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A Novel Bio-payload And Photo Capturing Cansat StructureFor More EfficiencyInSubsystems

Ramtin Mojtahedi[1], Pouria Behmandpoor[2], Esmaeil Khanmirza[3]
Iran University of Science and Technology, Narmak, Tehran, Iran

Abstract
This article discusses the details and constructions of novel bio-payload and photo capturing Cansat structureswhich have better efficiency intheir subsystems speciallyin electrical and communicational subsystems. For implementing this system designing, these Cansats have limitations on size and weight which bio-payload Cansat and photo capturing Cansat must be under 1.08 Kg and 0.35 Kg in weight, under 66 and 100 mm in diagonaland also under 115 and 340 mm in height respectively. Thus the system is so small and needs to bedesigned well to provide subsystems conditions. In this paper optimum construction, cancelling and preventing from occurring noises,communicational subsystem and its components, novel battery placement and novel graphical user interface (GUI) which is the heart of earth control station designed for bio-payload Cansat, will be discussed in details. First of all we describe the structure which has innovative model on preventing noises in electrical and communicational systemsby giving them the appropriate placement and also using shielding in electrical circuits specially to prevent from Flicker and thermal noises which have profound effects on PCBs tracks,then it is described the different communication subsystemsections such astransceiver modules, data acquisition board andearth stationwhich one of the most important of its duty is analyzing and categorizing each receiving data frame.These novel methods andfunctionalitieswere used to make data transmitting more accurate and safety to be a successful modelthat can be used for constructing new and different aerospace systems. Also these Cansatsshows theirfabulous functionality in achieving first and third ranks in the Fourth Iranian Cansatcompetition.

Keywords:*Cansat-bio-payloadCansat- photo capturing Cansat- optimized Cansat structure*

Introduction
Now a days,aerospace is known as one of the most important science branches which isalso known as one of the power factors of each country, as a result of the great impact of aerospace, many strategies and schedules are defined to reach the nationalaerospace goals, Cansats as a reliable systems which for the first time were propounded by professor emeritus in Stanford university in 1998, are small canes that can be considered as real satellites mock-upwhich they can prepare real situation and conditions in any satellites transferring mission, these conditions are frequently the common Cansats competitions rules
[1, 2]. Cansats can be used for simulating some space missions such as Atmosphere analysis mission, photo capturing mission, bio-payload mission, back to specific location mission, Mars landing mission and etc. Cansats should consider real limitations and should be resistant to different climates and position conditions thatis totally depended on structure of Cansat. Two important sections of each Cansat are structure and power which has vital role in the success of the mission [1, 2], this paper discusses these two pivotal sections with their new and novel constitutions. In the first chapter of this paper the paper talks about the designing of structure and it's innovation for considering subsystems placementswhich their position designed to prevent noise interference in electrical subsystems circuits specially in generating jitter in communicational systems and transmitting signals between Cansats and earth station, noises such as shot noise, thermal noise and flicker noise, can be occurred Thus the construction of systems has great importance to prevent occurring these noises [3-8].
In the second section, communicational system and the earth station are discussed in details, then some of the most innovation and advantages of this Cansat designing will be discussedas conclusion

I. Construction and Power Subsystem

One of the most important sections of Cansat is construction, which it must consider the best placement for each of the Cansat components.In our Cansats we have to consider best placement for communication electrical parts, PCB, C&DH, battery components, mechanical parts such as momentum wheel and servo motor for separation function and finally appropriate placement for parachutes which are necessary for landing function [1,2].

1- M.Sc. Student, Ramtin_Mojtahedi@yahoo.com(Corresponding Author)
2- M.Sc. Student, behmandpoor@gmail.com
3- Associate Professor, khanmirza@iust.ac.ir

After many researches about how to prepare Cansat resistance against trembles and also best placement of components, the construction designed in Solid Works for two Cansat models, construction for bio-payload was design which is shown in fig.1. In the bio-payload Cansat we have 2 sections, the above part is for parachutes and control unit for separation system and the below part is for photo capturing and bio-payload which in our Cansat we use egg as a life payload, also some of the sensors such as thermometer, accelerometer, barometer, humidity meter, height meter and magnetometer were used.The system defined in the mission when the Cansatheight goes under 100 meter from the ground the separation system must separate two Cansat parts then parachutes must guide the landing [2,3]. In the photo capturing Cansat which is shown in fig.2 the mission is defined that when the Cansat height is under 100 meter from the ground, the photo capturing system must start photo capturing from landing.

In the both Cansats we use ZM0.3Mpixel_serial for camera and ARMcortex_M4 as processor, GY-87 for measuring magnet and barometer andAccelerometer, Buzzer for better tracking of Cansat, NRF24L01 for transmitting data, PIC16F876A for detecting the height of the Cansat and commanding for separationand SD card for saving data.

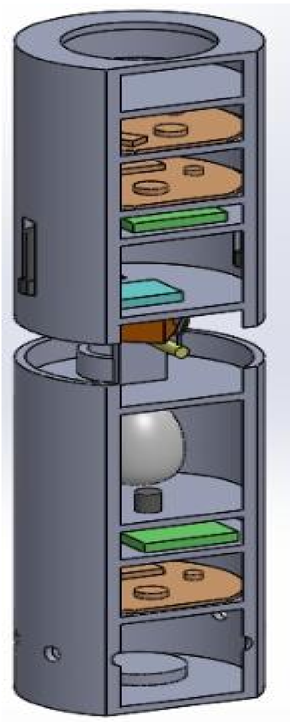

Fig.1. Bio-payload Cansat, which has two parts, the above part is for controllingthe landing (carrier)and below one is for saving bio-payload (lander).

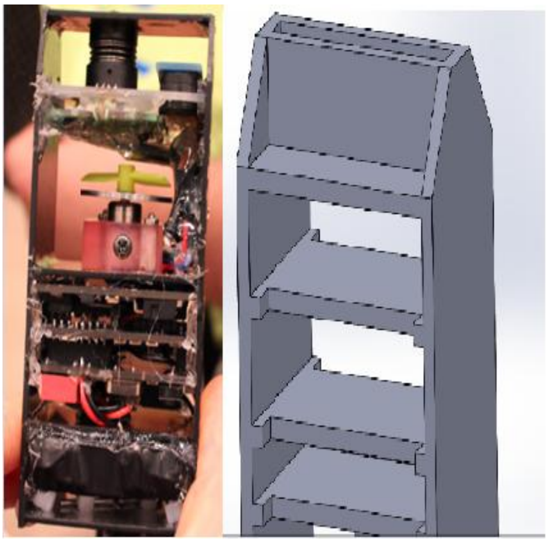

Fig. 2. Photo capturing Cansat, the camera starts capturing when the height of the Cansat goes under 100meter from ground.

On the other hand, one of the most important parts of these Cansats is how to convey the power to the electrical components.We first investigate about using solar cells as preparing power bank for using in the mission but this work is not so optimum because the angle of the sun radiation is not always 90 degrees and for our competition day itwas about 30 to 40 degrees,also the solar cells need a boost circuit for boosting voltage which can merely make thermal, shot and flicker noises and also the system needs more apace and weight which is one of the most important our system limitations.Thus it is betterto use batteries, because the batteries have better efficiency and also make noises less than solar cellsdue to their shielding. Before discussing batteries, all kinds of noises which are occur in the systems are discussed in the following[4-8].

Shot noises

Shot noises are always associated with current flow, it resulted when the current cross a barrier such as PN junction, shot noise has a uniform power density which the diagram of power and frequency is always constant it is also independent from temperature parameter but this noise ismostly depend on electrical devices quality so we try to use the best quality to decrease this noise.

Thermal noise

This is the most important noise which is considered in Cansat, because this kind of noise is generated by the thermal agitation of charge carriers in a conductor. It has a uniform power density and is independent from current flow.

We can show thermal noises as voltage or currentnoises. In the voltage noise, it is modeled with a noiseless series resistor on the other hand,in current noiseit is modeled withplacinga parallel noiseless resistor. The average voltage noise source or current noise source is calculated by (1) where the$\bar{e}$is the average voltage of noise source, K is Boltzmann's constants ($1.38 \times 10^{-2}\ \frac{J}{K}$), T is absolute temperature in kelvin (K), R is the resistance of the conductor in ohms and d is differential frequency:

$$\left(\bar{e}^2\right) = \int 4KTRdf = \int (\frac{4KT}{R})df \quad (1)$$

The term $4KT$ and $\frac{4KT}{R}$ are voltage and current power densities with units $\frac{V^2}{Hz}$ and $\frac{A^2}{Hz}$ respectively.

Flicker noise

Flicker noise or 1/f noise always comes with DC current and its mean square voltage value is formulatedby (2):

$$\left(\bar{e}^2\right) = \int \frac{K_e^2}{f} df = \int (\frac{K_i^2}{f})df \quad (2)$$

$K_e$andK_i are the appropriate device constants, f is the frequency and df is the differential frequency.

Flicker noise is proportional to the DC current which the terms $\frac{K_e^2}{f}$ and $\frac{K_i^2}{f}$ are voltage and current power densities whichtheir units are $\frac{V^2}{Hz}$ and $\frac{A^2}{Hz}$ respectively [4,5,6].

From the above noises thermal and flicker noises can be occur more than the shot noises, thus in construction of the Cansat, the noise sources which are battery wires, regulators and diodesshould be positioned far away from PCB tracks and communicational transmitters and antennas.For these reasons we have placed the batteries in bio-payload in drawer model which are in the side of the Cansat and have vertical position to prevent from Eddy current and magnetisms mutual flux influence in current leaping specially in the beginning or transmitting momentswhich current value is large and variable.

We have used two 3.7 v and 2300 mAh from Sonikcell company, the placement is shown in fig.3,for the photo capturing Cansat, because of the size limitation wehave useda Sonikcell battery which has 7.4 v and 800 mAh, we have placed the batteries near the parachutes for being far away from the PCB tracks.In this model as the same as bio-payload we have flicker and thermal noises but less flicker noise because the DC current is more less than the previous one since the electrical components are less than bio-payload Cansat. Placement of the battery is shown in fig.4. In these two Cansats thermal noise is generated mostly in regulators so we use fiber glass for insulating thermal also one of the innovation which was used is trying to design Cansat that the PCB tracks are short as possible, this designing short tracks model helps to prevent flicker and thermal noise specially in high frequency.

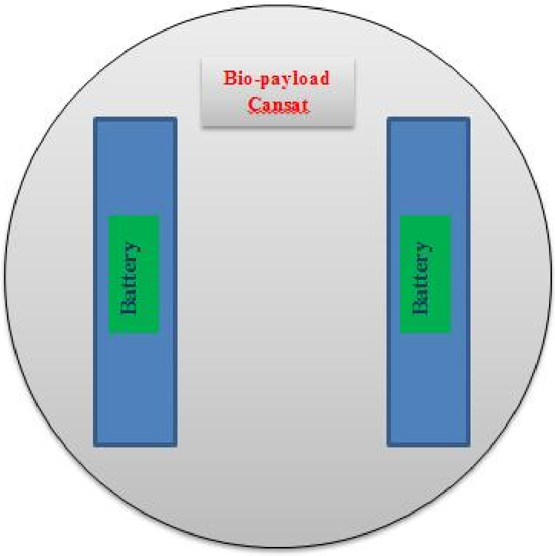

Fig. 3.Top view of Bio-payloadbattery Cansat placement which areplaced in the aside of the Cansatand puts drawer into the Cansatfor preventing from noises specially flicker and thermal ones.

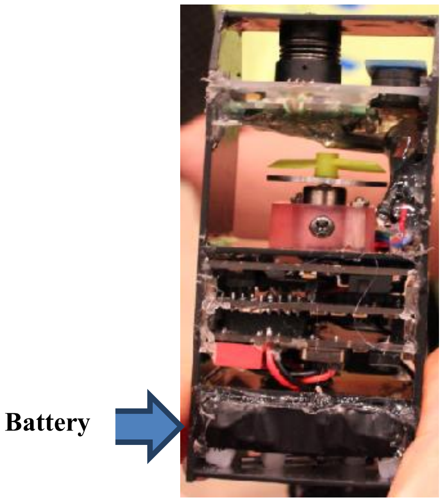

Fig. 4. Battery placement in photo Capturing Cansat which is specified with an arrow and has separate unit for preventing noises.

II. Communicational Subsystem

This section of Cansats consists of two parts, the software part which is earth station (GUI) and the hardware part which includes modules and antennas to create the downlink of Cansat. The bio-payload Cansat has an additional internal communication system to enable communicating two bio-payload parts, lander and carrier with each other. This additional part helps us to monitor online data received from lander after the separation.

In fig.5different parts of communication subsystem are shown [8, 9].

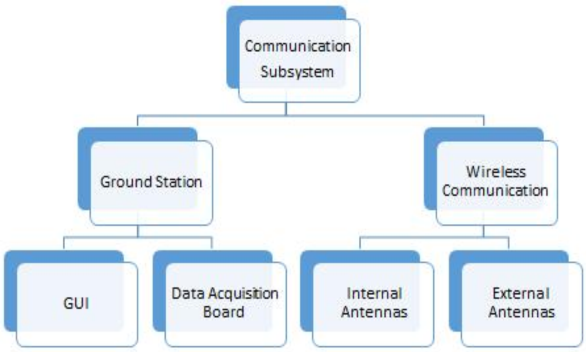

Fig. 5. Communication subsystem and its components.

A. Ground station

This section has been designed to monitor online information in a friendly user environment. The information is transmitted to the ground station in 1Hz frame rate. The schematic of this section with its different parts is shown in fig.7whereGUI is abbreviation of graphical user interface, OIT is the abbreviation of online information tracking, GPS is the abbreviation of global positioning system, CSR is the abbreviation of Cansat status report, SI is the abbreviation of saving information, PL is abbreviation of plotting, DAB is the abbreviation of data acquisition board, CM4 is the abbreviation of cortex-M4 and TM is the abbreviation of transceiver module, UI is the abbreviation of Universal asynchronous receiver/transmitter interface and SD is for SD card.

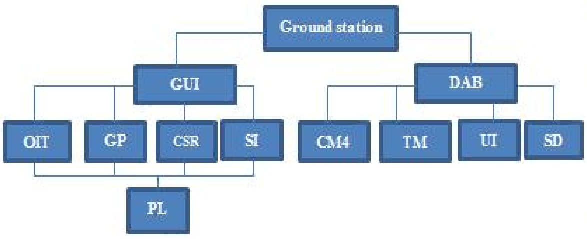

Fig. 7. Earth station and its sections.

GUI

The designed GUI in MATLAB environment [10]has been programmed as a multilayer GUI to increase the ability of monitoring and saving information which is received from Cansat. During the mission the GUI shows information numerically. By choosing one or more plots by checking the respective checkbox, second layer of GUI is shown and sensor information would be plotted from beginning of mission time to the present time. Thus this GUI is called multilayer. The designed GUI has been equipped to data management system, however, to save the memory space in the long missions, GUI deletes plotted information from memory without deleting them from the plot. In addition, in offline layer of GUI, information is saved in a notepad file. During the mission this text file can be opened and the frame information can be retrieved.

The functions of GUI which need more time to compile the received information like GPS are set in a manner that required time for parallel computations be less than 1 second, to avoid losing of next frame.

The ground station receives sensor information from Cansat by frames which are produced by electronic part of Cansat. Each sensor has an op-code in the frame to be recognized by GUI. These op-codes improve the reliability of communication by separating the frame, because noise may destroy the information of one or more sensors, GUI can get the rest of information from the frame using related op-codes to each sensor data.

Designed GUI reports the Cansat status continuously, status of different parts such as central system, communication system and GPS. If each part is activated and works normally the related button will be dyed to green. The sensor information which the GUI shows online are: acceleration in three axis, gyroscope, pressure, temperature, altitude, carbon mono-oxide and oxygen concentration and speed. These information are shown in online information section. In the other section the information of those sensors that are changed in a large scale during the mission will be plotted if the corresponding check box is checked. These plots are the information of altitude, pressure, speed and acceleration.

Fig. 8. GUI system design and its controlling components which designed for bio-payload Cansat.

The other section of GUI is belonged to GPS. In this section latitude and longitude information of GPS will be shown. In the GPS picturethe position of Cansat related to its first location can be seen by a red dot. Here it should be noted that the shown picture is an offline picture which has been saved to the GUI. The area that the picture shows can be adjusted in the GUI code in meters for each side of the picture.
In other section, by gyroscope information, the relative angle of Cansat to its first angle after turning ON can be shown. This angle is calculated in X-Y plane. Since the polarization of the used dipole antennas are linear, the orientation of receiver antenna should be parallel with orientation of transmitter antenna, thus with the gyroscope information the receiver antenna kept in the right angel.

Data acquisition board
Since during the mission sensors are not all activated in the same time (GPS is activated with a delay, camera is not activated all the time), length of data frame received from Cansat is a variant, thus it is very likely that Cansat sends next frame while the GUI is compiling the previous frame and however the new frame will be lost,thusto avoid data loss the data acquisition board works as a bridge between receiver module and the GUI. Also it is impossible to all parts of GUI to be shown in one monitor, the data acquisition board can be connected to two computers. This hardware saves the received information from receiver module to an SD card and sends it to the GUI when the GUI requests. This board can support two GUIs in two separate computers, after sending information to both of computers deletes the information to get ready for the next frame.
A voltage regulator has been used in the data-acquisition board of both Cansats to use USB as a power source. In addition cortex M4 has been implemented in data-acquisition board to manage the informationwhich received from receiver modules. Also FT232RL IC has been used to convert UART protocol to USB.

B. Antennas and modules

In the bio-payload Cansat two models of transceiver modules have been implemented, NRF24L01which its specifications are shown in table.1 was used for internal communication and XBEE Pro 900 which its specifications are shown in table.2 was used for external communication.The internal transceivers have been implemented to send sensors information that are located in payload part of the Cansat like CO and O2 sensors and IMU, to the carrier electrical board. Since these two transceivers should be line of sight, they have been placed in bottom and top of carrier and lander respectively. In the carrier part of bio-payload Cansat the XBEE antenna are located in the middle of the sections in diagonal orientation. This placement is due to used dipole antenna pattern which has null in direction of antenna axis. In order to avoid locating the ground station receiver in this null of antenna, antenna direction is not set fully perpendicular to the ground. [8, 9], the reson of this process is shown in (3)

where the θ is the degree respect to the antenna, l is the antenna length, k is the Propagation constant, I_0 is the input current, U is theRadiation intensity, η is the Wave impedance.

$$U = r^2 W_{av} = \eta \frac{I_0^2}{8\pi^2}\left[\frac{\cos(\frac{kl}{2}\cos\theta) - \cos(\frac{kl}{2})}{\sin\theta}\right]^2 \quad (3)$$

In photo capturingCansat the NRF24L01+LNA+PA transceivers which itsspecifications are shown in table.3 have been used. Since the dimensions of this module is larger than the Cansat, the transceiver module has been placed in the Cansat in diagonal orientation and its antenna has been placed bottom of the Cansat parallel to the ground because of its pattern characteristics which is as same as bio-payload's.
Here it should be mentioned that in both Cansats downlink communication has been activated and there is no uplink communication. The NRF24L01 module works in frequency 2.4 GH and the XBEE one works in frequency 900 MHz, thus there is no interference between two modules when they are working in a same time in the bio-payload Cansat [8, 9].

Table. 1. NRF24L01 module specification which used in bio-payload Cansat

Range	100 m	Antenna	patch
Transmiting power	1 mw	Nominal voltage	3.3 v
Receiver sensivity	-85 dbm	Current consumption	TX:11.3 (mA) RX:13.1 (mA)
Protocol& Modulation model	SPI GFSK	Nominal frequency	2400 ± 0.16 MHz ISM Band
dimensions &Weight	2.8 * 1.5 * 0.5 cm 3.8 g	Data transfer rate	1Mbps
Part number: 130 1CL			

Table. 2. Xbee module specification

Range in open space	3 Km	Antenna	2 dbi
Range in closed space	140 m	Data transfer rate	9600bps
Transmiting power	50 mw	Nominal voltage	3.3 v
Receiver sensivity	-85 dbm	Current consumption	TX:210 (mA) RX:80 (mA)
Protocol&Modulation model	UART FSK	Nominal frequency	902-928 MHz ISM Band
dimensions &Weight	4.5 * 2.5* 0.7 cm 7.1 g	Antenna length and weight	17 cm 22.7g
Part number: XBP09-DPSIT-156			

Table. 3. NRFL01 +PA +LAN which used in photo capturing Cansat

Range in open space	1.6 Km	Antenna	2 dbi
Range in closed space	140 m	Data transfer rate	2Mbps
Transmiting power	-18 dbm	Nominal voltage	3.3 v
Receiver sensivity	-82 dbm in2Mbps/ -85 dbm in 1Mbps/ -94dbm in250Kbps	Current consumptio n	TX:210 (mA) RX:80 (mA)
Protocol&Modul ation model	SPI	Nominal frequency	2.4GHz ISM Band

III. Conclusion

The architecture and construction developed in this paper introduced a new system design for implementing Cansats with more efficiency and accurate data transmitting.The construction is also more stable and resistance to different climates and trembles .Also a novel noise analyses is developed for preparing Cansats to be more resistant against noise interference. A graphical user interface (GUI) was introduced which has novel specifications and it can be simply prepared for different data transmitting monitoring and controlling.Also a data acquisition board was introduced to handle receiving data more efficiently in ground station.

The Cansats which were constructed showed their successful operation in Iranian national Cansat competition and succeeded to achieve first and third rank in photo capturing and bio-payload missions respectively.

Finally in next system designing we can use polymer solar cells which are so light, resistant and efficient but are more expensive than common solar cells, also we can use a booster and power bank circuit to omit batteries, in this case Cansats can be better simulation devices for space missions specially for thelong-termspace mission because of rechargeable power system.

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