Development of a fly-back CANSAT in 3 weeks

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Abstract—**Two CanSats are developed in Wakayama University by international researchers in one month. The first CanSat was developed in less than three days. The second CanSat was more advanced and developed in three weeks. The design and development phases are explained in this paper.**

Keywords-component; CanSat, Guidance, Navigation, Flight Control

I. CONCEPT

CanSat concept was proposed by Prof. Twiggs in 1998. The main idea behind a CanSat was to create a simple satellite-like device by students, to gain hands-on experience. Generally LEO satellites have around 10min communication time. Typically a 4 km altitude launched CanSat also have around 10 min fly time. In CanSat mission students can read sensors on-board and simply they can simulate a simple satellite. There are two important things to consider. These are the launcher and the CanSat itself.

A. Launcher

The launcher is used to send the CanSat into a certain altitude. For launch rockets, balloons, UAV's, planes or helicopters, basically anything that flies could be used. Generally a rocket is used for competitions or main mission. For testing a balloon or a helicopter is more reliable and cheap solution. In this case a rocket is used for the main launch and a balloon is used for testing.

For a safe launch a launch site was defined for this case. After the ejection the rocket opens its own parachute for a safe return.

In this case launcher was an independent source for the development team. The requirements were set before launch.

B. CanSat

CanSat is the main payload. Avionics and structure could be named as CanSat. There are several CanSat requirements. Different competitions have their own requirements, but can generalize some main requirements. These are;[1]

- All the components (CanSat, parachute etc.) shall fit in the rocket cargo.
- The CanSat shall be compatible with the launching system.
- The CanSat should have a recovery system like a parachute to be able to be reused after launch.
- CanSats can use RF communications. CanSats with RF Transmitters shall have properly licensed operators;
- Depending on the competition the total cost of the CanSat cannot exceed a certain amount. (in this case 50.000¥)
- Volume: The CanSat should be equal or smaller than a cylinder with dimensions of 10cm radius and 26cm height.
- Mass: The CanSat mass is defined by the rocket, thus the heavier mass means lower altitude. For a safe parachute opening altitude mass of the CanSat should be lower than 1kg
- The CanSat should be able to eject when the cargo bay opens after reaching the apogee.

Basically there were 3 main methods to accomplish the mission.

- Rover
- Para-glider
- Glider

Surely the most successfully one of these methods is the rover. Rover is a simple toy –car which goes to the target after it lands. Landing is aided by a simple parachute. After landing the rover comes out of the parachute and simply navigates to the target by onboard avionics. Rover is successful because it is simple, it doesn't require any complex flight systems. All it needs is to roll the tires until it reaches the target.

Para-glider is simply a parachute with controller. It is easier compared to glider, due to its static stable nature. As a controller para-glider has two strings attached to the parachute. If the strıng on the right should be pulled the para-glider will try to turn right, or pulling the left string will turn the para-glider left.

Glider is considered the most challenging version of a come-back mission CanSat. Glider is not stable as other types and it requires complex algorithms to navigate.

The glider type is chosen due to its complexity. The main mission was to learn how to do a CanSat, therefore choosing a difficult mission made sense.

The CanSat is called as TANGsat 2. The name comes from developers. Developers and the writers of this paper are from Turkey, Australia, Nigeria and Guatemala. TANGsat 1 was a simple telemetry receiving CanSat, which was built in 1 week.

II. Structure

The main difficulty of the structure is the way to put the glider inside the rocket. The cargo of the rocket has a cylindrical shape, but the glider should have wings, which won't fit in to the rocket. Two different methods were selected for the first trade off. One of them was rolling the wings using steel measurement tape. Advantage of this type is its wing size, but this design is flexible and has limited airfoil option.

The other option was to use foldable wings. This design is used on F-14 aircraft [2]. The wings are folded in the rocket and after the ejection they unfold using a spring. This version has smaller area of wing but it has an efficient airfoil and structurally it's more stable. The wings of F-14 could be seen on Figure 1. The wings have high aspect ratio on high speed cruise and low aspect ratio on low speed cruise or take-off and landing.

After the trade-off foldable wings are chosen, because of its stable structure and efficient airfoil. The cross-section of the wings is 7cm on the tip and 4,6cm on fuselage. The airfoil is NACA 64412. The ribs are cut from simple foam. The wings are covered by shrinking film. Javafoil [3], an online development software is used to determine the airfoil. A Javafoil screen capture of the airfoil is presented on Figure 2.

Figure 1. Wing shape of a F-14

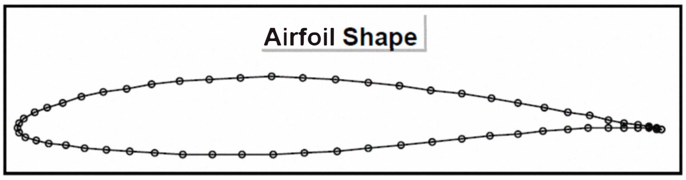

Figure 2. NACA 64412 airfoil

First version of the CanSat was built of aluminum. But the weight of the glider was too heavy to lift itself. Our calculations showed that cruise flight speed was around 90km/h without any payload or electronics. After some unsuccessful attempt the structure was changed to balsa wood. The weight of the CanSat has dropped from 350grams to 170grams with payload. After optimizing the wing area and the angle between wings and fuselage the cruise speed has decreased to 40km/h.

Elevator of the glider is made of balsa wood. It has a size limit; therefore its width is limited to 10 cm. The size of the tail is important, because total length of the glider should be shorter than 35 cm; it's hard to have enough momentum from tail.

Because of the folding wings there were no space for a horizontal tail on the upper side of the glider; therefore the horizontal tail was put below the fuselage. The horizontal tail was also cut out from foam; it has a NACA 64012 airfoil section to increase the force on the horizontal tail. Because of the folding wings no ailerons were used on glider. Control and guidance of the glider will be maintained by rudder, therefore to increase the force of the horizontal tail. All the horizontal tail is used as rudder.

The payload of the CanSat could be considered as sensors, actuators and electronic systems. To attach the payload to the glider a special "gondola" was cut out of foam. This gondola has a shape to decrease drag of the payload and it will also help to float on water after a water-landing incidence.

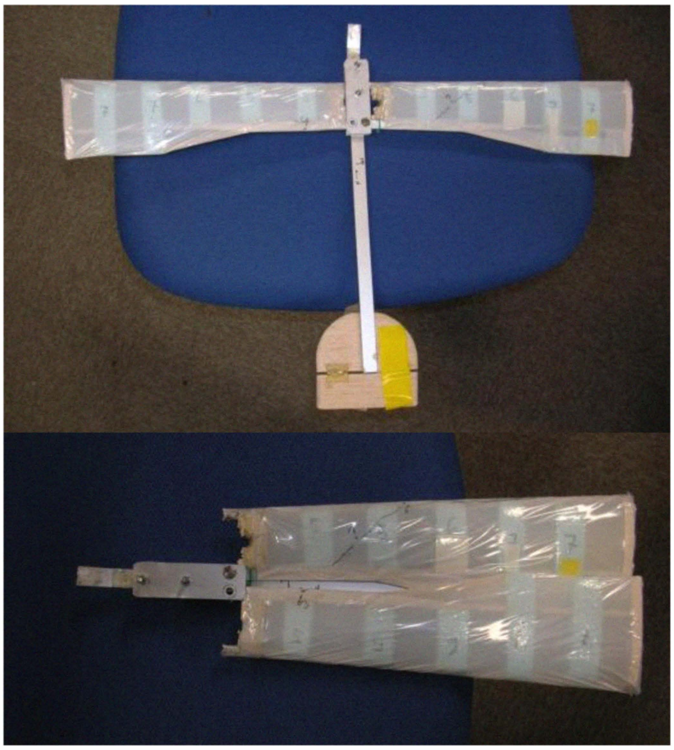

Figure 3. Mechanical design

Figure 3 shows the two different positions of the wings. The upper figure shows the glide (open) position of the wings. The figure bellow shows the launch position, in which the CanSat will wait safely in cargo untill ejection.

III. AVIONICS

Main on-board avionic is the microcontroller mbed [4]. It has a 100MHz microprocessor. Developed algorithms are running on this microprocessor. An online C++ compiler is available for mbed. Figure 4 shows the view of the mbed microcontroller.

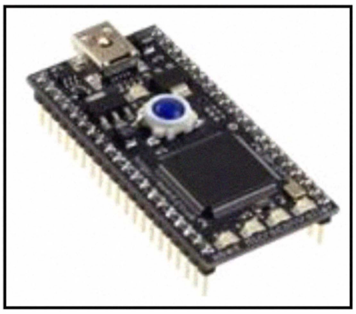

Figure 4. MBED Microcontroller overview

There are also sensors for attitude determination of the CanSat. These are 3-axis accelerometer, 3-axis gyro, 2-axis magnetometer, temperature and static pressure sensors. Accelerometer and gyro data is used for roll and pitch angle detection. Magnetometer is used for heading. Pressure sensor is used for altitude determination.

A GPS receiver is also used for navigation purposes. The receiver is an EM-411 GPS [5]. Commercial GPS receivers have acceleration, speed and altitude limitations. Depending on previous missions some receivers might lose tracking the GPS signal. Hot start of the GPS is around 30 seconds, therefore to ensure positioning a backup inertial navigation is also considered.

An xbee pro [6] modem is used for communication with the ground station. Every data from sensors are processed and packed in mbed and send to ground station using this modem. In ground station simple software just records this data for future processing.

3-axis accelerometer is an ADXL345 [7]. Its data is being read 100Hz using I2C bus. ADXL345 is selected because of its high g characteristics. It can read up to 16g. The rocket can reach up to 20g. This high acceleration should be read for the inertial navigation system.

3-axis gyro used on-board was an ITG-3200 [8] mems gyro. It is a serial output low-power high accuracy gyro. The common thing between these sensors is the availability and simplicity. All the sensors are easily available on the internet or even in local electronic stores. There are also lots of examples available on the internet about these avionics, which is essential in a fast development process.

Digital compass was a CMPS03 [9]. It has 2 magnetic sensors to measure the angle between the sensor and magnetic north. Since the sensor is 2-axis, it cannot compensate inclination and tilt angles; therefore custom tilt compensation is used for accurate heading detection.

The battery is a very small 200mAh 7.4V lithium-polymer battery, which only weighs 24 grams. According to the power budget the peak current of the satellite is 600mAh, therefore a 10C battery is selected. The battery can support the electronics for 20 minutes, which is enough for a fly-back mission.

IV. NAVIGATION AND GUIDANCE

To navigate the CanSat a GPS receiver is used. The GPS datasheet shows that positioning error is around 5meters, however by testing the accuracy is observed as 2 meters. The aim of the mission is to come closer than 100 meters to the target. The GPS provides time, longitude, latitude, altitude, speed and heading information in 10 Hz.

A 2-axis digital compass is used for heading data. The sensor has I2C output as heading value in degrees compared to magnetic north. Because of 2-axis magnetic measurement, the device doesn't have any tilt compensation; therefore a tilt compensation system had been developed for accurate measurement. Tilt angles are measured from accelerometer and using simple trigonometric functions with 2-axis magnetic measurements heading value was corrected. The new digital compass is able to work +-40 degrees of tilt with 10 degrees of accuracy. The heading angle from GPS and compass is measured and mean average value is used for guidance.

A command from ground station records the current position of the CanSat as the target position from GPS and the static pressure level from pressure sensor. The pressure is measured for altitude information. After ejection microprocessor receives the position information from GPS and compares that info with the target position. The turn angles are calculated using simple trigonometry with already calculated heading information. This turn value is required by control system.

For an accurate landing the altitude should be controlled. Altitude is measured using GPS and pressure sensor values. After ejection the glider should turn to target and dive with a specific angle. The altitude accuracy of the GPS receiver is around 15, which is not enough for landing; therefore the pressure sensor is important on landing. Before launch the static pressure is recorded and during dive when the pressure level becomes close to target point, a pitch-up command will send to the elevator for a soft landing.

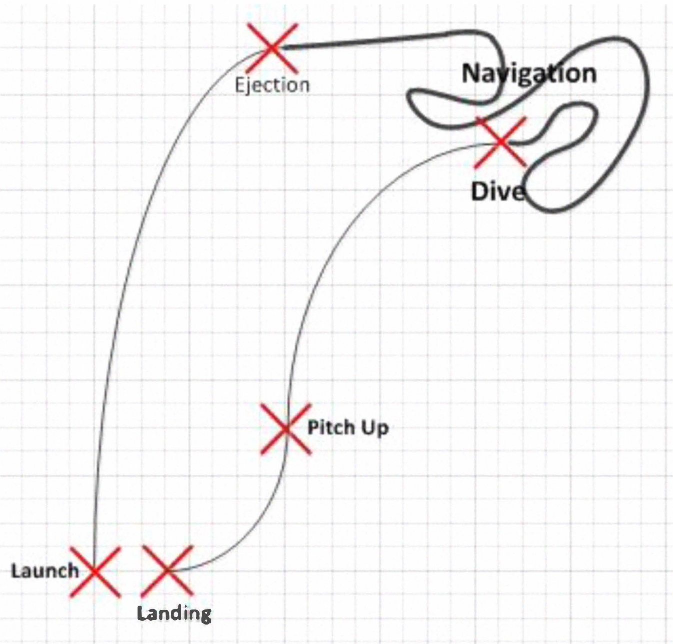

Figure 5. Flight Plan

Figure 5 shows the detailed flight plan of the CanSat.

V. Testing

For testing the CanSat a special balloon is used. The balloon is filled with helium and ascended about 50 meters. A special device is used for ejection, which has the same volume with the rocket. After testing it has been seen that the CanSats glide ratio [10] is around 1. This low glide ratio is an advantage, because higher glide ratios means faster dives, according to our flight plan. In a windy condition the rocket will launch with an angle compared to the surface of the earth.

Test with the final design of the CanSat could not be completed due to the earthquake happened in 11 of March 2011 in Japan.

VI. Conclusion

The CanSat project is considered as a successful project, because the aim of the project was to distribute CanSat idea to the world. Project members have gained experience on every topic of CanSat and they return to their countries eager to start their own CanSat group.

On technical aspect the final design could not be tested due to the disaster happened in Japan. This design could be tested in future by other groups or students in Wakayama University.

Acknowledgment

This project is built in Wakayama University Japan. Developers are grateful to those who organized "CanSat Leader Training Program" We also want to present our thanks to academic/non-academic employers, teaching assistants and students of Wakayama University. Finally we would like to express our sympathy to the kind people of Japan, who suffered from that disaster.

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