EML 4551C – Senior Design
Operations Manual

Team 18: CANSAT

Group Members: Samuel Rustan (EE), Andrew Grant (ME), Andrew Guerr (ECE), Maxwell Sandler (ME), Yasmin Belhaj (ME)

Technical Advisors: Dr. David Cartes (ME), Dr. Victor DeBrunner (ECE)

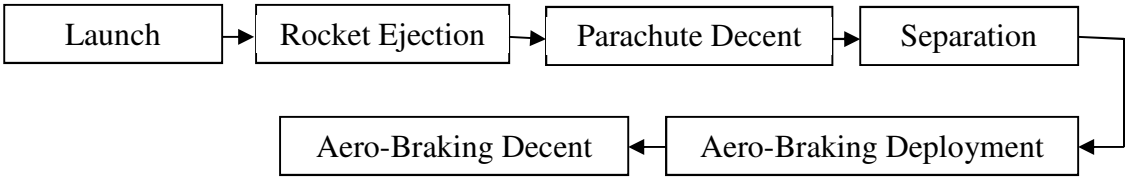
Faculty Advisor: Dr. Kamal Amin (ME), Dr. Michael Frank (ECE)

Report Submitted: 2-April-2013

Table of Contents

1. Functional Analysis/Flow Diagrams

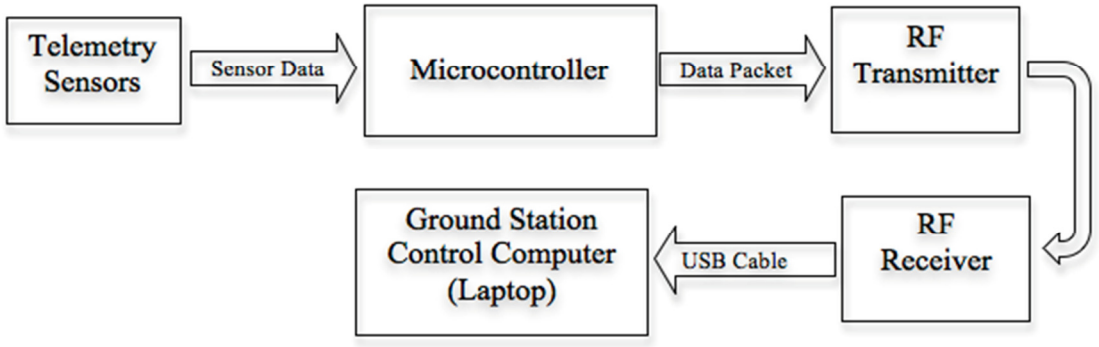
Mechanical



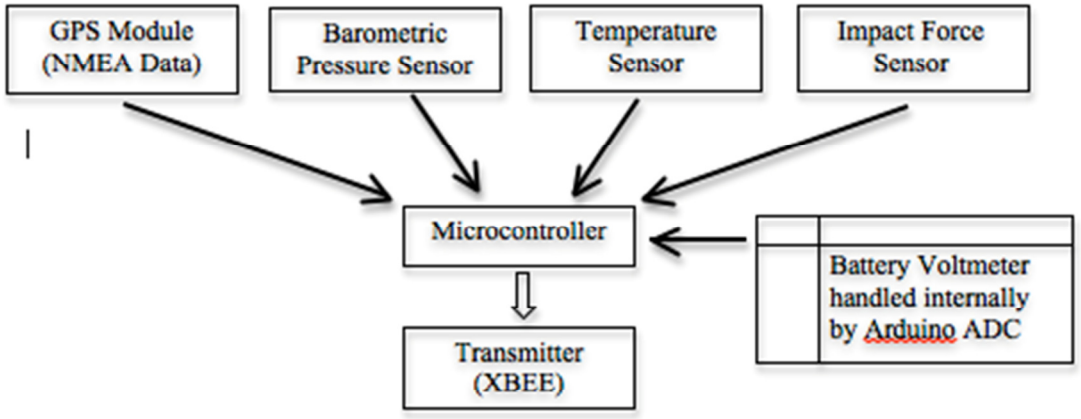
Electrical

- Flow diagrams
  - Subsystem flow diagrams
    - Microcontroller
    - XBEE, RF
    - Electrical Power System

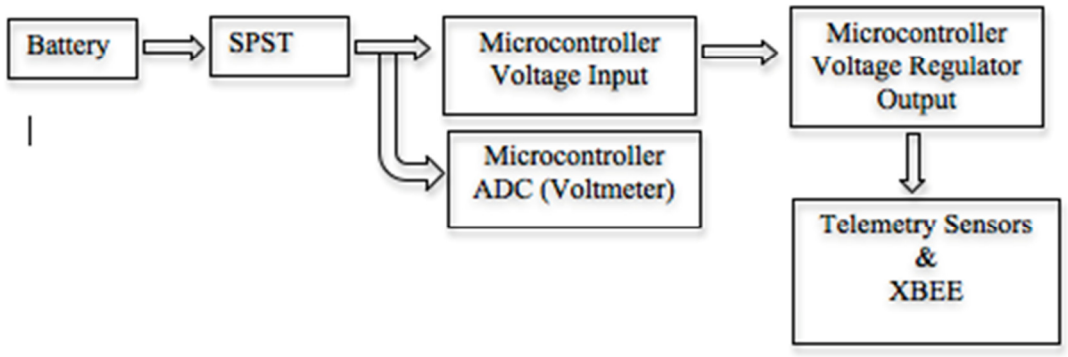
Flow Diagram: Communications and Data Handling System Overview



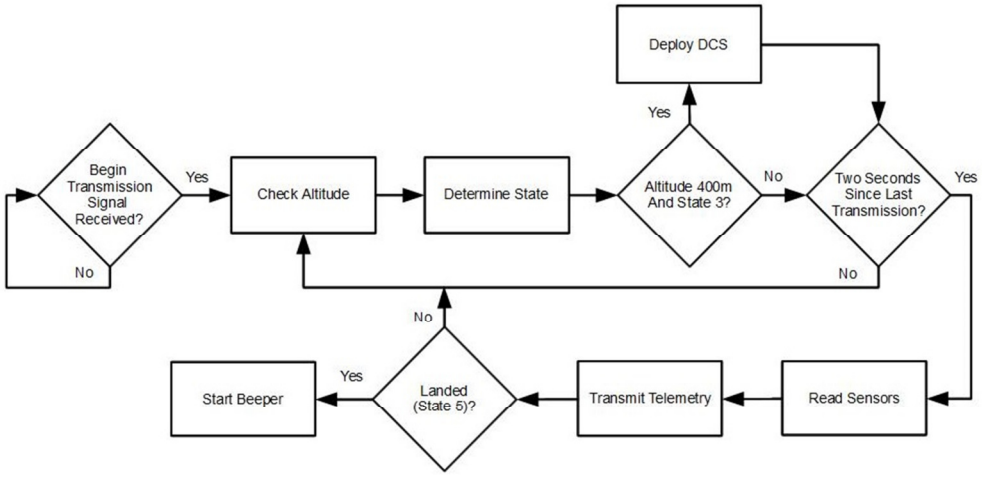
Flow Diagram: Telemetry Sensors Subsystem



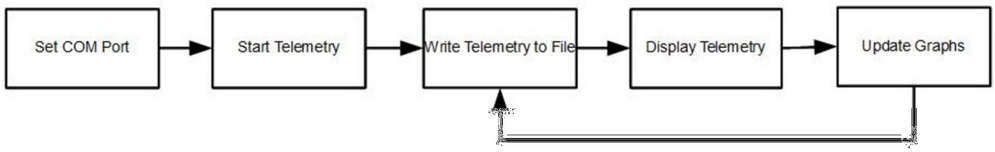
Flow Diagrams: Electrical Power System



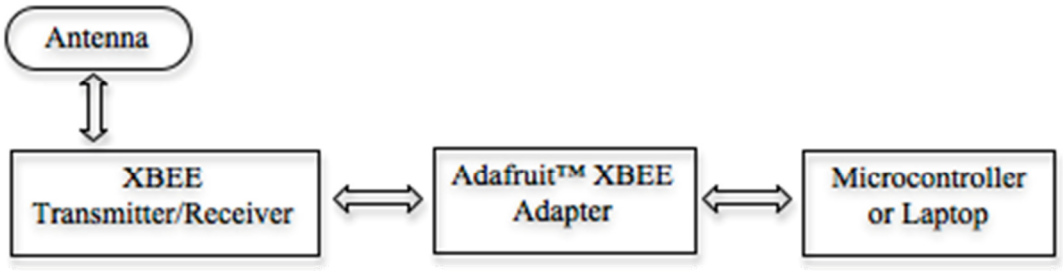
Flow Diagram: Flight Software



Flow Diagram: Ground Control Software



Flow Diagram: RF Transmitter and Receiver



- Analysis (Any mathematics, models, etc, including software code used to support the design)
    - FSW
        - Maybe just have the FSW section and for each device make a subsection with the relevant code.
    - GCS
        - Maybe abridge the coding for the GCS, depending on length
    - XBEE, RF
        - No software, but could put notes on the Firmware and the XTCU setup.
    - GPS Module
        - Just the coding used from the FSW
        - Explanation of how the GPS works
        - Any calculations done for integrating into M/C (Data Rate, baud rate, output vector size)
    - Press./Temp Sensor
        - Just the coding used from the FSW
        - Explanation of how the Bosch sensor works
            - Obtain from Datasheet
        - Altitude calculations (obtained from datasheet)
    - Accelerometer
        - Just the coding used from the FSW
        - Good details obtained from Adafruit website
    - Electrical Power System
        - Voltage divider calculation, a bit on the ADC, and the battery calculations.
        - 10-bit resolution calcs
        - Use any analysis stuff from the datasheets

2. Product Specs

Mechanical

Needed Product Specifications:

The CanSat must weigh 700g with a tolerance of 10g.

The CanSat must fit within the rocket's payload section that is 130mm in diameter and 250mm in length.

The CanSat must not have any sharp edges protruding beyond the container.

The container must not free fall.

The CanSat must fall at 20m/s with a tolerance of 1m/s when falling from 670m to 400m.

The payload must separate from the container at 400m.

The payload must use an aero braking structure to limit its velocity to below 20m/s, it cannot be a parachute or streamer.

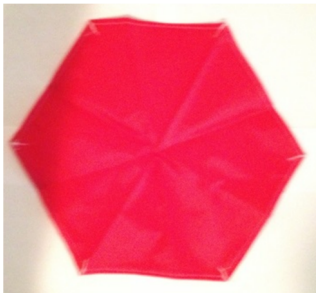
The payload will house the electronics and must protect a raw egg placed inside.

All components of the CanSat must be capable of surviving a 30 g shock.

The CanSat must be bright orange.

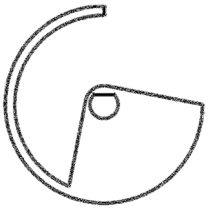
Container:
Material: HDPE
Length: 7.77in
Outer Diameter: 4.61in
Wall thickness: 0.041in
Strength: 3200psi
Color: Fluorescent Orange

Parachute:
Size: 9in
Fabric: Nylon
Color: Red

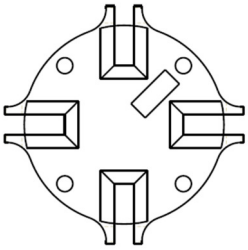


Nylon Eyebolt:
A: 1/4 in
B: 3/4 in
C: 5/8 in
Thread: 6-32

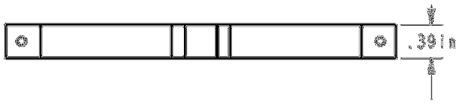
Separation Hook:
Material: Aluminum
Strength: 18000psi
Expected Stress: 6391psi

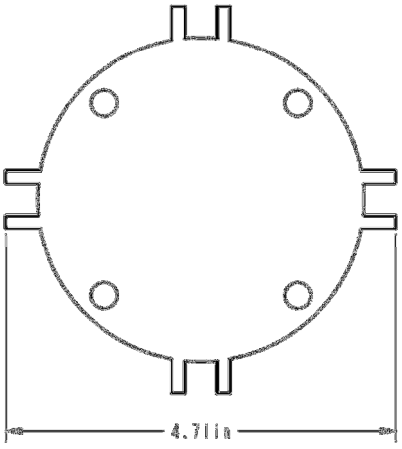


Payload Top:
Material: ABS
Strength: 6000psi
Expected Stress: 1663psi
Color: Fluorescent Orange



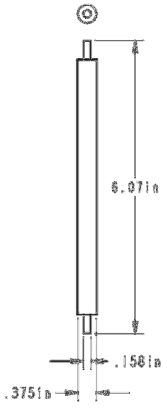
Payload bottom:
Material: ABS
Strength: 6000psi
Expected Stress: 0.087psi
Color: Fluorescent Orange





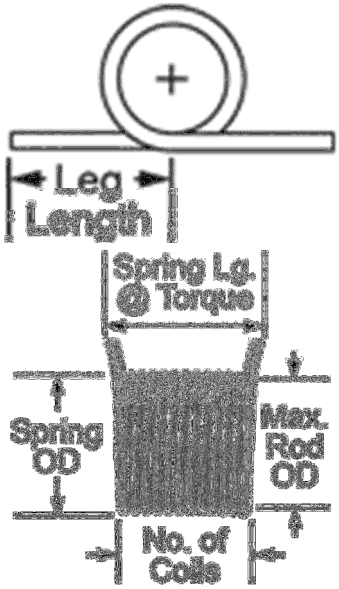
Payload Envelope:
Material: HDPE
Length: 5.29in
Outer Diameter: 2.85in
Wall thickness: 0.061in
Strength: 3200psi
Color: Fluorescent Orange

Structure Dowel Rods:
Material: Maple or Oak
Strength: 5500-8000psi
Expected Stress: 0.087psi
Color: Fluorescent Orange

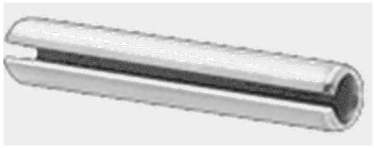


Aero Breaking Dowel Rods:
Material: Maple or Oak
Strength: 1800-2000psi
Expected Stress: 1325psi

Torsion Springs:
Wire Diameter: 0.032in
Leg Length: 1.25in
Max Rod Outer Diameter: 0.281in
Torque: 1.071in



Pins:
Size: 3/32 in
Length: 1 in
Breaking Strength: 650lb



Aero Braking Fabric:
Material: Tyvek
Tear Resistant
Color: White

Electrical

The CanSat transmits a telemetry data packet that consists of the following data:

Team ID, Mission Time, GPS Time, GPS latitude, GPS longitude, GPS altimeter, number of GPS satellites tracked, Non-GPS altitude, Ambient Temperature.

The XBEE Series 1, using the IEEE 802.15.4 standard, handles the RF transmit and receive functions. The following are the specifications relevant to the Cansat design:

- XBEE (Mfg: Digi Int'l)
    - Operating Frequency 2.4 [GHz]
    - Transmit power: 60 [mW] (equivalent to 18 [dBi])
    - Receiver current draw: 25 [mA]
    - Transmitter current draw: 215 [mA]
    - Supply Voltage: 2.8 – 3.4 [V]
    - Up to 1 mile (1600 m) outdoor range, RF line-of-sight (LOS)
    - Standard u.Fl connector to antenna

- Antenna (model: A24-HASM, Mfg: Maxtream)
    - ½ wave Dipole, 360º pattern
    - Frequency: 2.4 [GHz]
    - Gain: 2.1 [dBi]
    - VSWR: 2
    - Swivel, Tilt
    - Height: 111 [mm] (4.35")
    - RP-SMA to u.Fl cable

- XBEE Adapter (Mfg: Adafruit)
    - Supply Voltage: 3-5 [V]
    - Onboard voltage regulator
    - Current (maximum): 250 [mA]
    - Level shifting circuitry for connection to 5V circuitry
    - Two LEDs, one for activity (RSSI), the other for power (Associate)
    - 10-pin 2mm sockets included to protect the modem and allow easy swapping, upgrading or recycling
    - Specifically created for use with an FTDI cable to connect to a computer via USB. This means that you can use or upgrade the adapter with a computer simply by plugging in a cable
    - Works with XBEE series 1 and 2 as well as series 1 and 2 Pro modules

The Adafruit™ Ultimate GPS module handles the GPS functions of the Cansat. This module is based on the MTK 3339 chipset and allows for an external antenna connection. The following are the specifications relevant to the Cansat design:

- GPS Module (Adafruit Ultimate)
  - MTK3339 Chipset
  - 66 channel
  - Supply Voltage: 3-5 [V]
  - Satellites: 22 tracking, 66 searching
  - Update rate: 1 to 10 Hz
  - Position Accuracy: 1.8 meters
  - Warm/cold start: 34 seconds
  - Acquisition sensitivity: -145 dBm
  - Tracking sensitivity: -165 dBm
  - Maximum Altitude for PA6H: tested at 27,000 Meters
  - Maximum Velocity: 515m/s
  - MTK3339 Operating current: 25mA tracking, 20 mA current draw during navigation
  - Output: NMEA 0183, 9600 baud default

The Bosch™ BMP-085 available via the Adafruit breakout board handles the non-GPS altimeter and temperature functions. The following are the specifications relevant to the Cansat design:

- Non-GPS Altimeter (Bosch BMP-085)
  - Pressure sensing range: 300-1100 hPa (9000m to -500m above sea level)
  - Up to 0.03 [hPa] / 0.25 [m] resolution
  - -40 to +85°C operational range, ±2°C temperature accuracy
  - I^2C Interface, I^2C data transfer: 3.4 [MHz]
  - Current Draw: < 1 [mA]
  - Supply Voltage: 3-5 [V]
  - Logic: 3 [V] and 5 [V] compliant
  - 7 pin 0.1” standard header

The ADXL-326 from Analog Devices will handle the impact force sensor functionality. This chip is mounted on the Adafruit breakout board and features a reference voltage pin and test pin. The Adafruit board also features an onboard 3.3 [V] regulator. The following are the specifications relevant to the Cansat design:

- Accelerometer (ADXL 326)
    - Sensitivity: -16g to 16g, scalable output
    - 10,000 g shock survival
    - XYZ filter capacitors: 0.1 [uF]
    - Bandwidth: 50 [Hz]
    - Current Draw: < 1 [mA]
    - Supply Voltage 3-5 [V]
    - Logic: 3 [V] and 5 [V] compliant

The Analog-to-Digital converter (ADC) onboard the Arduino Pro Mini™ will handle the voltage measurement. The ADC has a 10-bit resolution allowing for the ±0.1 [V] tolerance precision of the voltage measurement.

- Arduino Mini Pro
    - ATmega328 @ 16 [MHz], external resonator
    - FTDI cable connection
    - Auto-Reset
    - 5 [V] Voltage Regulator
    - Over current protection
    - DC Input: 5-12 [V]
    - Analog Pins: 8
    - Digital (I/O) Pins: 14
    - Less than 2 grams, 0.8 [mm] thick
- Voltmeter (Arduino ADC)
    - Pin current (max): 40 [mA]
    - 10-bit resolution, 5.86 [mV/bit]

The Release Motor is a Micro-Metal™ DC motor from Sparkfun™ Electronics. The motor will operate at 5 [V] pulsed from a digital output pin of the Arduino Mini Pro microcontroller. The following are the specifications relevant to the Cansat design:

- Release Motor
    - 100 : 1 Gear Ration
    - 120 [rpm] @ 6 [V]
    - 30 [mA] @ 6 [V]
    - 420 [mA] stall current
    - 13 [oz•in] of torque @ 6 [V]

3. Instructions for Operation

Assembly and Start up Launch Configuration

In order place the CanSat into its Launch Configuration, the sensory cargo must first be secured. The power switch (ON/OFF) “rocker-type” switch must be switched to the “ON” setting. This energizes the circuitry and allows for the Ground Control Software to communicate with the Cansat.

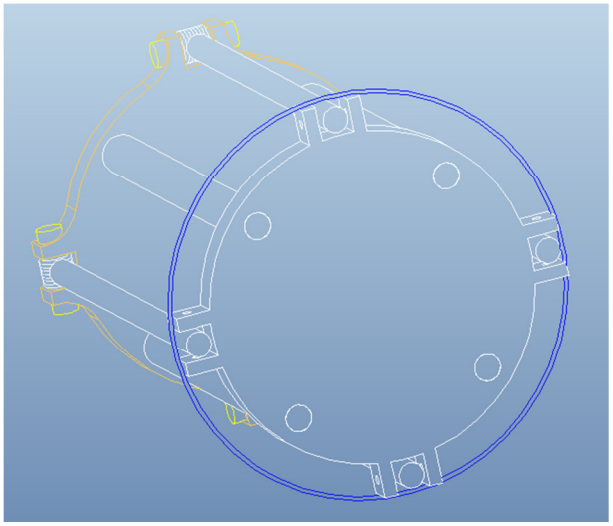
Ground Control Software operation:

1. Enter the COM port number in the entry field in the format “COM###” and click the set button. The software is ready to communicate via the entered COM port.
2. Pressing the test button will command the cansat to send three telemetry packets.
3. Pressing the start button will begin telemetry transmission.
4. When the cansat has landed and stopped transmitting telemetry press the exit button to close the program.

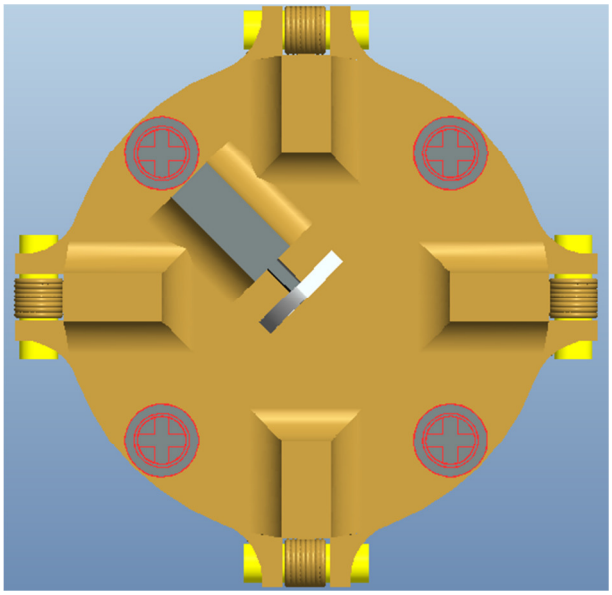
Telemetry data will be written to a “comma separated values” formatted file. The file will be saved as “CANSAT2013_TLM_1036_FIGHTING_MONGOOSES.csv” in the same folder as the ground control software.

To release the payload from the container, the rotate button must be pressed on the Ground Control Software to enable the separation motor, and then the components will be able to separate.

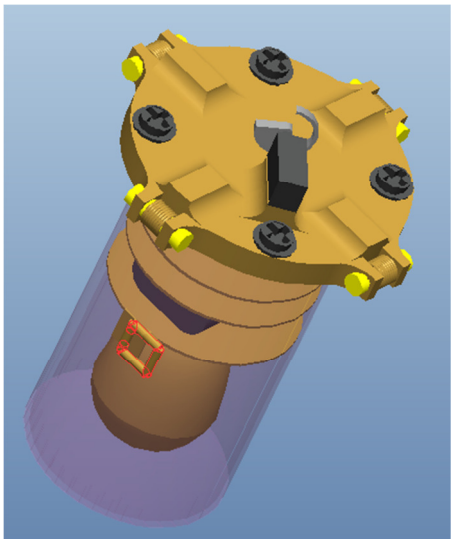
The next step is to locate the wire(Blue) holding down the Aero-Braking arms. Hold the four arms down while simultaneously sliding the release wire down off of the arms. Slowly let the arms extend.



Now locate the four screws(Red) at the top of the payload structure supports and remove them. The top section of the Aero-braking structure may then be separated from the structure supports.



Locate the latch(Red) at the side of the payload envelope and unlatch the hatch to open. The lower bay of the envelope houses the sensory payload between two pillow sections. Remove one and place in the cargo followed by reversing the steps to re-assemble the CanSat to launch configuration.



Be sure that the parachute is properly folded and stored atop the container before loading in the rocket bay.

4. Trouble shooting and diagnosis

Mechanical

The aero braking mounts may have stress concentrations at the corner. To increase strength, it may be necessary to increase rounding at the corners.
The dowel rods have a low factor of safety so a different material may be better. Metal cannot be used as it will interfere with radio signals.
The way that the dowel rods connect to the torsion springs could be a weak point in the system and redesigning the method of attachment could improve performance.

Electrical

If no communication with Cansat, check to be sure the power switch is in the “ON” state. Also, check to be sure the battery is positioned correctly, so that it is making contact with the battery terminals.

If the ground control software fails or no telemetry comes through when the test or start button is pushed it may have the wrong COM port. Restart the software and enter the COM port number.

5. Regular/Routine Maintenance

Mechanical

Running routine maintenance on the mechanical portion of the CanSat is very simple. There are no moving parts that require any form of lubrication, however, a quick inspection should be performed before and after use. This inspection would include examining the payload for any forms of cracking that could lead to failure. Cracks may form where the screws go into the support structures which could cause it to fail. In order to avoid this, when accessing the payload envelope, be sure not to over tighten the screws. If the screws are too tight, this could lead to the immediate formation of cracks or may cause stresses within the structure in which a shock may start the crack formation. Be sure to inspect the release wire and verify that there is no slack. This could cause a pre-mature opening of the aero-braking structure which could cause failure or even personal injury. The aero-braking material is tear resistant but may be damaged if in contact with sharp objects. If a major portion is damaged, replace the material.

Electrical

XBEE

The XBEE Series 1 firmware must be maintained regularly. This is done through the XTCU software available from the Digi International website. The URL for the software follows below:

http://www.digi.com/support/productdetail?pid=3352

Once downloaded for the relevant operating system, the user selects “upgrade firmware” from the “Modem Configuration” tab. The manual for the XTCU software is available via the following URL:

http://ftp1.digi.com/support/documentation/90001003_A.pdf

Battery

The Battery will need to be replaced after about 40 hours of continuous use. This is done by sliding the battery compartment out of the payload bay via the electronics access of the Cansat payload.

Released XBee firmware are available from the X-CTU program for general download. To download released versions:

Go to the **Modem Configuration** tab in X-CTU.
Click on **Download New Versions** and select **Web**.
You may need to disable your firewall in order to download new versions.

Note that downloading the firmware does not automatically update any modules attached. To update the firmware on an XBee:

1. In **Modem Configuration**, click **Read** to get the current settings off of the radio.
2. In the Version dropdown box, select the desired firmware revision.
3. Click **Write** to update the firmware.

Ensure that you are using the latest Ground Control Software and Flight Software.
To load the Flight Software onto the microcontroller:

1. Connect the microcontroller to a computer using a USB cable.
2. Open the Flight Software file in the Arduino software.
3. Under Tools->Board select the model microcontroller you are using.
4. Under Tools->Serial Port select the COM port the microcontroller is connected to.
5. Click the “Upload” button (right facing arrow above code window).

If the upload fails ensure that the COM port is set correctly and that the XBEE radio is not connected to the TX/RX pins on the microcontroller.

7. Future repair

There are two types of components in this design. Expendables categorize those that are exhausted during the descent and must be replaced every launch. Reusable components are those that should not be damaged during regular operation. Expendables include the parachute for Phase 1 descent and the External Container. These components are not likely to be retrieved, since they contain no electronic devices for locating after separation. These are very low cost elements and replacements should be regularly available. Given the modular design, the new parachute and container can be attached to the existing Payload for subsequent launches. A new egg must be inserted every flight, and though it is not provided with the design, can also be considered a component in need of regular replacement.

Reusable components are those included in the Payload—the Internal Container, shelving, electronic components, polystyrene beads, and descent structure. Assuming favorable descent conditions and a successful flight and landing, these parts remain functional for several cycles of operation. Due to wear and component degradation, there are parts that should be replaced after several runs. Based on preliminary testing and manufacture specifications, the mechanical components within the aero-braking structure, such as the torsion springs, have high cycle fatigue strength, and will not likely have to be replaced. Additional testing based on the cyclic stress state, distribution of internal defects, geometric loading effects, and environmental factors can be performed to get a more accurate fatigue life for these parts. The portions that may wear over time and can be replaced include the wings, the release wire, and polystyrene beads

8. List of Spare Parts

Based on these component categories, the spare parts that should regularly be available are the parachute, external container, and egg. Additional components that could be available to provide constant operation over time include wings, release wire, and polystyrene beads.

Electrical components have been obtained from SparkFun and Adafruit companies. The only electrical spare parts available are:

- 1 – “2CR5” Energizer Battery