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Development of Appropriate Power Distribution Design for Can-Sized satellite (canSAT)

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Abstract: Can-Sized satellite (canSAT) is a small satellite that is used for educational purpose. CanSAT offer student to build their satellites with their creativity which make the learning process more effective. In Malaysia, SiswaSAT is held by the Malaysia Space Agency for students in different categories to participate and build their satellites according to rules set and it should be a low-cost project. CanSAT can be divided into few parts which are communication system, onboard data acquisition, ground control station and power system. The power system is one of the important and heaviest subsystems, it needed to supply power, but weight and size are one of the main concerned as the canSAT should not exceed the required weight and selecting power supply that is matched with the overall power budget that has small size and lightweight is challenging. Therefore, the power supply selection should consider this detail. The power distribution design should be able to supply an appropriate amount of current and voltage to the components according to their specification. This study aims to develop and test the proposed prototype which is named ScoreSAT able to provide data and have enough power supply for the whole operation. Therefore, an initiative to develop the appropriate power distribution design for canSAT is taken to overcome the problem of the power system. Moreover, each subsystem needs to be tested by obtaining the results from the onboard data acquisition and transmit the data using the communication system before integrating into the power system. ScoreSAT prototype needs to carry the system that is mounted inside, thus the space inside the prototype needs to be fully utilized for the whole system to fit in. ScoreSAT completes the mission by obtaining data acquisition during the operation.

Keywords: canSAT, ScoreSAT, power distribution design, power consumption, data acquisition

1. Introduction

Can-Sized satellite (canSAT) is used for educational purposes to do a simulation for a real satellite where the system integrated into a drink canned size [1]. CanSAT competition was introduced in the late 1990s where typically the competition gathers a lot of students to launch their satellite and competing for the prizes [1]. The weight of canSAT should not more than 1 kilograms but it can be different according to the rules set. Malaysia Space Agency competition 2020, specified that the size of the canSAT should be $11\ cm \times 6.6cm$ and weighing of 350 grams. The total cost to build the canSAT should not more than RM1000 [2]. CanSAT have few major subsystems which consist of the power system, onboard data acquisition, mechanical structure, and communication system. Electrical power system

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is one of the major subsystems because it provides a power supply to enables communication, flight control and data acquisition to function [3]. Power systems can be influenced by a lot of factors especially when there is higher power consumption which usually causes by the extra load used, for example, rover and propeller. This design consumes more power therefore it needed a bigger power supply.

The current study is to provide sufficient power to the prototype that is named ScoreSAT which name after the first communication satellite: Signal Communication by Orbiting Relay that is launched on 18 December 1958 [4]. There are few things that need to be considered while developing the power system which are the overall power consumption of the components used and distribution of power according to the component's voltage and current needed. The selection of the DC power supply depends on the battery capacity, overall power budget, and margin power allocation. Testing the onboard data acquisition and communication system to make sure it able to obtain and transmit data which then would be store in SD card as CSV files [5] before integrating them into the power system. ScoreSAT should be able to operate and obtain data and transmitting it to the ground control station and the operation takes not more than 20 minutes to finish.

1.1 Problem Statement

ScoreSAT's system depends on the power supply to keep it operates. Each component in the ScoreSAT needs to be powered up by currents to function. If the power supply is insufficient, the whole system will collapse therefore no data can be obtained and transmit to the ground control station. Power supply is important however if the current cannot be distributed carefully it could cause damage to the components or even disable the whole system since each component has different specification especially in their voltage and current needs [6]. DC power supply only can be selected after considering the battery capacity, overall power budget and margin power allocation. The margin power allocation is the calculation of the power and current consumed by ScoreSAT and this calculation usually includes the times of operation which in the ScoreSAT the operation usually takes up to 20 minutes to finish. Therefore, the margin power allocation would consider the power consumed in 20 minutes to select the DC power supply. Each subsystem in ScoreSAT need to be tested to make sure that it just works perfectly fine. The onboard data acquisition should be able to obtain the data from the GPS module, sensors and the Pi camera and the communication system it should be able to transmit and received the data at the ground control station. It is a challenge to fit all the subsystem in the ScoreSAT as it has a minimal volume of space.

1.2 Project Objective

The specific objectives of this project are to develop power system for prototype can-size Satellite mission operation including power consumption budget, integrate onboard data acquisition system, communication system and onboard power system and to perform individual subsystem testing on onboard data acquisition system, communication transmission system and integrated system testing.

1.3 Project Scope

The scope study for this project is to calculate the overall power consumption by the components used in ScoreSAT, batteries capacity, margin power calculation for a maximum of 20 minutes and designing the power distribution design for ScoreSAT. Integrate the communication system, onboard data acquisition and power system in the satellite that size not more than $11cm \times 6.6\,cm$ by connecting the subsystem into one system and able to function together. The design implemented in ScoreSAT and will be verified by calculation margin power of both batteries in a maximum time of 20 minutes period which is the maximum time for ScoreSAT to operate and obtain the testing result of data telemetries.

1.4 Literature Review

Study related to power distribution design, show that the electrical system differs according to the overall uses of components and weight. The selection components need to be considered since the initial canSAT requirement is to build low cost and low current consumption. Components such as switches, regulators and voltage divided used to distribute power to another subsystem. The system will be packed up in the canSAT prototype as it has minimal space volume.

1.5 Methodology

All The methodology covers the main aspect of the research, designing and collecting data. The methodology also contains the documentation and report writing of an explanation to be used as evidence to support the conclusion. In Fig. 1 show the hardware procurement that is done according to the ScoreSAT's mission. The hardware procurement was then studied thoroughly to obtain the overall power consumption so that the power supply can be selected by considering the power budget of ScoreSAT, battery capacity, and margin power calculation. The subsystem then would be tested before integrating them into one system as each subsystem needs to be able to obtain from the onboard data acquisition and transmit/receive data by the communication subsystem. This whole system then will be mounted into the prototype and tested again to make sure it able to operate in the prototype.

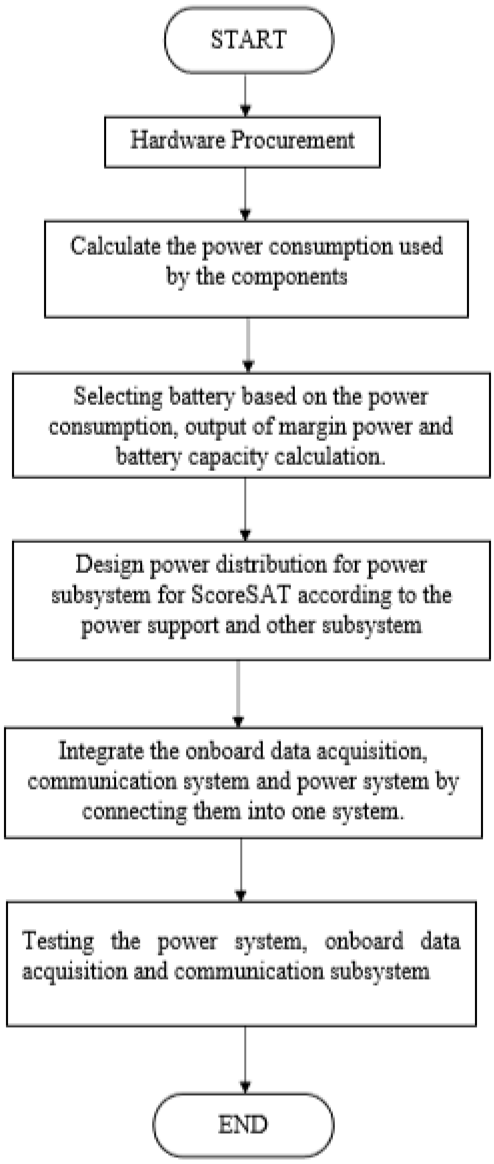

Fig. 1 - Methodology of power system workflow

In Fig. 2 shows the electrical block diagram for the main battery, which can be seen, that it supports the APM 2.8, 3DR radio telemetry and GPS module. The power system integrates with the APM 2.8 which is used to collect data of altitude, latitude, and longitude. The 7.4V battery would go through the APM power module which then would be regulate to 5V, then it would supply power according to the APM 2.8 specification. The power distribution board would distribute power according to the electrical feed. Fig. 3, it shows the electrical block diagram that integrates with the power system to support the Raspberry Pi Zero WH, sensors, camera and 3DR radio telemetry. This subsystem then would collect data of humidity, pressure, temperature, and landscape image. The UBEC is used to regulate the 9V battery down to 5V according to Raspberry Pi Zero WH.

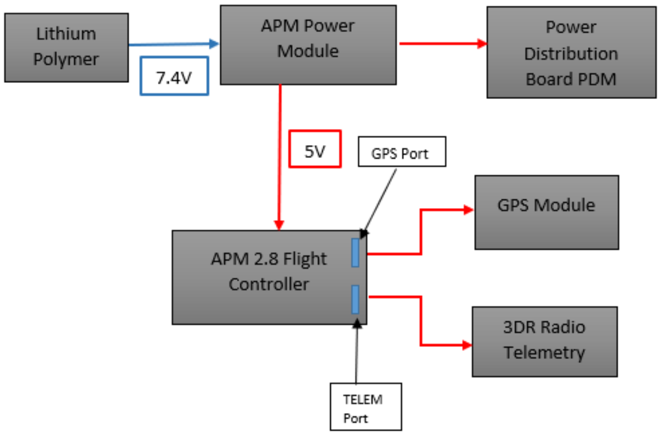

Fig. 2 - Electrical block diagram of main battery

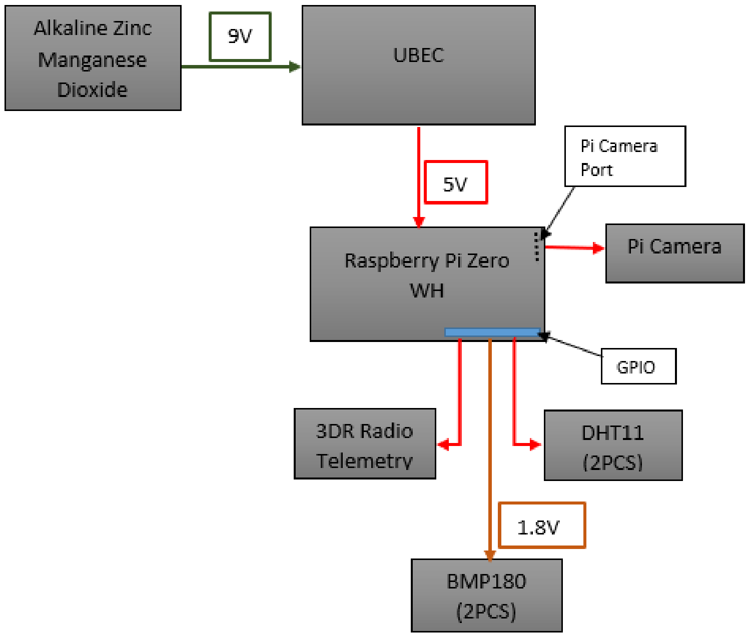

Fig. 3 - Electrical block diagram of secondary battery

1.6 Design of Power System

Few calculations are needed in this project which are the power consumption budget, margin power calculation and battery capacity calculation. The power supply only can be selected by considering the overall power consumption, battery capacity and margin power calculation. This calculation required these equations:

$$P = IV \qquad Eq.1$$

$$Overall\ current\ consume\ (mA) \times Hour\ (h) = mAh \qquad Eq.2$$

$$Overall\ power\ consume\ (W) \times Hour\ (h) = Wh \qquad Eq.3$$

$$Battery\ capacity\ (mAh) - Current\ consumed\ in\ 20\min(mAh) = mAh \qquad Eq.4$$

$$Battery\ power\ (Wh) - Power\ consumed\ in\ 20\min(Wh) = Wh \qquad Eq.5$$

$$t = {}^{Q}/_{i} \qquad Eq.6$$

2. Results and Discussion

This process will discuss the results obtained in this project. Therefore, the result obtains in this project is the final design of ScoreSAT, the result obtains from the calculation, battery selection, the electrical system for both main battery and secondary battery and finally the result from the onboard data acquisition testing. Table 1 and 2 shows the power budget for the main battery and secondary battery, this calculation is using the equation [Eq.1]. Table 2 shows higher power consumption than in Table 1 this is because there is a lot of components compared to Table 1.

Table 1 - Main battery power budget

Components	Voltage (V)	Current (mA)	Power Consumption (mW)
APM 2.8 Flight Controller	5	500	2500
APM Power Module	5	-	-
3DR Radio Telemetry 915 MHz	5	50	250
GPS Module	5	67	335
Power Distribution Board PDB	5	-	-
Total		617	3085

Table 2 - Secondary battery power budget

Components	Voltage (V)	Current (mA)	Power Consumption (mW)
Raspberry Pi Zero WH	5	240	1200
Hobbywing 3A UBEC 5V 6V	5	500	2500
Pi camera	5	250	1250
3DR Radio Telemetry 915 MHz	5	50	250
BMP180 (2 pcs)	3.6	5.4E-03	0.0194
DHT11 (2 pcs)	10	5	50
Total		1045.0054	5250.0194

Table 3 shows the battery capacity calculation of both batteries used in ScoreSAT which show the calculation of working time of batteries. This calculation is referring the equation [Eq.6]

Table 3 - Battery capacity calculation

Gaoneng GNB 2S 7.4V	PKCELL Ultra Alkaline 9V
Voltage = 7.4V Capacity = 550 mAh	Voltage = 9V Capacity = 500 mAh
Working time (550/617) = 53.48 minutes	Working time (500/1045.0054) = 28.71 minutes

Table 4 and Table 5 show a margin power calculation for 20 minutes for both batteries. This calculation is done to prove that the batteries is sufficient to support ScoreSAT during its operations. The power and current consumed were both calculated from the subsystem for 20 minutes which indicate the maximum operation time of ScoreSAT. This values then would be subtracted from the battery power and current to get the margin allocation. Both batteries showed there is balance power and current left, which shows power supply is sufficient. Equation 2 until the equation is used to calculate the margin power. Equation 2 is used to calculate the overall current consumption in 20 minutes [Eq.2]. These values then used in equation 4 to find the balance current left after 20 minutes of operation [Eq.4]. This method then repeated to calculate the power consumed using equations 3 and 5 [Eq.3] and [Eq.5].

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Table 4 - Margin calculation for main battery

	The margin of current consumption (20 minutes)	The margin of power consumption (20 minutes)
Battery power and capacity	550 mAh	4.07 Wh
Power and capacity used	205.461 mAh	1.0273 Wh
Balance of power and capacity in a battery	344. 539 mAh	3.0427 Wh

Table 5 - Margin calculation of secondary battery

	The margin of current consumption (20 minutes)	The margin of power consumption (20 minutes)
Battery power and capacity	500 mAh	4.50 Wh
Power and capacity used	3447.986 mAh	1.749 Wh
Balance of power and capacity in a battery	152.014 mAh	2.751 Wh

2.1 Finalize Design of ScoreSAT

ScoreSAT has two design which is the initial design and finalized design, Fig. 4 shows the finalize design of the ScoreSAT. The difference between both designs is that the components were stack vertically, level by level for the initial design but it has just had one 3DR radio telemetry, however, the good side of the initial design is the weight is less, approximately 200 grams. The final design use two 3DR telemetries which each one of these radio telemetries is to transmit data from APM 2.8 and Raspberry Pi Zero WH. Two 3DR Radio Telemetry have opted because there is no connection between APM 2.8 and Raspberry Pi, therefore it is hard to use one transmitter.

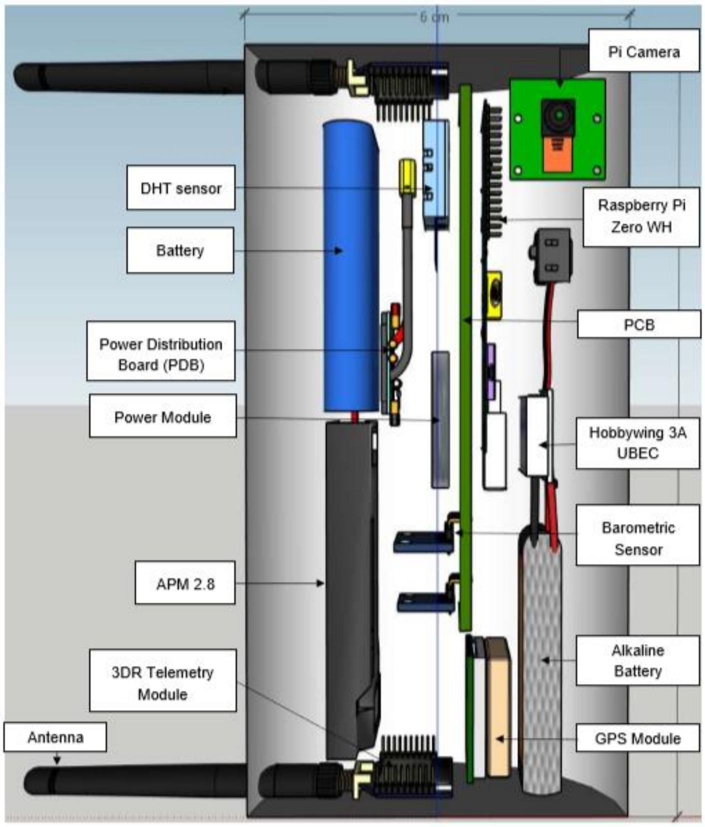

Fig. 4 - Finalize design of ScoreSAT

Fig. 5 is the onboard data acquisition that has been successfully connected. As for Fig. 6, the power system has been integrated with the Raspberry Pi and APM 2.8. Two batteries that were selected to supplying power to the system are Gaoneng GNB 2S 7.4V and PKCELL Ultra Alkaline 9V. These batteries were selected because it was sufficient to support the system during its operation. Gaoneng GNB 2S 7.4V weighing about 44 grams and ($1.3 \times 3 \times 5.6$) cm and PKCELL battery weight about 33 grams and $(4.8 \times 1.76 \times 1.3)$cm. ScoreSAT used two batteries to support each APM 2.8 and Raspberry Pi due to the limited size, weight restriction and if there are failures in power system thus only the affected subsystem would down instead of two. The possibilities of ScoreSAT failure are high with one power supply therefore to prevent system from failing, two batteries were opted. The voltage regulator used in the circuit undergo thorough study before being implemented. The margin power allocation shows that after operating in 20 minutes it still has more power left therefore the battery health can be maintained. This subsystem then would be tested before being mounted into ScoreSAT. Fig. 7 showing the ScoreSAT structure with a parachute attached to it. The system is mounted inside the prototype by fully utilizing the space. The small hole at the middle of ScoreSAT is made so that the Pi camera able to capture the surrounding, both antenna that is attached to APM 2.8 and Raspberry Pi pointing out from both side of prototype just as shown in Fig. 4.

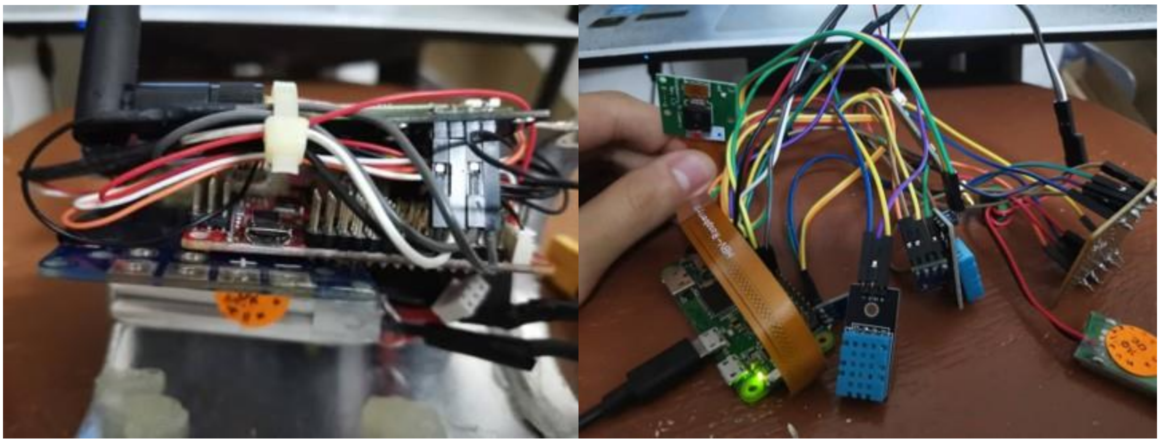

Fig. 5 - Onboard data acquisiton

Fig. 6 - Power system integrate to Raspberry Pi and APM 2.8

Fig. 7 - ScoreSAT exterior

2.2 Subsystem Testing

Each of the subsystems would be tested to make sure that it is able to provide data needed. The onboard data acquisition would be tested by connecting it to the power supply and it should be able to provide data of altitude, latitude, longitude, pressure, humidity, temperature, and images. The programming language used is phyton language that were written and saved in the Raspberry Pi. Fig. 8 shows the data obtain by the sensors; the data should be obtained for each second however the data sometimes cannot be received in a required time when it was mounted inside the prototype. This might cause by the loose connection of the sensors or low accuracy setback from the sensors. Fig. 9 shows the data that are obtained from APM 2.8 which is latitude, longitude, and altitude. This data would be shown in the APM firmware at the Ground Control Station which also verifying that the communication system works perfectly by transmitting and receiving data. The data obtained then displayed on the GUI at the ground station control. All sensors, GPS module and Pi camera work well but when mounted in the prototype, it slightly affecting the DHT11 sensor. The data also would be store inside the SD card that are inserted in the microcontroller, the files would be save as a CSV files for comparisons and backup data at the end of operation.

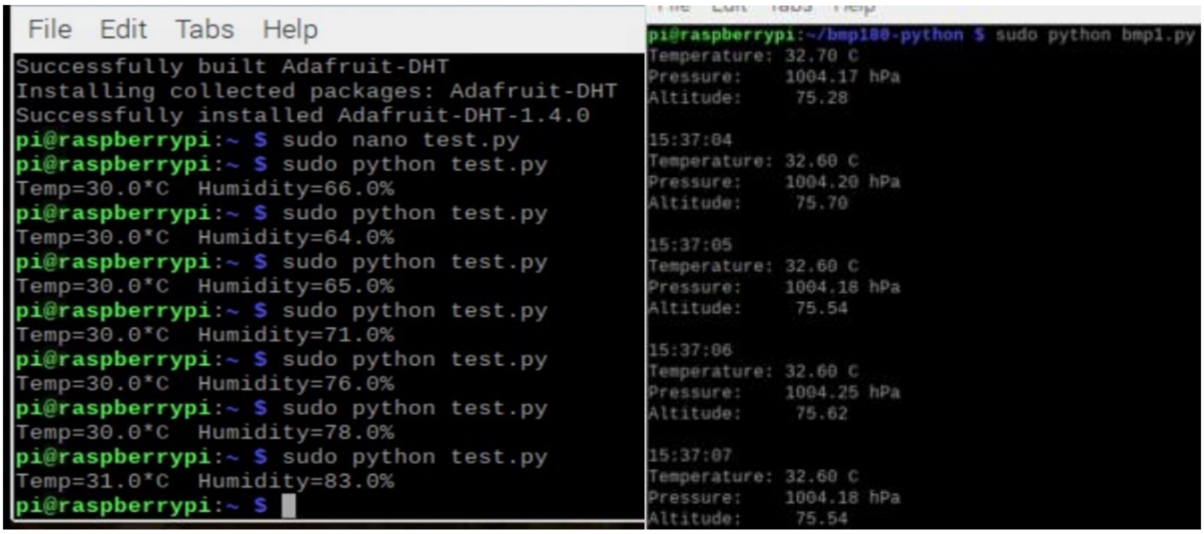

Fig. 8 - Data from DHT11 and BMP180

Fig. 9 - Data from APM 2.8

3. Conclusion

According to this study, it can be concluded that the objectives of this projects are achieved. The first objective for this project is to develop a power system for canSAT prototype. Two batteries are used to support the system, then power distribution is designed to make sure that the components get the right amount of power supply. A voltage regulator is especially important to use before connecting the components as voltage regulate help to regulation the voltage and current to match with the components to prevent them from damage. ScoreSAT used the APM power module, UBEC and power distribution design to protect other components from high current flows. Power supply for ScoreSAT was selected based on the calculation that was made. It is important to know the importance of power budget consumption, battery capacity, and margin power allocation. This calculation can help to estimate the current and power consume by ScoreSAT therefore selecting the batteries can be easily done. Other than the calculation and estimation, the weight, size, and prices of the batteries are also taken into consideration. This is to make sure that the selection made does not affect the overall weight of ScoreSAT. The subsystem still able to be fit into the ScoreSAT prototype, however after mounted the system inside the prototype it needed to be sealed tightly to prevent the prototype to crack open. Even though it is very packed inside the ScoreSAT it still able to provide the data acquisition needed.

3.1 Recommendation

There are few suggestions for future projects that could further carry out at the other Bachelor Projects. The follow up suggestions are:

- Use the voltmeter or multimeter to check the battery’s capacity for certain times. This can help in providing a graph that is easier to understand and read.
- The antenna should never point out horizontally, this could affect the size of ScoreSAT since they would measure the diameter up to the tip of the antenna so it no longer 6.6 cm.
- The system should be neater so it can easily fit into ScoreSAT, the system in ScoreSAT could lead to a loosen connection between the components which is highly risky during the operation.

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References

[1] SOYER, S. (n.d.). *Small Space Can: CanSat.* Istanbul, TURKEY

[2] Agensi Angkasa Malaysia, Kementerian Sains Teknologi Dan Inovasi. (2021, January 7). *Malaysia Siswasat Competition 2020*. Retrieved from SiswaSAT: http://siswasat.mysa.gov.my/

[3] Bulut, S. N., Gul, M., Beker, C., & Ipek, I. I. (2013). Model Satellite Design for Cansat Competition. *Recent Advances in Space Technologies (RAST) 2013 6TH International Conference Communication Satellite, SCORE*. (2021, January 8). Retrieved from Smithsonian, National Air and Space Museum: https://airandspace.si.edu/collection-objects/communications-satellite-score/nasm_A20030091000

[4] F. M, T. R., H.M, J. I., Islam, M. S., Azam, R., H.M, J. I., & Debnath, S. (2020). An Affordable CanSat Design and Implimentation to Study Space Science for Bangladeshi Students *CanSAT educational project*. (2021, January 8). Retrieved from Norway esero: https://www.esero.no/prosjekter/cansat

[5] Abdullah, M. K. (1989). *Modeling of Swirling Fluidized Bed Hydrodynamic Characteristics*. Universiti Tun Hussein Onn Malaysia: Ph.D. Thesis (Example for a thesis)