PandoraSat: Official Australian CanSat Team 2012

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***Abstract*–PandoraSat is the representative team from Melbourne and is the successor to last year's partnership between the Victorian Space Science Education Centre (VSSEC) and The King David School (KDS). [1]**

The team aims to successfully complete four scientific missions (plus a self-designed free mission) at the 2012 competition.

The four scientific missions are Atmospheric Sounding, Photo/Video, Deployment of an RF Antenna and Airbag Landing. The free mission involves using an IMU to obtain data pertaining to acceleration and three-dimensional orientation during the can's descent, and to transmit this data at least once every five seconds.

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 array of sensors in conjunction with a microcontroller, a microSD card and an XBee transmitter will be used to telemeter and detect hygrometry and other atmospheric data. A C429 camera unit will be used to record photo/video data and store it to a micro-SD card connected to a microcontroller. The RF Antenna will transmit the photo/video data once it is deployed. The Airbag Landing will be accomplished by programmed activation of a solenoid valve releasing CO2 into a bladder cushioning the can's landing.

I. Introduction

PandoraSat is Australia's representative team in the CNES and Planète Sciences CanSat France 2012 Competition. This will be the second time an Australian team will be competing in the highly esteemed international CanSat competition. The team will attempt to complete the Atmospheric Sounding, Photo/Video transmission, Deployment of an RF Antenna and Airbag Landing missions. A free mission; designed by the PandoraSat team, will also be attempted consisting of recording and transmitting data, describing the CanSat's acceleration and position upon descent.

II. Context of Development

A. Club

PandoraSat is the successor to the VSSEC-KDS team that competed in the CanSat competition last year.

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, its replacement by PandoraSat and beyond. The team is also actively pursuing corporate sponsorship.

PandoraSat is comprised of facilitator Milorad Cerovac who has been 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.

Former students currently completing tertiary studies are mentors working in conjunction with students and facilitators; acting as a bridge between the younger and older members of the team. Students also serve to benefit from their experience regard the CanSat competition, as all of the mentors were involved in the VSSEC-KDS team that competed last year.

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 were 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.

Sean Kozer is a skilled programmer and was a student member of last year's team.

The student team comprises of Max Elkin, Elie Loummer, Raphael Morris and Isaac Moulton. Reuben Barylak, Jeremy Bereszkowski and Jason Krowitz are junior members who will have a larger role in years to come.

B. Work plan

PandoraSat currently meets three times a week in order to allow the students time for academic commitments.

Task delegation was organised in March 2012, and was finalised in April, with mentors and students nominating tasks that they felt they could accomplish.

Students and mentors were divided into sub-teams in order to run tasks in parallel. The team communicated regularly to keep track of progress.

Time management has been a significant factor due to the many new challenges presented by the competition with our ambitions being significantly higher than they were last year.

In order to have a functional CanSat before August, 131 man hours are required (see Table 1).

TABLE 1. MAN HOURS ESTIMATION

Task	People	Hours	Man Hours
Parachute	3	2	6
Can Construction	3	8	24
Testing	4	15	60
Calibration	2	4	8
Airbag	3	11	33
Total			**131**

Our total anticipated budget is $750 AUD. This includes all components, accessories, manufacture and testing costs incurred during the design, testing and construction of the can. We believe that this is a realistic budget and that it should not compromise the quality of the CanSat. We are, however, currently seeking sponsorship in order to increase our budget and purchase additional components.

III. DEFINITION OF THE MISSIONS

A. *Atmospheric Sounding*

Hygrometry and telemetry will be achieved through a variety of sensors connected to an Arduino microcontroller. From the Arduino unit, the data goes both to an XBee unit that will be transmitting during descent and to a microSD card that will store the data. The sensors we will be using are an HIH-4030 [3] for humidity, a BMP-085 [4] for barometric pressure, an LM35 [5] for temperature and an EM-408 [6] for GPS. Altitude will be obtained in two ways: by synthesizing pressure and temperature data, and by analysing GPS data; which method is our primary choice will depend on tests pertaining to the accuracy of GPS readings taken at the site. The XBee we chose is an XBee-PRO Digimesh 2.4 International model, which transmits at 10 mW power at a frequency of 2.4 GHZ.

The LM35 will be calibrated by placing the active sensor inside a sealed zip-lock bag, and placing this bag inside an ice water bath. This should cool the sensor to 0°C, with a margin of error of ±0.05°C given the 0.5°C accuracy range of the LM35 [5]. The HIH-4030 (humidity sensor) will be calibrated by placing the sensor in a small container, and removing the moisture in the air inside that container by leaving desiccant (silica gel) inside the container. Though this isn’t 100% accurate, it is the most accurate and effective means of calibrating the humidity sensor given our budget. The BMP-085 (pressure sensor) will be calibrated by comparing the data from a weather station with the data from the pressure sensor, bearing in mind that for every twenty eight feet increase in altitude, the pressure decreases by 1hPa. Comparison with a weather station will be secondary calibration for the temperature and humidity sensors. All calibrations will be confirmed against data used by the Bureau of Meteorology based in Melbourne for an extra level of confidence.

B. *Photo/Video*

Photo/Video data will be recorded by a C429 camera module [7], and stored on a micro SD card. After the CanSat lands, this data will be sent to the XBee and transmitted via the RF antenna. It should be noted that the data should be transmitted whether or not the antenna actually deploys, though the signal should be stronger once it is deployed. It should also be noted that the camera module supports on-the-fly JPEG encoding as well as raw data output. We are currently testing the performance of each configuration.

C. *Deployment of RF Antenna*

The deployment of the antenna is completed through the use of only four modules. It involves a motor, a small hollow tube fitted with a spring and washer caps (so that the antenna doesn’t fall out of place), 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. The spring will prevent the antenna from falling out. The other end of the antenna will be connected to the XBee in order to allow data transmission (see Fig. 1).

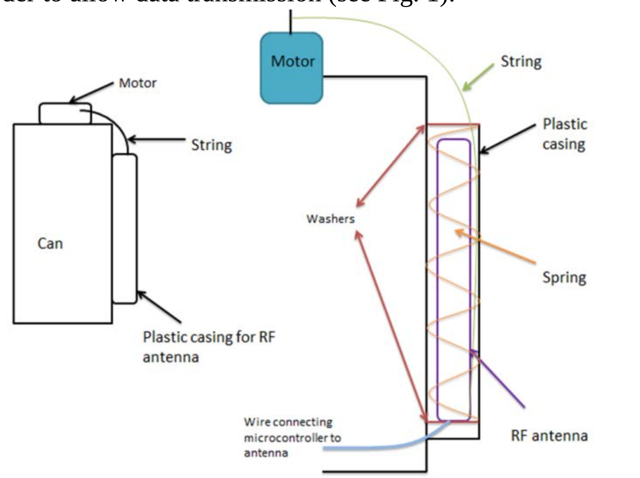

Fig. 1. RF Antenna Mechanism

D. *Airbag Landing*

The airbag system involves using a solenoid valve to release a cartridge of compressed CO2 gas through a tube to a custom made ripstop nylon airbag. The solenoid valve will be powered by an 11.1V LiPoly battery [10] and will be connected to the Arduino microcontroller, which will open the valve once data from the GPS, Pressure and Accelerometer sensors indicate that the CanSat is in close proximity to the ground. The solenoid valve and cartridge will be interfaced with a Halkey-Roberts 840 [11] life jacket inflation mechanism. This will allow for pre-puncturing of the cartridge ensuring that the C02 will be released when necessary.

E. Free Mission

The PandoraSat team designed a free mission, which is oriented around using an ADXL-345/ITG-3200 [12] IMU to measure the CanSat's acceleration and three-dimensional orientation during descent. The IMU is an integrated sensor unit consisting of a gyroscope and an accelerometer. The free mission consists of transmitting data from the CanSat about its acceleration and 3D orientation at least once every five seconds during descent.

IV. CanSat Architecture

A. Electrical architecture

The electrical architecture of the can is oriented around the Arduino microcontroller unit, which controls all electrical functions of the can and directs data from the sensors and the camera module to the XBee for transmission and to the micro-SD card for storage. The microcontroller is also responsible for directing power to the solenoid valve and the motor at appropriate times through the use of relays. The electrical architecture of the can incorporates two batteries: an 11.1 LiPoly battery that powers the solenoid valve, and a 9V battery that powers everything else. The microcontroller will have a 5V output. Both 5V and 3.3V sensors are utilised by the CanSat, so a voltage divider circuit will be used to supply the correct voltage to each sensor.

B. Mechanical parts

This year's CanSat will be custom manufactured with a 3D printer. The design chosen was a 2mm thick hexagonal prism (see Fig. 2) printed in ABS plastic due to its increased flat surface area for mounting internal components. Another advantage of using this unique design is a lighter weight. By using a hexagonal shape as opposed to a circle, we use less material in the frame, thus lowering our structure's weight without decreasing mountable space internally. The dimensions of the frame will allow for protrusion of an airbag and camera module while remaining within the legal volume for our class. The parachute will be attached to the 6 pre-drilled holes on top of the CanSat structure (see Fig. 3).

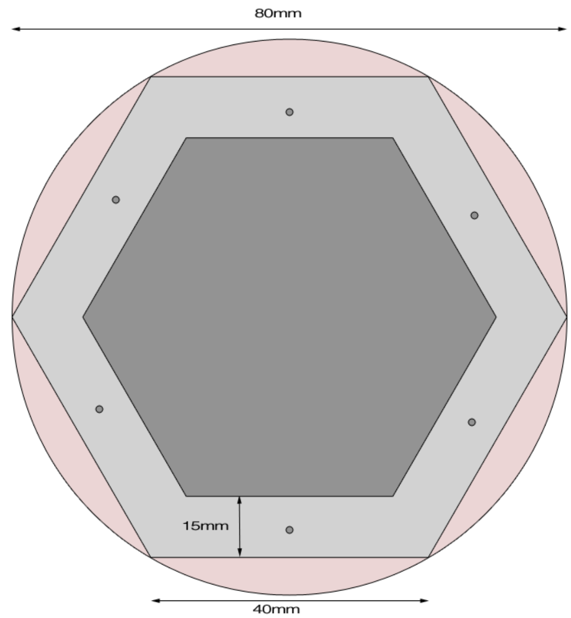

Fig. 2. Top View Diagram

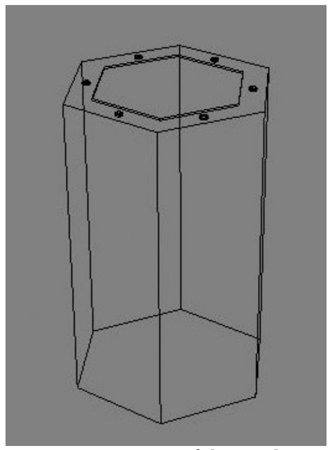

Fig. 3. CAD Design of the PandoraSat

C. Telemetry

During descent, telemetry of atmospheric sounding, GPS and IMU data will be achieved by using an Arduino microcontroller in conjunction with an XBee transmitter to send data to an XBee receiver at base. The Arduino will also direct this data, along with data from the camera module, to a micro-SD card, and all the data contained on the micro-SD card will be transmitted after landing to base via the XBee through the RF antenna. At base, another Arduino unit will connect the XBee receiver to a computer, where any unprocessed data will be processed. However, we expect most data to be processed before transmission with the exception of photo/video data. Fig. 4, below, indicates the flow of data between the can's internal components. It should be noted that it is not a wiring diagram, and does not display movement of current.

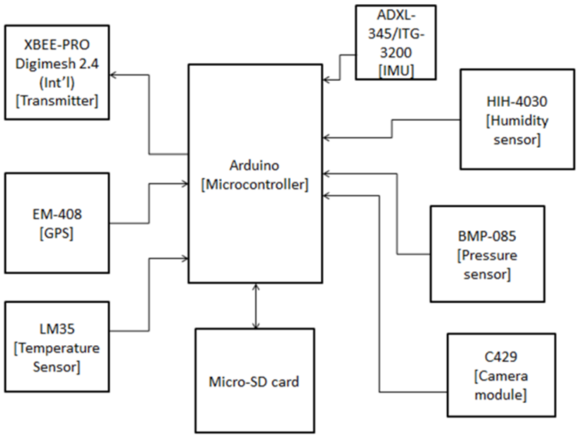

Fig. 4. Electronics Diagram

D. Parachute

The CanSat requires a controlled descent within a velocity range of 2-15 m s^{-1}. To produce the required velocity, kinematic analysis was used for optimal design.

Wind resistance is determined as follows (1).

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

Where F_d is the drag force, ρ is the density of air, 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 C_d has been determined at 0.75 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 (2).

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

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. To determine the required shroud length there is a known relationship of shroud length : radius of approximately 1:3.7 for small radius parachutes [13]. 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 1 August 2012.

Acknowledgment

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References

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