# Model satellite design for CanSat Competition

**Conference Paper** · June 2013

DOI: 10.1109/RAST.2013.6581344



**10 authors**, including:

Can Beker
Middle East Technical University


Ahmet Kirli
Yildiz Technical University


Hasan FATİH Ertugrul
Yildiz Technical University

# Model Satellite Design for CanSat Competition

[1]Sultan Nur Bulut*, [4]Mahircan Gül, [2]Can Beker, [1]İbrahim İlge İpek, [1]Ömer Eren Can Koçulu, [3]Çınar Topaloğlu, [1]Nurullah Dinçer, [1]Ahmet Kırlı*, [1]Hasan Fatih Ertuğrul, [1]Celal Sami Tüfekci

[1]Dept. of Mechatronics Eng., [2]Dept. of Mechanical Eng., [3]Dept. of Metallurgical and Materials Eng.
Yildiz Technical University, Istanbul, Turkey
[4]Dept. of Computer Eng.
Kultur University, Istanbul, Turkey
*Corresponding authors. E-mails: sultannurbulut@gmail.com, akirli@yildiz.edu.tr

***Abstract*****—** Objective of this work is to design and manufacture a model satellite named Vecihi that is able to perform some of the basic tasks that artificial satellites perform. The satellite is developed under the rules of CanSat Competition 2013, which aims to promote innovative space solutions and to improve the current systems. The Vecihi satellite designed around budgetary, dimensional, and mass requirements as set in the competition guidelines, while carrying and landing its payload successfully.

**Keywords— model satellite, CanSat, aero breaking, telemetry transmission.**

## I. Introduction

The term satellite refers to a device that is capable of rotating around a planet or around another satellite on a specific orbit. Satellites are divided into two parts; artificial satellites and natural satellites [1]. This study includes information about experiments over an artificial satellite named Vecihi, which is constructed for the prestigious CanSat Competion [2] 2013 that takes place in Burkett, TX, USA on 7-9 June 2013.

Artificial satellites which are developed by humankind are in a continuous technological evolution and used in the fields of telecommunications, observation, surveillance, astronomy meteorology, and military. Model artificial satellites and actual artificial satellites show a significant similarity when compared to each other [3].

CanSat (can-sized μ-satellite) competition has constraints about budget, dimensions and weight; and expects an appropriate satellite design that has the following subsystems: sensors, storage module, wireless transmission, control, and optional imaging subsystems. Sensors consist of positioning, latitude, altitude, pressure, temperature and direction. All the data acquired with sensors has to be stored in a Micro SD storage device with an appropriate format and has to be sent to a ground station for processing. Moreover the model satellite records the separation, and keeps recording until landing. After landing, satellite will be located with the help of GPS module. In case of a GPS device failure, satellite will be located with buzzer device attached to it.

The main mission of this study is to deploy a payload, “the CanSat”, from a launcher and have it land safely using aero-braking techniques that are not based on parachutes or streamers. It is also mandatory to acquire and transmit data (telemetry) continuously between the ground station and the model satellite as well as to protect the payload, a large hen’s egg that is located inside. This article includes information about innovative designs and analyses for the satellite Vecihi in order to meet competition rules. As a result, a robust, innovative and modular real-time satellite system is designed.

Model satellites generally have the following common features; sensing, processing and storing sensor data, sending it to a ground station, and decision-making in a necessary situation. Tracking down the satellite will be performed by a ground station, which runs on a personal computer with an application in a graphical user interface. All the acquired data can be read on the application with proper graphics and tables. The data that are stored in ground station will be compared with the data that is stored by the satellite after landing. This comparison will give information about packet losses, and improvements will be made accordingly.

Vecihi satellite has a constructive design that will satisfy the rules of the competition. It is made out of light materials that are resistant to shock forces such as 10G–30G. It has a surface that enables a smooth separation on its peak, after launching with rocket. Satellite descends until a specific distance with a parachute. Then the real-time information acquired from sensors enables the separation mechanism and satellite and container gets separated [4].

This paper is organized as follows. Next section explains the satellite system overview. It details the mission particulars and subsystems. Then, engineering analyses results are presented in section 3. Finally, conclusion section summarizes the entire effort.

## II. System Overview

The project is developed in an incremental approach. Firstly, team is established and gathered in September 2012. After setting up a stable team member list, project is started in November 2012. Alternative subsystems (sensors, mechanics, etc.) were determined and first model for satellite has been

978-1-4673-6396-9/13/$31.00 ©2013 IEEE

designed in January 2013. First prototype has been produced in February 2013.

### A. *Mission*

Mission definition is concluded as follows.

- Base Mission: The base missions of satellite is to descent the payload to earth in a safe and controlled manner and prevent the egg inside it to be damaged. Satellite consists of two parts, namely container and payload.
- Side Missions: Side missions are listed as the following, with priority order; (1) to design the descent and separation mechanisms of payload and container, to make them maintain a constant speed of 20 m/s until the point of separation at the altitude of 400 meters while protecting the egg inside the payload, (2) to read the values obtained via sensors, (3) to design the interface of the ground station, (4) to transmit the data properly to the ground station, (5) to record the data into memory unit, (6) to designate the point of landing using a GPS module.
- Optional Missions: Following missions are listed as optional in competition rules; (1) to record a video of descent moment using camera sensor, (2) to measure the landing reaction force with the speed of 100 samples per second. However, we have decided to fulfill only the mission number 1.

### B. *CanSat Vecihi and Subsytems*

The name Vecihi is given after Vecihi Hürkuş (6 January 1895 - 16 July 1969) was the first civil aviator in Turkey. He also built the first airplane in Turkey [5]. The subsystems of the Vecihi satellite are developed under three separate topics.

*1. Mechanical Parts:* Mechanical design's main mission is to provide a safe landing, protect the egg while carrying all of the electrical and mechanical components safely and, be a safeguard against "g" forces. In this regard our design is an innovative, robust, and functional solution. The mass is limited with competition requirement of ±700 gr. Mainly, Mechanical design consists of four parts as depicted in Fig. 1.

- Chassis
- Flight mechanism
- Egg protection system
- Container

*1.1 Main Body:* Main body is composed of 3 different subcomponents. While designing the main chassis, our design limitation was competition requirements. This model has been designed to work under 30g shock forces and 10g normal stress concordantly carbon fiber material has been used to resist g forces because of its material properties. Mainly, the structure stands by help of carbon shafts and we designed carbon disc panels for electronic component settlement and used gasket (rubber) for keeping the disc panels stable because of its high friction capability and electrical isolation, Fig. 2.

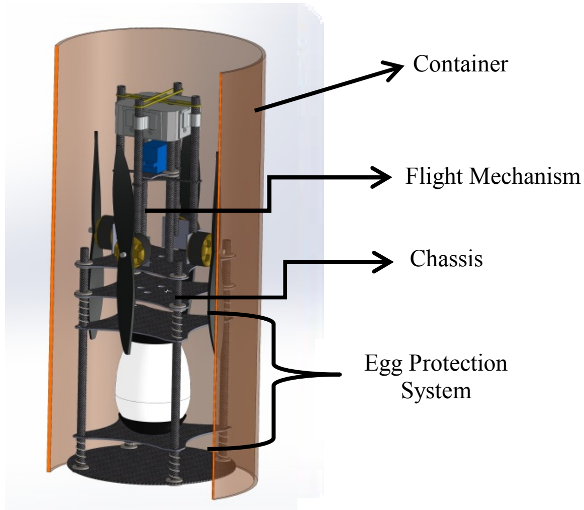

Fig. 1 General schematic of the design

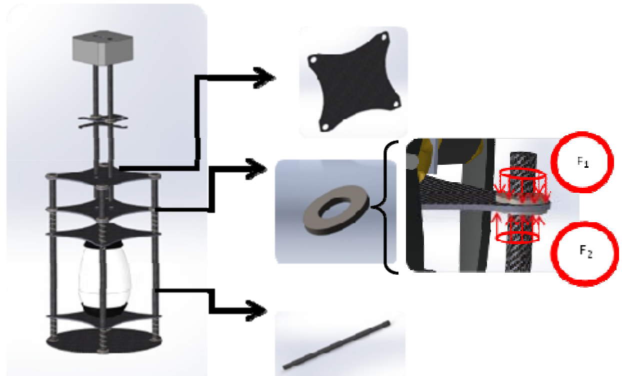
Fig. 2 Chassis structure

*1.2 Flight Mechanism:* At 400 m CanSat splits into two parts which are named container and payload, respectively. Then, the payload section uses its *active* descent control system; while the container section uses its *passive* descend system for landing. We designed quad–copter model as the active descend control system. It is used as the triggering mechanism during the separation and is used as the stabilizing mechanism afterwards, Fig. 3.

At 400 m servo runs and grabber releases the quad-copter's bar. Then, rubbers which are used for triggering, helps the bars to overcome their own inertia. Eventually, propellers start to work, Fig. 4. Chosen materials for flight mechanism and key design considerations are as follows:

- Supporting element: Poly-amid material has been chosen for the supporting element because of their durability and good vibration absorption features.

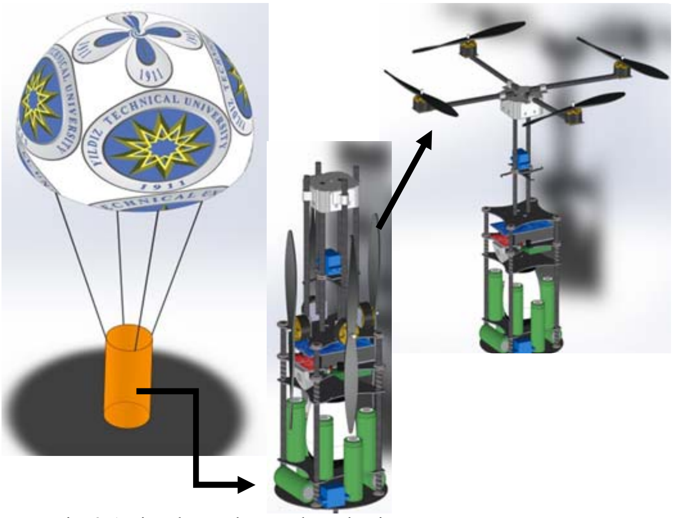

Fig. 3 Active descend control mechanism

Fig. 4 Quad-copter swing up design

- Hinge: Aluminum material has been chosen for hinge and it has low friction.
- Quad-copter bar: Materially, carbon-fiber has been chosen because of its durability. We designed quad-copter bar as cylindrical profile because of its low inertia rectangular profile.

*1.3 Egg Protection System*: Safety concern, low-cost and light-weight egg protection system has been designed with springs and a soft seat, Fig5.

a b

Fig. 5 a. Design b. Actual system

*1.4 Container:* Container was made by carbon-fiber and covered by shiny orange color for easy locating. The container doesn't contain any sensors or electronic devices. But it has significant mission with protecting the payload from the environment. After 400 m Container separates from Payload. Container-payload connection has been shown at Fig 6. Container payload connection:

- After 400 meters, a servo runs and releases itself from the container.
- Magnet prevents to turn the container around its axes

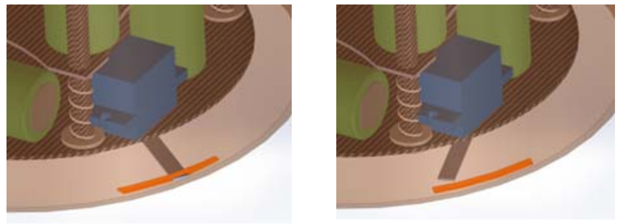

Fig. 6. Container payload connection system

*2. Electrical Architecture*

Electrical architecture is summed up in two divisions as follows.

*2.1 Electrical Diagram:* The CanSat needs electrical system for flight control, communication and landing. In choosing electrical system, we considered requirements of mission. The electrical architecture includes sensors, microcontroller, motors and drivers, battery, memory card, and other circuitry, Fig 7. We need to power up enough power to other subsystems. We choose Li-Ion batteries. The batteries connect to each other 4 parallel and 2 serial structures. So, we got 7.4 V voltage level and a 6400 mAh current capacitiy. The brushless motors are supplied by 7.4 V. The other servo motors, microcontroller, distance sensor, camera, GPS, and the memory card supplied by 5 V. All sensors and transmitter/receiver modules are supported by 3.3 V. Besides, we can make a measurement system for battery level by a voltage divider.

*2.2 Ardupilot:* The controller for CanSat is chosen to be Ardupilot Mega APM2, Fig 8. The first reason of choice is to optimize system for flight data acquisition. The APM2 is more durable and stable than handmade cards. We can get all data needed to balance and decide to run actuators from APM2. The APM2 includes accelerometer, gyroscope, barometer, temperature sensor, magnetometer, logic level converter, ATMEGA2560 microprocessor and a voltage regulator. The APM2 has 16 MHz clock speed. The GPS and the memory card can be easily integrated with this configuration.

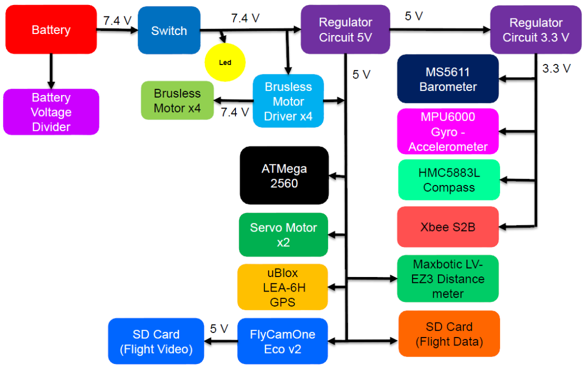


Fig 7. Electrical architecture block diagram

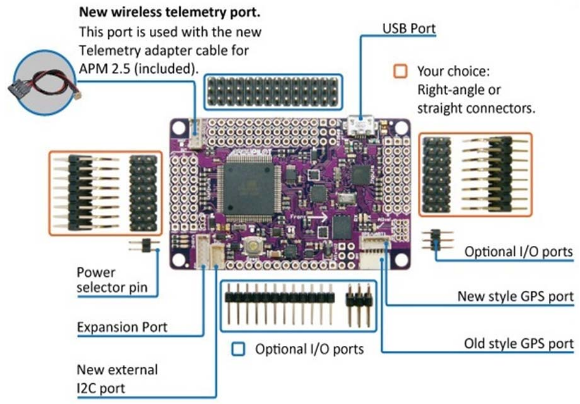


Fig. 8. Ardupilot

*3. Telemetry and Ground Station:*

Telecommunication part of the system consists of a Zigbee network, which is implemented with XBee Pro S2B model communication modules. Network is set up with one communication module attached to the satellite and another module that is connected to the terminal in ground station. Module on satellite receives all the sampled data via serial interface from microcontroller, and send it to the module on ground station via radio waves. Both modules work on 2.4 GHz frequency. Congestion control is enabled on communication with setting the API mode on, for both devices.

Data rate for communication is 250 kbps including headers and acknowledgement overhead. Hence, actual data rate is lower. Most of the controls, such as frequency hopping and modulation, are provided by lower level Zigbee protocols (Network Layer and Medium Access Protocol).

Communication module on ground station acts as a relay, and transmits all the received data from remote module to the terminal via serial USB interface. Serial data rate for both modules is 9600 bps without parity and handshaking. On ground station terminal, a .NET 4.0 application is written specifically for this system. All the received data is prompted to the user in a grid view. Specific data types of temperature, voltage, and altitude are plotted to charts, except GPS data. For GPS data, Google Earth™ is used for plotting the real time coordination of the satellite. Ground station application also shows RSSI (Received Signal Strength Indicator) information, which shows the quality of the received signal. Smart loss control mechanisms are designed for the case if received signal strength falls under a specified threshold.

For an extended range of sight, a 3 dBi RP-SMA duck antenna is used on the satellite and it is attached to the communication module. For ground station, a 7 dBi RP-SMA duck antenna that is elevated 3 meters from ground is used to minimize connection losses and for fulfillment of competition requirements.

All the data that is carried on a telemetry packet is shown at Table 1.

TABLE I. TELEMETRY

| Offset | Data | Size (Byte) | Description |
|---|---|---|---|
| 0 | HEADER | 6 | Telemetry header |
| 6 | TEAM_ID_LOW | 2 | Group ID(1168) |
| 7 | TEAM_ID_HIGH | | |
| 8 | GPS_TIME_H | 1 | GPS time, divided into three parts |
| 9 | GPS_TIME_M | 1 | |
| 10 | GPS_TIME_S | 1 | |
| 11 | GPS_LAT_DEG | 1 | GPS latitude information divided into 4 parts |
| 12 | GPS_LAT_MIN | 1 | |
| 13 | GPS_LAT_SEC | 1 | |
| 14 | GPS_LAT_DIR | 1 | |
| 15 | GPS_LONG_DEG | 1 | GPS longitude information divided into 4 parts |
| 16 | GPS_LONG_MIN | 1 | |
| 17 | GPS_LONG_SEC | 1 | |
| 18 | GPS_LONG_DIR | 1 | |
| 19 | GPS_ALT_LOW | 2 | GPS altitude information with low and high bytes |
| 20 | GPS_ALT_HIGH | | |
| 21 | GPS_SAT | 1 | Number of GPS satellites being tracked |
| 22 | ALT_SENSOR_LOW | 2 | Altitude in meters measured by altitude sensor |
| 23 | ALT_SENSOR_HIGH | | |
| 24 | TEMP | 1 | Temperature |
| 25 | BAT_V_WHOLE | 1 | |
| 26 | BAT_V_FRAC | 1 | Battery voltage represented in whole and fractional parts |
| 27 | STATE | 1 | State of satellite device |
| | | | |

## III. SYSTEM ANALYSIS

During the launching of the satellite, not only the payload has to be protected, but also the mechanical system must stay together. In order to ensure the required strength of the system, stress and displacement analysis have been performed using frequency spectrum analysis for 30g shock force and a normal stress analysis for 10g normal stress as depicted in Figs. 9 and 10 respectively. The configuration shown in Fig. 11 and in equation (1) is utilized for the modal analysis. These estimation will be verified with further experimental work and any mismatch will be accommodated before the competition.

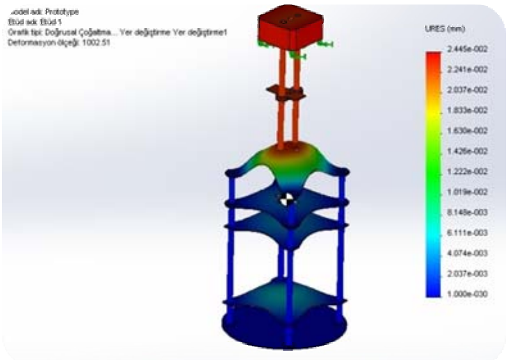

Fig. 9. Displacement Analyses

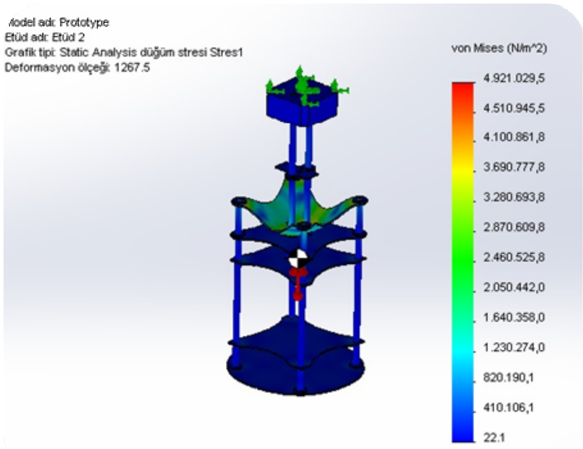


Fig. 10. Stress Analyses

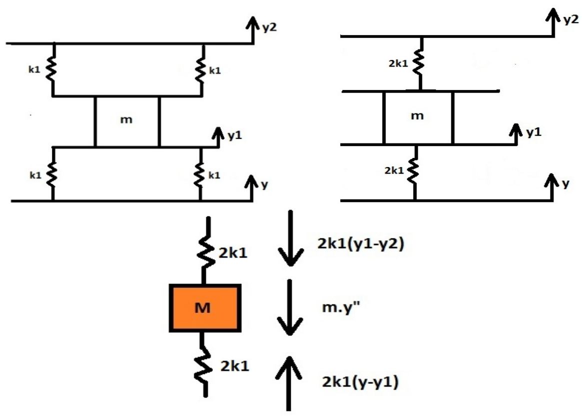


Fig. 11. Mathematical modeling of egg protection system

$$m_1\ddot{y}_1 + 2k_1(y_1 - y_2) + 2k_1(y - y_1) = F \qquad (1)$$

Locations of the components such as sensors, batteries, etc. are defined due to these analyses. Mechanical structure design is also examined with these mechanical analyses.

## IV. Conclusion

In this study, a model satellite, Vecihi, that fulfills the requirements of the competition is designed and produced. After launch phase, while the satellite traces an orbit, satellite sends all the sensor data via wireless communication system to the ground station terminal. In the meantime, all the sensor data and image data that is taken by image sensor is stored on the storage device on the satellite. Satellite system has three mechanisms; separation, both aero dynamic and passive breaking, egg protection. Our modal satellite has several innovative properties. One of them is the aero dynamic breaking system; the same mechanism that is used on quad-copter devices is adapted to the satellite. Second property is the egg protection system; an arc system is designed by considering the fact that the vertical poles of the egg is more resistant to the external forces than the other parts. For general satellite production, simple, inexpensive and applicable solutions are chosen. To sum up, in every component of the model satellite; mechanical, electrical and software, familiar mechanisms with a proper artificial satellite are made available. It provides a beneficial study model for people who are willing to perform practical exercise in satellite design field.

## Acknowledgment

We would like to thank the following companies for their precious help in terms of advice and money. Rectorship of Yildiz Technical University, Baykar Makina, Istanbul Chamber of Commerce (ITO).

## References

[1] Larson and Wertz, *Space Mission Analysis and Design*, Microcosm Press, 7th Print, 2005.

[2] http://www.cansatcompetition.com/Main.html–retrieved 31.03.2013

[3] http://en.wikipedia.org/wiki/Satellite – retrieved 31.03.2013

[4] https://en.wikipedia.org/wiki/Communications_satellite – retrieved 31.03.2013

[5] http://en.wikipedia.org/wiki/Vecihi_H%C3%BCrku%C5%9F– retrieved 31.03.2013