \\ I_{yy} &= \frac{1}{\Sigma m_i} \cdot \left( \Sigma \sqrt{(x_i - x_{cg})^2 + (z_i - z_{cg})^2} \cdot m_i \right) && (6.2) \\ I_{zz} &= \frac{1}{\Sigma m_i} \cdot \left( \Sigma \sqrt{(x_i - x_{cg})^2 + (y_i - y_{cg})^2} \cdot m_i \right) && (6.3) \end{aligned}$$

and so on; where $x_i$, $y_i$ and $z_i$ are the positions of each component and $m_i$ is the mass of each component. The inertial matrix was computed using *Solidworks*. It was found to be:

$$I = \begin{bmatrix} I_{xx} & I_{xy} & I_{xz} \\ I_{yx} & I_{yy} & I_{yz} \\ I_{zx} & I_{zy} & I_{zz} \end{bmatrix} \tag{6.4}$$

Table 6.1: SnapSat Mass Budget

| **Subsystem** | **Mass (g)** | **Contingency (g)** | **Mass and Contin-gency** | **Fraction of Total Mass** |
|---|---|---|---|---|
| Structural | | | | |
| ADCS | | | | |
| EPS | | | | |
| OBS / OBDH | | | | |
| TT&C | | | | |
| Thermal | | | | |
| Payload | | | | |
| Integration | | | | |
| Total | | | | |
| Mass Margin | | | | |
| Inertias | | | | |

## 6.2 Power Budget

Table 6.2: SnapSat Power Budget

| | | | Average Duty Cycle by Mode (%) | | | | |
|---|---|---|---|---|---|---|---|
| **Load** | **Power Consumption (W)** | **Number of Units On** | *Safe Mode* | *Recovery Mode* | *Payload Mode* | *Other Mode* | |
| OBC | | | | | | | |
| VHF Rx | | | | | | | |
| S-band Tx | | | | | | | |
| Reaction Wheels | | | | | | | |
| Power Board | | | | | | | |
| Camera | | | | | | | |
| etc. | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **Sum Loads (W)** | | | | | | | |
| **Efficiency** | | | | | | | |
| **Power Consumed (W)** | | | | | | | |
| **Power Generated (W)** | | | | | | | |
| **Power Margin** | | | | | | | |

## 6.3 Pointing Budget

Since this spacecraft is performing Earth observation, it requires a pointing budget. This refers to the ability to orient the spacecraft towards a target having a specific geographical orientation. Along with the pointing accuracy, the satellite needs to be able to map the location from its own location. Errors in both pointing and mapping accuracies will be discussed here.

## 6.4 Link Budgets

Calculations for both link budgets (list assumptions here).

### 6.4.1 Uplink Budget

The uplink budget allows for XXX. The specifications are

- Antenna type at satellite: (omni, directional+gain)
- Frequency Band: (VHF (145.800MHz) , UHF (435.xxx MHz), SHF etc.)
- Objective C/N:
- Bit rate and modulation type:
- Expected occupied bandwidth:

#### 6.4.2 Downlink Budget

The downlink budget allows for XXX. The specifications are

- Antenna type at satellite: (omni, directional+gain)
- Frequency Band: (VHF (145.800MHz) , UHF (435.xxx MHz), SHF etc.)
- Objective C/N:
- Bit rate and modulation type:
- Expected occupied bandwidth:

### 6.5 Data Budget

Data budget CALCULATIONS.

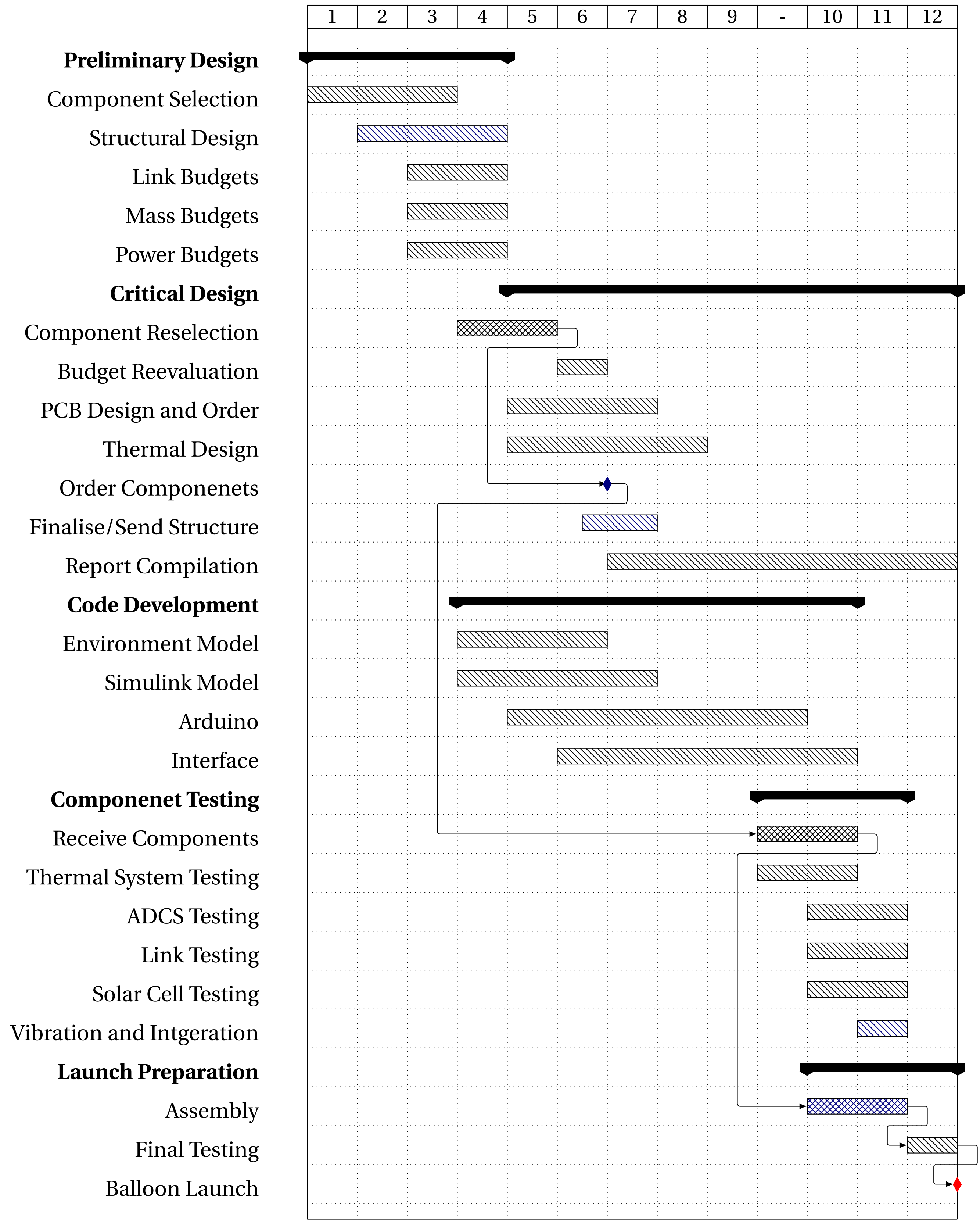
# 7 Project Plans and Schedule

A general schedule for the SnapSat project is outlined below. A Gantt chart is provided on the following page.

Table 7.1: SnapSat Project Schedule

| Major Task | Responsibility | Start Date | End Date |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

## 7.1 Gantt Chart



# 8 Comments by Independent Reviewer

One page maximum. (Not quite sure what this is)