Proposed Cube Satellite for Measuring Radiation

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***Abstract*—As advances in technology build payloads and instruments for area missions smaller, lighter, and additional power economical, a distinct segment market is rising from the university community to perform quickly developed, inexpensive missions on terribly little artificial satellites - small, nano, and picosatellites. Among this category of an artificial satellite, area unit CubeSats, with a basic kind of ten times ten times ten cm, advisement a most of 1kg. so as to function viable various to larger artificial satellites, little satellite platforms should offer the tip user with access to the area and similar practicality to thought missions. However, despite recent advances, few satellites haven't been able to reach their full potential. while not launch vehicles dedicated to launching little satellites as primary payloads, launch opportunities solely exist within the kind of co-manifest or secondary payload missions, with launches usually backed by the govt. additionally, power, size, and mass constraints produce further hurdles for tiny satellites. To date, the first technique of accelerating a tiny low satellite's capability has been centered on the miniaturization of technology. The CubeSat Program embraces this approach, however has additionally centered on developing associate degree infrastructure to offset inevitable limitations caused by the constraints of little satellite missions. the most elements of this infrastructure are an intensive developer community, standards for satellite and launch vehicle interfaces, and a network of ground stations. This paper can specialize in the CubeSat Program, its history, and therefore the philosophy behind the varied parts that build it a sensible associate degree sanctionative various for access to the area.**

I. Introduction

We are a group of third year undergraduates from the Faculty of Engineering at University of Peradeniya. As we participated in the lecture series organized by the SEDS SL, SEDS PERA and IEEE MTT-S of UOP, it sparked an interest within us in gaining knowledge with regard to space applications.

With the knowledge gained during the webinar series, we have proposed a cube satellite design that can be deployed for the purpose of recording radiation data. By implementing components using novel technologies, the proposed cube satellite is capable of providing data accurately.

II. Structure subsystem (STR)

A. Role of the structure subsystem

The structural subsystem is the skeleton of the satellite. It performs many important functions, such as maintaining the structural integrity of the system, shielding the internal circuitry from radiation and bearing all mechanical loads on the satellite. It also acts as the mechanical interface to the launch vehicle.

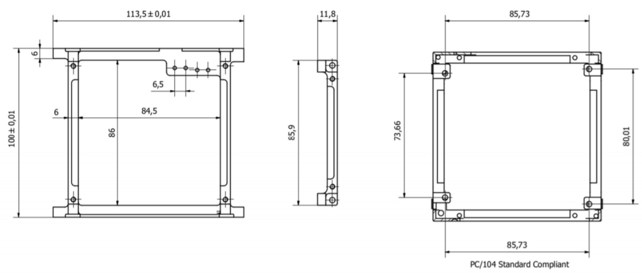

Fig. 1. Dimensions of CubeSat

B. Proposed materials

The proposed satellite will have dimensions of 10cm x 10cm x 11.35cm, the standard 1U size, with a payload area of 10cm x 10xm x 10cm compatible with the PC-104 standard mechanical interface, as shown in Fig 1.

Fig. 2. Primary structure of CubeSat

The primary structure, shown in Fig 2, of the satellite will be made of Aluminium 6061, due to its low weight and ease of machinability. It has a lower yield strength compared to more exotic materials such as inconel and titanium, but it is sufficient for our requirement. Each individual component of the structure will be CNC machined and then hard anodized for additional protection, even though AL-6061 provides significant corrosion resistance, even in its raw form. The anodization process will also provide a layer of electrical insulation, preventing accidental short circuits. The structure will be assembled using allen head fasteners, for ease of assembly and strong torquing. The weight of the assembled primary structure will be approximately 98g.

C. Thermal Controls

The thermal control of the satellite will be passive. The only high heat generating component in the satellite will be the battery pack. This will be mounted close to the bottom surface of the cubesat, and attached to a passive radiator for good heat dissipation.

D. Manufacturing costs, budget and feasibilty

TABLE I
BUDGET CALCULATION

Component	**Price**
ATmega328 IC	$16
Aluminium Structure	$25
piDOSE-DCD Radiation Sensor	$3640
Solar Cells	$1705
18650 Li-ion batteries	$50
INA 219 - Adafruit Sensors	$10
Other Components (Diodes, Buck/Boost Converters)	$40
AT86RF215 Communication Module	$7
CubseSat Antenna System	$7
Miscellaneous	$600
Total	**$6100**

III. ON BOARD COMPUTER (OBC)

The on-board computer is connected to every other subsystem.

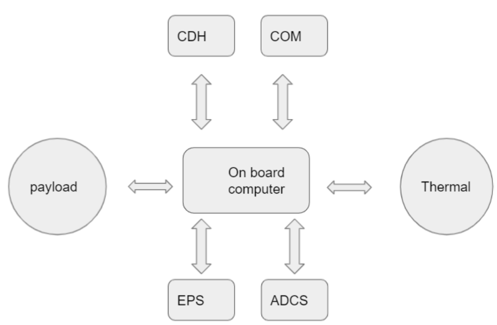

Fig. 3. On Board Computer Purpose

CDH: Communication and Data Handling
COM: Communication
EPS: Electronic Power Subsystem
ADCS: Altitude Determination and Control System

A. Role of OBC

Storage of telemetry and payload data. Encode and decode data packets. Processing of telecommands from ground stations. Monitoring subsystems, resetting subsystems if necessary.

B. Micro-controller proposed

The micro-controller selected for the satellite is an ATMEGA328. It has the following specifications :

1) Speed
   0-4 MHZ @ 1.8 - 5.5 V
   0-10 MHZ @ 2.7 - 5.5 V
   0-20 MHZ @ 1.8 - 5.5 V
2) Power Consumption
   Active mode : 0.2 mA
   Power - down mode : 0.1 uA
   Power - save Mode : 0.75 uA
3) Logic Level : 3.3V
4) Input-output pins
5) Communication modes 7.Working on different Temperature range -40 celsius

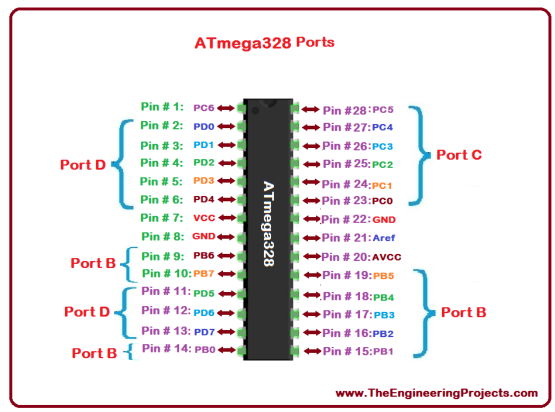

Fig. 4. ATMEGA328 architecture

C. Attitude Determination and Controls (ADCs)

When a cube satellite is released from an aircraft it has a rotational motion. Altitude and determination control system is used to detumbling and stabilize the aircraft. It is also used to maintain the satellite orientation.

For altitude control, we use a permanent magnet. It is a passive altitude control method. It can save lots of power rather than using reaction wheels. And it takes less weight compared to reaction wheels.

D. Memory/EEPROM

The micro controller contains 8 32-bit general-purpose working registers. In addition, there will be 1k bytes of electrically erasable programmable read-only memory (EEPROM), capable of over 10 000 write erase cycles. The EEPROM has a data retention capability of more than 20 years.

E. Watchdog timer

It is a device that is used to recover and detect malfunctions in a microcontroller.

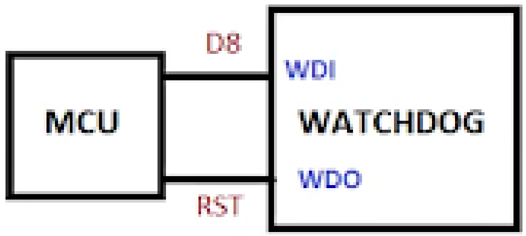

Fig. 5. Watchdog Timer

IV. Electrical power subsystem (EPS)

A. Role of EPS

Electrical Power Sub System is one of the critical Sub-Systems in the Cube Satellite. EPS is a fully autonomous system capable of providing power via the power source and distributing it to various subsystems of the satellite. Mainly there is Battery for providing and Solar cells for generating the power. The primary power source in space is the sun, and the satellite has to produce the energy using solar cells. There are two main operations in power generation and consumption. Those operations are handled using a maximum power point tracker (MPPT). If the power obtained from the power supply is greater than the consumed power, it should charge the Battery. Also, if the power consumed by the subsystems of the satellite is more than the power produced, the Battery should be able to provide the power. Power optimization is also essential, and during the malfunction, if a subsystem consumes more than the desired current, the EPS should limit the current. Furthermore, power handling and power monitoring have to be handled under EPS System. INA 219 – Adafruit sensor is used for power monitoring.

B. Solar Cell selection and justifications

In the satellite, five solar panels are body mounted on the surfaces. Body mounted configuration is simple to handle the power requirement of this cube satellite; therefore, this method is appropriate for the task. When considering the solar cells, TJ Solar Cell 3G30C solar cells are used in the proposed cube satellite. For one, the solar cell can produce around 2.4V and 0.5A s. Also, the solar cells are working around with 30% efficiency. The main reason for selecting these solar cells is their high efficiency. Because the only power generating method in space is using solar cells and high efficiency is indeed for that. When moving to other factors, these solar cells are less weight, which will be very cost-effective. Also, considering the operational temperature, these cells are working in the -120°C to +150°C range. Thickness is another important factor, and in this, solar cells have around 1.6 mm.

C. Solar Array configuration

The dimension of the cube satellite is 1U (10cmx10cmx10cm). Therefore the satellite surface can add two solar cells. Considering the power usage, satellites need around 4.2V from the solar cells. Consequently the cells are connected in a series configuration to get the required voltage. So the maximum voltage that can be generated from the solar array is 4.8V. Due to the thermal losses and the angle created with the sun can vary the voltage output. Because the cells are in series connection, the output current will be 0.5As. Then the two surfaces are connected in parallel to get two arrays from that scenario and one single surface solar panel. Those three are connected in parallel to get the desired current as shown in Fig 6.

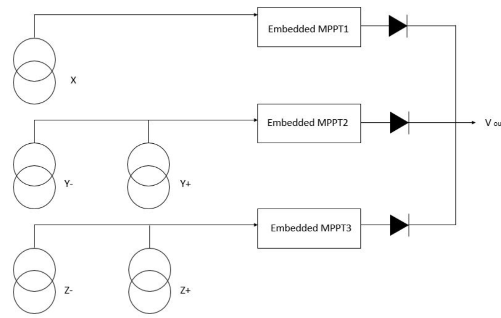

Fig. 6. Solar Array Diagram.

Atomic oxygen protection with space grade silicone for pads proposed for the protection of the solar panels. To prevent the current flowing back, blocking diodes are connected in series combination. Blocking diodes are used in PV arrays when there are more than one parallel branches and there is a possibility that one side gets shaded and another does not. During the shading, the current flows through the shaded part. When it happens for a longer period of time, the cell gets heated and damaged. Therefore bypass diodes are used and it prevents this occurrence.

D. Battery selection and justifications

18650 Li-Ion batteries are used as the batteries in the cube satellite. Batteries are used in the 2S 2P configuration (42 Whr) and 8.4V terminal voltage at the end of charge. Each cell has to be provided with a heater to prevent cold temperature (below -5°C) monitored by temperature sensors. Overprotection, as overcurrent, overcharge, over-discharge, has to be implemented. The main reason for choosing the Li-Ion is it is less weight. But the cell protection is needed for the Li-Ion due to the probability of an explosion. Also, the battery cells must be balanced when charging. Also, to get the desired voltage output, buck/boost or boost converters are used. Another critical factor is the temperature of the Battery. To stand the temperature at the maximum efficient level is indeed. For that, battery heaters and dissipation systems are used.

V. Communications Subsystem (COMMS)

A. Role of COMMS

Artificial satellites are sent to outer space to perform certain tasks. When considering cube satellites, the number of tasks that it can perform is limited due to the limited power generated and limited volume. When performing these tasks, instructions must be sent from a controlling centre (ground station) to the satellite, information must be sent from the satellite to the ground station and in certain scenarios, satellites must be able to communicate with other satellites. Communication Subsystem is responsible in performing those communications.

B. Types of communications proposed

For the cube satellite that we have proposed, detecting radiation patterns is the main focus. This requires transmission of data constantly.

Among the two most commonly used modulation techniques PSK (Phase Shift Keying) and QAM (Quadrature Amplitude Modulation), a modulation technique based on PSK was selected as the modulation technique for modulating data in our system.

QPSK (Quadrature Phase Shift Keying) is the modulation technique which is proposed to be used in the system.This method has better performance over the QAM system and has a less bit error rate compared to QAM. However, the spectral width used by this technique is wide and has 2 bits per symbol when transmitting.

QPSK modulation is also known as 4QAM modulation. This technique compared to 16QAM, 32QAM techniques requires less SNR (Signal to Noise Ratio) and can be transmitted over large distances. Therefore, considering all above facts, QPSK modulation scheme was selected.

Telemetry : As the purpose of the satellite is to record radiation, these recorded data will be transmitted to the ground station for analysis purposes.

Tele-command : The ground station will have to send instructions to the satellite in order for it to know when to record the radiation data/ to give it the proper attitude etcetera.

Payload: The data recorded can be stored in a storage available in the On Board Computer and then be transferred at a later time. Apart from that, the power available, satellite attitude data etcetera are also stored in the payload section.

C. Link Budget Analysis

Transmitter power output (P_{TX}) = 14.5dBm
Transmitter Antenna gain (G_{TX}) = 33dB
Losses from transmitter (L_{TX}) = 10dBi
Free space path loss (L_{FS}) (at 6GHz and 500km)= 100dBm
Miscellaneous losses (L_M) = 20dB
Ground station antenna gain (G_{RX}) = 40dBi
Losses from receiver (L_{RX}) = 10dB

Received power(dBm) = Transmitted Power(dBm) + Gains(dB) - Losses(dB)

Received Power(dBm) = $P_{TX}+G_{TX}-L_{TX}-L_{FS}-L_M+G_{RX}-L_{RX}$
Received Power(dBm) = -52.5dBm

D. Communication microchip selection

Two microchips supporting QPSK modulation and operating in the satellite communication frequency range were compared.

1)AT86RF212B microchip
2)AT86RF215 microchip

Among the two, the first microchip uses a maximum power of 0.065W whereas a maximum power of 0.25W is used by the second. However, the second microchip has a low receiver sensitivity of -123dBm compared to -110dBm of the first microchip. Also, the gain of the second microchip is +14.5dBm which is 3.5dBm higher than that of the first.

Considering these facts, the second microchip was selected.

E. Regulations applicable when communicating with the satellite and reserving the frequency

Satellite communication normally happens in the radio frequency range, which is 1GHz to 300GHz. When reserving the frequency for the satellite, the International Telecommunication Union (ITU) must be coordinated through the National Regulatory Body responsible for ITU coordination.

As the satellite communication system must be able to transfer data quickly with the proposed application, a higher frequency must be selected. However, when the operating frequency increases, the free space path loss increases. To minimize this loss, have efficient data transmission rate and to have the frequency in the range suitable for satellite communication, a frequency in the range of 5GHz to 6GHz is proposed as the frequency of operation of the satellite.

VI. Payload and Mission

A. Types of the payload

Space radiation is different from the kinds of radiation we experience here on Earth. Space radiation consists of atoms in which electrons have been stripped away as the atom accelerated in interstellar space to speeds approaching the speed of light – eventually, only the nucleus of the atom remains.

Space radiation is made up of three kinds of radiation. particles trapped in the Earth's magnetic field, particles shot into space during solar flares (solar particle events), and galactic cosmic rays, which are high-energy protons and heavy ions from outside our solar system. All of these kinds of space radiation represent ionizing radiation.

Too much radiation can cause significant adverse effects like Sunburn, immunodepression, photoaging, and photocarcinogenesis. Also, too much radiation can degrade the performance of the worlds' communication system. Therefore it is important to be on alert of the radiation level of the space.

Therefore we have used a Radiation sensor to measure the radiation of space. The Radiation Sensor Boards will monitor the radioactivity levels generated by space phenomena such as sun storms and background activity.

B. Compoents planning to use

piDOSE-DCD radiation sensor was selected based on the facts; low mass, low power consumption, good measurement range and low cost.

Measurement range - 0.01 to 9000 uSv/h

Power Consumption - 30 mW @ 3.3 V, 70 mW @ 5 V.

Price - 3095 EUR

Mass - 32 grams

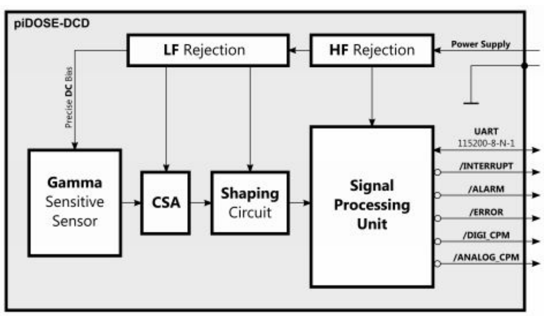

Fig. 7. The piDOSE-DCD Block Diagram.

Compared with other sensors it has a low power consumption and low mass. From the material point of view components are soldered on the 2-layers FR4 PCB, using 60/40% (Tin/Lead) compound. White PCB conformal coating and Mapsil 213B surface finish is used to stabilize extra low leakage currents and prevent outgassing. The 3M Scotch Weld Epoxy adhesive is used for radiation shielding screw fixings. The aerospace-grade NC-machined 6061-T6 Aluminium alloy is used for the product housing. Vacuum-proof electronic components from ESA and NASA-preferred vendors are used (i.e. no electrolytic capacitors) in industrial temperature grade, where possible.

C. Data Processing

The dosimeter provides serialized information about the ambient radiation situation in milliSieverts per hour format. As an extension, each 10 seconds a datagram containing Counts per 10 seconds information is sent. Data is sent in fixed length format consisting in a total of 17 bytes per datagram. Thus, each minute a total of $17 \times 7 = 119$ bytes are sent. Output is represented by conventional ASCII character form and thus could be easily displayed using computer with any terminal software for COM port data reception.

A warning signal can be sent to the ground station when the dose rate is more than 40 µSv/h. This signal is deactivated below this threshold during the following second period. 40 µSv/h is equivalent to twice the average radiation exposure inside of the International Space Station.

Conclusion

The CubeSat proposed in this paper is designed to orbit earth at a height of 500km above Earth's surface and collect data about the radiation levels in the upper atmosphere. This is useful in detecting sudden spikes in solar radiation occurring due to solar storms, which can be used as an early warning system for dangerous solar radiation. It can also be used to detect anomalous radioactive activity occurring in the upper atmosphere, and prevent harmful radiation causing damage to people on the earth's surface.

Acknowledgment

The authors would like to thank SEDSSL, SEDS PERA and IEEE MTT-S of UOP for organizing a series of CubeSat workshops. This gave us a lot of knowledge about Cube Satellites and their construction, and created an interest within us, to take part in this competition.

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