SPACE MISSION CHARACTERIZATION AND ANALYSIS FOR UNIVERSITY CUBESAT

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ABSTRACT

For this research, the secondary mission for the MYSat-Cubesat is developed with intention to attract the targeted group to fund the mission. The development of the secondary mission for this nano satellite would benefit not only in term of funding but also gain public awareness and interest about this cubesat. The research for selecting the suitable secondary mission is done by considering the objective of the mission and the requirements. The public interest of the Malaysia toward science, technology and innovation also is taken into account to create a mission that be able to attract their interest. The development of the secondary mission is done by conducting the experiment after the suitable secondary mission has been decided. It including the component performance and reliability to carried out the secondary mission. The analysis of the result is performed afterward.

PENCIRIAN MISI ANGKASA DAN ANALISIS BAGI UNIVERSITI CUBESAT

ABSTRAK

Thesis ini disediakan untuk membangunkan misi sekunder bagi MYSat-Cubesat untuk menarik minat golongan yang tertentu untuk menaja misi ini. Pembangunan misi sekunder untuk nano satelit akan memberi manfaat bukan sahaja dari segi penajaan malah dapat meningkatkan kesedaran orang ramai .Kajian yang dilakukan untuk memilih misi yang sesuai adalah berdasarkan objektif dan kehendak misi utama. Minat rakyat Malaysia terhadap Sains, Teknologi dan inovasi juga diambil kira bagi mencipta misi yang mampu menarik minat mereka. Pembangunan misi sekunder ini dilakukan dengan menjalankan eksperimen setelah misi sekunder yang bersesuaian dipilih. Ini termasuklah eksperimen untuk mengkaji mengenai prestasti dan keupayaan komponen misi sekunder tersebut. Setelah itu, analisis terhadap keputusan eksperimen dijalankan.

ACKNOWLEDGEMENTS

With a grateful heart, I would like to express my outmost gratitude to my supervisor,Puan Siti Harwani Md Yusuff for giving me the endless support throughout this process. I would able to complete this thesis through her encouragement and guidance. I also would like to offer my deepest gratitude to En Muhammad Azwan Nasirudin who has helping me to complete the analysis despite his busy schedules. Without his assistance, comment and suggestion, I might not be able to perform the analysis by my own. Finally, I would like to thank to all staff members, relatives, seniors and friends would always support me morally and physically.

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Date:

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organizations.

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LIST OF ABBREVIATIONS

COB	Chip-on-board
LED	Light emitting diode
STI	Science, Technology and Innovation

CHAPTER 1

INTRODUCTION

1.1 General Overview

A Cubesat is a miniaturized satellite for the space research and exploration that provides a low cost platform for mission. This Cubesat was initiated by a group of university student of California Polytechnic State University, San Luis Obispo and Stanford University's Space Systems Development Lab in 1999. This space project was introduced to facilitate the access of space study for university student. This Cubesat standard has been adopted by hundred of organizations around the world including universities, educational institute, private firm and government organization. Most of the Cubesat launched addressed the research in science and technology, space exploration and education. A Cubesat is a 10cm cube with a mass of up to 1.33 kg .

1.2 Introduction To MYSat-Cubesat

School of Aerospace Engineering, University Sains Malaysia is developing a 1U Cubesat called MYSat-Cubesat that will be the first university CubeSat in Malaysia. This developments is carried out by three different parties consist of University, Government Agency and Industry. The primary mission objective for this MYSat is to measure the electron density in ionosphere start from the F layer (400 km) to D layer (60 km) for local disaster management. This mission in initiated due to lacking of satellite and ground facilities to provide data for atmospheric studies specifically in South East Asia (SEA) region. This data is crucial to be used in disaster management such as earthquake, tsunami, volcano eruption, lighting and typhoon location.

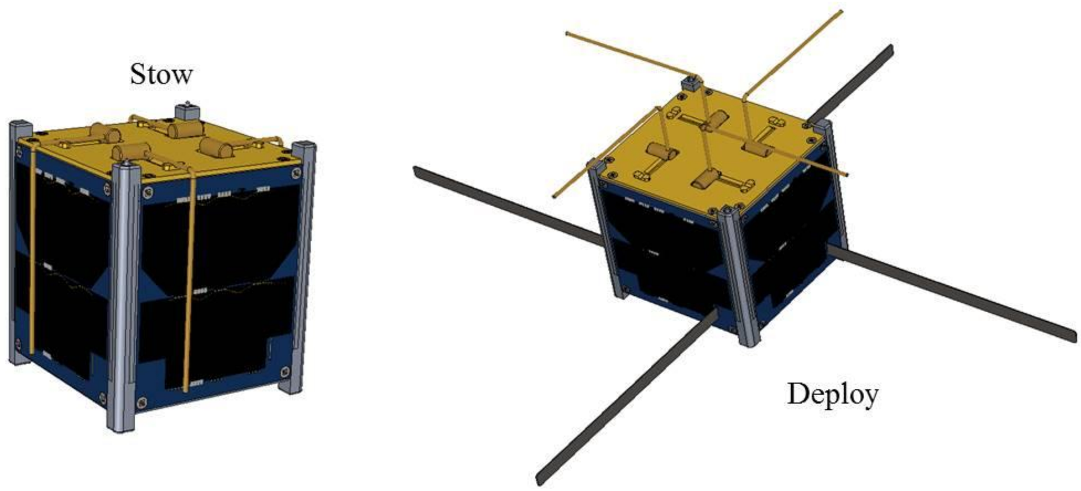

Figure 1.1: 3D View of MYSat

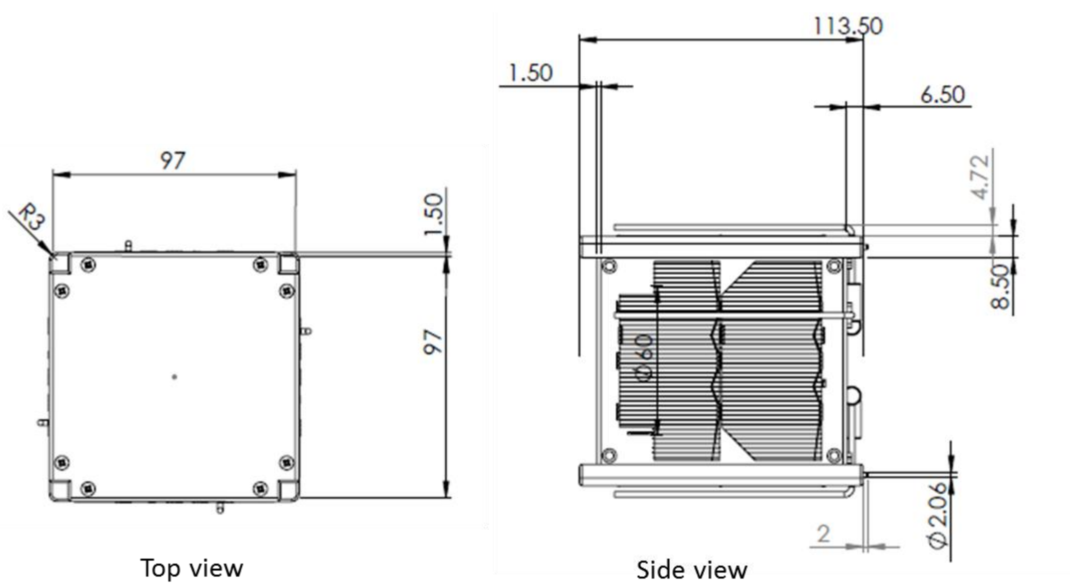

Figure 1.2: External Dimension

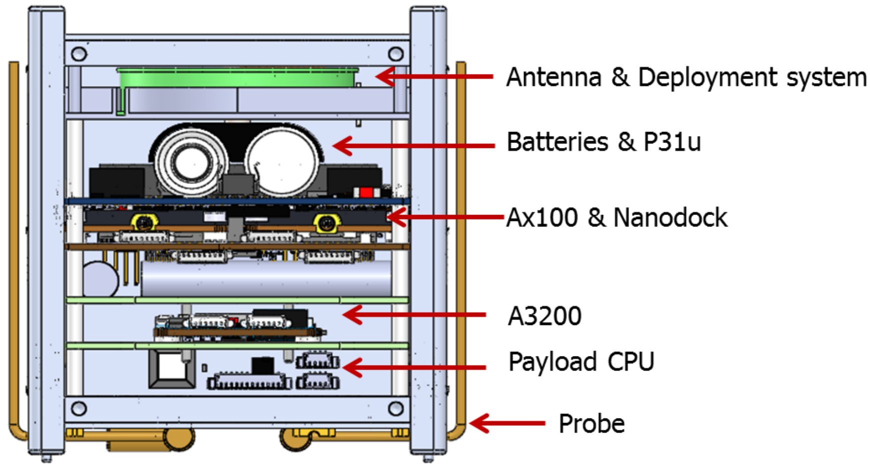

Figure 1.3: MYSat- Equipment Configuration

The mission objectives of the MYSat are divided into two primary and secondary mission objectives. The primary mission objective is to measure electron density in Ionosphere E layer for validation of electromagnetic model for natural disaster management developed by Universiti Sains Malaysia. The secondary mission objectives are to develop university capabilities in developing a Nano-satellite and to inspire and prepare future space-professional by provide university student with practical experience in all aspect for a real space project and to enhance their motivation to work in the fields of space technology and science, thus helping to ensure the availability of a suitable and talented workforce in the future. This MYSat will take 17 months to develop before it launch

The mission analysis and design process must be done thoroughly to ensure its successful launch and achieves the mission objective. However, there is an important aspect need to take into account to meet the mission needs which is funding. Funding is profound to keep ongoing research progress and development. The progress of a project will be affected without funding. MYSat-Cubesat nevertheless also faces the same problem. This mission has difficulty to find the appropriate amount of fund. Therefore, a secondary mission objective must be planned and carried out to overcome this problem by targeting a selected group to funding this MYSat.

1.3 Problem Statement

One of the main problems faced throughout the development of MYSat-Cubesat is the lack of funding. It is one of the most complicated and difficult task to be completed. Therefore, a secondary mission of MYSat-Cubesat need to define that it can fits the need and potential funder's priorities. The secondary mission defined must have specific goals to raise finance with primary intention to pursue funding application that targeting middle class citizen, hobbyist, and private company. The thorough research and analysis must be conducted to select the best secondary mission that has the highest potential to attract the targeted group but must be affordable to be developed within the cubesat specifications.

1.4 Objectives of Research

The aims of this research are:

1. Define the secondary mission objectives.
2. Conduct the secondary mission experiment.

1.5 Thesis Layout

This thesis consists of five chapters that explaining about the analysis conducted. The first chapter consists of the general overview of the cubesat, introduction, problem statement, objectives of the research and the thesis layout. The second chapter is the literature overview. It consists of the information gathered related to the analysis that will be performed and also consist of the information about the previous work. The third chapter is about the methodology. All of the procedures, flow charts, and equations involved are explained in this third chapter. The fourth chapter consists of the result and analysis of the experiment conducted. The analysis on the problem and result is explained in this chapter. The last chapter of this thesis consists of the conclusion that can be made from the overall analysis that has been conducted. The list and explanation about the future works also included.

CHAPTER 2

LITERATURE REVIEW

2.1 Secondary Mission Analysis

Before a space mission is perform, detail analysis need to be done with particular attention on derivation of requirements. The design of complex mission and system are not easy task. It requires brainstorming and iterations to analyze several alternatives and refine both requirements and methods of achieving them[1]. The very first design step is mission statement and objectives definition[1] without ignoring the interrelationship between mission requirements and system capability[2]. This mission statements and objectives should be fixed early as they represent mission foundation and shall not be modified for the following iterations[1]. Then a mission-execution decision making problem focuses on the best execution option in a set of possible mission need to be performed. Then, the analysis should be proceeding with the assessment of requirement. This can be done by Functional Analysis and Concept of Operation[1] as far as the understanding and analysis of numerous risks involved are concerned [3].

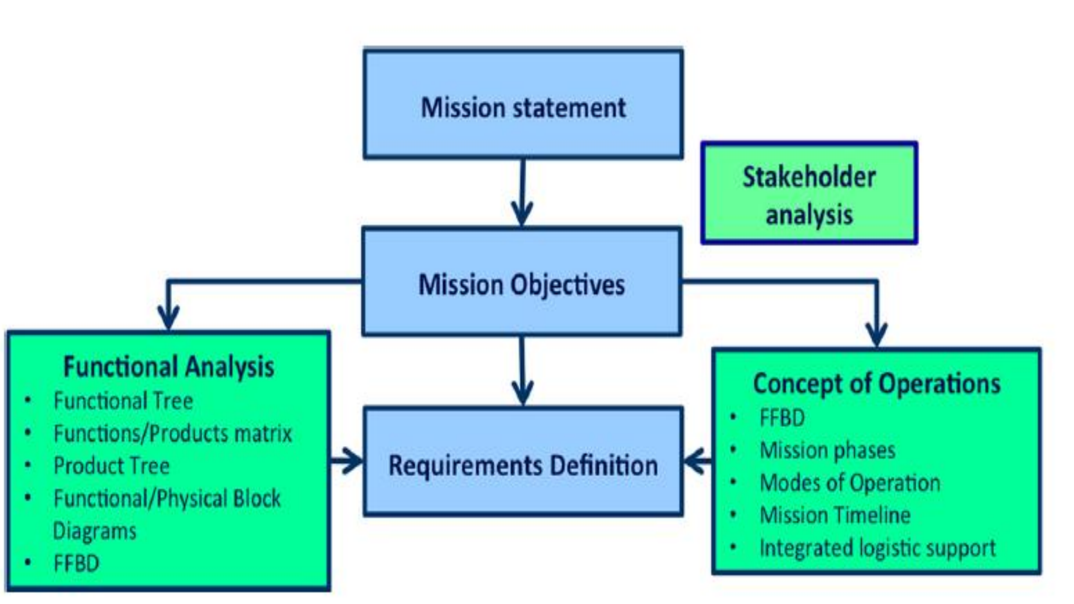

Figure 2.1: General Methodology Overview [1]

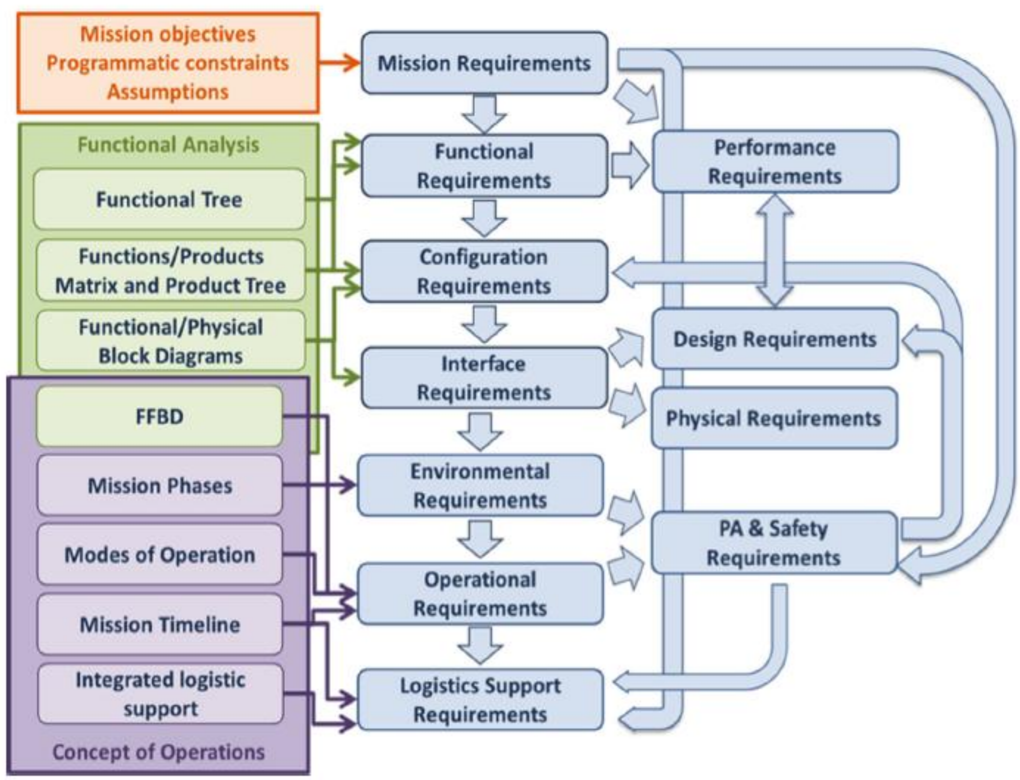

Figure 2.2: Requirements Definitions Methodology [1]

The stakeholders engagement is one of the important elements in mission objective and mission requirements therefore the stakeholders engagement strategy should be studied. The research need to be conducted by using qualitative research methods [4] to see if it fulfill the essential criteria[5].There are five basic keys that need to be considered along the process [6]; identify stakeholders, generate stakeholder requirements, model stakeholder use case scenarios, create/ update validation plane and perform review. However, these processes must also include the communication routine study and project culture[7].These stakeholders analysis must not limited to one stakeholder per project but spread the scope as widely as possible[5].As a result, the secondary objective should be derived from these analysis[1]. The details analysis is needed before defining the mission objectives and requirements. This step is also influence by the stakeholders' expectation by constructing appropriate stakeholder engagement strategy.

2.2 Science, Technology and Innovation

The main objective of development of the MYSat-Cubesat secondary mission is to find the funding of this cubesat. One of the elements that need to be considered in deciding the secondary mission is the public interest science, technology and innovation. According to the report of the Public Awareness of Science, Technology and Innovation Malaysia 2014 [8] more than 75% of 1500 respondents stated that they were very interested or interested in science, technology and innovation (STI) issues.

This studies on the public awareness and interest in STI is crucial as it help to decide the appropriate secondary mission that has the high level of acceptance among the public to invest in this mission. However Malaysia still has to reach the target to attract the interest among the students [9]The survey that has been conducted [8] among permanent residents of Malaysia aged between 12 and 64 of 1500 households shows that 77.9 % respondents were interested in “innovation” and 75.7% in “new scientific discoveries” which are particularly high. However, “the use of new inventions and technology” issue shown the highest interest among respondents. This survey proved that Malaysian welcome any scientific discoveries that has beneficial to them. The number of percentage of very interested responses is higher in 2014 compared to 2008. The information gathered through this survey is useful to conclude any possible future trend [9] that can be developed especially for MYSat-Cubesat secondary mission that can attract the potential stakeholders.

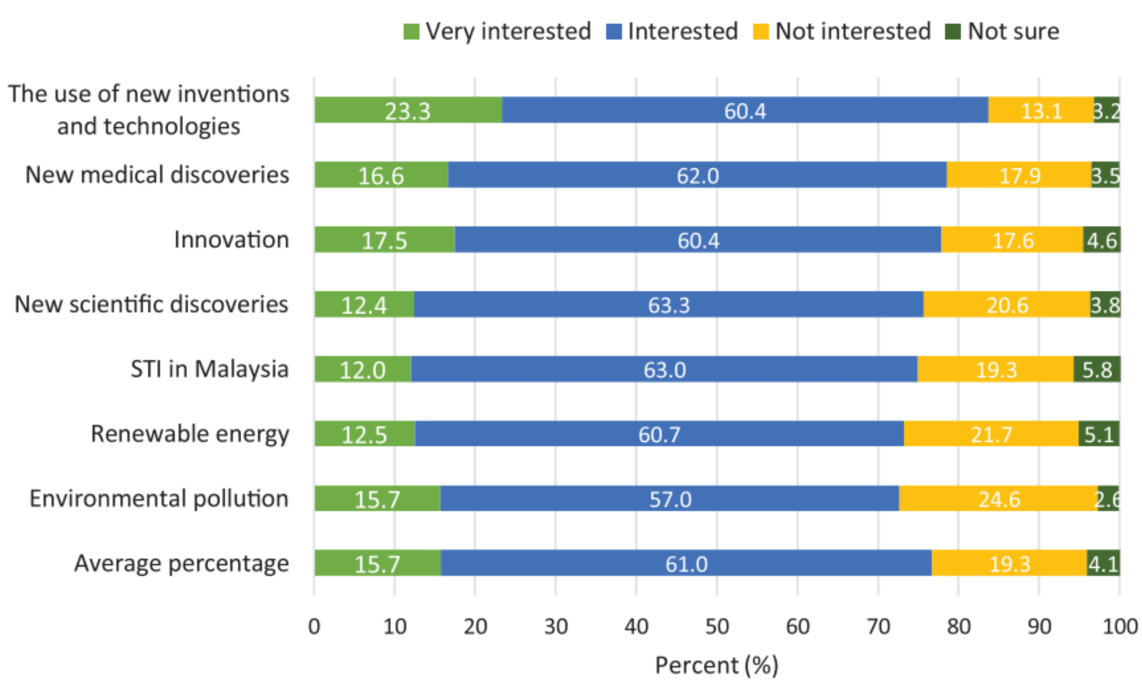

Figure 2.3: Public interest in selected STI issues [8]

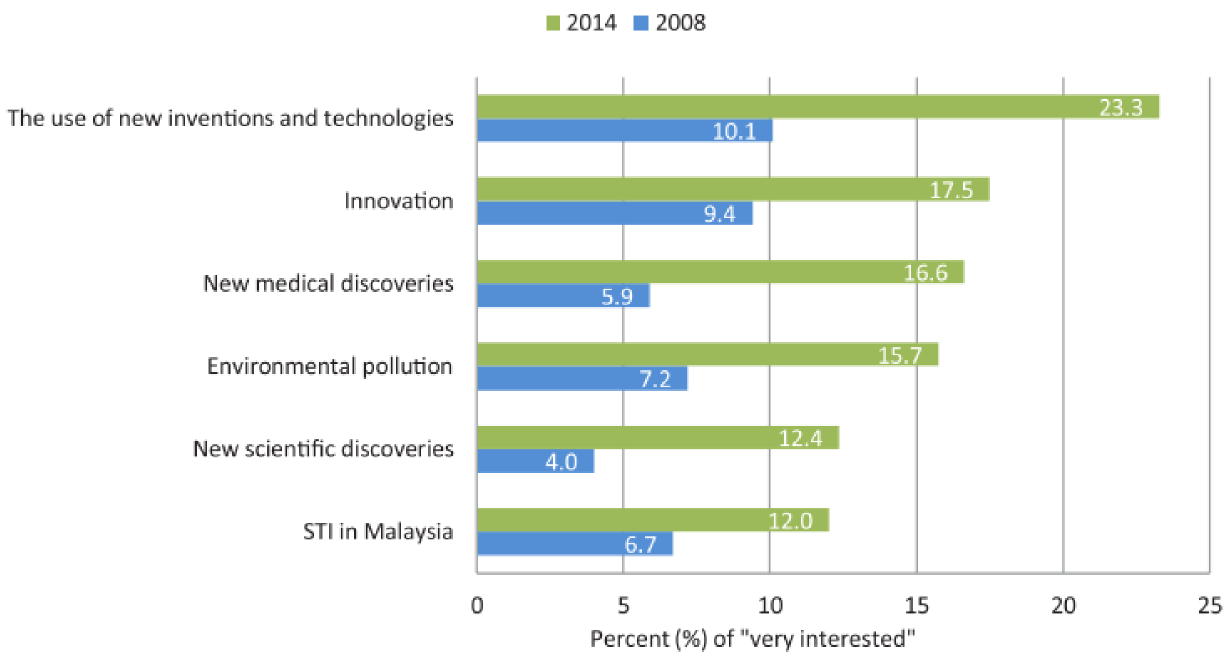

Figure 2.4: Public Interest in Selected STI Related Issues in 2008 and 2014 [8]

CHAPTER 3

METHODOLOGY

This chapter will be explained about the method used to obtain the data, formula and the procedure of the experiment.

3.1 Defining Secondary Mission

The secondary mission objective need to be defined based on the mission requirement. Abundant of researches and analysis need to be performed to collect the data on the stakeholder priorities and interest to derives the secondary mission. The secondary mission will be listed and finally selected based on the needs (including stakeholder expectations), mission concept, requirement definition, payload requirement, design requirement, operation system requirement and risk assessment (impact and feasibility).

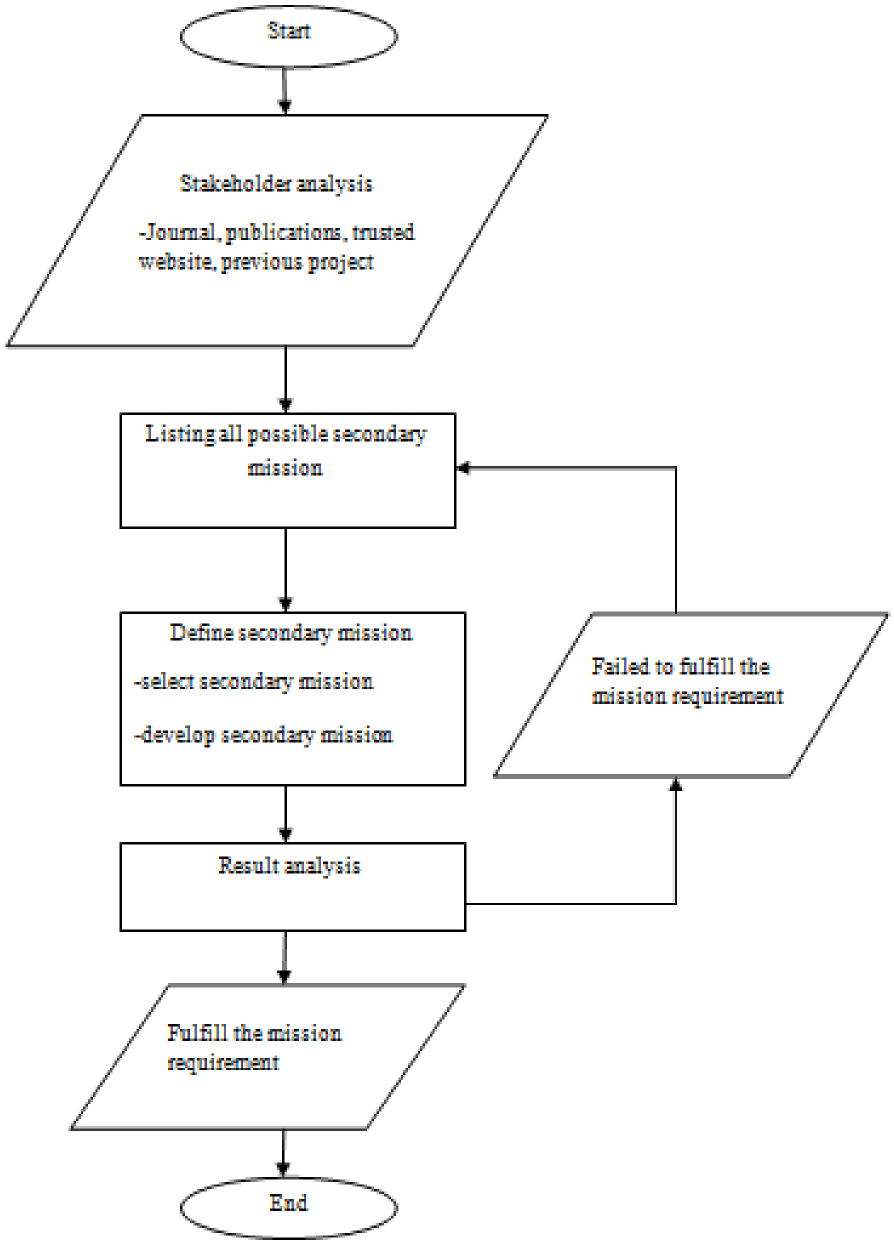

Figure 3.1: Project Flow Chart

After several research has been done, the secondary mission that is possible to carried out on the MYSat-Cubesat is by using the Chip-on-board (COB) LED at the bottom of the cubesat. This LED has potential to be observed from the 400km distance from the outer space. However, experiment and analysis need to be carried out to determine the properties of this LED such as its power consumption and light intensity. This experiment is important to determine whether this secondary mission is possible to be set up based on the MYSat-Cubesat mission requirements. There are two parts of experiments for this LED which to measuring the battery performance and also to determine the LED properties and characteristics.

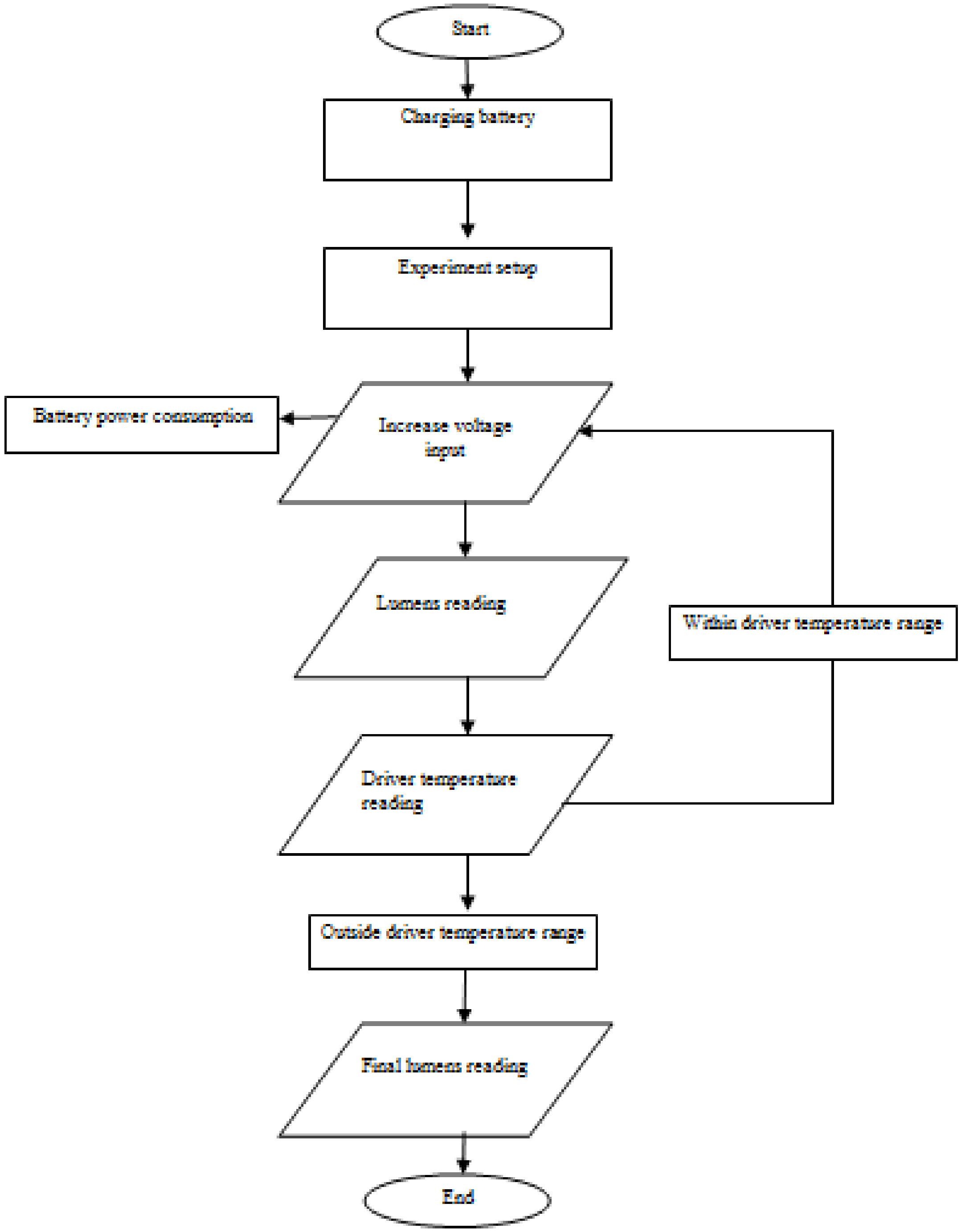

Figure 3.2: LED Experiment Flow Chart

3.2 Measuring Lithium Iron Phosphate (LiFePO4) Battery Performance

3.2.1 Objectives

To measure the maximum voltage and total amount of energy of the LiFePO4 battery.

3.2.2 Introduction

Lithium-iron phosphate (LiFePO4) battery is a rechargeable lithium-ion battery that design for high power application such as RC hobby and electric bike. It basically has nominal voltage of 3.2V and will cut off when it reaches 3.7V or 3.8V during charging. This battery has higher discharging current, longer life cycle compared to the normal non-rechargeable lithium-ion. It offers much constant discharged voltage therefore it safer than the other lithium-ion battery. However, this LiFePO4 battery has lower energy density which is one of its disadvantages. The 26650 rechargeable lithium-iron phosphates with 4000mAh and 3.7V has been used in this experiment. The details characteristics of the battery is shown in Table 3.2

Figure 3.3: LiFePO4 Battery

Table 3.1: Detail Characteristics of Battery

Battery Model	3.7V 4 000mAh rechargeable 18650
Type	Li-ion battery
Nominal Capacity	4 000mAh
Nominal Voltage	3.7V
Battery Size	26 x 65mm
Charging Current	0.5C
Max Discharge Current	1C

3.2.3 Apparatus and Components

Lithium iron phosphate ($LiFePO_4$) Battery, battery charger (BT-C3100)

3.2.4 Procedure

First, the Two $LiFePO_4$ batteries are labeled with number 1 and number 2. Then, the battery charger is connected to the power supply. Both of battery number 1 and 2 are placed in the battery charger slot at both ends respectively and the charger is turned on. The maximum charging rate 2000 mA is selected for both batteries. The process of charging is being monitored every 20 minutes to ensure the batteries are charging. The maximum voltage and charging capacity for both batteries are recorded when they are fully charged. All the readings taken are recorded in Table 4.1.

3.3Determine the Properties of Chip-On-Board (COB) LED

3.3.1 Objectives

1. To calculate the minimum and maximum power consumption of the COB LED.
2. To measure the operation temperature range for the LED driver.
3. To measure the lowest and highest lumens of COB LED.

3.3.2 Introduction

Chip-on-board LED is the combination of multiple LED chips to form one light source. It is capable to provide very high lumens compared to the traditional LED of the same size and area due to its multiple chips. Therefore, this COB LED is very beneficial in terms of space and energy saving. The COB LED is useful for high performance illumination application such as high-bay lightning, tunnel lighting and street light as it is super bright and small in size. It is available in various colors such as blue, green, pink, red, cool white and warm white depends on its lumens or color temperature. The cool white 5000K LED has been used in this experiments as it has long term color stability, superior optical emission uniformity , good color over angle consistency and excellent thermal conductivity for uniform heat spreading. The optical and elcetrical characteristics of this LED is shown in Table 3.2.

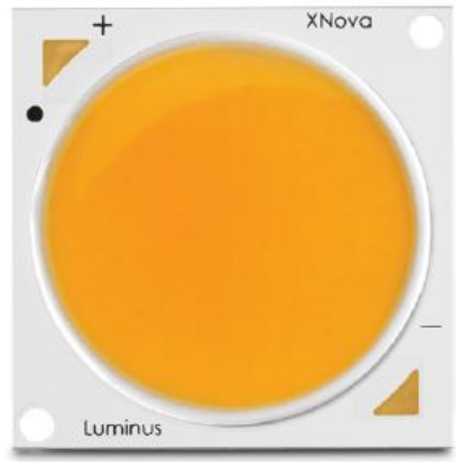

Figure 3.4: COB LED

Table 3.2: Detail Characteristic of COB LED

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Forward Current	I_f		2 700	4 000	mA
Forward Voltage	V_f	33.5	35	37.5	V
Power			95	150	W
Operating Case Temperature	T_c			105	ºC
Light Emitting Surface Diameter	LES		26.5		mm
Thermal Resistance (junction-to-case)	O_{jc}		0.16		ºC/W
Junction Temperature	T_j			140	ºC
Viewing Angle			120		Degree

LED driver is an electrical device that responsible to provide constant amount of power to the LED and overall circuit for the best performance. The LED need this specialized driver to convert the alternating current from the power supply to the direct current and also needed to step down the high voltage provided by the power supply. This LED driver also ensures the power supply through the LED is match with the LED characteristics and power requirements. It will prevent the LED to become too hot and may contribute to its failure if it operates outside its voltage and current range. There are two types of LED driver, constant-current and constant-voltage driver. The constant current driver provides current to the LED with vary range of voltage meanwhile the constant-voltage driver provides constant voltage with vary range of current. The LED driver that has been used in this experiment is constant-current driver with the characteristics and descriptions as shown in Table 3.3.

Figure 3.5: LED Driver

Table 3.3: Detail Characteristic of LED Driver

Module Properties	Non-isolated step-up module
Input Voltage	8.5 to 48V
Output Voltage	12 to 50V (adjustable)
Output Current	10A (Max) *please enhance heat dissipation if more than 6A
Output Constant Current	0.2 to 8A *please do not short the output to adjust the current
Conversion Efficiency	96%
Working Frequency	150kHz
Output Ripple	2% (Max) 20M-bandwidth
Operating Temperature	-40 to +85ºC
Size	70 x 46 x 13mm

Lux meter is uses to measure the amount of light or luminance at the specific area or space. Luminance is the measure of the amount of light falling on a surface. It is useful to adjusting the level of light intensity of the lightning system to produce appropriate amount of light. This lux meter comes in small size enable it to used at the limited working area and has been widely used in construction and photography fields. The lux meter used in this experiment to measure the minimum and maximum light intensity in lumens produce by the COB LED at given voltage.

Figure 3.6: Lux Meter

Table 3.4: Detail Characteristic of Lux Meter

Display	3-1/2 digit 18mm LCD
Power	9V
Ranges	0-50 000 Lux
Accuracy	±5%
Sampling rate	0.4 second
Operating temperature	0-50 °C

Thermal compound or also known as heat sink compound is a sticky paste that helps to direct heat away from the surface of metal. This heat compound is usually applied at the CPU that acts as the interface between the chip and heat sink. It will prevent the chip from overheating by promotes heat conductions throughout the heat sink or metal surface. It also helps to close the air gap between these two surfaces since not all the surfaces of the heat sink or chip are flat.

Figure 3.7 : Thermal Compound

3.3.3 Apparatus and Components

Chip-on-board LED, LED driver, lux meter, thermal compound, metal plate, wires, soldering kit, stripboard ,Lithium iron phosphate (LiFePO4) battery, ammeter, voltmeter, banana socket, banana socket, banana plug and heat sink (computer heat sink) .

3.3.4 Procedures

The components and apparatus have been prepared before the real experiment begins. The first step need to be done is the set up preparation. First, the COB LED is soldered with wire at both positive and negative terminal. The LED then is attached on the 9cm x 7cm metal plate that act as heat sink using thermal compound before they are attached together on the computer heat sink as shown in Figure 3.8.

Figure 3.8: LED Attached on Metal Plate

The stipboards are then soldered with wire to hold the LiFePO4 battery together. The LED and LED driver then connected together according to their polarity. The banana plug and socket are adjusted on the both side of computer heat sink to connect the battery holder with the LED, ammeter and voltmeter.

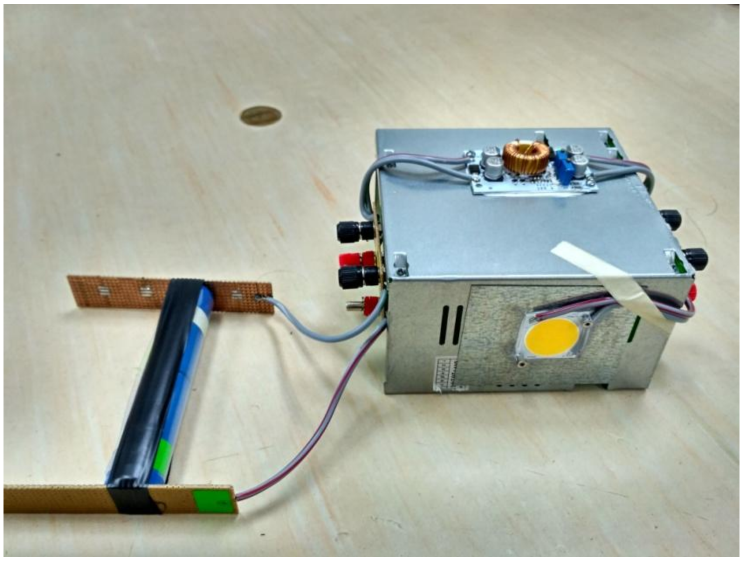

Figure 3.9: LED Setup

After the apparatus has been set up as Figure 3.10 the real experiment is conducted. The voltmeter reading of the battery and lumen for LED is recorded for the open circuit. Then, the battery is connected on the battery holder and the readings of battery and LED voltmeter, battery and LED ammeter, lumens and driver’s temperature are taken simultaneously. All this six parameters are recorded by increasing the battery input voltage. These steps are continued until when there is sudden temperature change in LED driver. The final readings of all six parameters are recorded. The power consumption of the LED is then being calculated and analyzed.