VSSEC-KDS: Yes Oui Can(Sat)

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Australia will be represented for the first time at an international CanSat competition in France this year run by CNES and Planète Sciences at the DGA-EM military base. VSSEC-KDS is the representative team from Melbourne and is the product of a partnership between the Victorian Space Science Education Centre (VSSEC) and The King David School (KDS). The team aims to successfully complete three missions at the 2011 competition and gain valuable experience for the future from participation. The three missions are Atmospheric Sounding, Deployment of a RF Antenna and Airbag Landing. At this stage, the team has preliminary solutions for each mission and is completing tests for optimisation. In order to complete the Atmospheric sounding mission, an OzeSat microcontroller and accompanying receiver will be used to telemeter and detect hygrometry. The RF Antenna, a real satellite's communication link will be lifted out of the can by a motor and flexible linkage. Finally, an Airbag Landing will be accomplished by synchronising an ultrasonic sensor, connected in series with a microcontroller and motor to release $C0_2$ into an inflatable trapezoid structure designed to cushion the can on impact.

I. Introduction

VSSEC-KDS is Australia's representative team in the CNES and Planète Sciences CanSat France 2011 Competition. This will be the first time an Australian team will compete in the highly regarded international CanSat competition. The team will attempt to complete the Atmospheric Sounding, Deployment of a RF Antenna and Airbag Landing missions.

II. Context of Development

A. Club

VSSEC-KDS is the product of an ongoing partnership between The King David School (KDS), its graduate mentors and the Victorian Space Science Education Centre (VSSEC). As a result of Milorad Cerovac and Dr. Naomi Mathers' interest in initiating Australian involvement in the CanSat competition, VSSEC-KDS was officially formed on 30/12/2010 [1]. This will be the first ever Australian team to compete in CanSat, their latest challenge after involvement with the Australian Space Research Institute's small sounding rocket program. The team is supported financially by the Robert Feigin Memorial Scholarship Trust [2] who have been trustees of The King David School since 2006. Since then they have continuously supported and developed the Science programs through to the creation of VSSEC-KDS and beyond. The team is also actively pursuing corporate sponsorship.

VSSEC-KDS is comprised of facilitator Milorad Cerovac who is the Head of Senior Science at The King David School since 2006. He completed his Masters of Science (Astronomy) in 2009. He is a member of the Moorabbin District Radio Club providing a great insight into radio technologies. Dr. Naomi Mathers is the adviser to VSSEC-KDS and currently works as a program developer for VSSEC. She completed her Bachelor of Aerospace Engineering and received her Doctor of Philosophy in 2010 for her research on inflatable antennas for rapid deployment of satellite communications [3].

The mentors work in conjunction with students and facilitators; acting as a bridge between the younger and older members of the team; all graduated from KDS within the past two years. Boaz Ash led team Golem at the Australian national LEGO Robotics team in the 2009 LEGO World Festival in Atlanta. Boaz is highly skilled in computer programming and electronics. Devon Boyd has broad technical skills and understanding ranging from mechanics through to electronics and programming. He has a great nous for problem solving, helping find solutions where none where thought possible originally. Michael Eisfelder is vastly knowledgeable in the fields of mathematics and rocketry, having held scholarships at KDS and The University of Melbourne (Physics). He was a coordinator in the High Powered Rocketry program, the foundation program for VSSEC-KDS.

The student team comprises of Kieran Hirsh, Jarryd Karsz, Sean Kozer, Joshua Marlow, and Yarden Rais. Raphael Morris and Joel Torbiner will participate in coming years but for now provide assistance where possible.

Fig 1: Team VSSEC-KDS

B. Work plan

VSSEC-KDS currently meets three times a week in order to allow the students time for academic commitments. Task delegation was organised January 2011 with mentors and students nominating tasks that they felt they could accomplish. Since then the sub-teams have been working hard on achieving their goals. Time management has been a significant factor due to the many new challenges presented by the competition with 2011 being the first year that VSSEC-KDS has competed. In order to have a functional CanSat before August, 147 man hours are required per the table below.

Table 1: Man hours remaining

Task	People	Hours	Man Hours
Parachute	3	2	6
Can Construction	3	8	24
Testing	4	20	80
Calibration	2	2	4
Airbag	3	11	33
			147

The current anticipated budget is $2000 AUD. This is a projected cost, includes as many team expenses as possible and backups of all major components as a contingency. We don't expect this figure to fluctuate dramatically.

III. Definition of the Missions

A. Atmospheric Sounding

In order to telemeter hygrometry data, the team has chosen to use an OzeSat Microcontroller and accompanying receiver to provide them with the necessary data. The OzeSat is made up of three circuit board modules: a sensor module (SM), a controller module (CM) and a transmitter module (TM) [4].

The SM contains three sensors allowing it to measure temperature, pressure and humidity. The temperature sensor is a Microchip TC1047A using a thermistor to relay temperature data. The pressure sensor is a Freescale MPX4115A designed to sense absolute air pressure in altimeter or barometer applications. The humidity sensor is part of the Honeywell HIH-4000 series.

The CM is used to interface the SM and TM. It includes an Atmel ATmega328P 12.288 MHz microcontroller with serial interface and a LED. It acts as the main unit linking the three components together.

The TM includes an Analog Devices ADF7012 transmitter and takes 1200 bit/s AFSK (audio FSK), at either 1200 Hz or 2200 Hz signals and are sent via TXDATA. The signal is transmitted with a frequency of 916.357 MHz or 916.363 MHz.

The signal is then picked up off a Yagi antenna and then re-modulated into readable hygrometry data. This data is then parsed through a Perl script that includes the calibration factors for the hygrometry data.

The calibration of the humidity sensor will be done by inserting the sensor inside a small sealed container and placing some desiccant (silica gel) and waiting for the moisture in the air to be removed. Though this is not 100% accurate, it is the most effective way to calibrate whilst on a strict budget. Temperature calibration will be done by creating an ice-water bath which will create a temperature to within a few centidegrees of 0°C and placing the sensor inside. To calibrate the pressure sensor; the knowledge that for every twenty eight feet increase in altitude, the pressure decreases by 1hPa is used [5]. However to initially calibrate the instrument, the plan is to use a weather station and compare the data from that. This will be secondary calibration will be done for the humidity and temperature as well. This will then be confirmed against the data used by the Bureau of Meteorology based in Melbourne.

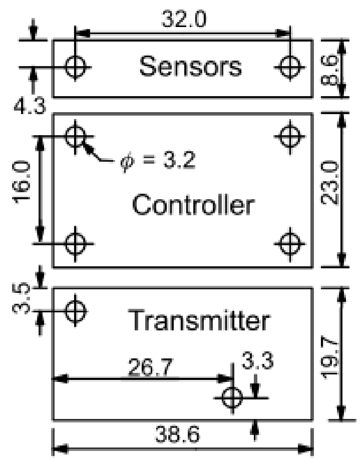

Fig 2: OzeSat Architecture

B. Deployment of a RF Antenna

The deployment of the antenna is completed through the use of only four modules. It involves a servo motor [6], a small hollow tube, a string and an antenna. The series is set up such that the string is wound around the axle extending out from the motor, with the other end attached to the antenna. The antenna sits inside the tube, located at one end, with the flexible linkage passing through to the other end. As the motor rotates, the string is wound further around the axle pulling the antenna up the tube. Just prior to the antenna being fully removed from the tube, the motor will cease rotating and a large proportion of the antenna will protrude and hence be deployed.

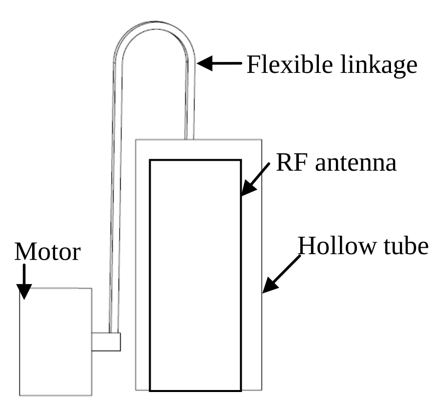

Fig 3: RF deployment configuration

Airbag Landing

In order to ensure a safe deployment of the CanSat on the alien surface, airbags will be deployed in order to absorb most of the impact from the shock of landing. The design is simple in principle; a cartridge of compressed carbon dioxide will inflate an airbag at an altitude of four meters.

The net of the airbag will form a trapezoid. To calculate the dimensions of the net, it was assumed that one litre of CO_2 at STP would need to be released, filling the airbag to a set, partially filled capacity. As the uppermost part of the trapezoid will be confined to the size of the base of the can, the appropriate lengths were determined using the following formulae:

$$V = \frac{1}{3} \times b^2 \times h_1 - \frac{1}{3} \times a^2 \times h_2$$

$$\tan(\theta) = \frac{2 \times h_2}{a} = \frac{2 \times h_1}{b}$$

$$V = \frac{1}{6} \times b^3 \times \tan(\theta) - \frac{1}{6} \times a^3 \times \tan(\theta)$$

$$6V = \tan(\theta) \times (b^3 - a^3) \quad (1)$$

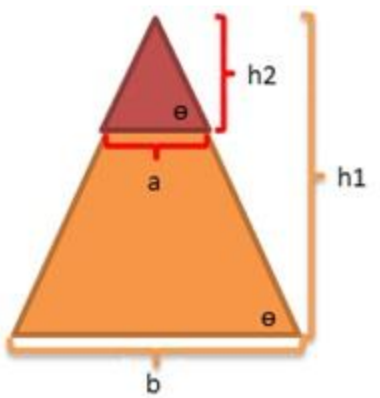

Fig 3: Trapezoid diagram from side

Using an iterative process, it was determined that to minimise surface area, and hence reduce the weight of the CanSat, $\theta \approx 65°$ was needed; given that **a** was restricted to the diameter of the can at 66mm.

In order to inflate the airbag at the correct time, a MaxBotix Inc LV-MaxSonar-EZ1 ultrasonic range finder with a maximum distance reading of 6.45 metres [7] will be used to detect the altitude above the ground. This data will be interpreted by an Arduino Duemilanove microcontroller based on the ATmega328 [8] which in turn will activate an Adafruit PF35-48 bipolar drive motor [6] controlling the release of CO_2 into the airbag. A T-junction valve will be used to regulate CO_2 flow to the desired volume. Once this is done, the valve will be closed leaving the airbag ready for impact.

IV. CanSat Architecture

A. Can Design

The CanSat itself will have diameter of 66mm and a height of 200mm. It will contain a frame wall made from a standard aluminium alloy used in generic soda cans and have a thickness of 0.4mm. The layout will have the OzeSat located at one end, with the sensor module closest to the edge of the can. Just above this will sit the parachute. Next to the OzeSat will be the tube containing the RF antenna. Between the tube and the OzeSat is the servo motor connected to the string attached to the RF antenna. Below these components sit the second motor which is connected to the T-junction valve, CO_2 canister and airbag inlet valve. This mechanism is controlled by the Arduino microcontroller which is located toward the bottom of the can, just above the base. In addition, two 9 Volt batteries will be placed within the can to provide power to the microcontrollers. This will give the CanSat a total mass of 0.6kg.

B. Parachute

The CanSat requires a controlled descent within a velocity range of 2-15m/s. To produce the required velocity, kinematic analysis was used for optimal design.

Wind resistance is determined through the equation below:

$$F_d = \frac{1}{2} \times \rho \times C_d \times A \times v^2 \quad [9](2)$$

Where $\mathbf{F_d}$ is the drag force, ρ is the density of air, $\mathbf{C_d}$ is the drag coefficient, **A** is the area of the chute and **v** is the velocity through the air.

Choosing a simplistic parasheet design, through experimental evidence $\mathbf{C_d}$ has been determined at 0.75 [10] and the area is equal to $\pi \times r^2$. Letting this equate to the weight of the CanSat, it is possible to determine the necessary relationship between the velocity and diameter of the parachute. From here we let **v** = 2 m s^{-1} to minimise descent velocity and achieve maximum reduction of impact shock. Then, solving for the required radius of the parachute we get:

$$r = 2 \times \sqrt{\frac{8 \times m \times g}{\rho \times r \times C_d \times v^2}} \quad (3)$$

After finding the total mass for the CanSat at 0.6 kg, taking g to be 9.81m s^{-2} and ρ as 1.2 kg m^{-3}, r is found to be 1.017 m giving a total area, **A** of 3.254 m^2.

However, to stabilise the CanSat it is necessary to have a spill hole to allow better airflow and a steadier descent. This spill hole area is 4% of the total area [11]. To determine the required shroud length there is a known relationship of shroud length:radius of approximately 1:3.7 for small radius parachutes [12]. This provides us with new dimensions; an outer radius of 1.0379 m, an inner radius of 0.2076 m and a shroud length of 3.85 m.

V. Conclusion

In the upcoming months, much progress is required to have a fully integrated and functional CanSat. The sub-teams will work on their respective tasks and should be completed by the self-imposed deadline of July 15th 2011. There is still potential for an additional mission to be successfully completed by the CanSat before competition day.

Acknowledgment

VSSEC-KDS would like to acknowledge the Robert Feigin Memorial Scholarship Trust for their ongoing support of our CanSat project.

We thank DGA-EM to welcome us on their military base for the flights demonstration of CanSat in 2011.

References

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