University of Petroleum and Energy Studies
CanSat 2015
Critical Design Review (CDR)

#2021

Team ASTRAL

March 31, 2015

Presentation Outline

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Team Organization

Pavan Kr. Nanduri (Faculty Advisor)

James Doggett (Team Mentor)

- RAGHAV RATHI — Team Leader (Junior)
  - MECHANICAL TEAM
    - Mechanical System Design
      - MSD Lead: Dishant Kothia (Junior)
      - Aman Arora (Sophomore)
      - Aman Singhal
    - Descent Control Mechanism
      - DCM Lead: Akanksha Dadhich (Junior)
      - Aman Singhal (Sophomore)
      - Chaitanya Baboo
    - Egg Safety Mechanism
      - ESM Lead: Raghav Rathi
      - Chaitanya Baboo (Sophomore)
      - Aman Arora
  - ELECTRONICS TEAM
    - Sensor Systems
      - SS Lead: Sakshi Drall (Junior)
      - Aditya Savio Paul (Sophomore)
    - Communication Systems
      - CS Lead: Nalin Shrivastava (Junior)
      - Amitabh Yadav (Sophomore)

Acronyms

A	Analysis
ADC	Analog to Digital Converter
CDR	Critical Design Review
CMOS	Complementary Metal Oxide Semiconductor
CONOP	Concept of Operations
D	Demonstration
DCR	Decent control requirement
DCS	Descent Control System
ES	Egg safety
FAT	File Allocation Table
FIFO	FIRST IN FIRST OUT
GCS	Ground Control Station
GUI	Graphical user interface
GS	Ground Station GPS – Global Positioning System
HW	Hardware
HWR	Hardware Review
I	Inspection
I/O	Input / Output
LCO	Launch Control Officer
LED	Light Emitting Diode
M	Minute

Acronyms

MB	Mega byte
MCU	Microcontroller Unit
MECH	mechanism
MSR	Mechanical system requirement
m/s	Meters per Second
PDR	Preliminary Design Review
SOE	Sequence of Events
SPI	Serial Peripheral Interface
SSR	Sensor Subsystem Requirement
SV	Science Vehicle
T	Test
TBD	To Be Determined
TBR	To Be Resolved
USART	Universal Asynchronous Receiver/ Transmitter
VM	Verification method
mA	milli ampere
µA	Micro ampere
dB	Decibel

System Overview

Raghav Rathi

Mission Summary

- **MISSION OBJECTIVES:**
  - To simulate a Science Vehicle travelling through a planetary atmosphere while sampling its composition during descent.
  - Safe deployment of Re-entry Container and Science Vehicle from rocket and timed separation to ensure stability and proper descent.
  - Use of Passive Helicopter Recovery method to bring the descent rate to less than 10 m/s.
  - To attach a camera to the SV to record video in the Nadir (Earth – pointing) direction, in real time and stabilizing it.
  - To collect and transmit the required atmospheric telemetry parameters at 1Hz transmission rate.
  - Science Vehicle shall hold a raw hen’s egg and keep it intact after the fall.
- **SELECTABLE OBJECTIVE:**
  - To use a three-axis accelerometer to measure the stability and angle of descent of the SV. Data will be transmitted at 1 Hz rate.

  RATIONALE: We chose this objective as it gives a clear idea of the stability of the SV and whether the design we have proposed is actually working in practice as well as in theory.
- **EXTERNAL OBJECTIVE:**
  - To use a pressure sensor to calculate the ambient pressure.

Summary of Changes Since PDR

Mechanical System Changes:

Re-Entry Container:

- The **material of the DCS of re-entry container** has been changed from tarpaulin to nylon cloth.

Science Vehicle:

- **Blade length** changed from 17cm to 14.5cm and twist angle changed from 8º to 6º
- **Ball bearing** was changed from model number SKF 6201 to NBC 6202.
- **Length of the shaft** attaching the ball bearing and the rotor is decided to be kept as small as possible.
- The **position of ball-bearing** was changed from bottom of the upper frustum to its top.

The rationale for all the changes has been provided in their respective sub-system slides.

Summary of Changes Since PDR

Electronics System Changes:

- **Re-Entry Container:**
  - LM35 has been replaced by BMP085 as the temperature sensor.
  - GPS has been replaced by BMP085 as the altitude sensor.
- **Science Vehicle:**
  - LM35 has been replaced by BMP085 as the temperature sensor.
  - GPS has been introduced as the Altitude Sensor.
  - AtMega 16 has been replaced by AtMega 328.
  - An additional source of power has been added to power the Real Time Clock – a 3 V CR2032 coin cell.
  - Data acquisition from two sensors has been tested with reset mechanism with two independent states namely, HIGH and LOW, using AtMega 328.

System Requirement Summary

ID	REQUIREMENT	RATIONALE	PRIORITY	CHILDREN	VM			
					A	I	T	D
SR-01	Total mass of the CanSat shall not exceed 600 gm. (without egg)	Competition Requirement	HIGH	MSR-01 DCS-08	✓	✓	✓	
SR-02	The container shall fit inside a container of 125 mm x 310 mm.	Competition Requirement	HIGH	MSR-02 DCS-01		✓	✓	✓
SR-03	Egg placed inside should be recovered safely.	Competition Requirement	HIGH	MSR-03 DCS-06			✓	✓
SR-04	Container shall use a parachute for descent. It should not free-fall.	Competition Requirement	HIGH	DCS-02 DCS-04 DCS-07	✓	✓	✓	
SR-05	The container shall not have any sharp edges or protrusions.	To facilitate leaving the rocket	HIGH	MSR-04	✓	✓	✓	
SR-06	Rocket airframe shall not be used to restrain any deployable parts or as part of CanSat operations.	Competition Requirement	HIGH	MSR-04	✓		✓	
SR-07	Separation should occur at appropriate the appropriate moment between container and SV.	To ensure stability and remove spin from video.	HIGH	MSR-07 DCS-05 SSR-01	✓	✓	✓	✓
SR-08	The Science Vehicle shall use a helicopter recovery system. The blades must rotate.	Competition Requirement	HIGH	MSR-09	✓	✓	✓	

System Requirement Summary

ID	REQUIREMENT	RATIONALE	PRIORITY	CHILDREN	VM			
					A	I	T	D
SR-09	There shall be no fabric or cloth between the blades.	Competition Requirement	HIGH	DCS-11	✓	✓	✓	
SR-10	The descent rate shall be maintained between 4 and 10 m/s.	Competition Requirement	HIGH	DCS-09	✓	✓	✓	
SR-11	All descent control devices and attachments shall survive 50 Gs of shock.	Competition Requirement	HIGH	MSR-10	✓	✓	✓	✓
SR-12	All structures shall be able to sustain 15 Gs of acceleration and 30Gs of shock.	Competition Requirement	HIGH	MSR-10	✓	✓	✓	✓
SR-13	Mechanisms shall not use pyrotechnics or chemicals.	To keep the SV from burning up.	HIGH	MSR-06 DCS-10	✓			
SR-14	During descent, the Science Vehicle shall collect and transmit pressure, temperature, FSW state, voltage, and accelerometer data.	Competition Requirement	HIGH	FSW-1,2,3 EPS-01,02 CDH-1,2,3,4,5 SSR-2,3,4,5	✓	✓	✓	✓
SR-15	All telemetry shall be displayed in real –time during launch and descent in engineering units at 1 Hz rate.	Competition Requirement	HIGH	CDH-01 FSW-04 FSW-05	✓	✓	✓	
SR-16	XBEE radios shall be used for telemetry.	Competition Requirement	HIGH	FSW-02	✓	✓	✓	

System Requirement Summary

ID	REQUIREMENT	RATIONALE	PRIORITY	CHILDREN	VM			
					A	I	T	D
SR-17	The SV shall have a video camera installed with a time stamp.	Competition Requirement	HIGH	SSR-06	✓	✓	✓	
SR-18	During descent, the video camera must not rotate.	Competition Requirement	HIGH	SSR-06	✓	✓	✓	
SR-19	The ground station shall include one laptop, XBEE radio and a hand held or table top antenna.	Competition Requirement	HIGH	GCS-01 GCS-02 GCS-03	✓			✓
SR-20	Cost of the CanSat shall be under $1000.	Competition Requirement	MEDIUM		✓			
SR-21	Flight Software shall maintain the count of packets received.	Competition Requirement	MEDIUM	FSW-06	✓	✓	✓	
SR-22	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	To inhibit their movement	MEDIUM	MSR-05 MSR-08	✓	✓	✓	
SR-23	The container shall be of a fluorescent color.	To increase visibility	MEDIUM	MSR-11	✓	✓		
SR-24	Audio beacon must be installed to the SV.	To facilitate recovery	MEDIUM	MSR-12	✓	✓		

System Concept of Operations

PRE-LAUNCH

- PRE-FLIGHT BREIFING
- SWITCHING ON MECHANICS CONTROL
- SWITCHING ON ELECTRONICS CONTROL
- TAKING CANSAT TO COMPETITION AREA

LAUNCH

- PUTTING CANSAT ON ROCKET
- LAUNCH OF ROCKET
- NEAR APOGEE DEPLOYMENT
- OPENING OF RE-ENTRY DCS (PARACHUTE)
- DEPLOYMENT OF SV FROM RE-ENTRY CONTAINER AT 450 M.
- OPENING OF PASSIVE HELICOPTER DESCENT MECHANISM
- RECEIVING OF DATA FROM SENSORS
- LOCATING THE SV AND THE RE-ENTRY CONTAINER

POST LAUNCH

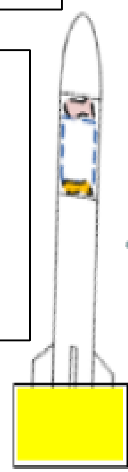
- SAVING DATA FROM GCS
- OBTAINING DATA CHIP FROM RE-ENTRY CONTAINER
- ANALYSING DATA
- PREPARING AND PRESENTING PFR

System Concept of Operations

LAUNCH

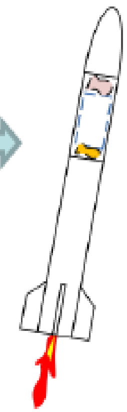
CanSat Crew will have the responsibility for preparing the CanSat, assembling it into the rocket and verifying its communication status with ground station crew and inform the mission control officer that it is ready for launch.

Mission Control Officer will have the responsibility to inform the flight coordinator that the team and CanSat is ready to be launched.

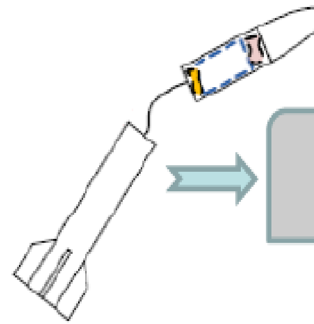


CANSAT IN ROCKET:- READY FOR LAUNCH

CANSAT DEPLOYED



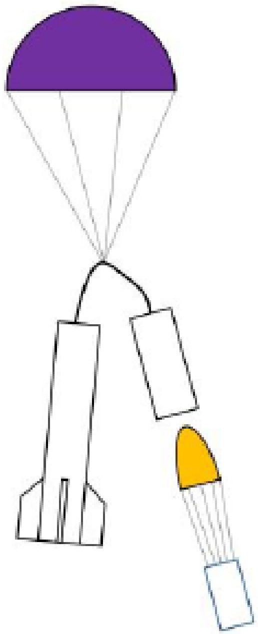
NEAR APOGEE DEPLOYMENT

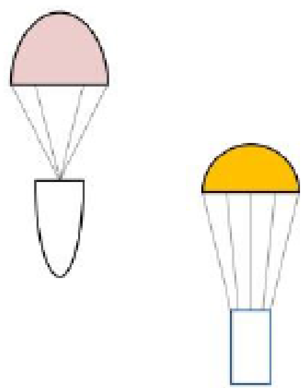


Name of Team Member	Post
Aman Arora	Mission Control Officer
Amitabh Yadav	Ground Station Crew
Raghav Rathi	Ground Station/CanSat Crew
Aditya Savio Paul	CanSat Crew
Dishant Kothia	Recovery Crew
Nalin Srivastava	Recovery Crew

System Concept of Operations

DESCENT



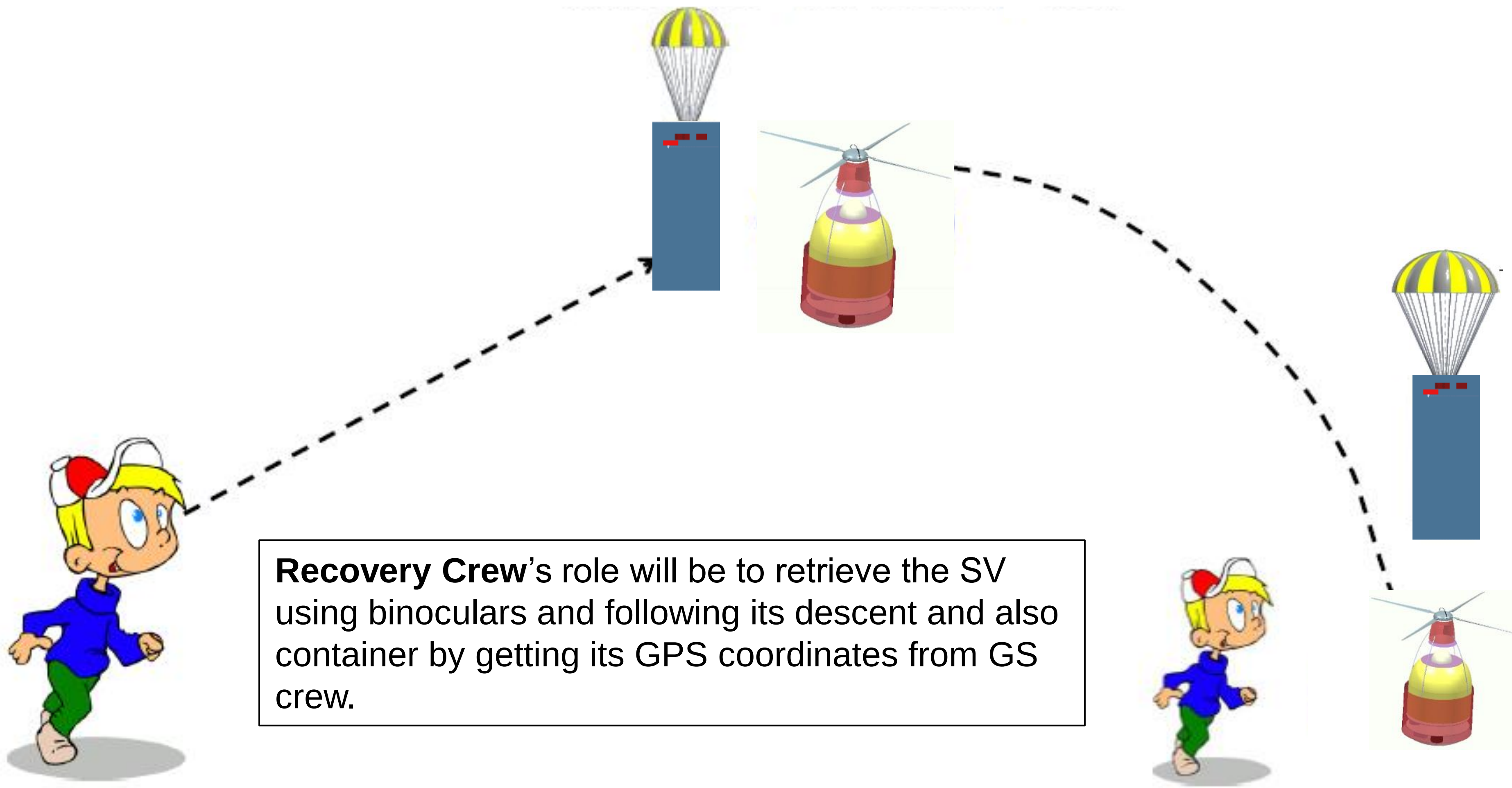


OPENING UP OF RE-ENTRY CONTAINER PARACHUTE

SCIENCE VEHICLE DEPLOYED AT 450 m

System Concept of Operations

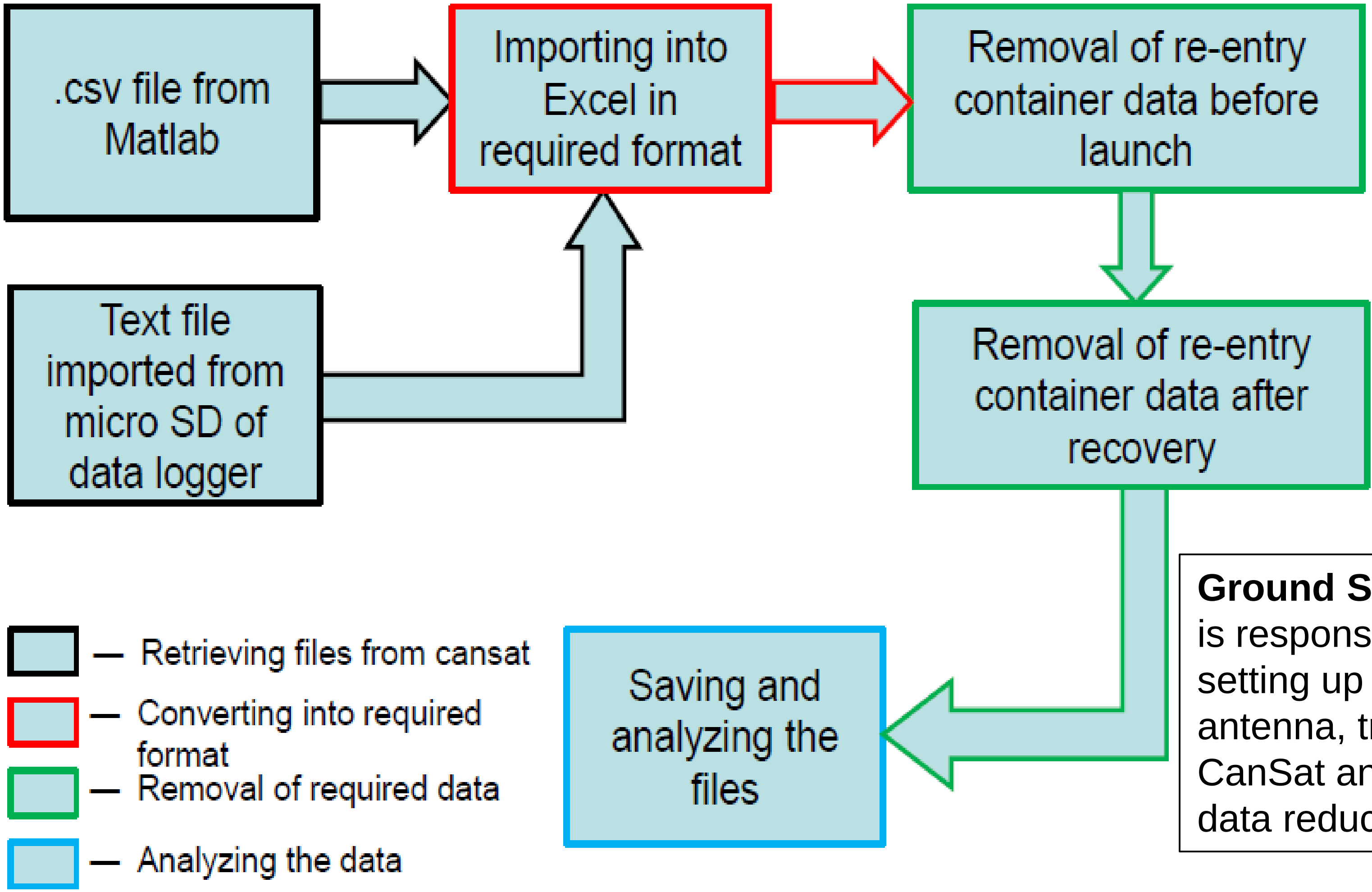
Post-launch recovery



Recovery Crew's role will be to retrieve the SV using binoculars and following its descent and also container by getting its GPS coordinates from GS crew.

System Concept of Operations

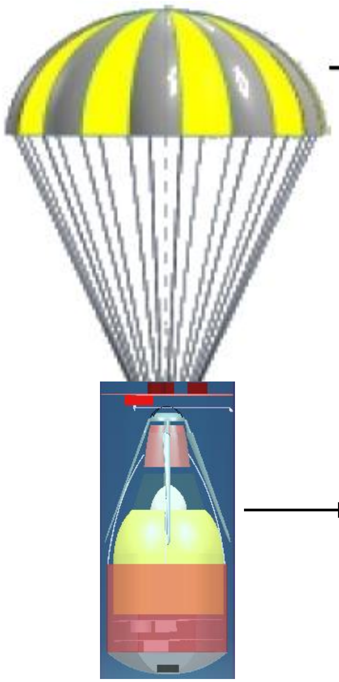
DATA REDUCTION



Ground Station Crew is responsible for setting up the GS and antenna, tracking the CanSat and performing data reduction.

Physical Layout

40 cm

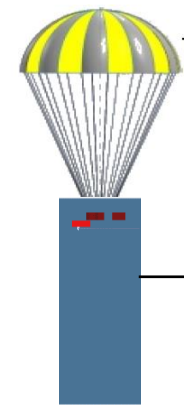


PARACHUTE DEPLOYED

1

RE-ENTRY CONTAINER + SCIENCE VEHICLE

2



RE-ENTRY CONTAINER

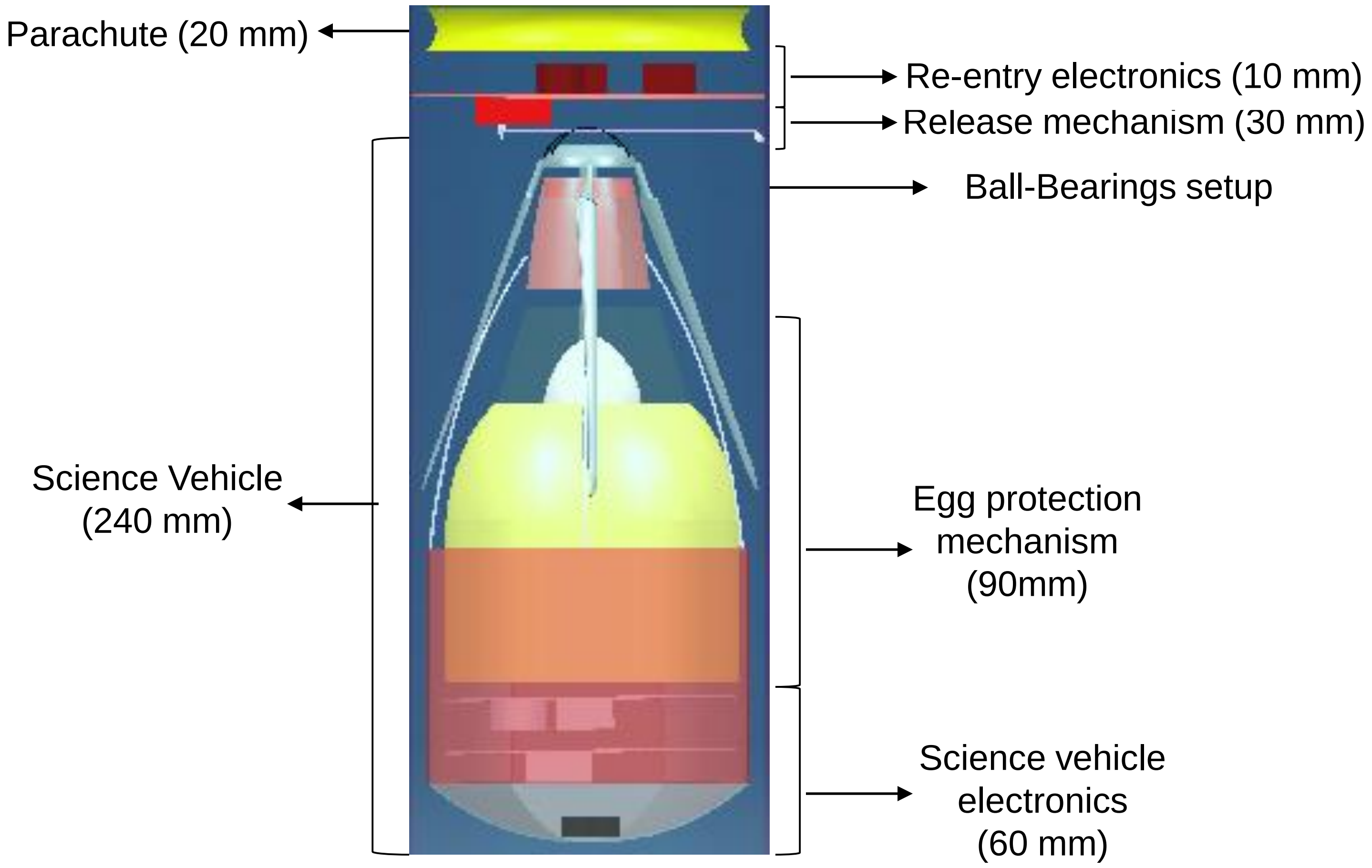
Separation at 450 m

SCIENCE VEHICLE

1. Re-entry container + science vehicle just after release from the rocket at 670 m.

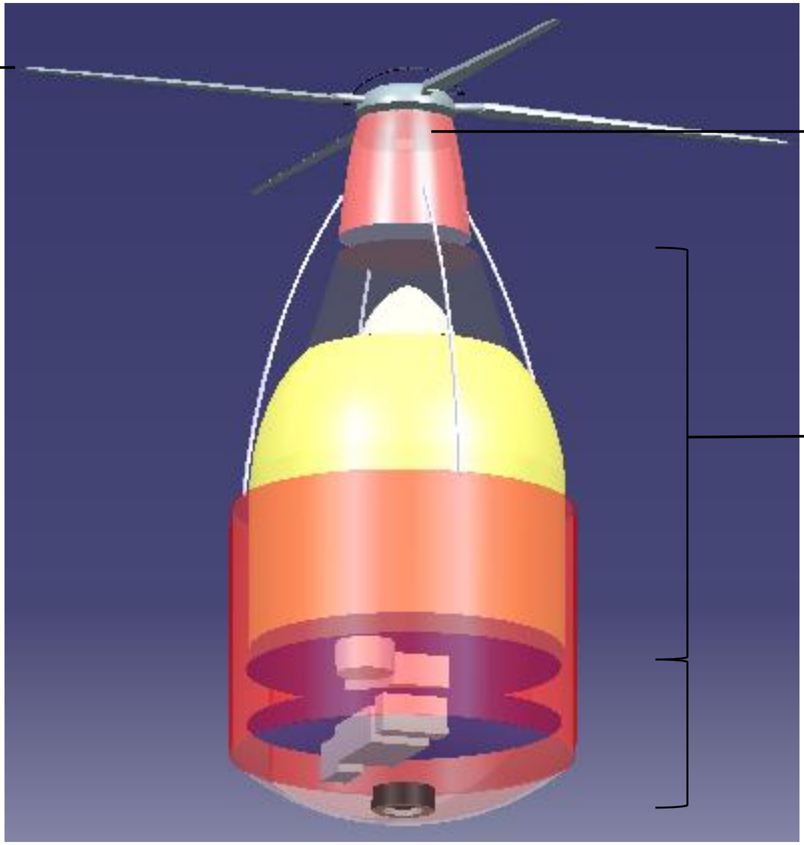
2. Science vehicle separated from the re-entry container at 450 m to resume its operations.

Physical Layout



Physical Layout

4-blade rotors



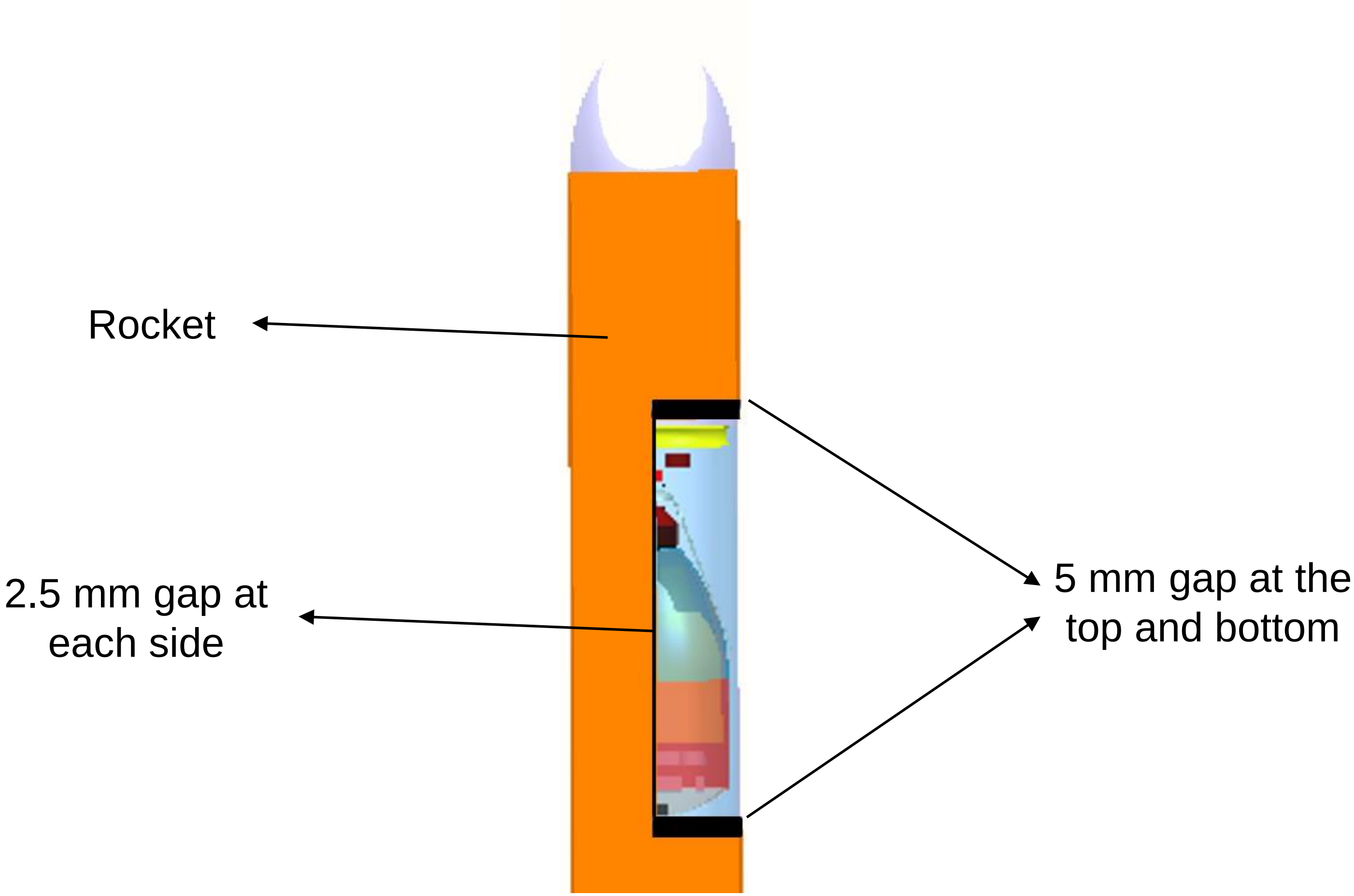
Ball-Bearings setup

Egg protection mechanism (90mm)

Science vehicle electronics (60 mm)

Launch Vehicle Compatibility

- The structure is designed strictly keeping in mind, the size and weight restrictions.
- Re-entry container will be placed upside down in the rocket payload section.
- For verification of launch vehicle compatibility, we will test the dimensions, a day prior to the launch day by making sure that the re-entry container slides in a container of dimensions 310x125 mm.
- The final measured dimensions are as follows:
  - Max. diameter of re-entry container is 120 mm which is 5 mm less than the rocket's payload section and there are no components protruding outside the re-entry container which will facilitate smooth deployment.
  - Height of the re-entry container is 300 mm. this is well under the given limit of 310 mm, ensuring that CanSat will not protrude out of the payload section.


Rocket
2.5 mm gap at
each side
5 mm gap at the
top and bottom

Sensor Subsystem Design

Sakshi Drall

Sensor Subsystem Overview

- **SENSORS FOE RE-ENTRY CONTAINER:**

  I. ALTITUDE AND TEMEPERATURE SENSOR:

    i. BMP085 is used as the altitude and temperature sensor in the re-entry container.
    ii. BMP085 calculates both altitude and temperature simultaneously.

- **SENSORS FOR SCIENCE VEHICLE:**

  I. TEMPERATURE SENSOR:

    i. BMP085 is used as the temperature sensor for the science vehicle. BMP085 can simultaneously calculate temperature ,altitude with the help of pressure values.

  II. ALTITUDE SENSOR:

    i. GPS is used as the altitude in the science vehicle.
    ii. FASTRAX UP501 is used as the altitude sensor to obtain the altitude values in the science vehicle.

  III. ACCELEROMETER SENSOR:

    i. ADXL345 is used as the accelerometer sensor same as mentioned in the PDR.

Sensor Changes Since PDR

CHANGES IN THE TEMPERATURE SENSOR:

- In the PDR submitted we preferred LM35 as the temperature sensor in the **science vehicle as well as re-entry container**. But now we prefer BMP085.
- **RATIONALE:** The temperature sensor in it has an inbuilt ability to calculate the temperature as well as altitude so it removes the need for an additional sensor thus helping to reduce the weight of the electronic components.

	LM35(PDR Specified)	BMP085(CDR)
Power Consumption	50uA per sample	5uA at 1 sample/sec
Operating Range	-55 to +150 *C	-40 to +85*C
Accuracy	0.5*C	+-2*C
Component Size	4.699mm x 4.699mm	5.0mm x 5.0mm

Sensor Changes Since PDR

- **CHANGES IN ALTITUDE SENSOR OF RE-ENTRY CONTAINER**:

Earlier we planned to use GPS as the altitude sensor in the re-entry container but now we prefer to use BMP085 as the altitude sensor.

RATIONALE: BMP085 can simultaneously calculate altitude as well as the temperature of the reentry container.

This in turn helps us to reduce our space and weight constraints.

	GPS(PDR)	BMP085(CDR)
POWER CONSUMPTION	75mW	5uA at 1 sample/sec
ACCURACY	2.5m CEP	-40 to +85*C
OPERATING RANGE	-40*C to 85*C	+-2*C
COMPONENT SIZE	20mmx20mmx8.0mm	5.0mm x 5.0mm

Sensor Changes Since PDR

- **CHANGES IN THE ALTITUDE SENSOR OF THE SCIENCE VEHICLE:**

  – In the PDR we mentioned to use BMP085 as the altitude sensor and now we prefer to use GPS sensor for the calculation of altitude values.

  – FASTRAX UP501 is used for this purpose.

  – **RATIONALE:** We are using GPS because it can help us in tracking our science vehicle along with the altitude values calculation.

Sensor Subsystem Requirements

ID	REQUIREMENT	RATIONALE	PARENT	PRIORITY	VM			
					A	I	T	D
SSR-01	Measurement of altitude (both science vehicle and re-entry)	Competition Requirement	SR–07	HIGH	✓	✓	✓	
SSR-02	Measurement of air temperature inside and outside (Both science vehicle and re-entry)	Competition Requirement	SR-14	HIGH	✓	✓	✓	
SSR-03	Measurement of battery voltage (both science vehicle and re-entry)	Requirement for Descent Telemetry and Housekeeping Data	SR-14	HIGH	✓	✓	✓	
SSR-04	GPS altitude (RE-ENTRY)	Descent altitude and determination of Landing	SR-14	HIGH	✓	✓	✓	✓
SSR-05	Acceleration Sensor (science vehicle)	For ejecting, mapping of motion and operational objective of landing data.	SR-14	MEDIUM	✓	✓	✓	
SSR-06	Camera at the bottom of the science vehicle	For recording the movement of the CANSAT and the surroundings	SR-17 SR-18	HIGH	✓	✓		

Altitude Sensor Summary

- **ALLTITUDE SENSOR FOR SCIENCE VEHICLE:**

  GPS SENSOR: **FASTRAX UP501** is used as the altitude and tracking sensor for the science vehicle.

DEVICE	SUPPLY	TYPE	SENSITIVITY	POWER	ACCURACY
FASTRAX UP501 GPS	1.65 to 3.6 V	UART and SPI	--165dBm	75mW	2.5m CEP

- GPS used in the re-entry container will use NMEA 0183 Protocol with a baud rate of 9600.
- The data received will be stored and the altitude values will be extracted.
- The data received from module will be:

  $GPRMC,023042,A,3907.3837,N,12102.4684,W,0.0,156.1,131102,15.3,E,A*36
  $GPGGA,023042,3907.3837,N,12102.4684,W,1,04,2.3,507.3,M,-24.1,M,,*75
  $GPGSA,A,3,04,05,,,09,,,24,,,,,2.8,2.3,1.0*36
  $GPGSV,3,2,11,09,47,229,42,10,04,157,00,14,00,305,00,24,70,154,33*79

Altitude Sensor Summary

- **ALTITUDE SENSOR FOR RE-ENTRY CONTAINER:**

  BMP085 SENSOR:

- BMP085 by BOSCH Company is used as the altitude sensor in the science vehicle.

- The BMP085 has a **digital** interface, I2C to be specific.

- With the measured pressure p and the pressure at the sea level p_0,the altitude in the meters can be calculated with the international barometric formula:

$$altitude = 44330*(1-(p/p_0)^{(1/5.255)})$$

Air Temperature Sensor Summary

SCIENCE VEHICLE AND RE-ENTRY CONTAINER:

- We are using BMP085 as the air temperature sensor which also works as the altitude and pressure sensor.
- The sensor provides the 16 bit temperature data.

DEVICE	ACCURACY	CONNECTION TYPE	OPERATING RANGE	ESD RATING	OVER PRESSURE
BOSCH BMP085	+-2*C	I2C	-40*C to +85*C	+-2kV	10,000hPa

- The temperature is calculated in steps of 0.1 degree Celsius. Using some calibration data and the real time temperature data provided by the sensor.
- The sampling rate can be increased to 128 samples per sec for dynamic measurements**.**
- The BMP085 has a **digital** interface, I^2C to be specific. This means there may is a bit more overhead to get it talking to your microcontroller, but in return you get data that is much less susceptible to noise and other factors that may hamper an analog signal.

Air Temperature Sensor Summary

- Formulas involved in internal calculations for temperature values are:

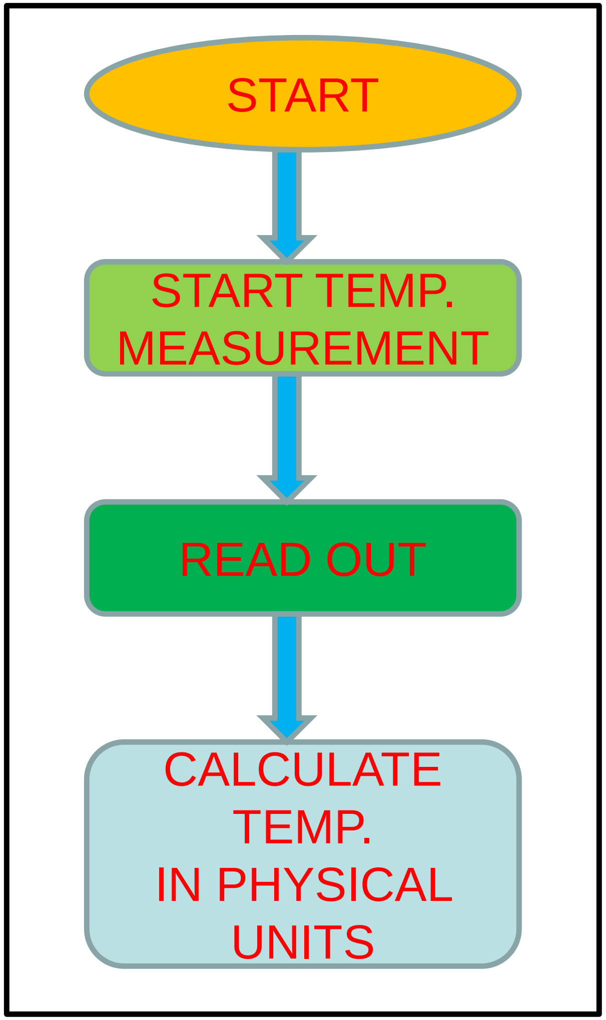
  – UT=MSB<<8+LSB
    (uncompressed temperature)

  – X1= (UT- AC6)*AC5/2^15

  – X2= MC*2^11/(X1+MD)

  – B5= X1+X2

  – T= (B5+8)/2^4



Camera Summary

Camera is also same as it was mentioned in the PDR:

CMOS OV7670.

MODEL	RESOLUTION	OPERATING TEMP.	SCANNING FREQUENCY	POWER CONSUMPTION
CMOS OV7670	728x488	20-70*C	15625KHz	6-20V
CMOS SEN11745 ROHS	640x480	25-70*C	17KHz	6-20V

CMOS OV7670 is selected:

- High operating temperature
- Low current consumption
- Works with 16 bit microcontroller
- High scanning frequency

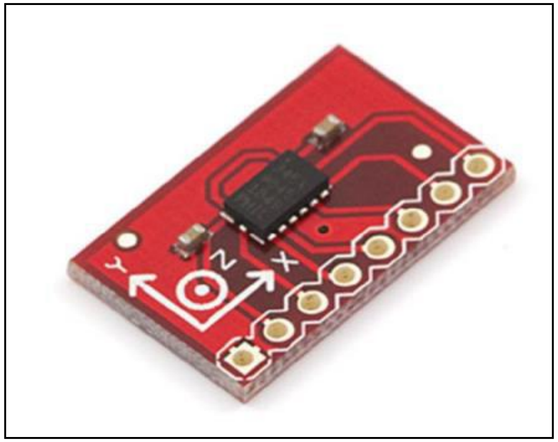
3-Axis Accelerometer Sensor Summary

Accelerometer is same as it was mentioned in the PDR.

DEVICE	WEIGHT(g)	CURRENT CONSUMPTION(μA)	CONNECTION TYPE	SIZE(mm)
ADXL345	2	145(0.1standby)	I2C&SPI	3.05x5.08
BMA180	2	650-975(0.5 standby)	I2C&SPI	3.05x3.05

Accelerometer Chosen –ADXL345

- Selectable sample rate (6.25 to 320Hz)
- Flexible range (2 g to 16 g)
- FIFO mode makes data storage simpler



Descent Control Design

Dishant Kothia

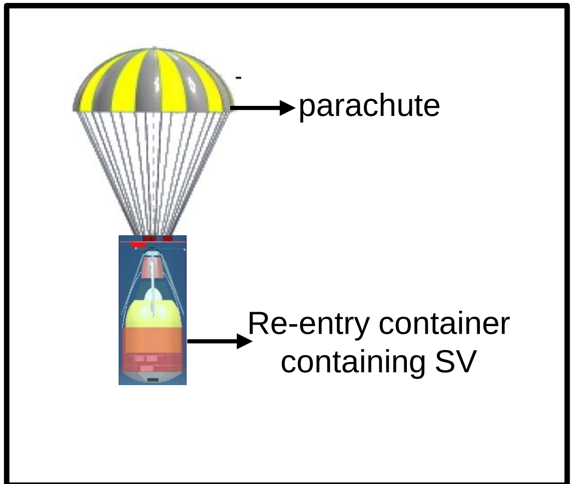
Descent Control Overview

RE-ENTRY CONTAINER:

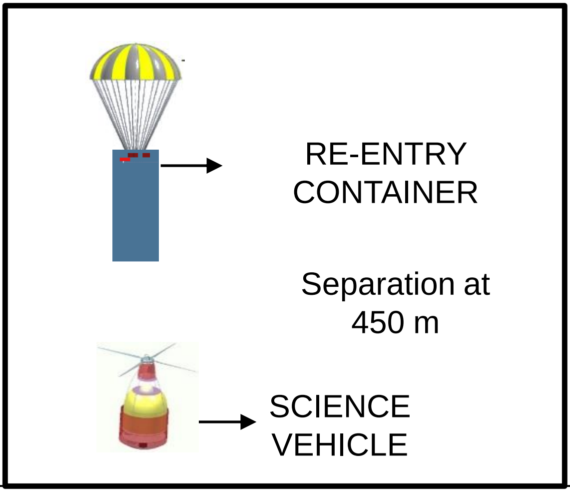
- Descent control system for REENTRY CONTAINER will consist of a parachute of radius 20 cm for re-entry container with a spill hole of diameter, 6.5 cm to provide stability.

- As DCS is not electronically controlled so proper design and right choice of material is important.

- Parachute will be folded such that it will occupy not more than 10 mm of space above the re-entry container.



Post deployment from rocket

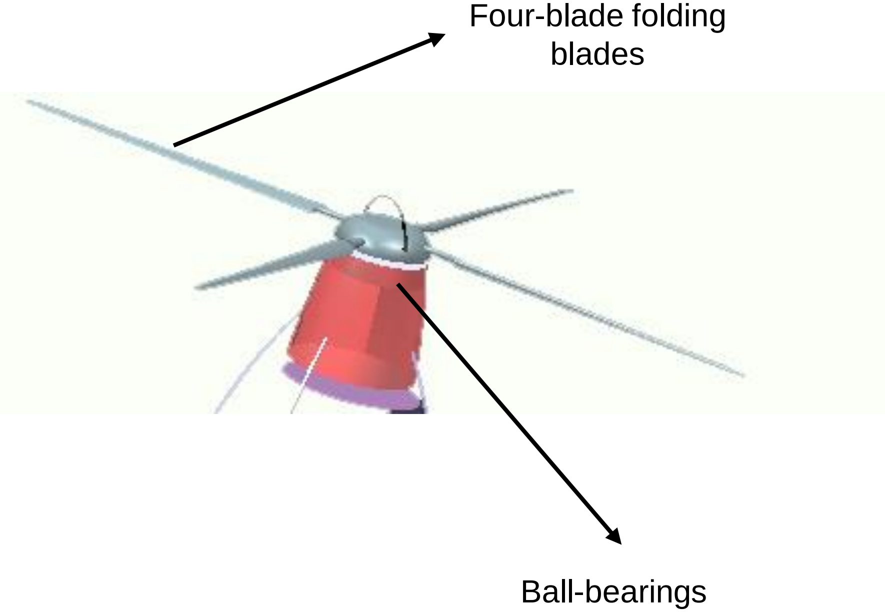


Post separation from Re-entry Container

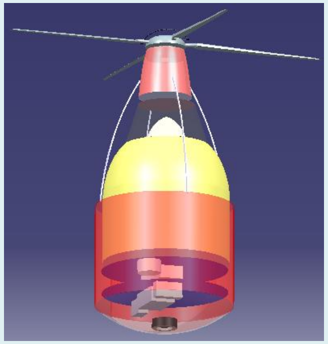
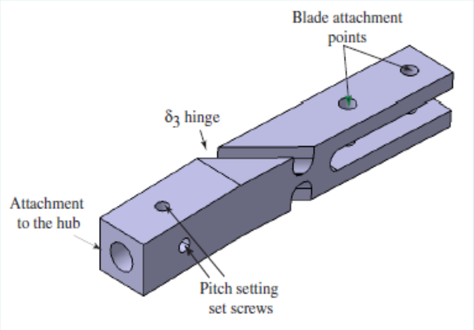
Descent Control Overview

SCIENCE VEHICLE:

- For the SV, a four-blade customized rotor of radius 14.5 cm is used.
- At the time of separation, passive helicopter recovery system of SV will open automatically due to air flow and the rotation of the blades will provide stability. A ball-bearing setup is used to prevent the rotation of the lower part of the CanSat.
- At approx. 450m, a servo motor will be used to separate SV from re-entry container.
- The whole system will be controlled by ATMega16 microcontroller.



Descent Control Overview

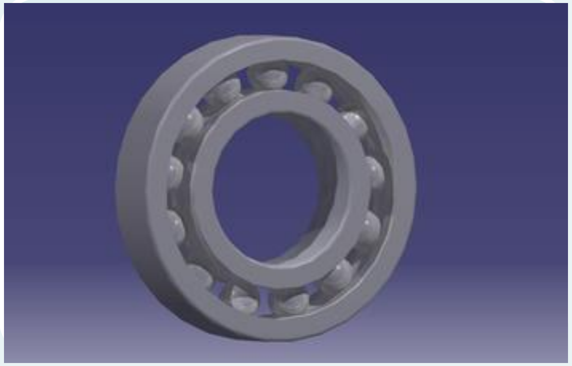




A passive helicopter recovery system consisting of customized blades of length 14.5cm has been finalized to give maximum possible drag so that the SV can descent with a speed less than 10 m/s.

At the time of separation, passive helicopter recovery system of SV will open automatically due to the upward air flow and the rotation of the blades will provide stability.

A negative value of pitch flap coupling angle (δ_3), a negative value of Pre-cone angle (β_p), a negative value of Pitch angle and a positive Twist angle will ensure auto-rotation of the rotors while descending. This auto-rotation will give enough up-thrust to reduce the velocity of the SV below 10 m/s.

Descent Control Overview



Ball – bearing setup is used to ensure that the lower portion of the SV does not rotate along with the blades. A lubricant will be used to reduce the friction inside the ball bearing.

This does not increase the weight of the SV much at the top and helps in keeping it stable.

The inner ring of the ball-bearing will be attached to the bottom part of SV and the outer ring will be attached with a smaller frustum on the top of the SV.

The rotor hub will be mounted on the top of the upper frustum.

A parachute of radius 20 cm with a spill hole of 6.5cm is attached to the re-entry container at the top of it.

The parachute will open because of the drag produced by the air and thus it will make the re-entry to descend at a velocity near to 14m/s.

Descent Control Changes Since PDR

Components Changed	Requirements	Rationale
Blade length changed from 17cm to **14.5cm** and twist angle changed from 8º to **6º**	The blade of the rotor is required to give enough up-thrust to control the descent rate of the SV to less than 10m/s.	Changing the length and the twist angle gave the required up-thrust in addition with easiness of accommodating it within the re-entry container.
Ball bearing was changed from model number SKF 6201 to **NBC 6202**.	Ball bearing is required to prevent the SV from rotating while descending.	NBC 6202 is much more smooth and matches our exact dimensions. Also it has inner plastic fixture.
The material of the DCS of re-entry container has been changed from tarpaulin to **nylon cloth**.	The material of DCS of re-entry container should be strong enough take the loads from air while descending.	Nylon cloth proves to be much stronger and air resistant than the tarpaulin.
Length of the shaft attaching the ball bearing and the rotor is decided to be kept as small as possible.	Shaft joins the ball bearing attached with SV to the rotors.	A small shaft will ensure less vibrations while rotating, which will make less energy loss. And also it will save some space in height.

Descent Control Changes Since PDR

Prototype Testing:

Balloon Test:

- This test was done to check the descent control of the system from two different altitude.
- The CanSat was sent up with the help of a weather balloon. It was tied with the balloon with the help of a thread.
- A servo motor was programmed to cut that thread after 15 minutes, at an approximate altitude of 250 m.
- Again it was tied and sent and now the programming was done for 150 m.

Observations:

- After falling, it took some time to get stabilized and start falling smoothly. The rotors were rotating with enough RPM to control the science vehicle's descent rate.
- It landed very smoothly at an approximate velocity of 9m/s and the payload (a large size hen's egg) was saved.

Descent Control Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
DCS-01	DCS of the SV must fit inside the 125 mm diameter cylinder	Mission requirement	HIGH	SR-02	✓	✓	✓	
DCS-02	The parachute shall not exceed a packing depth of 10 mm at the top of the re-entry container.	Allow for sufficient space allocated to the rest of the systems.	MEDIUM	SR-02		✓	✓	
DCS-03	Both parachute and rotors must be reasonably light (under 80g)	Keep the weight budget from exceeding 600 g	MEDIUM	SR-01	✓	✓	✓	✓
DCS-04	Parachute must be designed to avoid tangling of shroud lines while descending.	Prevent tangling during descent that could lead to a failed recovery	HIGH	SR-06 SR-03 MSR-03	✓	✓	✓	
DCS-05	The re-entry container and SV need to be separated at an altitude above 450m.	To make sure that the CanSat is at proper orientation for deployment of aero-braking structure	HIGH	SR-07	✓	✓	✓	
DCS-06	Egg safety mechanism (polystyrene balls + sponge).	To provide different damping ratio, to absorb the shock	MEDIUM	MSR-03	✓	✓	✓	✓

Descent Control Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
DCS-07	Parachute should provide a descent rate of 14 m/s to the CanSat before 450m.	To provide an optimum velocity to SV after getting deployed	HIGH	SR-06	✓	✓	✓	
DCS-08	Materials used to be light and flexible	To minimize mass and volume requirements.	MEDIUM	MSR-03 SR-01		✓	✓	
DCS-09	Deployment of umbrella should provide a descent rate less than 10 m/s and greater than 4m/s after deployment.	Mission requirement	HIGH	SR-08	✓	✓	✓	✓
DCS-10	Decent Control System (DCS) shall not use flammable or pyrotechnic devices	Mission requirement	HIGH	SR-19	✓	✓	✓	✓

Container Descent Control Hardware Summary

- For descent control of container no sensors or actuators will be used but the mechanical structure is made in such a way that the parachute will deploy automatically due to up thrust when the container is released from the rocket at 670 m.
- The descent control hardware for the container consists of a nylon parachute of radius 20cm with a spill hole of 6.5cm which deploys automatically at 670 m on coming out of the rocket.
- It is easy to design and fabricate/easily available according to the required descent rate. The design and size of the parachute has been chosen to obtain a descent rate of 14m/s.
- The color of the parachute is bright (red) and flashy so that visual contact can be maintained with the container while it is descending.
- Shock resistance tests have been done to check the amount of shock force that can be resisted by the parachute. It survived 50 Gees of shock force.
- The material of the parachute (Nylon) is chosen such that it resists the shock / impact force, it is elastic i.e., will not deform permanently, it is resistant to wear and tear, it is lightweight, has high strength, has good air blocking ability, that is non-porous and occupies small space.

Science Vehicle Descent Control Hardware Summary

- For descent control of SV no sensors or actuators will be used but the mechanical structure is made in such a way that the rotors will deploy automatically due to up thrust when the SV is released from the container.
- The descent control system of the SV is a 4 blade rotor with a blade of 14.5cm. The hub of the rotor will be 2.5cm wide and will be attached with the science vehicle at its top.
- The chord of cross-section of the blade is around 2.8cm having a CLARK Y airfoil. Pitch-flap coupling angle (δ_3) is -30^o, Pitch angle (θ_o) is -6^o, Pre-cone angle (β_p) is -6^o and the Twist angle is 6^o.
- The rotor is chosen such that it resists shock / impact force, it is elastic i.e., will not deform permanently, it is lightweight, has high strength.
- The hub of the rotor will be attached with a shaft, which on the other end will be attached with a ball bearing. Ball-bearing setup is used to ensure that the lower portion of the SV does not rotate along with the blades. A lubricant will be used to reduce the friction inside the ball bearing.
- The inner ring of the ball- bearing will be attached to the bottom part of the rotors and the outer ring will be attached with a smaller frustum on the top of the SV.

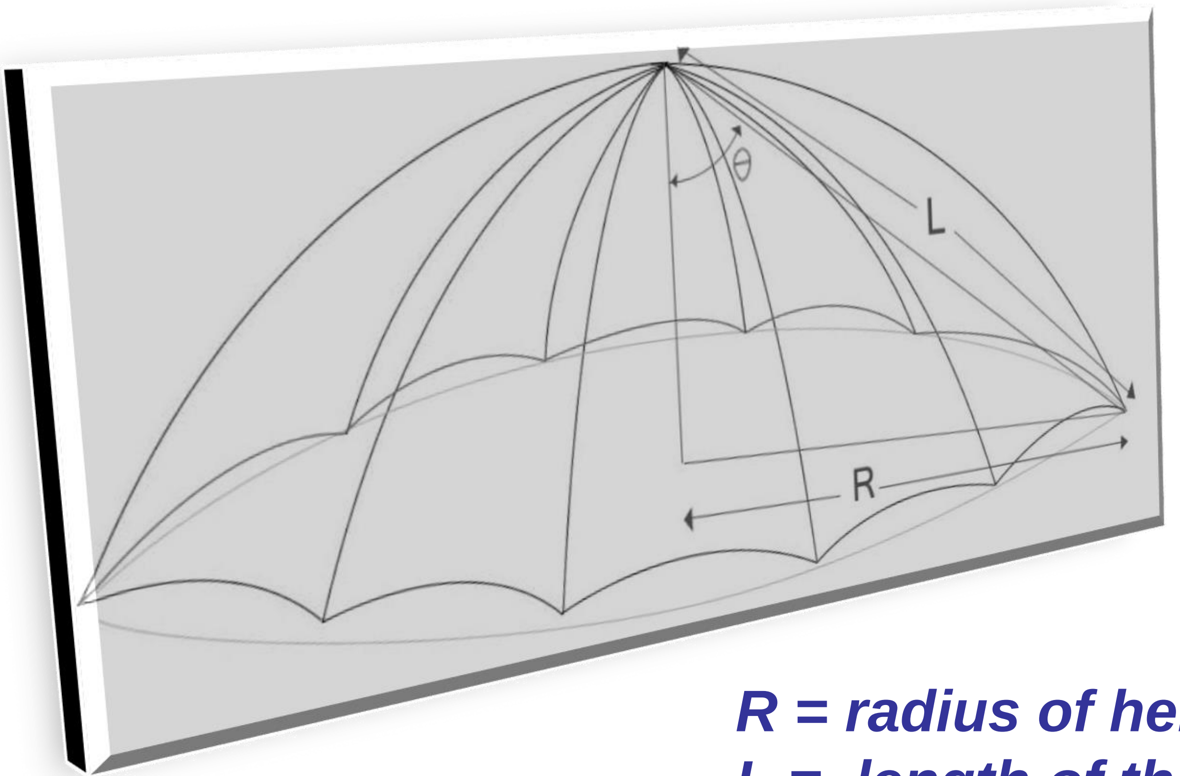
Science Vehicle Descent Control Hardware Summary

- In order to prevent the SV from toppling, proper dimensions of the rotors and the SV body were used keeping in mind the required descent rate i.e., less than 10 m/s.

- The release of the SV from the container will be governed by the release mechanism in which a pressure sensor will be used to determine the altitude. At an altitude above 450m the SV will be released and while descending the rotors will start rotating.

ANNUAL CANSAT COMPETITION

Descent Rate Estimation of Re-Entry Container :



R = radius of hemispherical umbrella
L = length of the spoke
θ = angle b/w the axis and spoke

Descent Rate Estimates

- A parachute will be used to control the descent rate of the re-entry container
- To get the required drag and vertical velocity, radius of the parachute can be calculated as follows :

$$R = \sqrt{(2F_{drag}/\pi\rho V^2 C_d)}$$

- Where,

- Π = 3.14159265359
- P = 1.15605 Kg/m^3 (b/w 700 m and 450 m)
- C_d = *0.4547 (drag coefficient of a hemisphere chute with a spill hole)*
- V = *14m/s*
- R = Radius of the chute = 20 cm (spill hole dia. = 6.5cm)
- F_{drag} = Drag Force = 6.543 Newton (Recovering from 22m/s)

Descent Rate Estimates

Calculation for descent rate of re-entry container
After rearranging the equation and finding the velocity:

$$R = \sqrt{(2} \times 6.543)/(3.14 \times 1.15605 \times 142 \times .4547)$$

R = 20cm

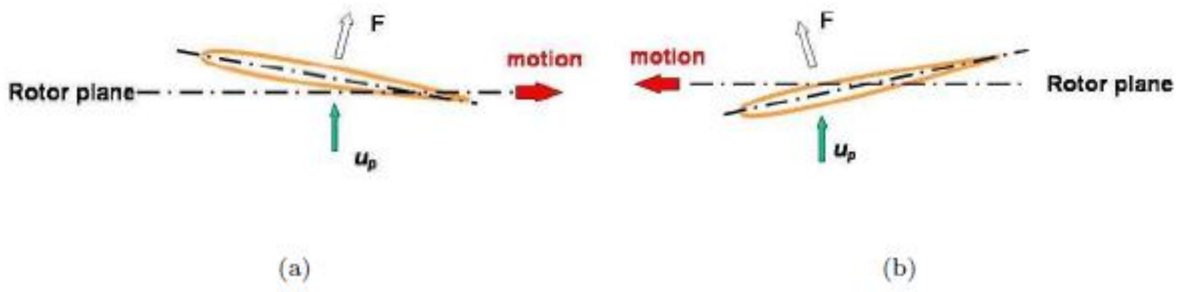
So the Descent rate of the re-entry container comes out to be 14 m/s

Post-separation of SV and container, weight of the container is remained just 250gm which leaves it with a velocity of **8.5m/s**

Descent Rate Estimation for Science Vehicle

As the chosen design for DCS of SV is a customized rotor with a ball-bearing setup, so it is important to do all the calculations related to the designs of the rotor:

Pitch Angle(θ_o) : If the blade is set at a positive pitch, the air flows towards the leading edge of the profile, creating a force F as seen in Figure a, with an in-plane component acting towards the trailing edge. This causes the rotor to start rotating trailing edge first. If the blade is set at a negative pitch, as shown in Figure b, it ensures that the flow is directed towards the trailing edge, generating a force F which gives rise to a rotor rotation in the direction of the leading edge. Therefore a negative collective pitch at the blade root allows the rotor to spin up in the appropriate direction: **leading edge first.**

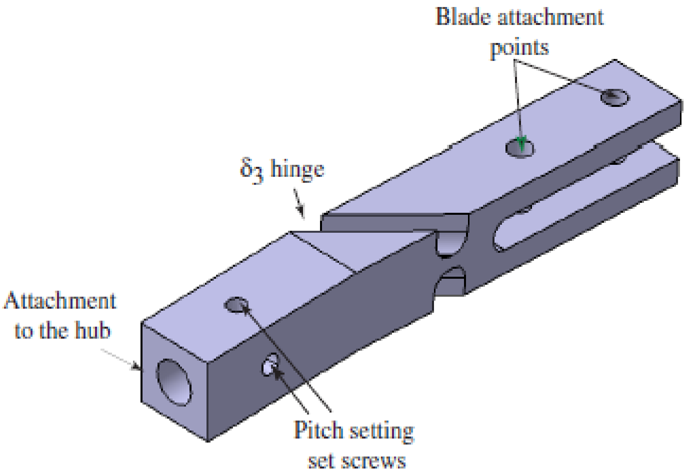


Descent Rate Estimates

However, a negative pitch would result in a low steady state thrust. Therefore, to obtain a high steady state thrust, the steady state pitch should be less negative or slightly positive. **The rotor pitch settings required to start the rotor rotation in the correct direction and to generate a high steady state thrust are therefore contradictory.**

For solving this problem we can use,

Pitch-Flap Coupling Angle(δ_3) - This coupling can be achieved by incorporating a flap hinge with a negative pitch-flap coupling angle as shown in Figure. below. As a result, as the rotor RPM increases, a positive change of flap angle will result in an increase of pitch.



$$d\theta = d\beta.\tan(\delta_3)$$
$$= -(\beta - \beta_p).\tan(\delta_3)$$

where **dθ** is the change in pitch angle and **dβ** the in flap angle. **β** is the flap angle and **β_p** is Pre-cone angle It follows that it is necessary to generate a change large flap deflection in order to obtain large increase in pitch and thereby a high thrust.

And also, a negative δ_3 is required.

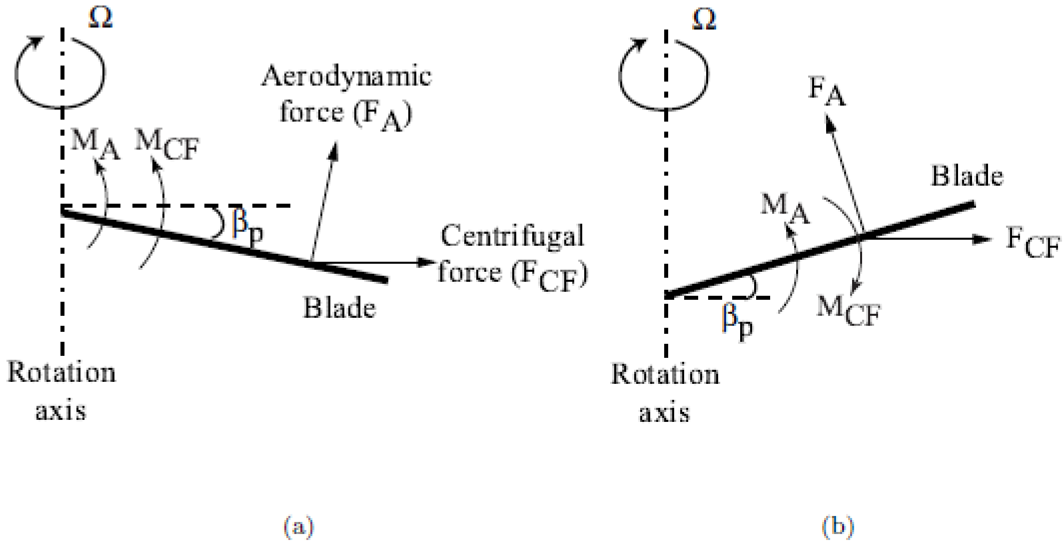
Descent Rate Estimates

For higher change in pitch angle

Pre-cone angle (β_p): The flapping moment about the flap hinge is the sum of the aerodynamic moment M_A and centrifugal moment M_{CF}. In Figure. a, the blade **pre-cone angle β_p is negative.** In this case, the aerodynamic and centrifugal moments add up, generating a large flap deflection of the blade upward.

On the contrary, **a positive pre-cone β_p**, as shown in Figure. b, will result in the centrifugal moment impeding the action of the aerodynamic moment.

It is noted that introducing a **negative pre-cone angle β_p** helps to generate a larger flap deflection, and thus more change in pitch angle and finally more steady-state thrust will be produced.



Descent Rate Estimates

Twist Angle: A positive twist angle will result in higher angle of attack at the blade tip during steady state which will increase the steady state thrust. From Momentum theory we also know that a positive twist angle improves autorotative performances.

Calculations:

Assuming that the velocity of the SV while separating is near to 14m/s, and it has to be reduced from 14 m/s to 6m/s in 100m of height, so the force required would be:

$$v^2 - u^2 = 2.a.s$$

$$(6)^2 - (14)^2 = 2 \times a \times 100$$

$$a = -0.8 \text{ m/s}^2$$

$$\text{Force} = \text{mass} \times \text{acceleration}$$

$$= 0.35 \times (-0.8)$$

$$= -0.28 \text{ Kg.m/s}^2$$

$$= -0.28 \times 9.81$$

$$= -2.7468 \text{ N (in opposite direction as assumed positive)}$$

Descent Rate Estimates

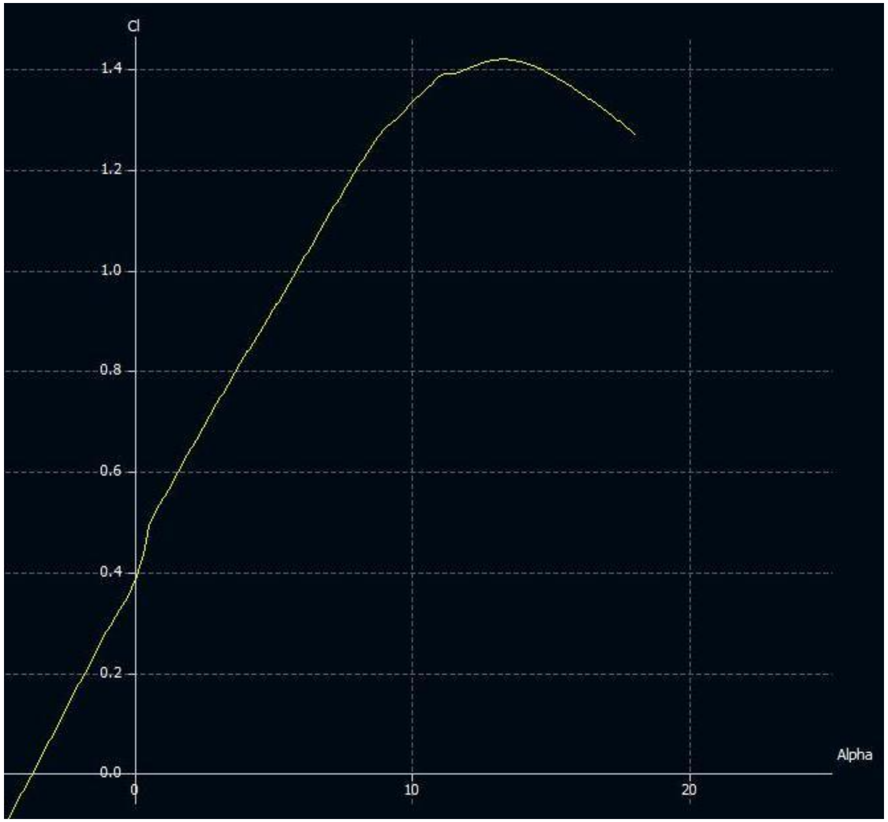
After looking at many airfoils for propellers we came at the conclusion of using CLARK Y airfoil which would be quite suitable according to our auto-rotating requirements.
Now for calculating the radius of the rotor (i.e., length of the blade) we need to apply the following formula for a descent rate of 6m/s between 450m and 350m.

The rate of descent is minimum when C_L^3/C_D^2 is maximum this occurs at a particular angle of attack (i.e., twist angle of the blade). So the characteristics of CLARK Y were observed in the software and its maximum value of C_L^3/C_D^2 was noted at the required altitude and Reynold's number and substituted in the formula of descent rate.

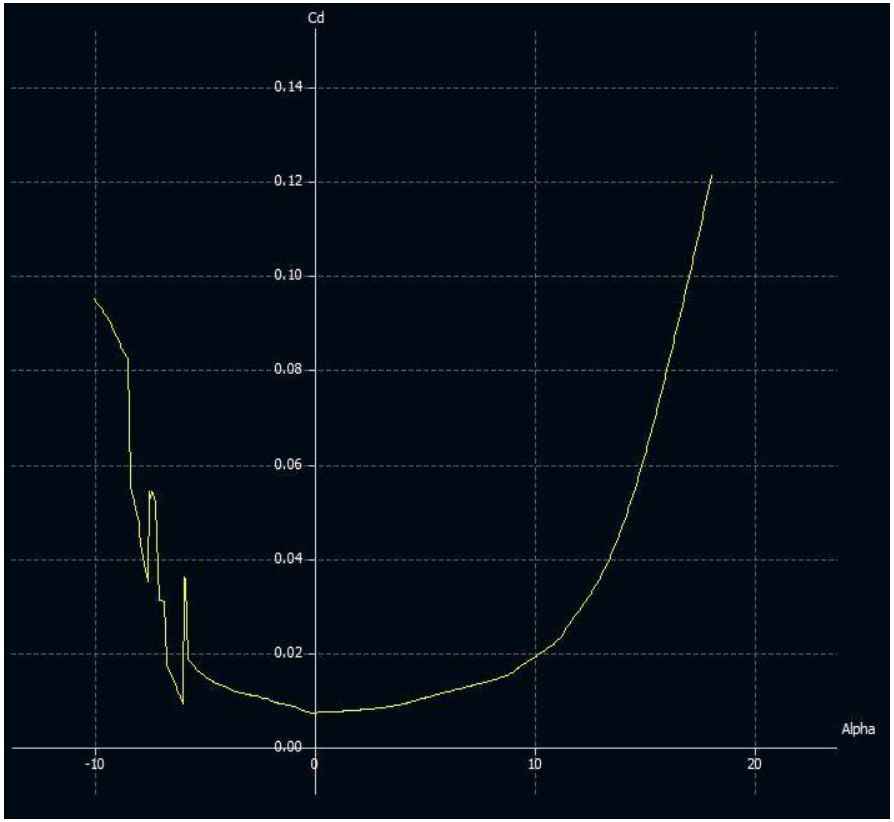
Rate of descent, RD = $\sqrt{\frac{W}{S} \times \frac{2}{\rho} \times \frac{{C_D}^2}{{C_L}^3}}$

C_L Vs α graph and C_D Vs α graph were plotted using XFLR5 software and the values of C_L and C_D were noted at different values of α.

Descent Rate Estimates



C_L Vs α graph for CLARK Y airfoil



C_D Vs α graph for CLARK Y airfoil

Descent Rate Estimates

Values of C_L and C_D at different angle of attack were accounted and thus C_L^3/C_D^2 was calculated at different angle of attack:

α	C_L	C_D	C_L^3/C_D^2
0	0.385	0.00738	1047.77
2	0.643	0.008	4153.87
4	0.833	0.009	7135.92
6	1.016	0.012	7283.13
8	1.201	0.014	8838.38
10	1.333	0.019	6561.19
12	1.400	0.029	3262.78

From the results we can tell that value of $(C_L^3/C_D^2)_{max}$ is 8838.38 at α = 8º.

Now substituting all the values in the formula to find out the radius of the rotor.

ρ = 1.196 kg/m³

W = 2.746 N

RD = 6m/s

C_L^3/C_D^2 = 8838.38

After putting all the values in the formula we finally get R = 14.46cm.

A four blade rotor is chosen to provide an optimum mass flow rate without creating much resistance to the airflow.

Now for deciding other configurations of the rotor, tests were being conducted in ANSYS (taking velocity, v = 14m/s) and the rotor which gave the optimum thrust (near to our requirement) was chosen.

Descent Rate Estimates

Results of the tests conducted in the CFD software are as follows:

Pitch-Flap Coupling Angle (degree)	Pitch Angle (degree)	Pre-cone Angle (degree)	Thrust (Newton)
-30	-6	-4	1.762
-30	-8	-6	2.203
-45	-6	-4	2.165
-45	-8	-6	3.186
-30	-8	-4	3.102
-30	-6	-6	2.862
-45	-8	-4	3.265
-45	-6	-6	3.203

Looking at the test results, we can tell that the rotors with
δ_3 = -30º,
B_p = -6º
and θ_o = -6º,
gives the optimum thrust required to reduce our descent rate from 14m/s to 6m/s.

In the balloon testing done recently, we found that the above configuration for the rotor is giving the required results and thus can finally be used in the science vehicle.

Descent Rate Estimates

From the above test results and calculations we came to the conclusion of using a rotor of following configuration:

Specification	Dimensions
Rotor Diameter (cm)	31.5
Blade number, N_b	4
Blade span (cm)	14.5
Blade chord (cm)	2.8
Airfoil	CLARK Y
Pitch-flap coupling angle (δ_3)	-30^o
Pitch angle (θ_o)	-6^o
Pre-cone angle (β_p)	-6^o
Twist angle	6^o

Mechanical Subsystem Design

Chaitanya Baboo

Mechanical Subsystem Overview

The total weight of the CanSat is 600 gm without including the egg.

Major structural components of the CanSat include the re-entry container and the SV.

Re-entry container:

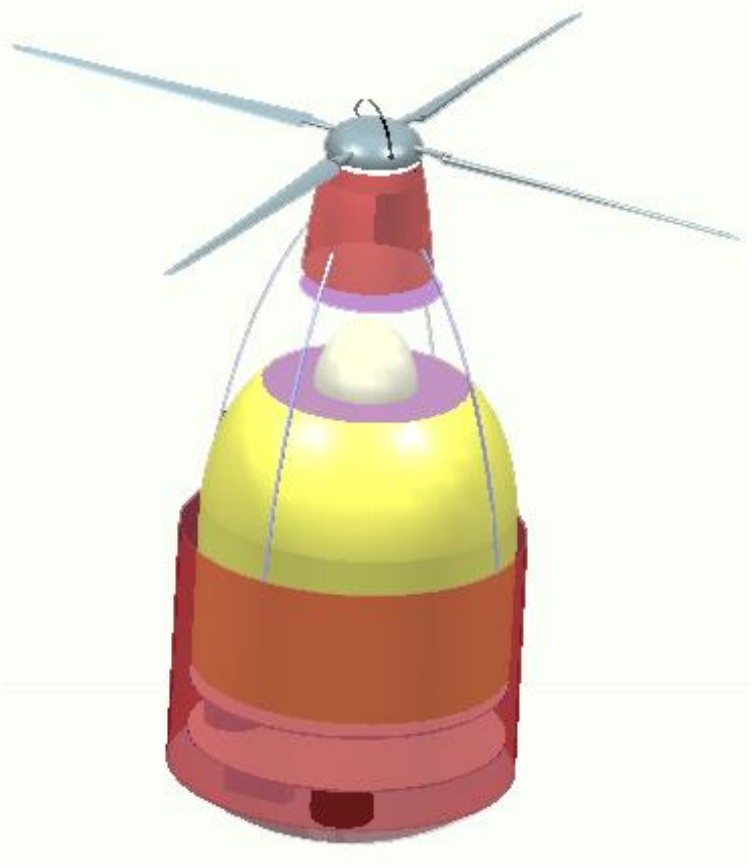
- **Structure** is to be made of high density polyethylene which will provide strength and will be lighter in weight. The total height of the re-entry container is 300 mm.
- **Descent Control Mechanism:** Consists of a hemispherical parachute of radius 20 cm with a spill hole at its center so the velocity above 450 m will become less than 14 m/s.
- **Electronics:** Electronics in the re-entry container include a BMP 085, and a servo motor for the release mechanism.
- **The SV system is connected to the re-entry container with a rod controlled by a servo motor.**

Science Vehicle:

- **Structure** consists of a small frustum (rotatable) on the top which will be connected to the rotors. Below it, is a bigger frustum (non-rotatable) consisting of the ball bearing setup, and at the bottom, a cylindrical structure which will contain part egg-safety, electronics, camera etc. Total height of SV is 240 mm.

- **Descent Control Mechanism:** Consists of a rotor with four specially designed blades of length 14.5 cm each, connected to the upper small frustum with a ball bearing setup in between. This allows it to act as an auto-gyro, stabilizing the remaining body. The design of the rotors will be such that they will provide an up-thrust to the science vehicle.

- **Electronics:** Electronics in the SV include BMP 085, temp. sensor LM35, voltage monitor, accelerometer and XBEE radio.



Mechanical Subsystem Changes Since PDR

Components Changed	Requirements	Rationale
Ball bearing was changed from model number SKF 6201 to **NBC 6202**.	Ball bearing is required to prevent the SV from rotating while descending.	NBC 6202 is much more smooth and matches our exact dimensions. Also it has inner plastic fixture.
Length of the shaft attaching the ball bearing and the rotor is decided to be kept as small as possible.	Shaft joins the ball bearing attached with SV to the rotors.	A small shaft will ensure less vibrations while rotating, which will make less energy loss. And also it will save some space in height.
The position of ball-bearing was changed from bottom of the **upper frustum to its top**.	The position of ball-bearing should be such that it shouldn't create any resistance while rotating and should move freely with the rotors.	After testing the ball-bearing we found that when it was kept at the top of the upper frustum, it was able to rotate more smoothly without letting the remaining body to rotate with it.
The material of the DCS of re-entry container has been changed from tarpaulin to **nylon cloth**.	The material of DCS of re-entry container should be strong enough take the loads from air while descending.	Nylon cloth proves to be much stronger and air resistant than the tarpaulin.

Mechanical Sub-System Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
MSR-01	Total mass of the CanSat shall not exceed 600 gm. (without the egg)	Competition Requirement	HIGH	SR-01	✓	✓	✓	
MSR-02	Container shall fit in the envelope of 125 mm x 310 mm	Competition Requirement	HIGH	SR-02	✓	✓	✓	
MSR-03	Egg placed inside should be recovered safely.	Competition Requirement	HIGH	SR-03	✓	✓	✓	
MSR-04	The container shall not have any sharp edges protruding.	To facilitate leaving the rocket	HIGH	SR-05 SR-06		✓	✓	
MSR-05	Proper placement of GPS, antenna and other sensors	To ensure safe landing of SV on surface	HIGH	SR-22	✓		✓	✓
MSR-06	CanSat shall not use any flammable or pyrotechnic devices.	To prevent the CanSat from burning and causing a fire.	HIGH	SR-13	✓	✓	✓	
MSR-07	The science vehicle shall release at an altitude above 450m from the container.	Competition Requirement	HIGH	SR-07 SR-08	✓	✓		
MSR-08	All electronics shall be hard mounted.	To prevent them from getting displaced during descent.	HIGH	SR-22	✓	✓	✓	✓

Mechanical Sub-System Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
MSR-09	The SV shall use a passive helicopter recovery method for descent.	Competition Requirement	HIGH	SR-08	✓	✓	✓	✓
MSR-10	All devices and attachments shall survive 50 Gs of shock and 30Gs of acceleration.	Competition Requirement	HIGH	SR-11 SR-12	✓	✓	✓	
MSR-11	Container shall be of a fluorescent color.	Competition Requirement	MEDIUM	SR-23	✓	✓		
MSR-12	Audio beacon shall be installed to the SV.	Competition Requirement	MEDIUM	SR-24	✓	✓		

Egg Protection Overview

No change has been made in the egg protection mechanism.

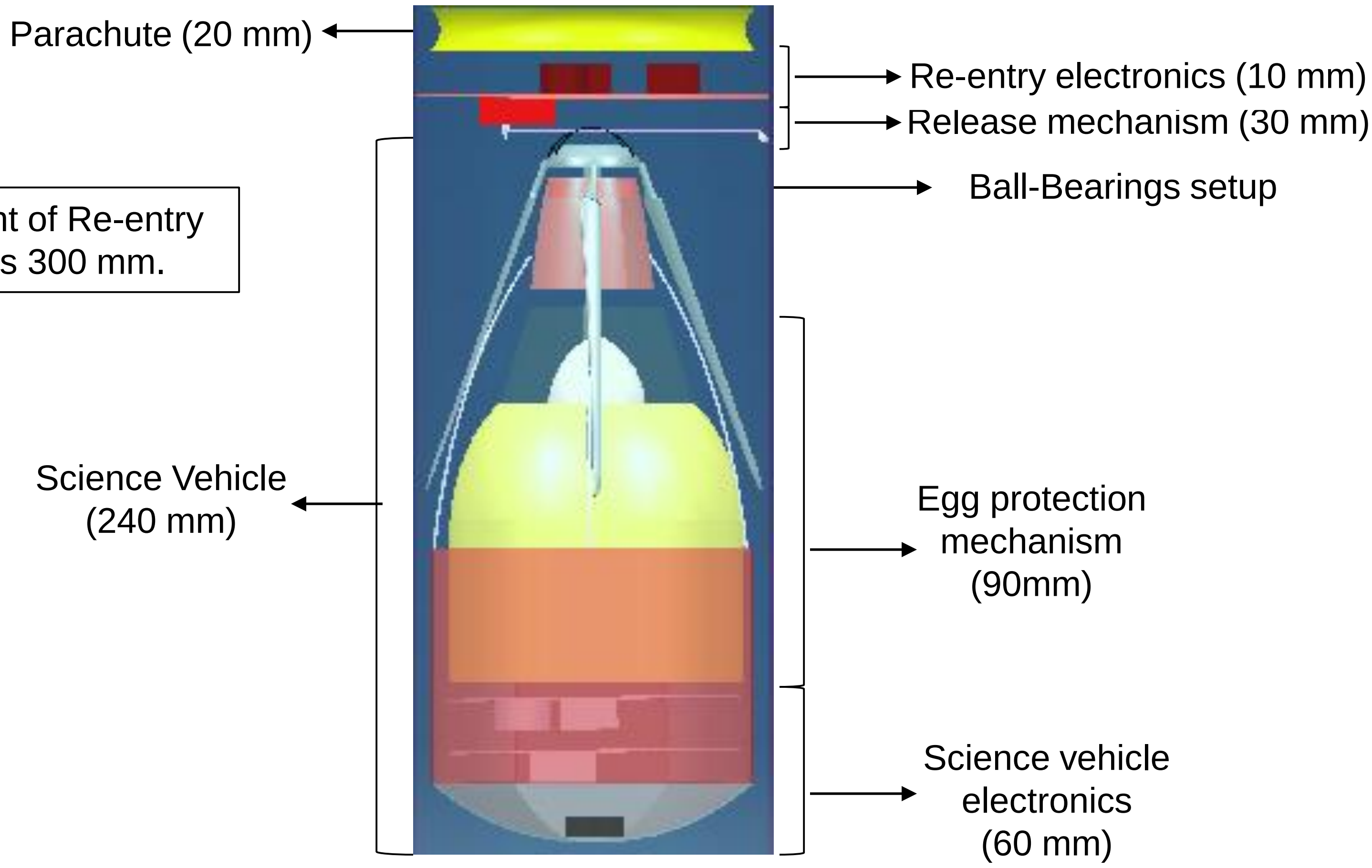
- A Styrofoam cup filled with polystyrene balls will carry the egg. The egg is surrounded by the polystyrene balls inside the cup, and held in its place with the help of plastic tape.

- This assembly is kept inside a sponge. This will keep the cup with the egg intact and provide stability during impact.

- The polystyrene balls along with the sponge, damp the force as the SV strikes the ground.

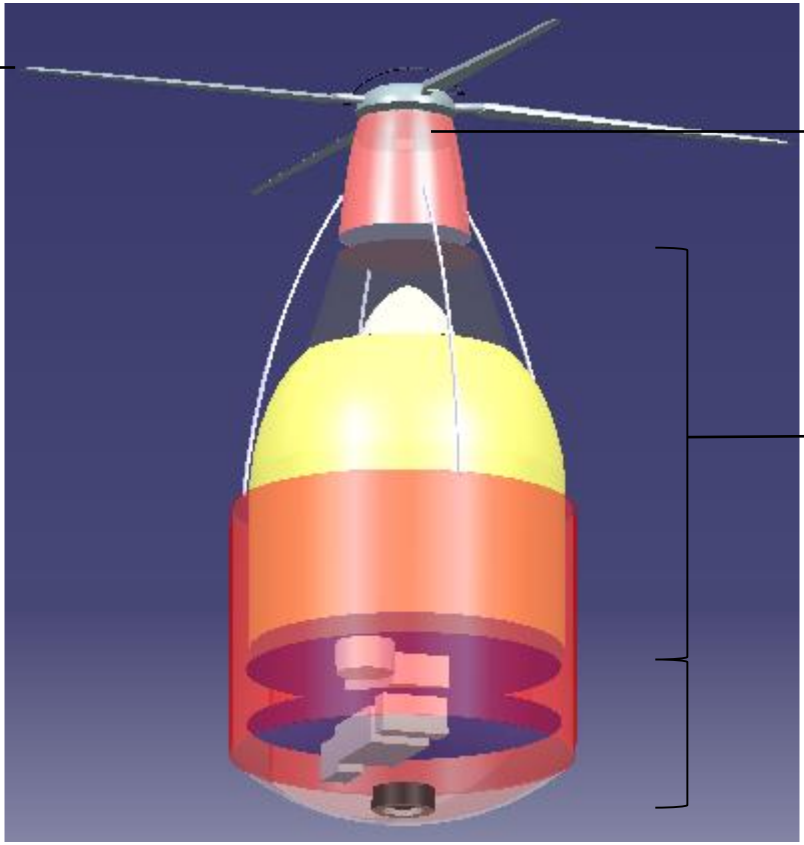
- Due to the small air gaps left by polystyrene balls assembly, the egg is exposed to low momentum change

Mechanical Layout of Components



Total height of Re-entry container is 300 mm.

Mechanical Layout of Components



Total height SV is 240 mm.

Material Selections

- **Re-entry container:**

  The re-entry container is made of high density polyethylene as it is strong, lightweight, cheap and easily available, easy to fabricate

- **SCIENCE VEHICLE System:**

  The final design is ready and fabricated using Aluminium sheets and the skeleton is formed using galvanized spokes due to the following reasons:

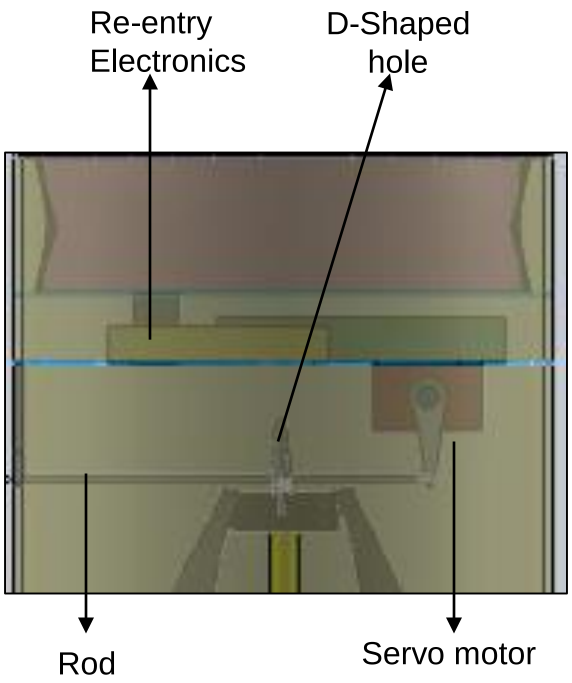
  - Economical
  - Easy to fabricate
  - Easily Available
  - Lightweight
  - Sufficient strength

- **Helicopter Recovery Mechanism:**

  The blades have been fabricated using carbon fiber and the spinner connecting them is formed of glass fiber sheets. The contact between the spinner and ball bearings has been made from Aluminium.

Container – Science Vehicle Interface

- The container and SV system are interfaced with a rod mechanism which is controlled by servo motor.
- The rod is attached to the SV through a D shaped hole and one end is connected to the servo motor.
- The D-shaped hole is at the top of the spinner of the blades and holds the SV in place.
- **METHOD OF OPERATION:**
  - At an altitude above 450m the servo motor will rotate and pull the rod out of the SV.
  - Due to its weight and the effect of gravity, the SV system will be released and it will unfold its rotors.
  - After unfolding, the rotors will rotate because of the upward air flow.
  - The up-thrust produced by the rotors will decrease the descent speed of science vehicle, and the ball bearing setup will ensure that the bottom portion does not rotate.



Structure Survivability

- **Mounting Method:** All electronic components are hard mounted with the SV frame using screws, hot glue and standoffs. No electronics are exposed to the outside atmosphere except for the sensors.
- **Enclosures:** A removable structural coating made of high quality sponge is being used to protect the electronic components during impact. A thin film of polythene covers the electronic circuits and sensors. In case the egg breaks, it would not damage them.
- **Connections:** All electrical connections are verified and secured using insulation tapes.
- **Descent Control attachments** are connected and secured with the lower body using brazing process.
- The skeleton of the structure is made using galvanized spokes to increase the strength.
- The final model was tested using a helium balloon from a height of 250 m. The model sustained very minor damages and the structure was intact.
- The Drop Test as suggested by the Environmental Testing Guide was performed and the results are shown in the following slides:

Drop Test Observations:

- The parachute attachment point didn't fail and was in a good shape.
- the science vehicle remained well attached with the container.
- No visible damage to the science vehicle during the drop test, which gives us surety about the reliability of our mechanisms.
- The visual proof of the Drop Test has been provided in the CanSat Integration and Test slides.

Re-entry container containing the SV post Drop test. The parachute attachment did not break and also, the SV did not fall out under the force.

***NOTE: The image is undoctored and as recorded by the video camera on a mobile phone. It is cropped for a comparatively better view.**

Mass Budget

SYSTEM		SUBSYSTEM	SUBSYSTEM MASS (gm.)	PERCENT (%)	VM
Range according to Requirements: 590-610 gm.	Re-Entry Container	Body	60	10	MEASURED
		Servo motor	50	8.334	MEASURED
		Batteries	40	6.667	DATA SHEET
		Parachute	10	1.667	ESTIMATE
		Electronics	60	10	MEASURED
		Margin	10	1.667	
	Science Vehicle	Body	80	11.667	MEASURED
		Electronics	124	20.667	MEASURED
		Egg cushioning	50	8.334	ESTIMATE
		Helicopter Recovery System	70	11.667	MEASURED
		Ball-Bearings	40	6.667	MEASURED
		Margin	6	1	
	Egg	Not part of the limit		67 gm	ESTIMATE
TOTAL		600 gm. (W/o Egg)		667 gm. (W/ Egg)	

Communication and Data Handling Subsystem Design

Aditya Savio Paul

CDH Overview

Micro-Controller Utilized :

1. **Atmega328**:

   Interfacing of sensors to the Atmega328 with higher data processing speed would enable faster transmitting of data through telemetry.

Sensors Interfaced :

1. **Temperature and Altitude**:

   Using the BMP085 sensor, would enable simultaneous recording and analysis of pressure measurements and for Temperature measurement in the Science Vehicle.

2. **Pressure and GPS**:

   Fastrax GPS Module will efficiently measure and transmit the Pressure conditions as well as the Global Positioning.

CDH Overview

3. Accelerometer:
With Low Power Consumption and high resolution, ADXL345 is Apt to be utilized for 3-axis positioning.

4. Voltage Measurement and Real Time Monitoring

5. Real Time Clock has been interfaced for time stamp and recording Flight Time of the CanSat.

CDH Changes Since PDR

Component Changed	Requirements	Rationale
AtMega328 has replaced Atmega16	To gather and process data acquired through sensors.	Process Telemetry Data Format at every 1 second
BMP085 has replaced LM35 in the re-entry container	Measuring accurate temperature and pressure condition at high altitudes	Measure and process the temperature and process to the microcontroller.

- The Atmega328 Microcontroller has been brought in use by replacing the earlier mentioned Atmega16.
- With faster rate of data processing the Atmega328 has been considered apt for application.
- Availability of programmable Watchdog Timer in Atmega328 is another reason for the replacement.
- Rest all the mentioned Sensors are the same and have been tested for various real time conditions.

CDH Requirements

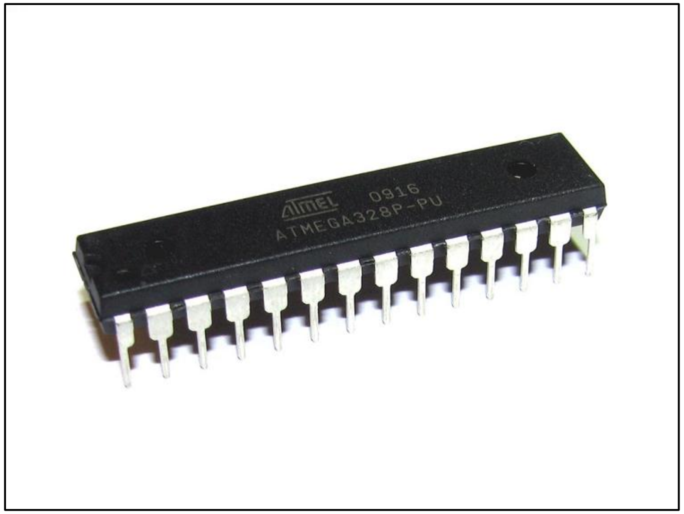
ID	REQUIREMENT	RATIONALE	PARENT	PRIORITY	VM			
					A	I	T	D
CDH-01	Receive Data Stream	Descent Telemetry Package (receiving in every 1 second)	SR-14 SR-15	HIGH	✓	✓	✓	✓
CDH-02	Transmit Altitude in Meters	Descent Telemetry Package (receiving in every 1 second)	SR-14	HIGH	✓	✓	✓	
CDH-03	Transmit air Temperature in Degree Celsius	Descent Telemetry Package (receiving in every 1 second)	SR-14	HIGH	✓	✓	✓	
CDH-04	Transmit Battery Voltage in Volts	Descent Telemetry Package (receiving in every 1 second)	SR-14	HIGH	✓		✓	
CDH-05	Terminate Telemetry	Terminate Telemetry within 1 Minute of Landing	SR-14	HIGH	✓	✓	✓	✓

Processor & Memory Selection

Microcontroller	Operating Voltage	Speed Grade	Power Consumption	Active Mode	Power Down
Atmega328	2.7V-3.3V	0-16MHz	1MHz, 1.8V at 25ºC	0.6mA	>1µA
Atmega16	2.7V-3.3V	0-16MHz	1MHz, 2V at 25ºC	0.6mA	0.6mA

Atmega328 is selected:

1. Higher EEPROM and Flash Memory; 328Kb
2. 10 bit Analog to Digital Convertor
3. Programmable Watchdog Time
4. Lower Power Consumption



Model	Size	Capacity	Software	Selection
Kingston	Medium	4Gb	Complex	
Sony	Medium	4Gb	Ease of access	✓

Sony Memory Card is selected :

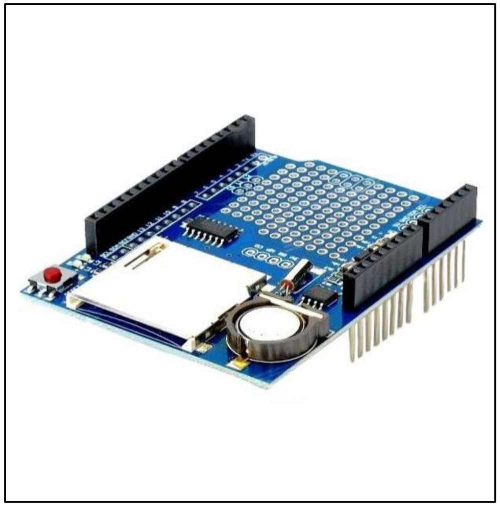
1. Ease of Programming Software
2. Easy Retrieving of Data
3. Supports all Format Data
4. Use of Surface Mount SD Adapter

Processor & Memory Selection

The Data Logger Xd-05 records the incoming data signals and logs it to a Text Document. The Text Document is saved in a Memory Card that can be physically utilized to acquire data onto a computer system using a Memory Card Reader.

Selection Criteria :

- Accepts Micro SD cards from 2Gb to 64Gb
- Multiple Baud Rate supported.
- Low Cost
- Dedicated Start and Stop Log Button
- LED Notification



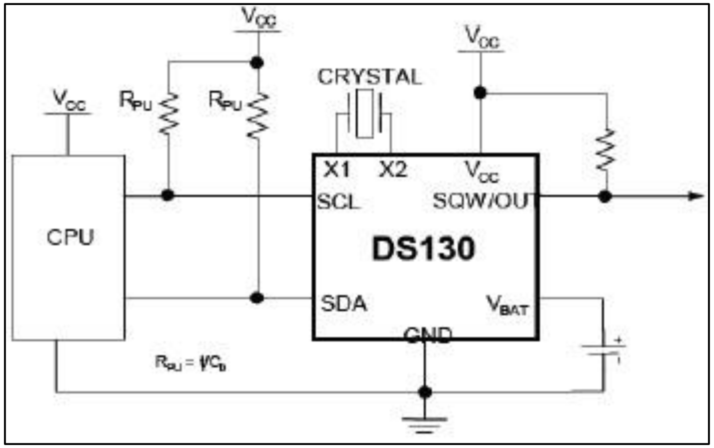
Real-Time Clock

Real Time Clock (RTC) is utilized to calculate the total time taken by the CanSat in Science Vehicle and re-entry container and duration of flight.

Type	Accuracy	Initiation Time	Selection
Hardware	+0.1	2s	✓
Software	+0.3	5s	

Hardware Clock is selected :

1. Faster initialization
2. More Accurate
3. Tolerance Level is 100ppm



Antenna Selection

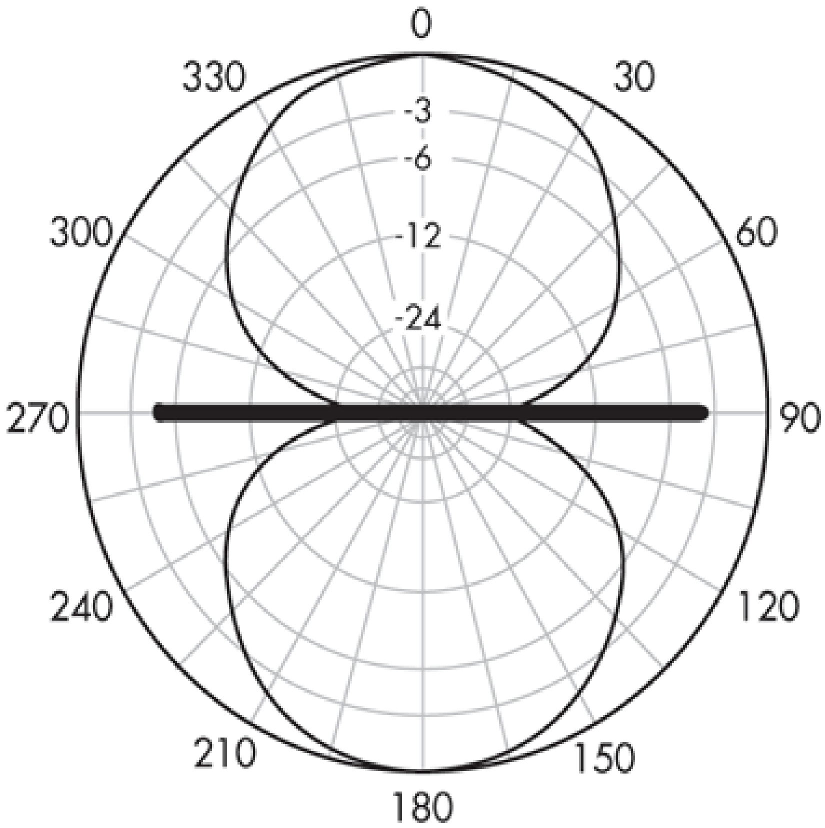
Model	Range	Gain	Frequency	Selection
A24-HASM-525	40000sqm	2.1db	2.3Hz	
S467-xx9155	50000sqm	3.5db	3.4Hz	✓

S467XX-9155 is selected:

- Field Pattern are utilized.
- Lesser Dimensions, Low Space Consumption.
- Similar frequency to that of XBee Module.
- Higher Range Antenna
- Mass : 40g

Antenna Selection

Data Transmission will be achieved using field patterns of a half dipole antenna.



Radio Configuration

The **XBEE Radio** is configured is accomplished using API Mode and Nodes. The RF Module transfers data at a rate of 250 Kbps.

Indoor transmission and Receiving Range is 90m and the RF Line-of-Site-range is 3200m. The transmission will not be in broadcast mode.

XBEE Radio Module is interfaced to the microcontroller, ATMega328 using USART Communication Transmission(Tx) and Receiving(Rx) Ports. The NETID, transmitted will be the team number-2021.

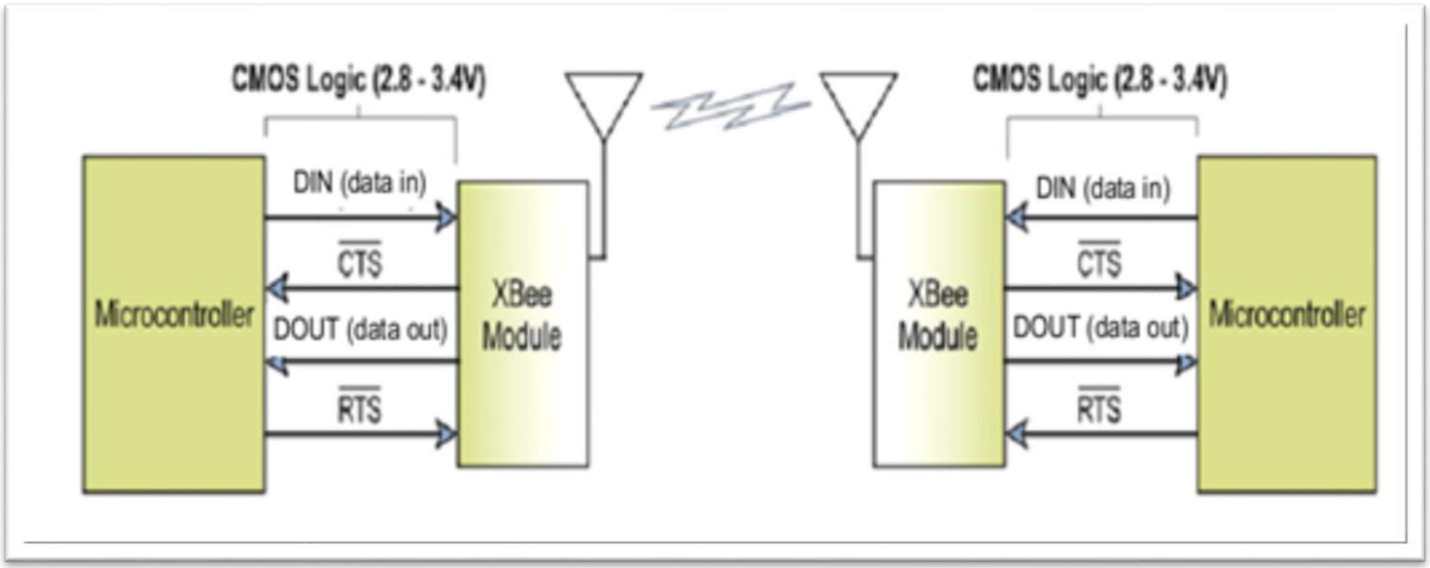
- The Antenna for Science Vehicle will be facing downward for ease in transmission of data packages.

Modes in USART with XBEE PRO ZB	
Data Bits	8
Baud Rate	9600
Flow Control	None
Parity Counter	None
Transmission Mode	Asynchronous
Stop Bits	1
UART Receiver	ON
UART Transmitter	ON

Radio Configuration

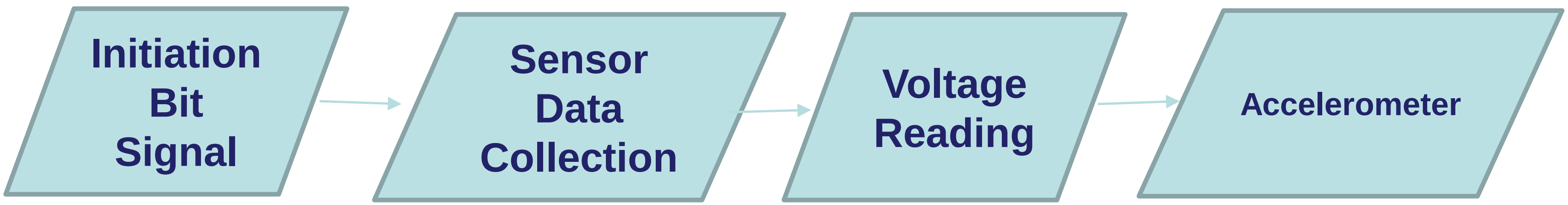
- The radio configuration protocol will be transmitting data at every 1 second of descent.
- All transmitted data will be received by the Ground Control System and logged on to the developed software.
- Data is transferred through the entire time of ascent and during FSW and Descent time effectively.
- At every phase, logging is done onto the software at the Ground Control.
- RADIO PROTYPING IS ACCOMPLISHED and TESTING IS YET TO BE DONE.

Radio Configuration



Telemetry Format

- **Science Vehicle System Data Transmission**



- **The Above mentioned Data Flow comprises of :**

1. A starting Symbol : #

2. Received Sensory Data in Standard Engineering Units

3. Data is transmitted at default Baud Rate : 9600
   - Data is transmitted at every 1 second in ASCII Format with values separated by a comma (,)
   - Data rate of packets will be Continuous.

#<TEAMID> , <MISSIONTIME> , <Altitude> , <Temp> , <Voltage> , <Accelerometer>

- ***The presented format matches the Competition Guide requirements.***

Electrical Power Subsystem Design

Nalin Srivastava

EPS Overview

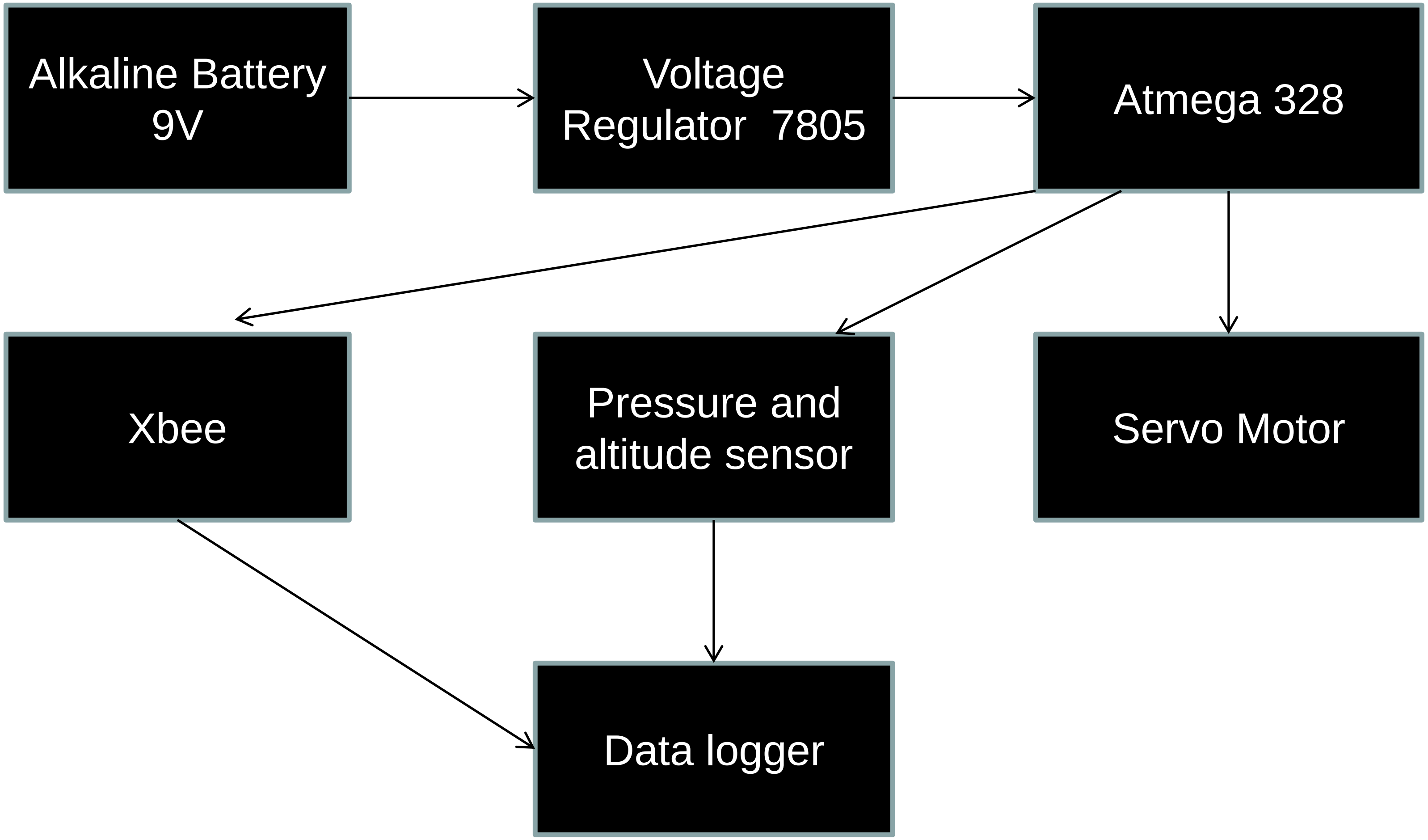
RE-ENTRY CONTAINER:

- Alkaline battery are used to power the re-entry container and various electronics components like gps , microcontroller , Xbee ,SD card.

- Voltage regulator LM7805 and LM1117 used for regulating the voltage of 5V in the circuit .

- Voltage divider is used to read voltage measurement

EPS Overview

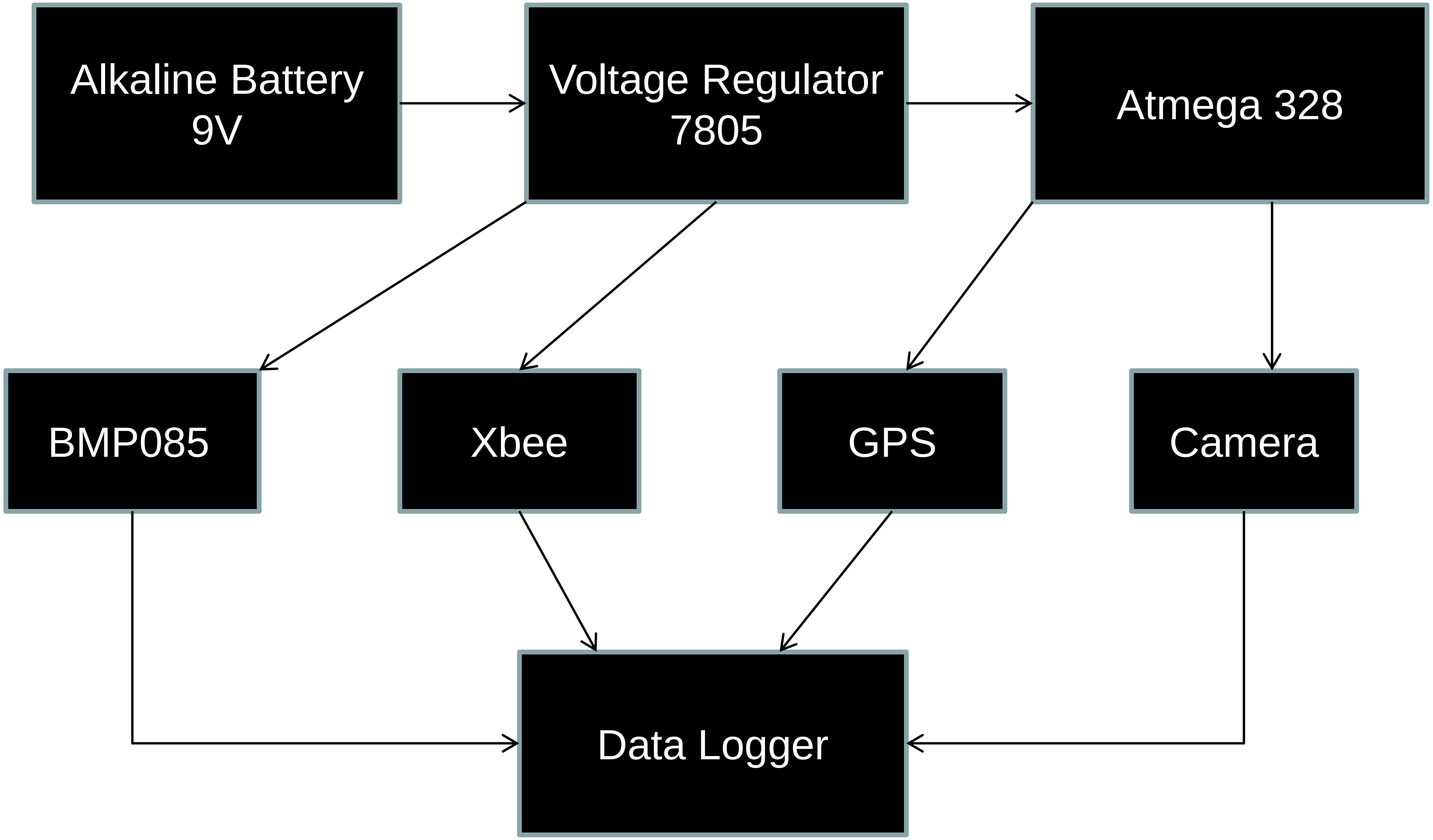


EPS Overview

SCIENCE VEHICLE:

- All power and electrical requirements accomplished by Alkaline battery 9V.
- Voltage regulator LM1117 and LM7805 used to regulate the voltage 5V and 3.3V in the system .
- We use Sensor BMP085 to read temperature measurement .
- Voltage Divider circuit used to monitor power Budget
- Using power saving method for microcontroller such as idle mode or power down mode .

EPS Overview



EPS changes Since PDR

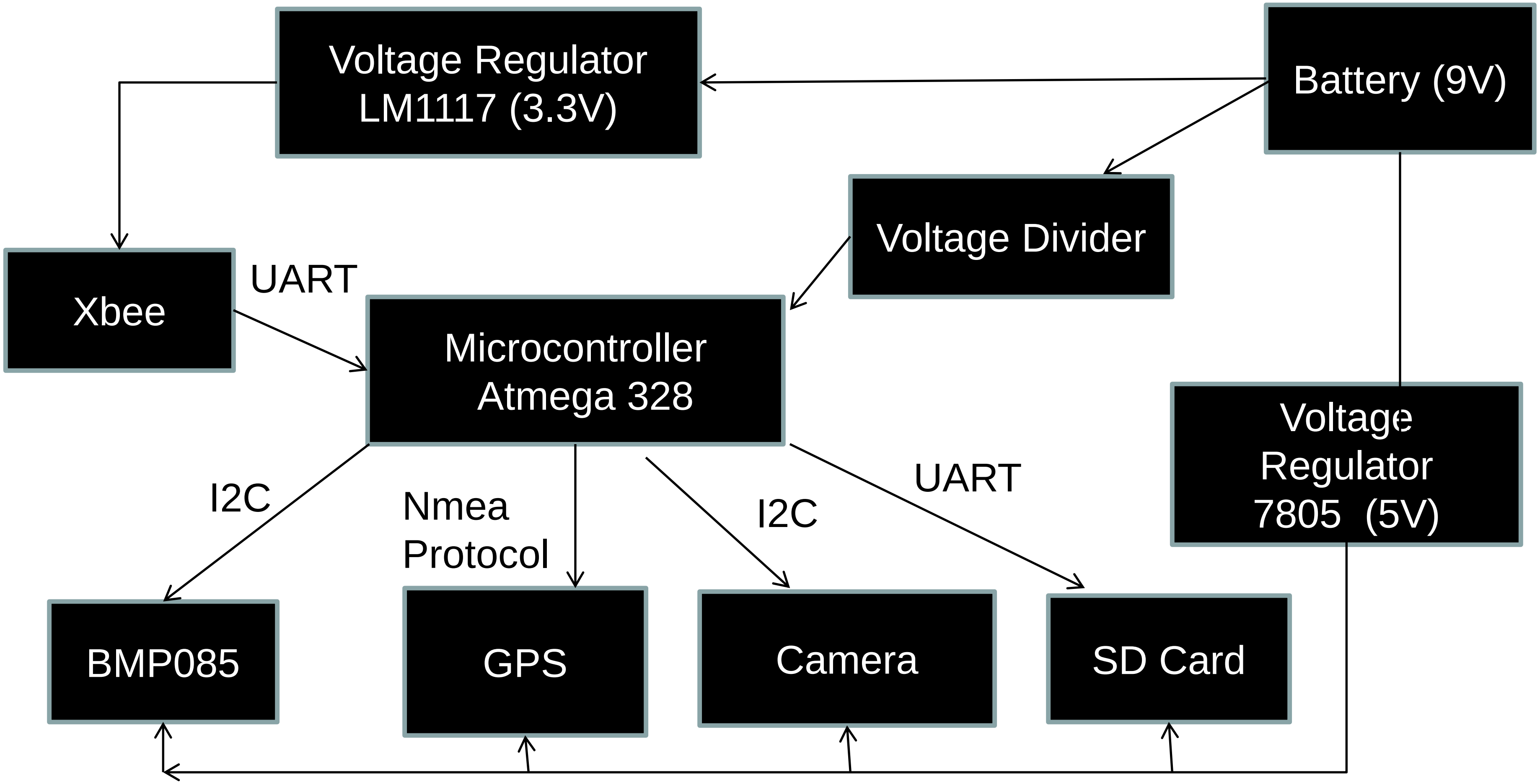
- We use Microcontroller **Atmega 328** instead of Atmega 16
  - The reason for this is, the automatic restoration to correct the FSW state require the program to divide the flow of control to be function based .
  - This makes the program length, hence more flash memory is required to store the program
  - Use of external RTC module because it has own power supply so we don’t need to set the time every time we turn the system on
  - It’s reduce the complexity of the FSW program and it is easy to operate and use.
- **An additional source of power has been added to power the Real Time Clock – a 3 V CR2032 coin cell.**

EPS Requirements

ID	REQUIREMENT	RATIONALE	PARENT	PRIORITY	VM			
					A	I	T	D
EPS-01	Battery Requirement (9V)	4.5V required for Micro Controller and Pressure, Temperature Sensor, Servo •3.3V for Memory, GPS and Transceiver 3V required for Camera.	SR-14	HIGH	✓	✓	✓	✓
EPS-02	Battery Requirement (9V)	To be able to provide adequate power for the whole period of flight	SR-14	HIGH	✓	✓	✓	✓

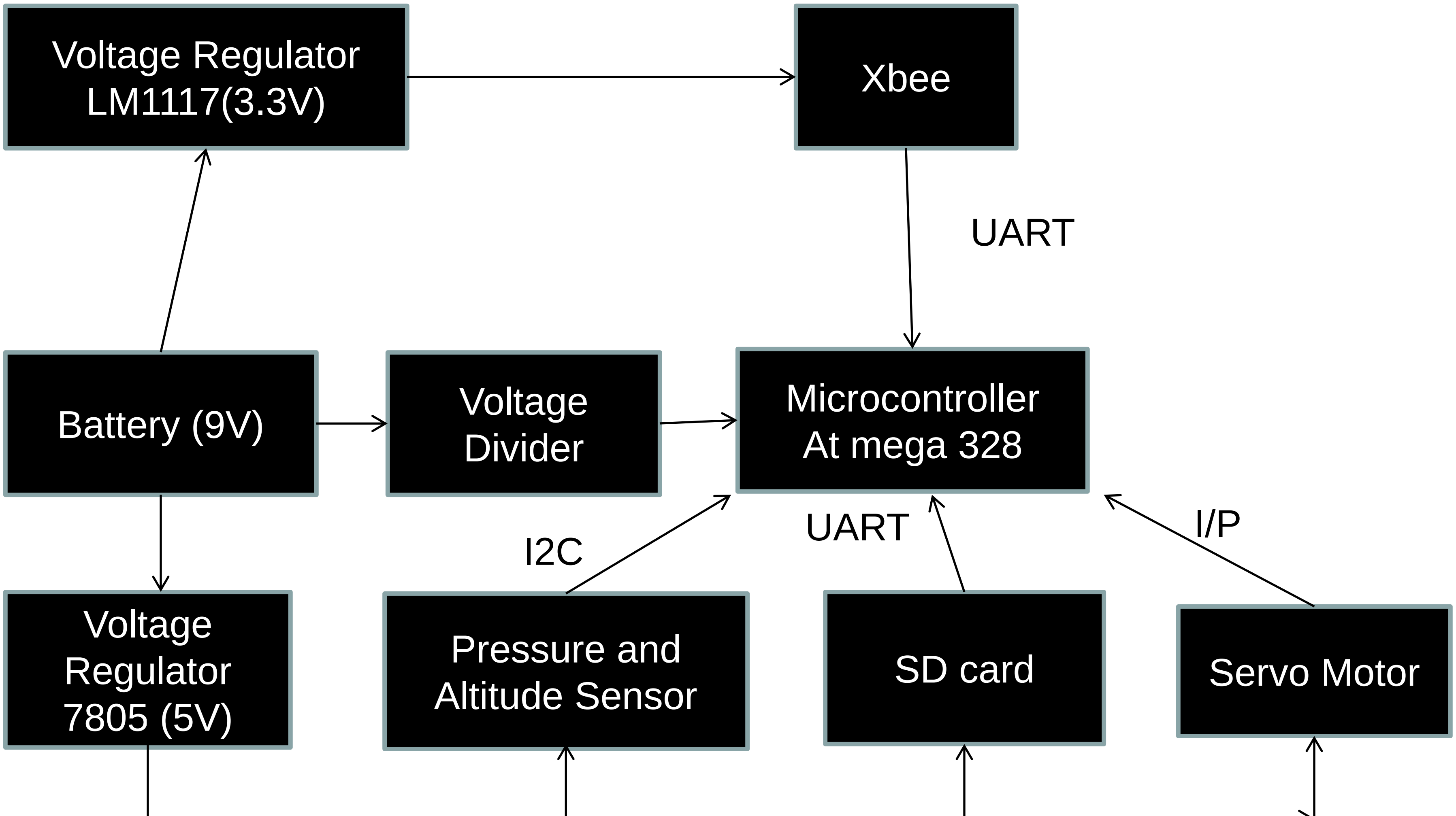
SCIENCE VEHICLE:

An external power switch will be provided near the base of the SV to verify the electronics without disassembling the CanSat.



Electrical Block Diagram

Re-entry Container



Science Vehicle Power Source Selection and Design

Battery (9V)	Capacity (mAH)	Operating Range	Selection
Alkaline	570	-20ºC to 54ºC	✓
Lithium-ion	500	0 - 45ºC	
Ni-MH	200	-20ºC to 50ºC	

We use alkaline 9V battery for power source to provide constant power supply to the system. We have done testing on this battery and it works properly.

Rationale

- High Energy Density
- Low internal resistance
- Performs equally well in low and as well as high rate of discharge.
- It's low in weight so slight weight is increased .

Power Budget

Re-entry Container:

Device	Avg. Power Consumption	Voltage	Current	Time
Microcontroller Atmega 328	12mW	1.8to 5.5 V	3.6mA	100%
XB24-BZ7WIT-004	63mW	3.3V	12-18mA	100%
SD Card	0.3 mW	5V	1 mA	100%
Regulator LM1117 LM7805	Negligible negligible	5V 9V	800mA 1A	100% 100%
Pressure Sensor Altitude sensor	2.5 mW	5V	22.7 mA	100%

Power Budget

Total power Consumption	77.89mW
Power Available	9W
Margins	8.9W

Supply Voltage	9V
Needed Voltage	3-6V

Power Budget

Science Vehicle:

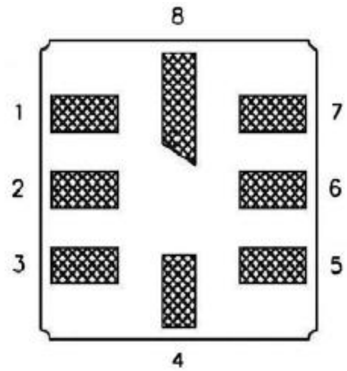
Device	Avg. Power Consumption	Voltage	Current	Time
Camera	60mW	2.5 to 3.0V	20 mA	100%
Temperature Sensor	5mw	5V	1mA	100%
XB24-BZ7WIT-004	63mW	3.3V	12-18mA	100%
SD Card	0.3mw	5V	1mA	100%
Data Logger	1000mw	5V	200mA	100%
Regulator LM1117 LM7805	Negligible negligible	5V 9V	800mA 1A	100% 100%
Microcontroller Atmega 328	12mW	1.8to 5.5 V	3.6mA	100%
GPS	90mW	5V	20uA	100%

Power Budget

Total Power Consumption	1232.8mW
Power Available	9 W
Margins	7.7W

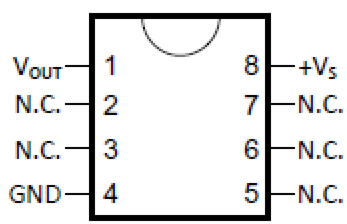
Supply Voltage	4.5V
Needed Voltage	3.3-4.5V

- **Pressure sensor :**

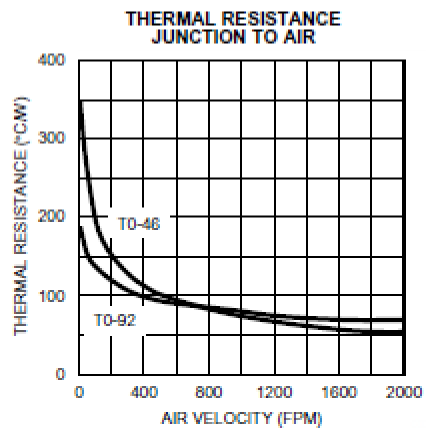


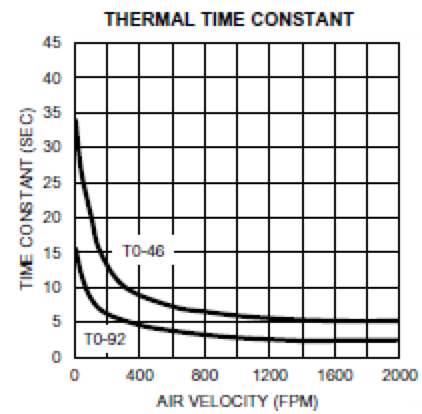
Pin No.	Name	Function	Type
1	GND	Ground	Power
2	EOC	End of conversion	Digital output
3	V_{DDA}	Power supply	Power
4	V_{DDD}	Digital power supply	Power
5	NC	no internal connection	-
6	SCL	I^2C serial bus clock input	Digital input
7	SDA	I^2C serial bus data	Digital bi-directional
8	XCLR	master clear (low active) input	Digital input

SMALL-OUTLINE MOLDED PACKAGE
SOIC-8 (D)
TOP VIEW



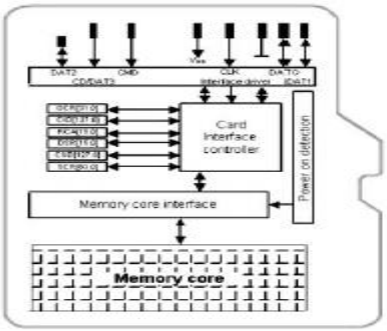
N.C. = No connection





Power Budget

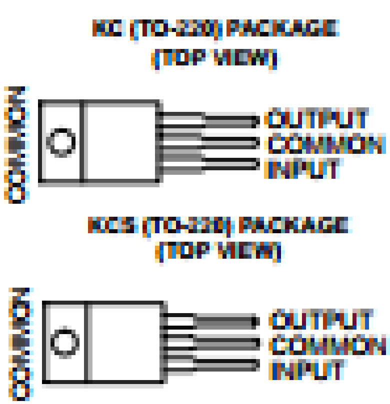
- **SD card**



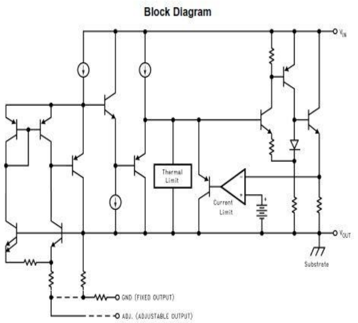
Pin Definition

Pin No.	SD Mode			SPI Mode		
	Name	Type	Description	Name	Type	Description
1	DAT2	I/O/PP	Data Line [Bit2]	RSV		Reserved
2	CD/DAT3	I/O/PP	Card Detect / Data Line [Bit3]	CS	I	Chip Select
3	CMD	PP	Command / Response	DI	I	Data In
4	V_{DD}	S	Supply voltage	V_{DD}	S	Supply voltage
5	CLK	I	Clock	SCLK	I	Clock
6	V_{SS}	S	Supply voltage ground	V_{SS}	S	Supply voltage ground
7	DAT0	I/O/PP	Data Line [Bit0]	DO	O/PP	Data out
8	DAT1	I/O/PP	Data Line [Bit1]	RSV		Reserved

- **Regulator 7805**

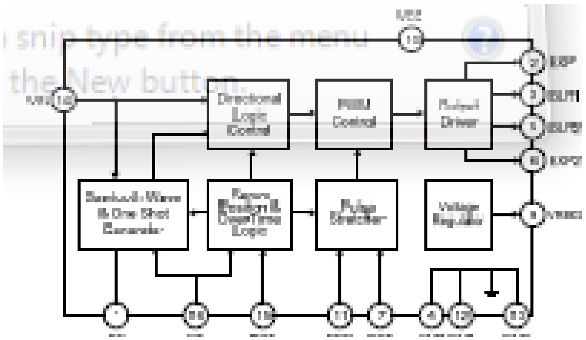


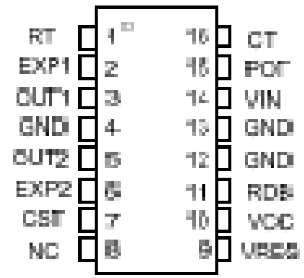
Maximum Input Voltage (V_{IN} to GND)		20V
Power Dissipation (3)		Internally Limited
Junction Temperature (T_J) (3)		150°C
Storage Temperature Range		-65°C to 150°C
Lead Temperature	TO-220 (T) Package	260°C, 10 sec
	SOT-223 (IMP) Package	260°C, 4 sec
ESD Tolerance (4)		2000V



Power Budget

- **Servo Motor**





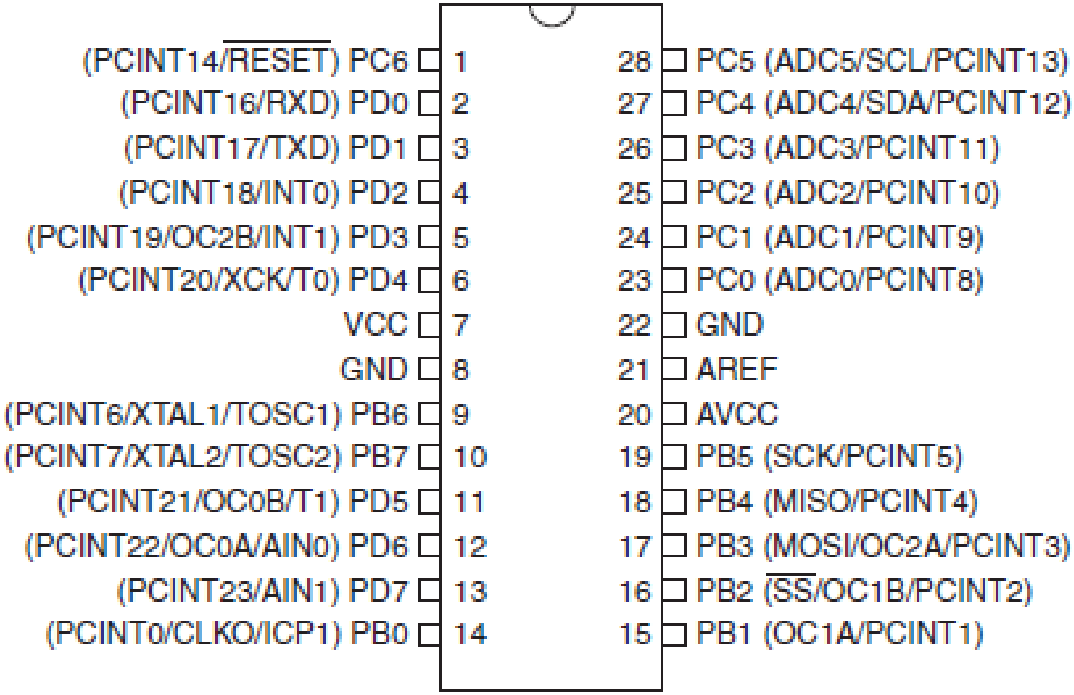
PIN NO.	PIN NAME	FUNCTION
1	RT	Timing Resistor
2	EXP1	External PNP Transistor 1 output
3	OUT1	Output Driver 1
5	OUT2	Output Driver 2
6	EXP2	External PNP Transistor 2 output
7	CST	Stretcher capacitor
8	NC	No Connection
9	VREG	Regulated Voltage output
10	VCC	Power supply pin
11	RDB	Error pulse output
4,12,13	GND	Ground pin
14	VIN	Input signal
15	POT	Servo position voltage
16	CT	Timing Capacitor

XB24-BZTWIT-004

- Transmit power :63 mW (+18 dBm) / Int'l 10 mW (+10 dBm)
- Receiver sensitivity: 102 dbm in boost mode
- Supply Voltage : 2.1-3.6 VDC
- Power down Current : 3.5uA @ 25 ºC
- Transmit Current : 202 mA
- Receive Current : 47mA

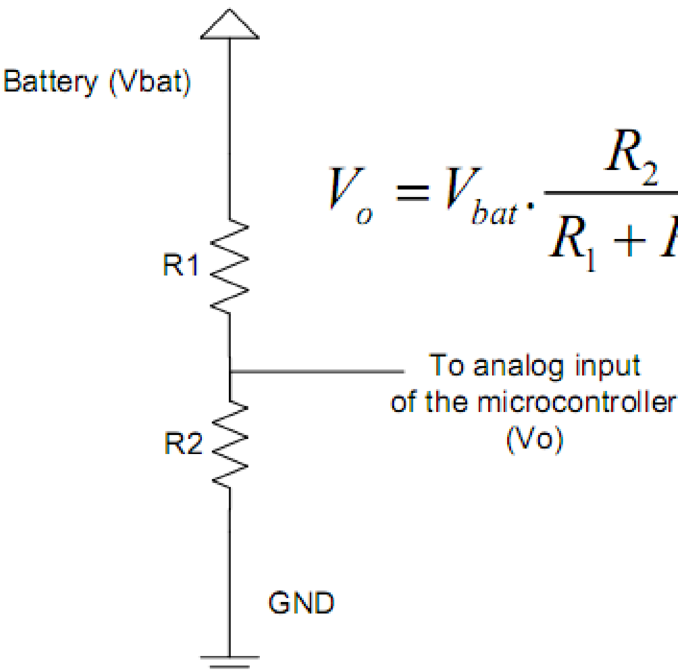
Power Budget

Microcontroller Atmega328



Power Bus Voltage Measurement

- Power Bus voltage measurement (Battery) is done by microcontroller Analog to digital Converter channel (ADC)
- Microcontroller takes 5V as the input. Therefore bus voltage measurement used to read voltage measurement
- Figure Shows that how the operation is done



$$V_o = V_{bat} \cdot \frac{R_2}{R_1 + R_2}$$

R_2=330 kΩ
R_1=270 kΩ

We choose this way, because:

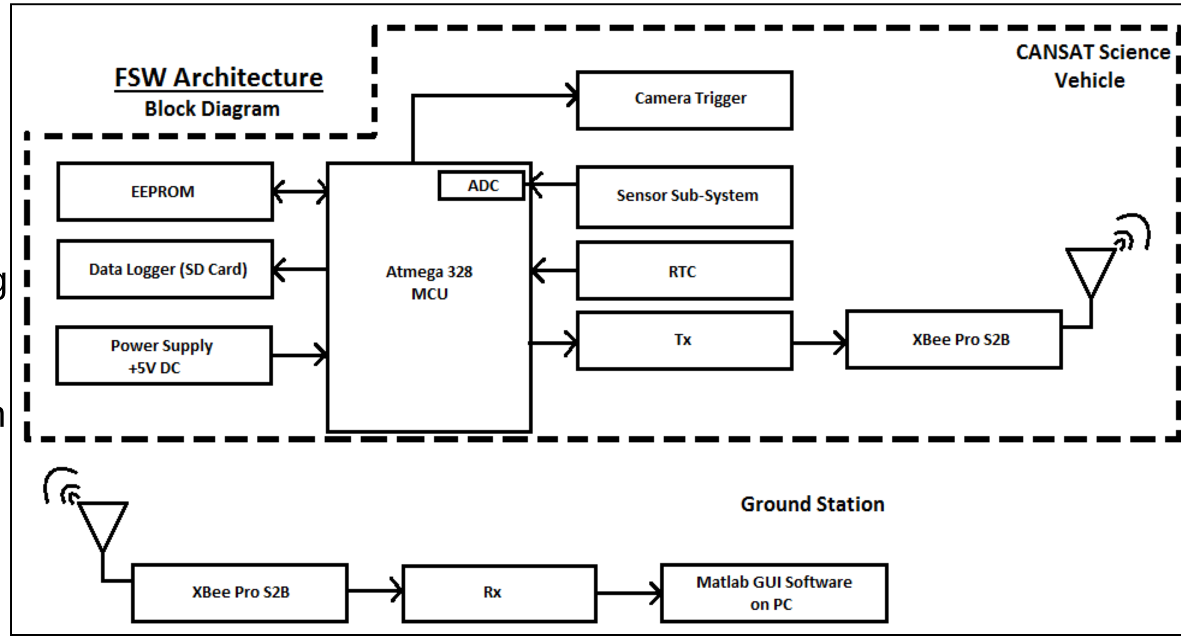
- Simple way to divide the voltage
- If resistors are selected as high valued, the current drawn by these resistors is negligible

Flight Software (FSW) Design

Amitabh Yadav

FSW Overview

- To keep the architecture of FSW simple, we keep the programming, structural and function based.
- Instead of multi-threaded programming approach for gathering data, function based approach is preferred, as it keeps the code simple to design and has low margin for errors. Also, function based approach gets the desired results at negligible time interval difference.
- The main programming languages employed is Embedded C for AVR-MCUs & MATLAB for the GCS Software.
- Atmel Studio 6.1 IDE is used for programming the MCU & MATLAB R2013a for designing the GCS Software.



FSW tasks (on SV):
1. Record Mission Time
2. Check & Change the FSW_State parameters using the altitude reading from BMP085 sensor.
3. Gather and transmit the telemetry to ground station at 1Hz.
4. Save the recorded data on an On Board SD Card
5. Activate Separation Mechanism
6. Trigger Camera mechanism for on board video recording with a time stamp.
7. Recover to correct state during processor rest.

FSW Changes Since PDR

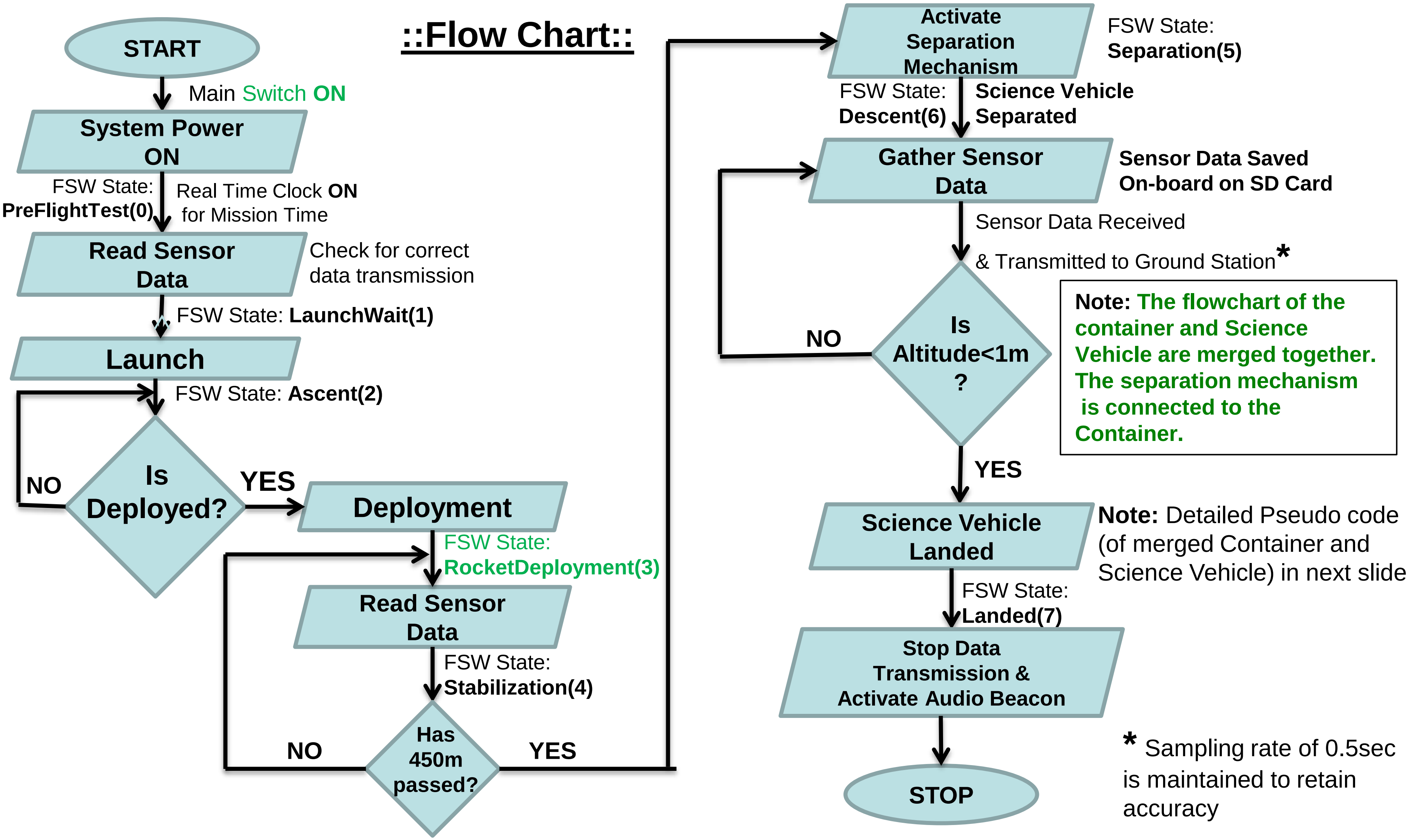
The major changes proposed in FSW are as follows:

- Detailed description about the <u>FSW on the CANSAT </u>added to this section.
- The State Flow diagram has been presented in more clear and more detailed manner and detailed Pseudo-code of operations added.
- The FSW_State parameter which was, earlier, handled on the Ground Station Software is now programmed on the FSW running on Science Vehicle.
- On-board recording of ‘Mission Time’ using Real Time Clock added.
- Plan of mechanism for FSW recovery to correct state after processor reset during flight modified.

FSW Requirements

ID	REQUIREMENT	RATIONALE	PRIORITY	PARENT	VM			
					A	I	T	D
FSW-01	Telemetry shall include SV mission time with one second or better resolution, which begins when the SV is powered on.	Competition Requirement	HIGH	SR-14	✓	✓	✓	
FSW-02	Collection of sensor data in processor.	Competition Requirement	HIGH	SR-14 SR-16	✓	✓	✓	✓
FSW-03	Sample programs are made to simulate significant events such as the need for separation and approaching ground to ensure the appropriate action is taken.	Competition Requirement	HIGH	SR-14	✓	✓	✓	✓
FSW-04	Telemetry shall be displayed in engineering units.	Competition Requirement	HIGH	SR-15	✓	✓	✓	✓
FSW-05	Plotting of data in real-time.	Competition Requirement	HIGH	SR-15	✓		✓	
FSW-06	Flight Software shall maintain the count of packets received.	Competition Requirement	HIGH	SR-21	✓	✓	✓	

CanSat FSW State Diagram



CanSat FSW State Diagram

::Pseudo-code::

```
Start                //Power ON the system
Start_RTC();
Memory.fetch_FSW_state();    //initially, FSW State set to 0
//Memory refers to OnBoard Memory preferably EEPROM or SD Card
If(FSW_state()==0)    //recovery to correct state after processor reset
{
 While (1)
 {
  readSensorData();
  WriteSensorData_toSdCard_CSV();
  //Write SensorData,RTC & FSW_state
  TransmitSensorData();  //Perform Pre-flight test
  If(Launch_Button==HIGH && FScount0==0)
  {
   FSW_State=1;
   WriteFSW_StateToMemory();
   FScount0=1;
   //FScountX ensures that this condition is checked only once
  }
  If(alt_reading>=10m && FSW_State==1 && FScount1==0)
  {
   FSW_State=2;
   WriteFSW_StateToMemory();
   FScount1=1;
  }
  If(FSW_State==2)
  {
   while (1)
   {
    readSensorData();
    WriteSensorData_toSdCard_CSV();
    TransmitSensorData();
```

```
    preAlt=Fetch_Previous_Altitude_Reading();
    if(preAlt>AltNow && FScount2==0)
    //Previous Altitude > Altitude Now
    {
     FSW_State=3;
     WriteFSW_StateToMemory();
     FScount2=1;
    }
    if(Stabilization Condition && FSW_State==3 && FScount3==0)
    //Previous Altitude > Altitude Now
    //Stabilization Condition by seeing a stable decrease in altitude for
    // a specified period
    {
     FSW_State=4;
     WriteFSW_StateToMemory();
     FScount3=1;
    }
If (alt_reading<=550 && FSW_State==3 &&cnt==0)
    {
     FSW_State=4;
     WriteFSW_StateToMemory();
     cnt=1;
    }
If(alt_reading<=500 && (FSW_State==4 || FSW_State==3) && FScount4==0)
    {
     ActivateSeparationMechanism();
     FSW_State=5;
     WriteFSW_StateToMemory();
     FScount4=1;
```

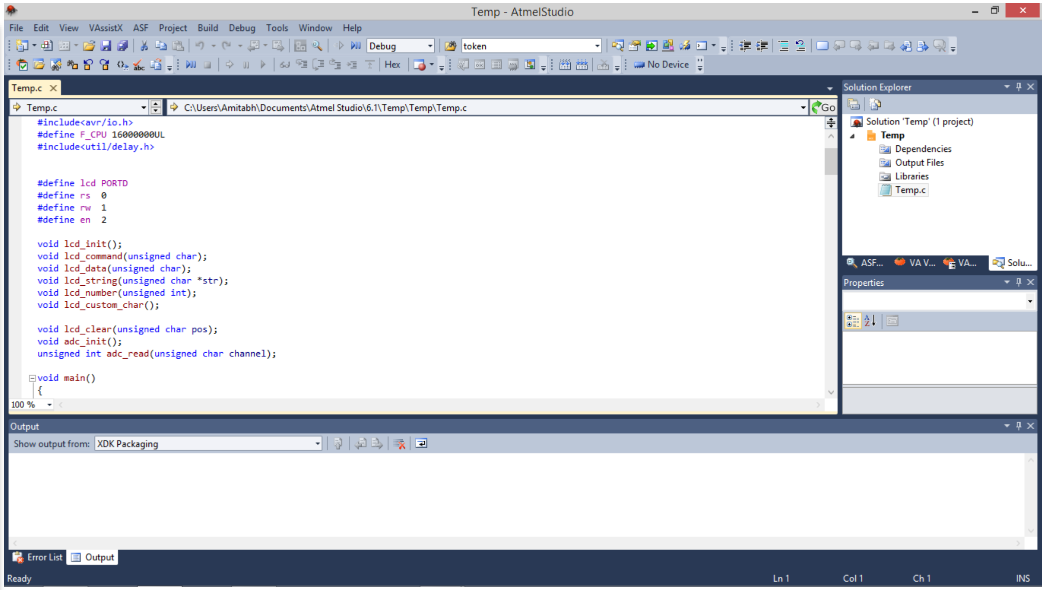
Pseudo-Code Contd…

CanSat FSW State Diagram

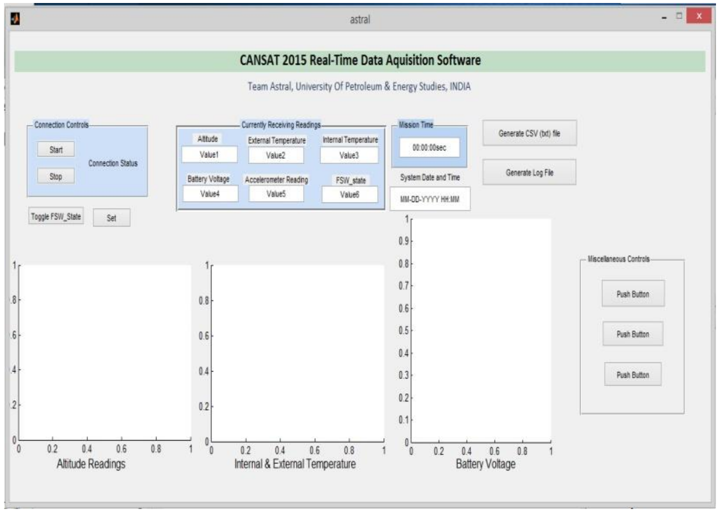
Pseudo-Code Contd…

```
while (1)
        {
          readSensorData();
          WriteSensorData_toSdCard_CSV();
          TransmitSensorData();
          if(FSW_State==5)
            FSW_State=6;
          if(alt_reading<1m && FSW_State==6 && FScount5==0)
          {
            FSW_State=7;
            WriteFSW_StateToMemory();
            FScount5=1;
            while(1)
            {
              readSensorData();
              WriteSensorData_toSdCard_CSV();
              TransmitSensorData();
              Activate_Audio_Beacon();
              while(1)
              {
            //Blink LED Infinite Loop. Data Transmission Stops here!
              } } }} } }}}}
Else If(FSW_state()==1) //or 2, 3, 4, 5, 6
    {
      //Call the desired functions after that particular FSW_state
    }
```

Note: Data is always transmitted until landing, to keep the design simple and we can always use extra data in analysis.



Atmel Studio 6.1 IDE ***(up)***



Real Time Data Acquisition Software using Matlab GUI ***(right)***

CanSat FSW State Diagram

- Sampling rate for all sensor reading is set to 0.5sec. CANSAT will transmit telemetry at 1Hz rate.
- The data is transmitted via the Serial UART protocol using Xbee radio.
- The telemetry data from CANSAT is saved as a Comma Separated Value (CSV) file on the Ground Station Software and also, on an on-board SD Card.
- Various mechanisms are activated by checking the altitude readings from BMP085 sensor. Release from rocket is determined by seeing a stable decrease in altitude for a specified period. We choose that because adding extra sensors will add extra weight and complexity.
- Major changes in FSW_State parameter are controlled using the data from BMP085 sensor.

- Major Decision Points:

  1. Checking for Rocket Deployment using altitude reading.
  2. Activation of separation mechanism at the desired point.

- Power Consumption from battery is kept as low as possible by avoiding any unnecessary component/resistors etc.

CanSat FSW State Diagram

- **FSW recovery to correct state after processor reset during flight:**

  – To recover the correct state after processor reset, we retrieve the data from the on board SD Card using SPI protocol and/or EEPROM at the beginning of the FSW program on CANSAT, using the conditional operators on the last obtained FSW_State parameter, we are able to retrieve the correct state of the program and redirect the control to the correct function for that particular state.

  – Thus, instead of using watchdog timer as an interrupt, we are able to handle the situation using programming. This makes the programming simple and less complicated.

  – The detailed mechanism of recovery to correct state after processor reset is presented as part of the Pseudo Code, marked under the comment, “// recovery to correct state after processor reset”.

Software Development Plan

- **To reduce the risk of late software development, the development sequence of CANSAT software has been divided into 3 Phases:**

I. Phase 1: (i) Development of separate programs for working of different sensors to check functioning and acquire telemetry data, initially, in wired configuration and then, wireless.
(ii) Development of GUI layout using Matlab

II. Phase 2: (i) Developing the program for Multiple Sensor Data Acquisition and telemetry.
(ii) Testing different algorithms for checking various FSW_state Operations.
(iii) Selection of appropriate microcontroller.

III. Phase 3: (i)Developing the Camera Recording Mechanism
(ii) Developing the mechanism to tackle Processor Reset.
(iii) Testing the overall CANSAT software for Real-Time Data Acquisition.
(iv) Integrating the Acquisition system with Matlab's Data Acquisition Toolbox and GUI Development toolbox.

- **Prototypes are tested using Breadboard and AVR Development Boards in real-time testing environments.**

Team A (Aditya Savio Paul & Amitabh Yadav) : Algorithm design, Reset Mechanism and GCS Software Development using Matlab.

Team B (Sakshi Drall & Nalin Srivastava) : Sensor Sub-System Programming to gather multiple sensor data and communication.

Current Progress: Phase I is successfully completed.
Phase II is in progress & is nearly complete. Multiple Sensor Data Acquisition has been tested since PDR.
FSW_State operation testing is in progress.

Ground Control System (GCS) Design

Aditya Savio Paul

GCS Overview

Laptop adapter

Power supply for board

GCS uses the data to populate real time plot graphs

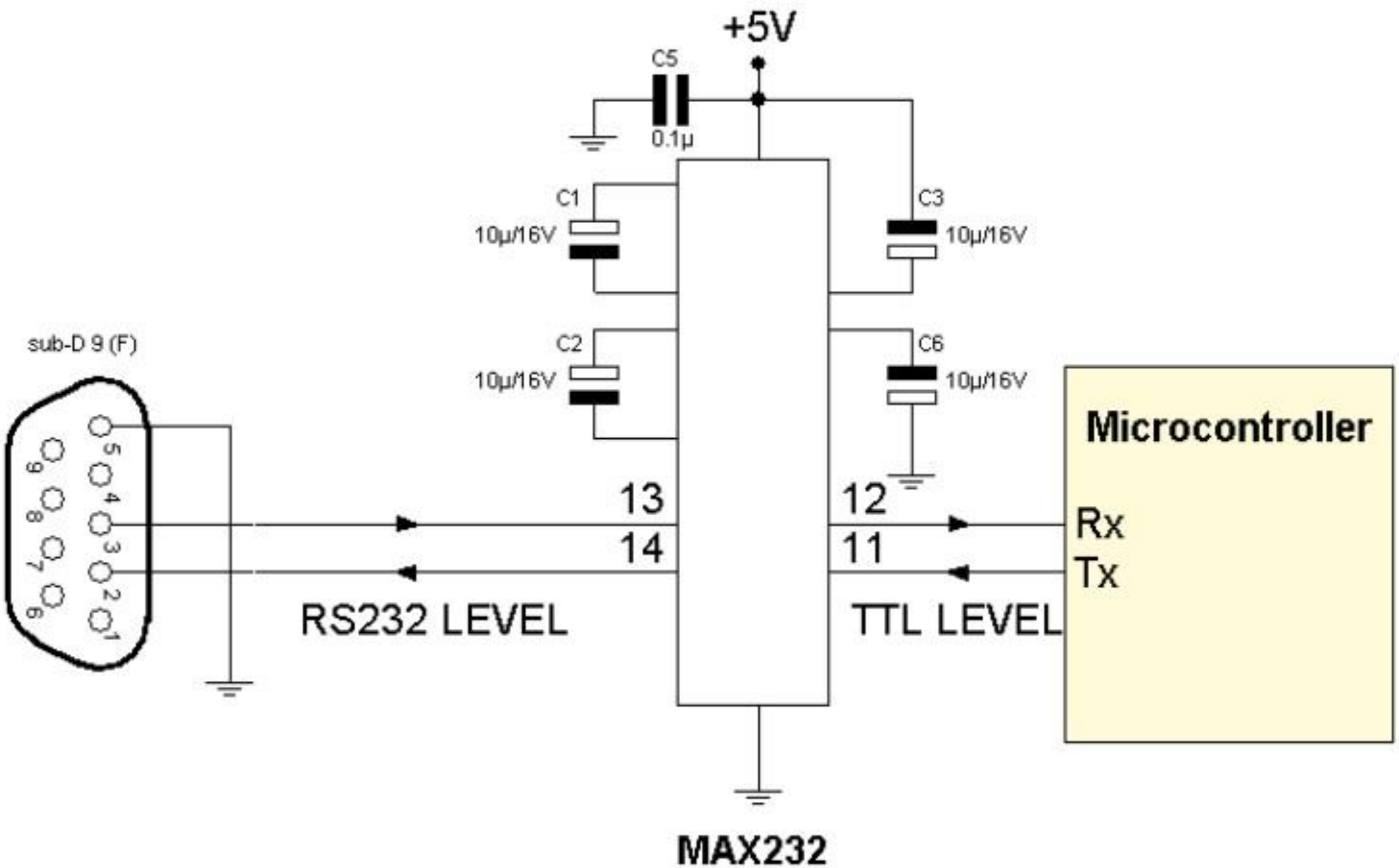
Antenna receives data from the SV system through X-Bee at 2.4 GHz

Microcontroller interface connected to USB of the Laptop

GCS Overview

- Serial interface between microcontroller and laptop requires the use of MAX-232 IC which is used to convert signal voltage levels.
- To communicate over UART or USART, we just need three basic signals vij, RXD (receive), TXD (transmit), GND (common ground). To interface MAX232 with any microcontroller, the three basic signals are required.
- At ground station we will be having a X-bee module which will receive data from another X-bee modules in SV and re-entry system.
- ATMega328 will receive the signal from X-bee module and transmit to MAX232 which will be received by serial port of the computer.

- **Communication Between Laptop and Microcontroller**



GCS Changes Since PDR

- There have been no changes in the CDR since the compilation of the PDR.

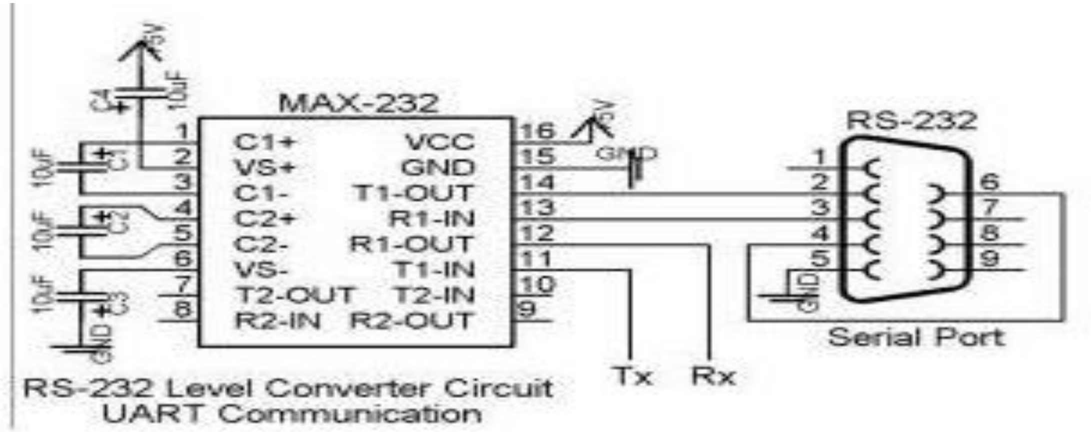
- All details mentioned are as per stated in the PDR and are being tested in real time conditions and processing.

GCS Requirements

ID	REQUIREMENT	RATIONALE	PARENT	PRIORITY	VM			
					A	I	T	D
GCS-01	Antenna placement : Antenna will be pointing upward, towards the Can Sat	For better signal reception and efficient data transmission.	SR-19	MEDIUM	✓	✓		
GCS-02	Computational requirements : Data is received at 0.5 Hz	Computational speed is entirely based on the fact that GCS laptop has a reasonably fast processor	SR-19	LOW	✓	✓	✓	
GCS-03	Power Requirement : should be able to receive and display data for approximately 4 hrs	GCS has to be ready always for the efficient communication. Availability of sufficient power makes it no issue.	SR-19	MEDIUM	✓	✓	✓	✓

GCS Requirements

- **Ground control system will comprise of a computer which will be connected to a circuit having ATMega328 through MAX232 IC.**
- **At ground station, an XBee module will be interfaced which will receive data of various sensors from another paired XBee module in the SV and also from an XBee module in the Re-entry container via antenna at the ground station.**
- **Data will be provided in real time at the ground station.**
- **ATMega328 will receive and transmit data signal via MAX232 which will be received by serial port of the computer.**

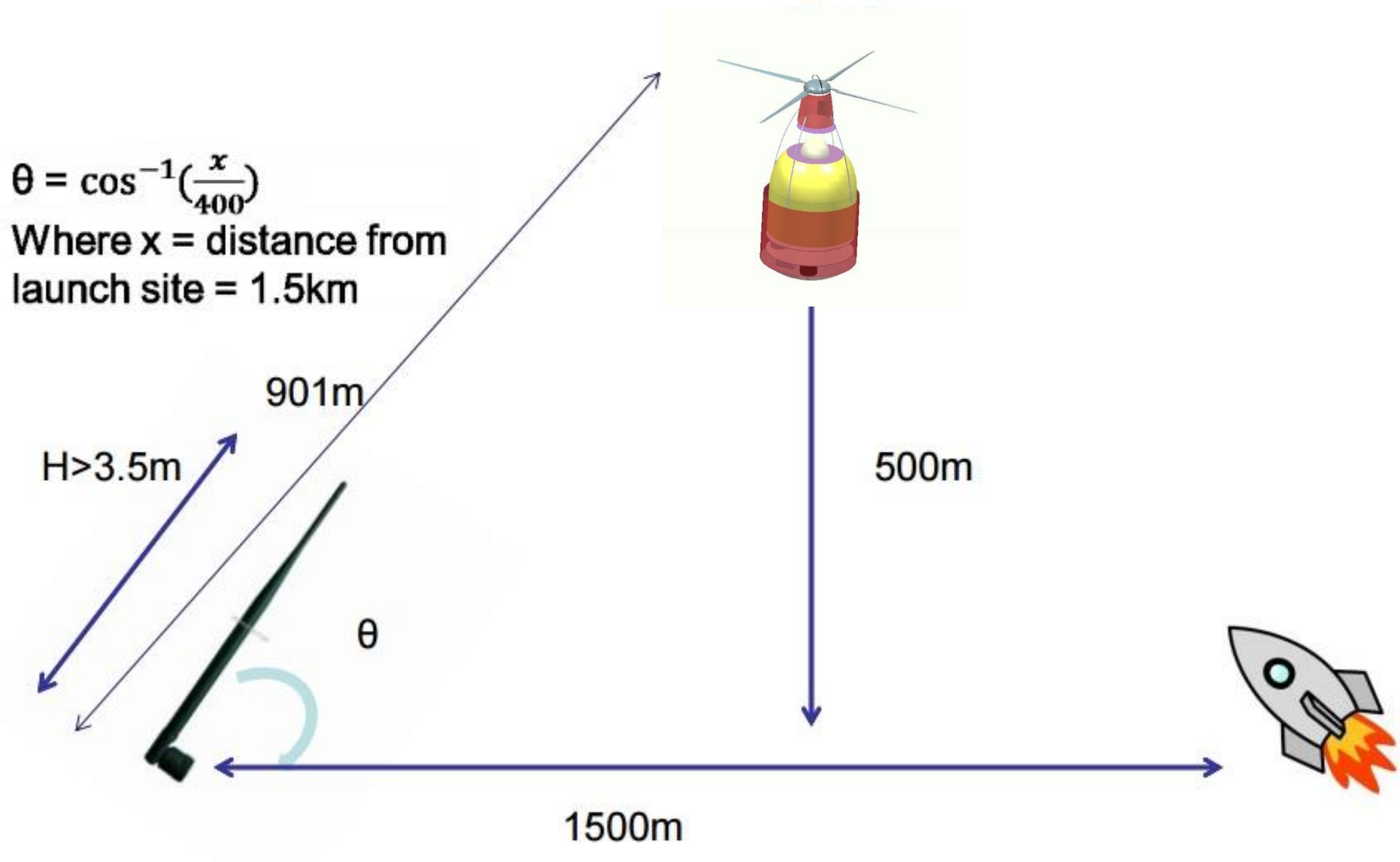


GCS Antenna

- Antenna is selected due to the following features :

1. High Gain – 20dbi
2. Easy Availability
3. High Accurate measurement
4. Long Range – 50,000 sqm.
5. Frequency – 2.5Ghz

GCS Antenna



$\theta = \cos^{-1}(\frac{x}{400})$
Where x = distance from
launch site = 1.5km
901m
H>3.5m
500m
θ
1500m

GCS Antenna

- Distance Link Margin

$$FSL = 20\log\left(\frac{4\pi Rf}{c}\right)$$

Where,

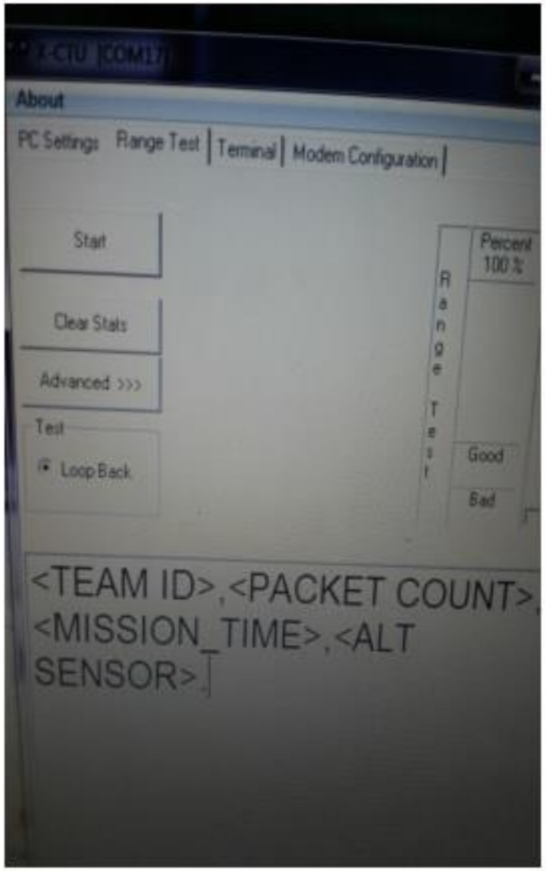
R = 901m

f = 2.4GHz

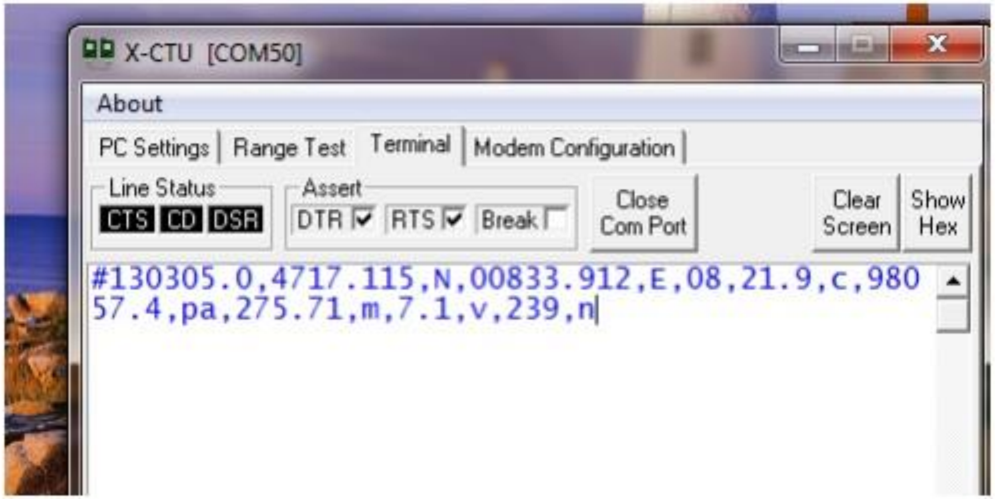
The estimated Loss is about 70-80db without counting the gain of the receiving antenna from which it can be concluded that the receiving antenna is appropriate for efficient receiving of data from the CanSat.

GCS Antenna

Real-time plotting design



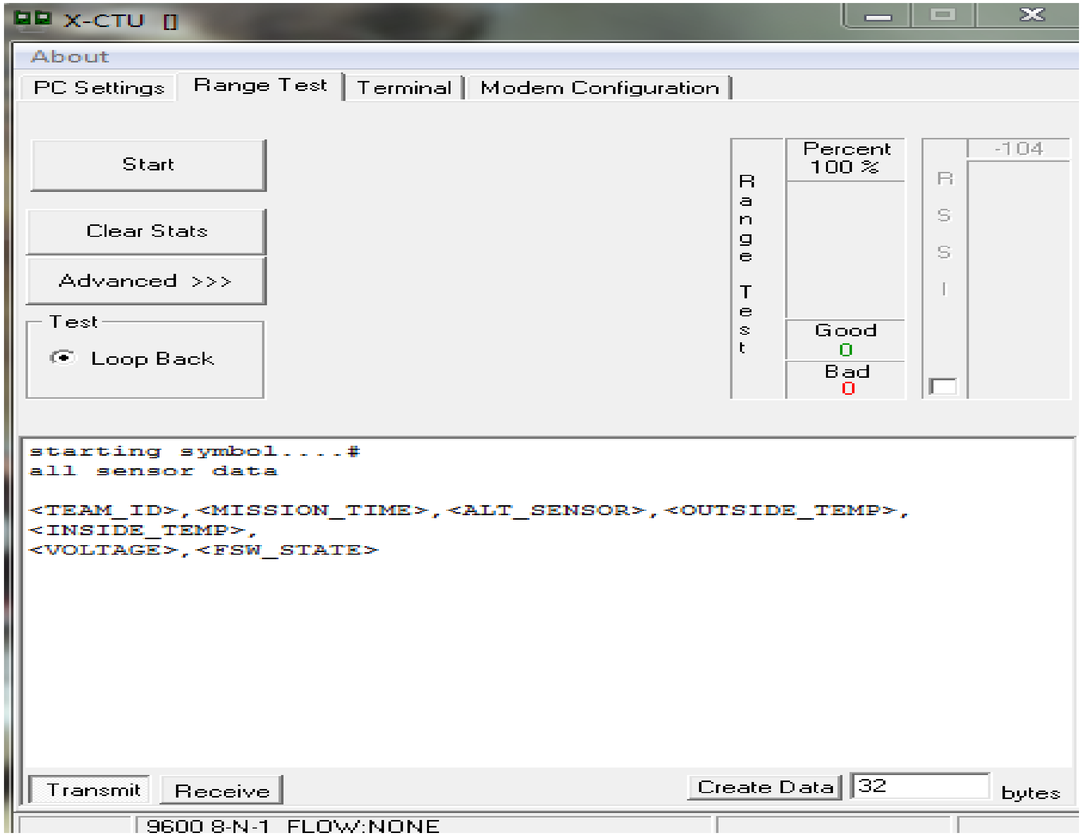
Screenshot of telemetry data



- Real-time plotting design is done in the GUI which has been developed in MATLAB software using MATLAB simulation.

Overview of GCS software

- Real-time plotting design is achieved in the GUI which has been developed in MATLAB software using MATLAB Simulation.
- Telemetry data recording and testing is done in Putty software / x-ctu.
- Formation and testing of the GCS software has been completed since the PDR.
- Accordingly, the data will be stored in a '.csv; file and then stored in memory card in real time.



CanSat Integration and Test

Akanksha Dadhich

Amitabh Yadav

CanSat Integration and Test Overview

1. Descent Control

- First subsystem to be integrated because it is responsible for the lowering of the descent rate and in turn ensures the safety of the egg.
- Date: 4/3/2015

2. Communications

- Second subsystem to be integrated. Vital for other sub-systems.
- Base Competition Requirement.
- Date: 4/5/2015

3. Sensors

- Third subsystem to be integrated. Responsible for gathering the required data.
- Date: 4/10/2015

4. Electrical

- Fourth subsystem to be integrated. After the PCB is assembled, FSW integration can begin, and consequently, Mechanical assembly.
- Date: 4/14/2015

5. Flight Software

- Fifth subsystem to be integrated. Vital for the interpretation of the communicated data and graph plotting.
- Date: 4/19/2015

6. Mechanical

- Final subsystem involved with the CanSat to be integrated. Incorporates all other subsystems.
- Date: 4/24/2015

7. Ground Station

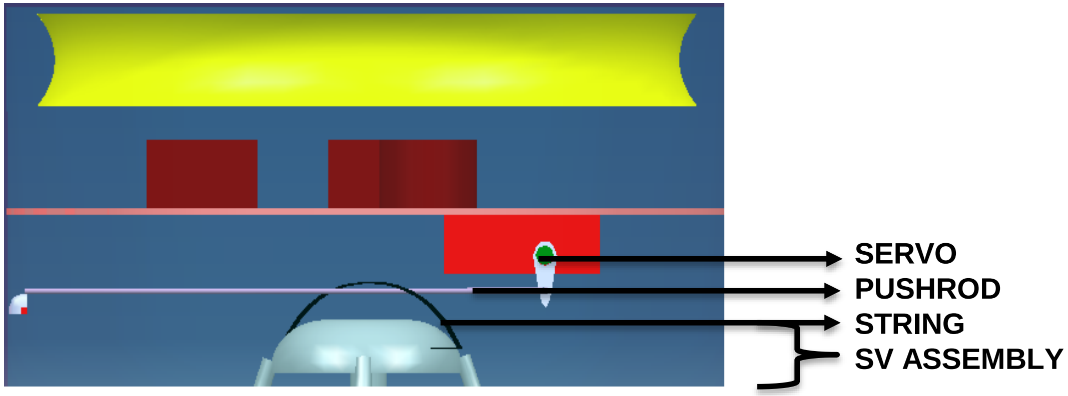
- Not located within the CanSat. Final system to be integrated and assembled.
- Date: 4/29/2015

***Note: The dates refer to the final fabrication completion, i.e. competition readiness**

The CanSat subsystems will be integrated as discussed below (sequence-wise):

OUTSIDE THE SCIENCE VEHICLE:

- A push rod controlled by a servo motor is used inside the container over which a string attached to the science vehicle is rounded. This is the **release mechanism**.
- This holds the **science-vehicle-container assembly** intact, till BMP085 sends a signal to the microcontroller.
- At an altitude between 500-400m, after receiving the signal, the servo rotates and the pushrod moves. Thus the string which was previously hung upon it gets released along with the SV detaching it from the SV-container assembly.
- CanSat shall have an external power switch and LEDs to indicate ON/OFF state.



CanSat Integration and Test Overview

INSIDE THE SCIENCE VEHICLE:

- The egg along with its protection system is placed above the electronics system inside the science vehicle.
- The rotors will be attached with the ball-bearing fitted inside the upper frustum. The rotors will be fixed with the help of screws, which will hold them intact in the system.
- The electronics including the sensors and processors will be at the bottom most position and below the egg protection system.
- The upper frustum will be attached to the bottom part (cylindrical and hemispherical) containing egg protection system and electronics with the help of spokes.
- Electronics except for sensors will be enclosed and shielded from the environment.

INSIDE THE CONTAINER:

- The parachute will be placed in the topmost position inside the re-entry container.
- The electronics will be below the parachute along with the servo and the push rod assembly.
- Below this will be the SV attached with the help of the servo-push rod release mechanism.

CANSAT SYSTEM-LEVEL TESTS:

(As per the Environmental Testing Guide Provided)

Drop Test:

This test was done to verify that the container parachute and attachment point will survive the deployment from the rocket payload section which can be very violent. The release mechanism was also tested to verify it can hold the science vehicle in the container. Component mounts and battery mount were also tested.

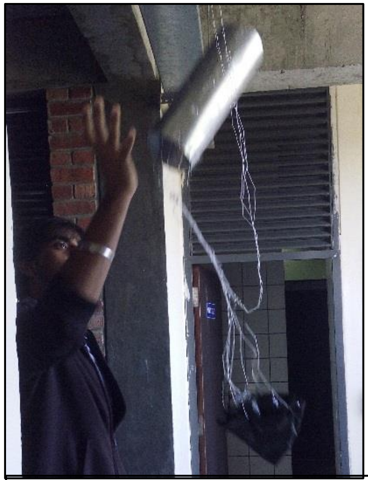
Equipment necessary: non-stretching kevlar cord, floor mat, ceiling.

Procedure:

- Secure the cord to the ceiling.
- Secure the other end of the cord to the parachute attachment point of the container.
- Raise the CanSat up 80 cm in line with the cord.
- Release the CanSat and let it drop.
- Observe the results of effect at attachment point. Remove the science vehicle from the container and inspect for any damage.

Screenshots of the Drop Test:

CanSat raised to roughly 80 cm with respect to cord.



CanSat during the fall.

Final position of the CanSat. No attachment was broken or deformed.

Observations:

- The parachute attachment point did not fail.
- The SV was intact inside the container, and did not separate.
- This test produced about 48Gs of shock which the CanSat survived.

Conclusion: Pass.

***NOTE: These images are undoctored and as recorded by the video camera on a mobile phone. They are cropped for a comparatively better view.**

Thermal Test:

This test was done to verify that CanSat and container can operate in a hot environment.

Equipment: Oven

Procedure:

- The science vehicle was placed inside the oven.
- After putting inside the oven, its electronics was turned on.
- Seal of the oven was closed and the heat source was turned on.
- The temperature inside the oven was maintained between 50°C and 42°C by monitoring it and switching the heat source off when it reached 50°C.
- Procedure was followed for next two hours.
- Heat source was turned off and visual inspection and other functional tests were performed to verify that the CanSat is surviving the thermal exposure and can be operated as expected.

CanSat Integration and Test Overview

The SV placed inside the oven

Door sealed and the test begins at 42°C.

45°C

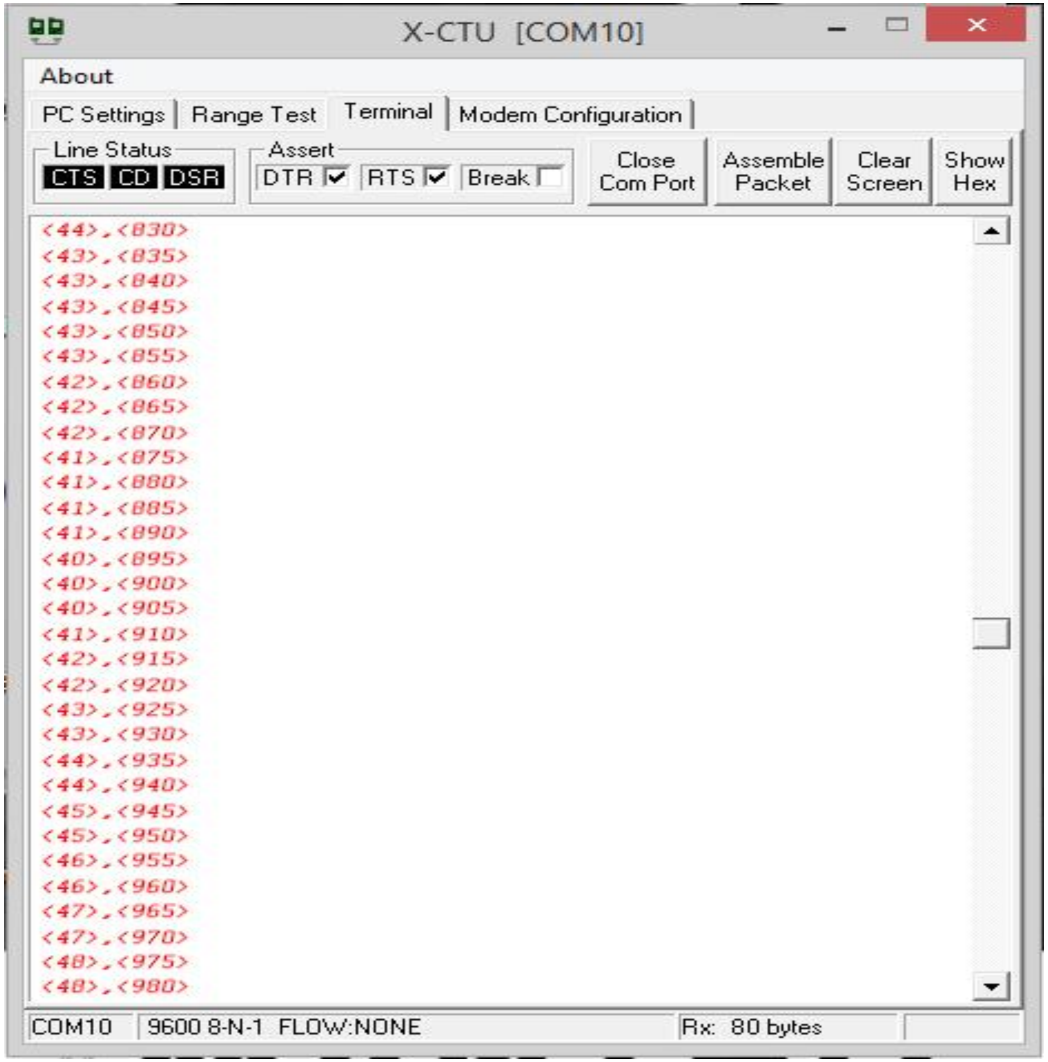
48°C

50°C

***NOTE: These images are undoctored and as recorded by the video camera on a mobile phone. They are cropped for a comparatively better view.**

CanSat Integration and Test Overview

The values from the temperature sensor during the thermal test are shown on the picture on the right. The sensor was set to give out values every 5 seconds. The oven was varied between 40 and 50° Celsius for a duration of approximately two hours.



Observations from Thermal Test:

- Electronics of the science vehicle was working perfectly and giving the telemetry for full 2 hours of test.
- No other parts of the science vehicle were damaged due to the heat exposure of 50^{o}C.

Conclusion: Pass.

CanSat Integration and Test Overview

Vibration Test:

This test was to verify the mounting integrity of all components, electronics and battery connections.

Equipment: orbit sander, benchtop vise, duct tape, power switch

Procedure:

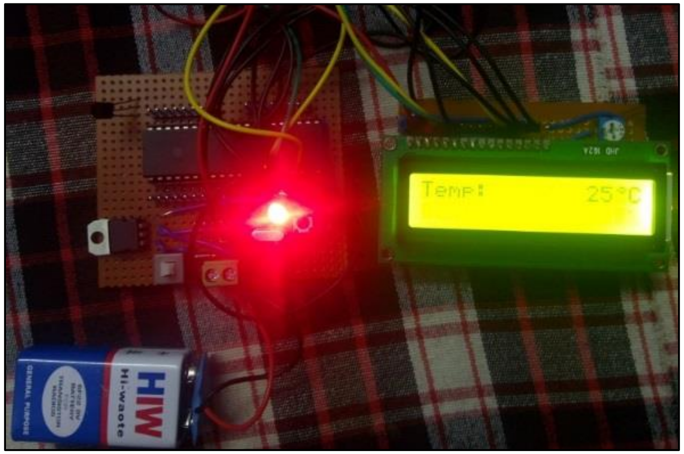
- Turn the power switch of the sander to the on position while it is not plugged in.
- Turn the sander upside down and secure it in the bench vise.
- With the power switch on the power strip in the off position, plug the sander into the power strip and the power strip into the local mains.
- Secure the CanSat on the sander, the part where sand paper is installed.
- Perform a functional test of the CanSat.
- Mount the science vehicle on the vibration fixture and secure it in place.
- Over a 1 minute period, turn the sander on. Let it power up to full speed, wait 2 seconds and turn off. As soon as the sander stops moving, repeat until one minute is complete.
- Remove CanSat from test fixture and inspect it for any damage.
- Perform a functional test.

Observations: All mounts were intact and did not detach from the SV.

Conclusion: Pass.

Sensor Subsystem Testing Overview

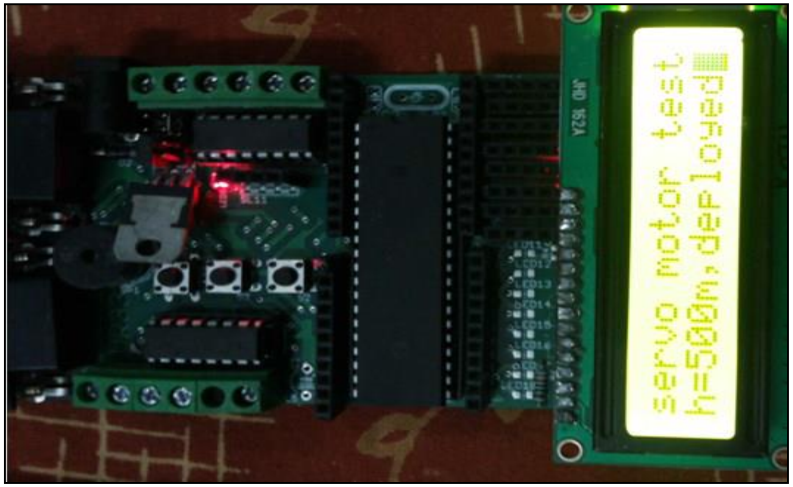
What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Electronics Component Integration: To verify the functionality of all the sensors and connecting them in one PCB.	• Sudden variation in temperature would inhibit data transmission until it stabilizes. • GPS and AVR must have constant power supply for optimal operation	• Accelerometer • GPS • Servo Motor • AVR • 16x2 LCD Display	• Temperature and altitude sensors have been tested till now for elevated temperature conditions. • Accelerometer, GPS and servo motor were tested using AVR MCUs, ADC, I2C and PWM ports.	• **Pass:** If the required data is displayed on the LCD screen. • **Fail:** If the data isn't displayed on the LCD screen.	Mentioned tests were successfully conducted by obtaining the readings at various temperatures, on a 16x2 LCD display.



Conclusion: Pass.

Sensor Subsystem Testing Overview

What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Servo Motor Tests: To ensure that the servo motor will rotate to release the SV from the Re-entry container.	Wouldn't rotate if appropriate data is not received by it.	• Servo motor • PWM port • Altitude sensor	• Servo Motor tests were conducted by varying its angle with the gap of 0° till 180°, by sending PWM signal to control the servo to the correct angle	• **Pass:** If the servo motor moves up to the desired angle. • **Fail:** If the rotation is incomplete or incorrect.	The servo showed movement to different specified angles, as according to the program running on the AVR MCU.



Conclusion: Pass.

Sensor Subsystem Testing Overview

- The data received for various sensors has been tested to appear in the following format:

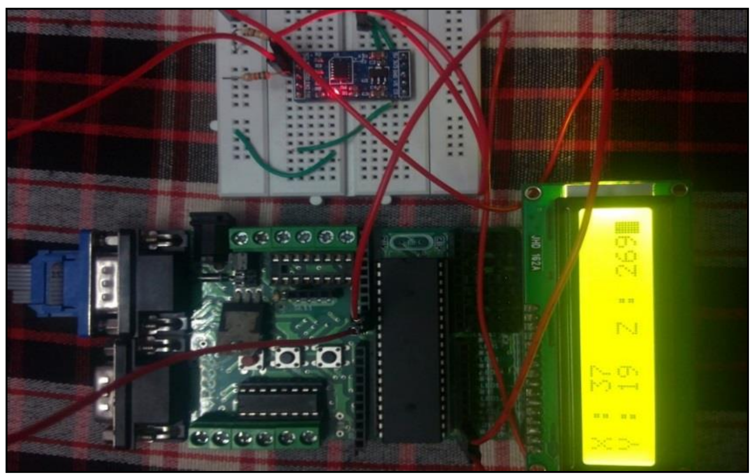
  TEAM_ID,MISSION_TIME,ALT_SENSOR,OUTSIDE_TEMP,INSIDE_TEMP, VOLTAGE,FSW_STATE,BONUS

- Tests have been conducted to display the values on a 16x2 LCD to demonstrate the process of data acquisition. The gathered data is redirected to AVR’s R_x and T_x pins and are serially communicated via Xbee to the GS software.

- **Initially, all the sensor subsystem tests are conducted using independent programs for various units. These will be integrated as functions in the main FSW of the overall Cansat system.** A function based approach is preferred in order to make the code readable and also integrate the Auto FSW_state recovery at processor reset. More details presented in Pseudo-code in FSW.

3-Axis Accelerometer Testing

What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
To verify that the accelerometer provides the correct readings for the x, y, and z direction.	• Sudden variation in temperature would inhibit data transmission until it stabilizes.	• Accelerometer • AVR board • LCD Display	• The data will be communicated as individual integer values along x-, y- and z- axes and displayed / stored as values along x-, y- and z - axes, as shown in the figure.	• **Pass:** If the correct readings for all the axes is provided. • **Fail:** If the correct readings are not received.	Correct reading at every 1 sec is obtained by varying axes.



Conclusion: Pass.

DCS Subsystem Testing Overview

What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Wind tunnel test: • To verify experimentally the autorotation, and thrust produced by the rotors. • To test the functionality of the folding blades and also to confirm that the ball bearings will be enough to stop the rotation of the lower cylinder.	Electric fluctuations can disrupt the flow of air in the wind tunnel.	• Wind tunnel • rotor stand to fit inside the wind tunnel • 4-blade customised rotors • free spinning hub	• Customized rotors were kept inside the wind tunnel. • The fan of the wind tunnel was allowed to rotate. • It was checked whether the rotors are rotating properly or not.	**Pass:** If the rotors are rotating properly without any friction due to ball-bearings. **Fail:** If the rotors are not rotating properly.	The rotors rotated generating thrust of about 3 N. Which is as per the theoretical value required for the descent rate of 4 to 10 m/s

Conclusion: Pass.

DCS Subsystem Testing Overview

What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Weather Balloon Test: This test was done to verify the functioning of the DCS and its purpose of reducing the descent rate of the SV and survivability.	If high cross winds are present then chances are there that the balloon will get drifted.	• Weather balloon • nylon cords • Sextant • pressure gauge • Ties • Tape • helium gas	• CanSat was tied to a weather balloon filled with helium gas. • A cutting mechanism was fitted to cut the cords at right time. • Height of the balloon was calculated using a sextant. • Members were ready to perform the exact actions as in the real competition	• **Pass:** If the descent of the SV is controlled within 10m/s, the telemetry is received and the egg is saved. • **Fail:** If the SV would have fallen freely in air, telemetry would have been not received and the egg is broken.	• The descent rate is found to be reduced. • The DCS devices survive 50Gs of shock force and were not found damaged or deflected after recovery. • Telemetry was received as was expected • The egg was saved.

Conclusion: Pass.

DCS Subsystem Testing Overview

Filling Helium in the balloon

Sextant – to measure the height attained by the weather balloon

Weather balloon at a height of 250 m right before the release of the SV.

DCS Subsystem Testing Overview

What to accomplish	Constraints	Equipment used	Procedure	Pass/Fail Criteria	Results
Drop Test: This test was done to verify that during descent the lower part of the SV does not rotate, and ball bearing functions properly.	Improper fitting of the ball-bearings can disrupt the rotation of the rotors. Any sort of friction can hamper the rotation of rotor blades.	• high rise building • video camera • SV with DCS and ball bearing attached.	• CanSat was assembled with rotors and ball-bearing. • Instead of electronics dead weight of equivalent mass was added. • CanSat was allowed to be dropped from a high rise building. • The drop flight was recorded.	• **Pass:** If the lower part of SV does not rotate and ball bearing works perfectly. • **Fail:** If the lower part rotates along with the rotors.	The SV does not rotate as can be seen by the screenshots from the video hence, the video camera attached at the bottom will not rotate, and its orientation can be maintained between +/- 90 degrees.

Conclusion: Pass.

Since we completed this test before the camera arrived, the image is not very clear. But on closer inspection, you will see that the two black buds attached on the lower cylinder are at the same position throughout the fall. Thus we conclude that there is no rotation of the lower portion of the CanSat.

***NOTE: These images are undoctored and as recorded by the video camera on a mobile phone. They are cropped for a comparatively better view.**

Mechanical Subsystem Testing Overview

What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Release Mechanism Test: This is to test the release mechanism of the SV from the container.	N/A	• SV-container assembly • servo motor • Pushrod • String • varying weights • GPS	• This involves releasing the SV from the re-entry container with the help of a servo motor and a microcontroller by moving the pushrod and releasing the string attached with the SV. • A test on release mechanism for SV weighing more than 350g has been performed to check if the release mechanism works effectively for SV heavier than 350g.	• **Pass:** If the SV is released from the container without any problem. • **Fail:** If it gets stuck while being released.	The release mechanism test was Pass as the mechanism worked for the weights experimented and released the SV at command from GPS.

Conclusion: Pass.

Mechanical Subsystem Testing Overview

What to Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Structure Survivability Test: This is to test the structure survivability of the SV.	Crosswinds might drift the weather balloon.	• high rise building • weather balloon.	• The SV was dropped from heights of 250m and 150m, with the help of a weather balloon. • This was recovered and checked for any damage or detachment.	• **Pass:** If the structure survives all the shocks and accelerations without any failure of it. • **Fail:** If deformation in Al sheets, bending in the spokes or breakage of the rotors is seen.	The structure is surviving 30 Gees of shock force as per the tests conducted.

Conclusion: Pass.

Mechanical Subsystem Testing Overview

What To Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Egg Protection System Tests: This is to test and verify the working of the egg protection system.	No control over orientation of the way the SV will land on the ground.	• high rise buildings • weather balloon • egg	This involved 3 tests: 1. First dropping the egg with only its protection system (without a descent control system) from a height of 12m. 2. Second test involving dropping of the SV containing the egg protection system from 50m. 3. Third test was with the help of a weather balloon which deployed the CanSat as one unit from heights of 150m and 250m.	• **Pass:** If the egg is saved. • **Fail:** If the egg breaks.	The egg protection system was found to work successfully in all three tests as the egg did not break.

Conclusion: Pass.

CDH Subsystem Testing Overview

What To Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
To test the range of communication and the extent of data transmission.	• XBEE Pro S2B has a range of 3200 m but maintaining proper line of sight is difficult for efficient data transmission and reception.	• ATmega328 PCB self designed developer board • XBee Pro S2B module both receiver and transmitter, • power source • Atmel Studio 6.1 for programming. • Balloon and Helium	1. Transmitter was attached with the helium filled weather balloon. 2. Receiver was at ground. 3. Weather balloon was release to the altitude of 250m. 4. Data was displayed on 16x2 LCD and also on Ground Station Software built on MATLAB R2013a. 5. Pictures are shown in FSW testing section.	• **Pass:** If the data gets transmitted and received correctly by the ground station. • **Fail:** If the data is not received properly.	Worked correctly up to 250m. Data received in correct format.

Conclusion: Pass.

EPS Testing Overview

What To Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
Obtain the desired voltage from 9V battery.	• Any wire left unattended would result in short circuiting. • All connections should be rendered tight.	• Linear Regulator (LM1117) used • 9V battery. • Oscilloscope • MultiMeter • Microcontroller Board	• After installation of all circuits short circuit tests were conducted to check any wrong connections. • LED is used as power indicator to check power supply in all electronic components. • ADC port were used results were obtained with an error of 5%.	• **Pass:** If constant output is observed. • **Fail:** If the output is not constant, distorted or has noise.	• Efficiency = 85% - 90 %. Constant 3.3v output is observed. • Same result also obtained for voltage regulator LM7805. • Voltage successfully tested by obtaining constant curve on Oscilloscope.
For power saving in CanSat			• Power saving is achieved during idle mode and power down mode of AtMega328. The Science Vehicle uses capacitor and current buffer circuit to store power temporarily.		

Conclusion: Pass.

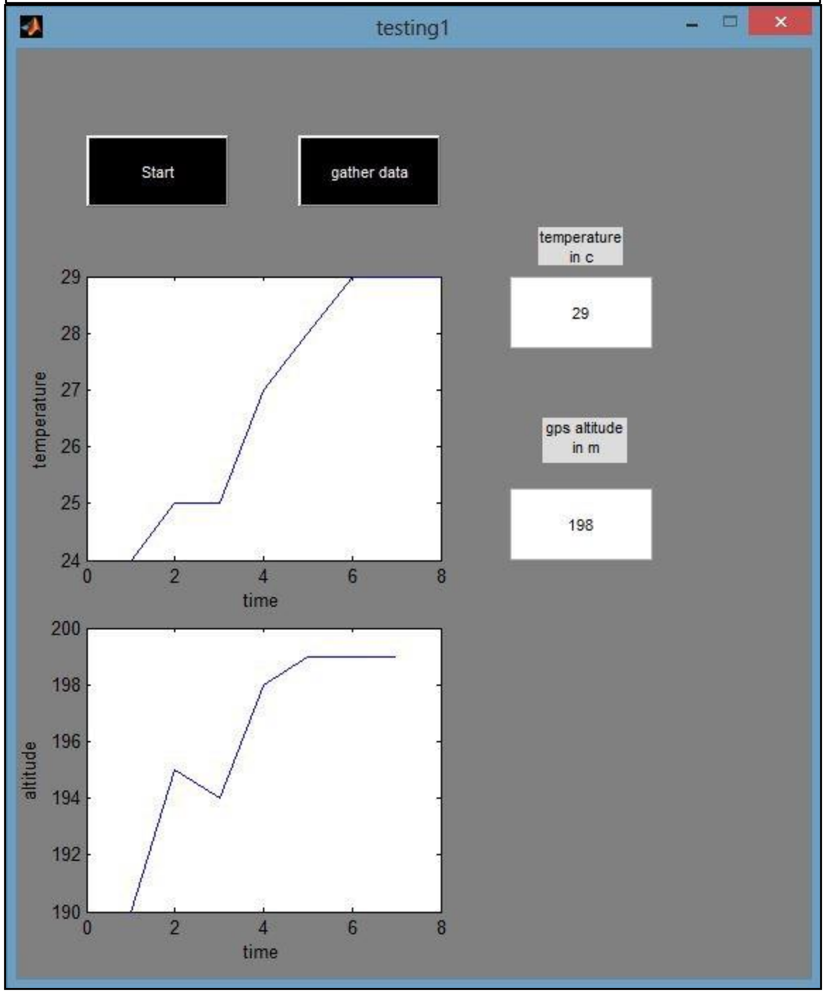
FSW Testing Overview

What To Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
• To verify that data acquisition takes place. • To transmit data to the ground station. • To plot the acquired data in real time.	The complexity of the program of the FSW determines the proper functioning of the MCU. Too much complexity may result in lag in data transmission and/or processor hanging.	• Atmel Studio 6.1 • Atmega328 development Board and RTC • X-bee Pro S2B transmitter and receiver • MATLAB R2013b • Various sensors for collecting data • X-CTU	• The data acquisition was programmed using a function based approach. • The initial test of auto-restore mechanism to correct FSW_State has been performed, using just two state parameters, HIGH and LOW, with correct readings on X-CTU.	• **Pass:** If the data is getting transmitted to the ground station and if the graph can be plotted based on the received values. • **Fail:** If the data is not transmitted properly.	Correct Readings of two parameters is obtained at the ground station.

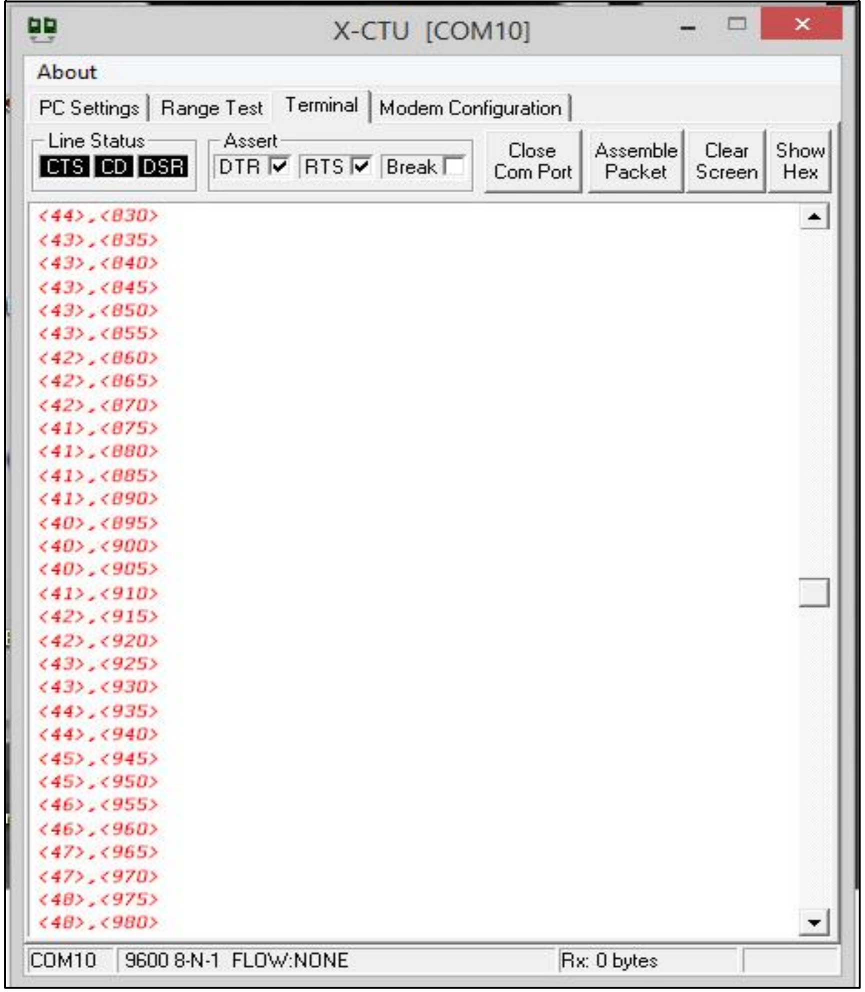
Conclusion: Pass.

FSW Testing Overview

Temp and Altitude readings on Matlab GUI



Temperature Readings received on X-CTU with carriage return.



GCS Testing Overview

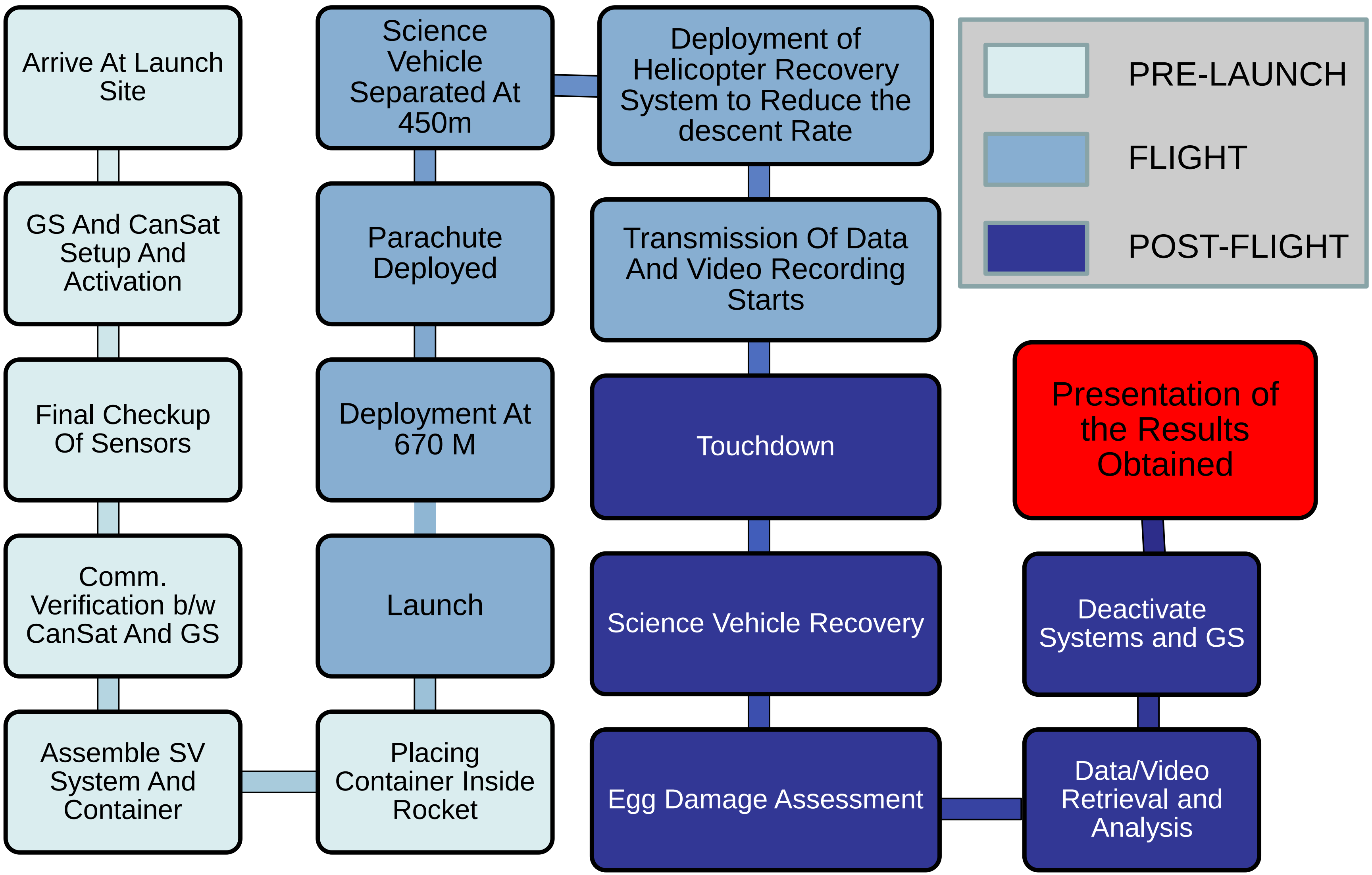
What To Accomplish	Constraints	Equipment Used	Procedure	Pass/Fail Criteria	Results
• To ensure that combined data received successfully on the ground station. • Display the data with respective graphs.	Constant voltage power supply is required for efficient working of the Development Board	• ATmega328 PCB self designed development board • Laptop • LCD(16x2) • USB serial cable • XCTU hyper terminal (for initial tests) • Matlab GUI built using Matlab R2013b.	• Serial interfacing between microcontroller and laptop by using MAX-232 IC • Receiving and Transmitting Data through Rx and Tx Ports. • Data to be Provided in real time to the Ground System • Sorting, Logging and Plotting of data simultaneously in the Ground System Software.	• **Pass:** If the data is received by the GCS. • **Fail:** If the data is not received.	Displayed the received data on LCD(16x4) and also on laptop by using serial communication on XCTU hyper terminal and later on Matlab GUI, graph was obtained.

Conclusion: Pass.

Mission Operations & Analysis

Aman Singhal

Overview of Mission Sequence of Events



Overview of Mission Sequence of Events

MISSION OBJECTIVES:

- Each team member will be assigned a specific task(s) on the competition day based on the level of expertise in his/her respective field and will be responsible for the successful completion of the assigned task and whether any task needs reviewing or troubleshooting.

- Team members will be divided into teams for ground station ,CanSat crew, recovery crew and one of the members will be Mission control officer.

Name of Team Member	Post
Aman Arora	Mission Control Officer
Amitabh Yadav	Ground Station Crew
Raghav Rathi	Ground Station/CanSat Crew
Aditya Savio Paul	CanSat Crew
Dishant Kothia	Recovery Crew
Nalin Srivastava	Recovery Crew

Overview of Mission Sequence of Events

- After setting up the ground station it is important to connect all the communication devices and verify whether the ground station is operational or not.
- The sensors and electronic subsystems inside the SV must be operational and it must transmit data to the ground station.
- Correct positioning of antennas on board the CanSat and GS, and verification of successful communication between the CanSat and the GS will be verified.
- CanSat will be assembled and tested for the weight and dimensions as per the rocket payload section.
- Telemetry data from data logger and that collected from flight software will be delivered to field judges for review in .csv format.

Field Safety Rules Compliance

- Development of operations manual is almost done and includes the basic checklist for the all the components of the CanSat systems and the GS, including troubleshooting guide and preparations and procedures prior to launch and after touchdown.

- Three ring binder copies will be made out of which one will be provided to flight coordinator and two will be provided for flight readiness review.

- The manual with the members with the major components being:

  – Ground station setup
  – Final CanSat systems test
  – CanSat - GS communication verification checklist
  – Re-entry container and rocket integration checklist
  – Final pre-launch checklist and preparations
  – CanSat in-flight procedures
  – SV recovery and data analysis
  – The manual is expected to be completed in next 3-4 days.

CanSat Location and Recovery

- The GPS sensor fitted inside the SV will continuously transmit its position to the GS.
- The body of the SV will be painted with a bright and shiny color which will allow us to maintain visual contact of the SV even before its reaches the ground. The same goes for the reentry container and the parachute.
- Audio Beacon will be fitted inside the SV and it will start buzzing when the SV is 50 m above the ground.
- The SV and the re-entry container will have the name of the Team, Team Leader, Alternate-Team Leader, Team Number, E-mail address of team leader, E-mail address of alternate team leader, Phone number of team leader and alternate tea leader written on their bodies to aid in their identification.

Mission Rehearsal Activities

REHARSAL ACTIVITIES:

1. GROUND STATION RADIO LINK CHECK PROCEDURES

We verified the communication procedures by using XBEE-PRO S2B, MAX-232 and DATALOGGER . The data was transmitted from XBEE and was received on the ground successfully.

2. LOADING THE EGG SAFETY MECHANISM

We rehearsed loading this into our CanSat prototype during testing. We used sponge, polystyrene balls and plastic cup with an egg and integrated it into CanSat.

3. POWERING ON/OFF THE CANSAT

We rehearsed it by two procedures:-

- by powering the whole circuit by on/off switch.
- by sending the $ sign to start the telemetry transmission

4. LAUNCH CONFIGRATION PREPARATION

The CanSat was assembled before the balloon test and all the appendages were checked by pulling the parachute.

5. LOADING THE CANSAT IN THE LAUNCH VEHICLE

We verified that our CanSat will fit into the payload section of rocket by assembling it and fitting it into a can of similar size.

6. TELEMETRY PROCESSING, ARCHIVING, AND ANALYSIS

Data received on the two sensors was converted to .csv format and plotted in graphs. This was analyzed and it showed accurate altitude and temperature values.

7. RECOVERY

We practiced it by recovering the CanSat after drop tests from 250m and 150m. We had florescent pink color as the color of our parachute so it was easier to locate.

Requirements Compliance

Aman Arora

Current design compliance to requirement:-

- Base requirements comply to the required requirements.
- All the descent and recovery requirements comply to the required requirements and the structure will sustain 30 Gees of shock force, as shown by the recently concluded testing.
- The communication requirements comply to the required requirements.
- The flight software requirements comply to the required requirements as the software is under development.
- Structure requirements comply to the required requirements.
- Mechanisms requirements comply to the required requirements.
- The requirement that during descent, the SV shall transmit the telemetry data once every 1 second complies with current requirement except flight software which is complete.
- Selectable objective requirement is complied.

Requirements Compliance (1 of 7)

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1	**Base Requirements**			
3.1.1.1	Total mass of CanSat, container, and all descent control devices shall be 600 grams. Mass shall not vary more than +/-10 grams.	Comply	13, 45, 63, 66, 75	
3.1.1.2	The Science Vehicle shall hold one large raw hen's egg which shall survive launch, deployment and landing.	Comply	10, 13, 44, 63, 135, 154	
3.1.2	The SV must be installed in a container to protect it from deployment out of the rocket.	Comply	10, 13, 24, 27, 66	--
3.1.2.1	The container shall fit inside the cylindrical payload section of the rocket defined by the cylindrical payload envelope of 125mm x 310 mm length control system including the descent	Comply	13, 24, 66	
3.1.2.2	The Container shall use a passive descent control system. It cannot free fall. A parachute is allowed and highly recommended. Include a spill hole to reduce swaying.	Comply	13, 39, 42, 47, 63	
3.1.2.3	The container shall not have any sharp edges that could cause it to get stuck in the rocket payload section.	Comply	13, 66	
3.1.2.4	The container must be a florescent color, pink or orange.	Comply	15, 67, 165	
3.1.2.5	No protrusions beyond the envelope defined are allowed while stowed in the rocket.	Comply	13	
3.1.2.6	The rocket airframe cannot be used to restrain any deployable parts of the cansat.	Comply	13	
3.1.2.7	The rocket airframe and payload section shall not be used as part of the cansat operations.	Comply	13	
3.1.2.8	The Cansat shall deploy from the rocket payload section.	Comply	10, 13, 22	

Requirements Compliance (2 of 7)

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1.3	**The CanSat shall comply with the following descent and recovery requirements:**			
3.1.3.1	The descent control system shall not use any flammable or pyrotechnic devices.	Comply	46,66	
3.1.3.2	The Container or Science Vehicle shall include electronics and mechanisms to determine the best conditions to release the Science Vehicle based on stability and pointing.	Comply	48,49,63,72,117, 134	
3.1.3.2	The Science Vehicle shall use a helicopter recovery system. The blades must rotate. No fabric or other materials are allowed between the blades.	Comply	10,13,40,41,67, 71	
3.1.3.3	The descent rate of the Science Vehicle shall be less than 10 meters/second and greater than 4 meters/second.	Comply	10, 14, 43, 49 ,147	
3.1.3.4	During descent, the video camera must not rotate. The image of the ground shall maintain one orientation with no more than +/- 90 degree rotation.	Comply	15, 42, 48, 65, 72, 150	
3.1.3.5	All descent control device attachments must survive 50 Gees of shock.	Comply	14, 47, 67, 148	
3.1.3.6	All descent control devices must survive 50 Gees of shock.	Comply	14, 47, 67, 148	

Requirements Compliance (3 of 7)

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1.4	**The CanSat shall comply with the following communications requirements:**			
3.1.4.1	XBEE radios shall be used for telemetry. 2.4 GHz Series 1 and 2 radios are allowed. 900 MHz XBEE Pro radios are also allowed.	Comply	121,129	
3.1.4.2	The XBEE radios shall have their NETID/PANID set to the team number.	Comply	87	
3.1.4.3	The XBEE radio shall not use the broadcast mode.	Comply	87	
3.1.4.4	The ground station shall include one laptop computer with a minimum of two hours of battery operation, XBEE radio and a hand held or table top antenna.	Comply	16, 122, 126	
3.1.4.5	The XBEE radio can operate in any mode as long as it does not interfere with other XBEE radios.	Comply	87	
3.1.4.8	The telemetry is displayed in engineering units in real time	Comply	14, 90, 113	

Requirements Compliance (4 of 7)

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1.5	**The CanSat shall comply with the following power requirements:**			
3.1.5.1	The CanSat shall have an external power control such as a power switch and some indication of being turned on or off.	Comply	114, 134	
3.1.5.3	Lithium polymer cells are not allowed due to being a fire hazard. Alkaline, Ni-MH, lithium ion built with a metal case, and Ni-Cad cells are allowed.	Comply	92, 94, 100	
3.1.6	**The CanSat shall comply with the following flight software requirements:**			
3.1.6.1	The CanSat flight software shall maintain and telemeter a variable indicating its operating state. In the case of processor reset, the flight software shall re-initialize to the correct state either by analyzing sensor data and/or reading stored state data from non-volatile memory. The states are to be defined by each team.	Comply	112, 115, 118	

Requirements Compliance (5 of 7)

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1.7	The cost of the cansat flight hardware shall be under $1000 (USD). Ground support and analysis tools are excluded.	Comply	15, 179	
3.1.8	Each team shall develop and use their own ground station. All telemetry shall be displayed in real-time during launch and descent. All telemetry shall be displayed in engineering units (meters, meters per second, Celsius, etc.). Teams shall plot data in real-time during flight.	**Comply**	14, 90, 113	

Requirements Compliance (6 of 7)

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1.9	**Structure Requirements**			
3.1.9.1	All electronics shall be enclosed and shielded from the environment. No electronics can be exposed except for sensors. There must be a structural enclosure.	**Comply**	73, 135	
3.1.9.2	The structure must support 15 Gees acceleration.	**Comply**	**14, 148**	
3.1.9.3	The structure must survive 30 Gees shock force.	**Comply**	**14, 148, 153**	
3.1.9.4	Electronic circuit boards must be hard mounted using proper mounts such as standoffs and screws. High performance adhesives are acceptable.	Comply	15, 66, 73, 142	
3.1.9.5	Both the container and SV shall be labeled with team contact information including email address	**Comply**	165	
3.1.10	Mechanisms Requirements	--	--	--
3.1.10.1	Mechanisms must be capable of maintaining their configuration or states under all forces such as acceleration and shock forces.	Comply	**14, 152, 153**	
3.1.10.2	Mechanisms must not use pyrotechnics or chemicals.	**Comply**	14, 66	
3.1.10.3	Mechanisms that use heat (e.g. nichrome wire) must not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	**Comply**	73	

Req ID	Requirement	Comply / No Comply / Partial	Slide(s) Demonstrating Compliance	Team Comments or Notes
3.1.10.4	The Container or Science Vehicle shall include electronics and mechanisms to determine the best conditions to release the Science Vehicle based on stability and pointing.	Comply	48,49,63,72,117	
3.1.10.5	The Science Vehicle shall have a video camera installed and recording the complete descent from deployment to landing. The video recording can start at any time and must support up to one hour of recording.	Comply	10, 15, 31, 111	
3.1.10.6	The video camera shall include a time stamp on the video. The time stamp must work from the time of deployment to the time of landing.	Comply	10, 15, 111	
3.1.11	**During descent, the SV shall transmit the following telemetry data once every one second:**			
3.1.11.1	Pressure in Pascal. Altitude in meters above sea level Air temperature. Battery voltage in volts. Accelerometer triple axis data.	Comply	14, 90, 113, 146	
3.1.11.5	The external power connection shall be a sturdy connector that is easily accessible when the SV is stowed in the container.	comply	114, 134	
3.1.11.6	Flight software maintained mission time and real time plots of data.	Comply	111, 112, 113	
3.2	Selectable Objective Requirements: Use a three-axis accelerometer to measure the stability and angle of descent of the Science Vehicle during descent. Sample at appropriate rate and store data for later retrieval.	Comply	10, 14, 27, 78	--
3.2.1	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission.	Comply	15, 113	

Management

Raghav Rathi

Status of Procurements

Part	Quantity	Order Date	Expected Arrival	Status
Flight Hardware				
Data Logger	1	3/18/2015	-	Received
PCB	2	3/14/2015	-	Received
Transistor	2	3/20/2015	-	Received
Programmer	1	3/20/2015	-	Received
Battery	2	3/17/2015	-	Received
Regulator	5	3/20/2015	-	Received
Pressure Sensor	1	3/20/2015	-	Received
Camera	2	3/24/2015	4/6/2015	Ordered
GCS Hardware				
Antenna	2	3/17/2015	4/2/2015	Ordered
XBEE	2	3/20/2015	-	Received
OTHERS		3/20/2015	-	Received

CanSat Budget – Hardware

CANSAT HARDWARE BUDGET	
Mechanical	$ 276.95
Electronics	$ 400.57
TOTAL	**$ 677.52**

Thus, the total hardware expenses are less than $1000, i.e. well within the competition requirement.

Separate tables are provided for the detailed electronics and mechanical hardware costs:

ANNUAL CANSAT COMPETITION

Electronics hardware cost

CATEGORY	MODEL	QUANTITY	COST	DETERMINATION
Microcontroller	ATMega 16L Arduino Nano	2 2	\$ 3.7 \$ 32	EXACT EXACT
XBEE Pro ZB S2	XBP 24BZ7WIT – 004	4	\$ 140	EXACT
GPS	FASTRAX UP501	2	\$ 50	EXACT
SENSORS: Temperature Pressure Accelerometer	LM35 BMP085 ADXL345	3 1 1	\$ 1.72 \$ 25 \$ 4.15	ESTIMATE EXACT EXACT
Base Board	UNI VOLT KS204	4	\$ 3	ESTIMATE
Antenna	A24 – P19NFPP	3	\$ 80	ESTIMATE
Misc.			\$ 16	ESTIMATE

CanSat Budget – Hardware

CATEGORY	MODEL	QUANTITY	COST	DETERMINATION
Battery	Duracell (9V)	4	$ 10	EXACT
Camera	CMOS OV7670	2	$ 35	EXACT
TOTAL			**$ 400.57**	

CanSat Budget – Hardware

Mechanical Hardware Costs

CATEGORY	MODEL	QUANTITY	UNIT COST	DETERMINATION
Structure Material	Aluminium	4 meter square	$ 10	ESTIMATED
Parachute		1	$ 31.95	EXACT
Servo Motor	RKI-1129	1	$ 17	EXACT
Egg Protection	Polystyrene Balls + Foam	1 mix	$ 10	ESTIMATED
Descent Control System	Customized Rotors + Ball bearings	3	$ 208	EXACT
TOTAL			**$276.95**	

CanSat Budget – Other Costs

Ground Control Costs

CATEGORY	MODEL	QUANTITY	UNIT COST	DETERMINATION
Antenna	S467XX-9155	1	$ 19	ESTIMATE
Microcontroller	ATMega 16L	1	$ 2	ESTIMATE
XBEE	XBP24BZ7WIT – 004	1	$ 66	EXACT
Others			$ 50	
TOTAL			**$ 137**	

CanSat Budget – Other Costs

CATEGORY	QUANTITY	UNIT COST	DETERMINATION
Ground Control Costs	-	$ 137	ESTIMATE
Travel	6	$ 11,000	ESTIMATE
Hotel Room	2	$ 800	ESTIMATE
Van	1	$ 500	BUDGETED
Food	5	$ 700	BUDGETED
TOTAL		**$ 13,137**	

Program Schedule

- Competition started in **October ‘14** with formation of team by selecting students who could best contribute to the requirements of the team. After the team was formed immediately the focus was converged on the mission statement of the competition, thinking about the ideas which could complete the task in the most efficient and effective way.

- In **December ’14**, the team was registered and after that, our **End semester exams** started during which we did the job of designing and printing brochure for attracting sponsors.

- In **January ’15**, different designs were being discussed and finally, a design was chosen to work upon. Around **January 15th**, work on **PDR** started and it was divided among different team members. On **January 25th** all the work was completed and final assembly and review of the PDR started. On 31st January, the PDR was be submitted.

- In **February ‘15**, small scale fabrication of the science vehicle was started along side with electronic circuits of the science vehicle. By the mid of February we started testing our model from the building of our college campus and one testing using a weather balloon and on the basis of the test results we chose our future actions.

Program Schedule

- In **March ‘15**, our **Mid semester exams** started. By the mid of March we started working on **CDR** and by 25th it will be completed for the final reviewing to start. CDR will be submitted on **31st March ‘15**. At this time, team members who do not hold U.S. VISA will apply for their VISA application.

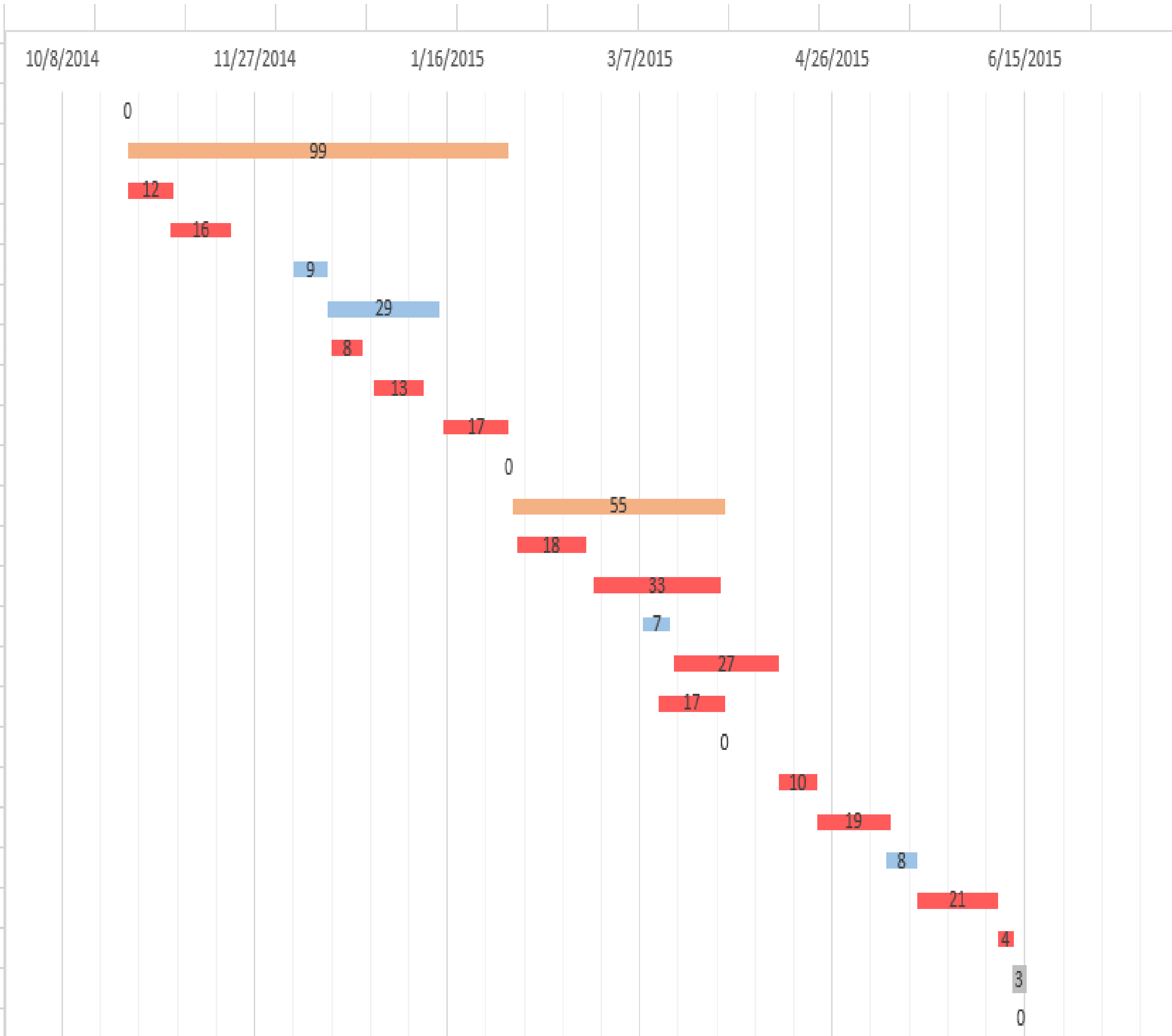
- In **April ‘15**, we will start full scale fabrication of the science vehicle; balloon testing from a height of 25m will be done 2 times to ensure everything is working properly. These tests will also include the SV camera. If any failures in balloon testing occur, it will lead us to make more improvements in our model and thus bring us closer to our success. The required changes will be incorporated immediately to the model and will be tested in the next balloon testing.

- In **May ‘15**, our **End semester exams** will start. By the end of May, our final model for the CanSat competition will be fabricated with precision.

- In **June ‘15**, other work like team T-shirts, team Banner and proper packaging of the CanSat will be done. And finally, on 11th June our team will depart for participating in the competition.

Program Schedule

1				
2	task name	start date	duration	finish date
3	Start of Project	10/25/2014	0	10/25/2014
4	Preliminary Design Phase	10/25/2014	99	1/31/2015
5	understanding the project	10/25/2014	12	11/5/2014
6	structure design	11/5/2014	16	11/20/2014
7	end semester examinations	12/7/2014	9	12/15/2014
8	end semester breaks	12/16/2014	29	1/13/2015
9	egg testing experiments	12/17/2014	8	12/24/2014
10	cad model designing	12/28/2014	13	1/10/2015
11	PDR assembly	1/15/2015	17	1/31/2015
12	PDR submission	2/1/2015	0	2/1/2015
13	Critical Design phase	2/2/2015	55	3/29/2015
14	final design improvement	2/3/2015	18	2/21/2015
15	Fabrication Begins	2/23/2015	33	3/25/2015
16	mid semester examinations	3/8/2015	7	3/15/2015
17	fabrications of final structure	3/16/2015	27	4/12/2015
18	CDR assembly	3/12/2015	17	3/28/2015
19	CDR submission	3/29/2015	0	3/29/2015
20	hardware integration	4/12/2015	10	4/21/2015
21	final testing	4/22/2015	19	5/10/2015
22	end semester examinations	5/10/2015	8	5/17/2015
23	missin planning	5/18/2015	21	6/7/2015
24	travel to texas	6/8/2015	4	6/11/2015
25	competition	6/12/2015	3	6/14/2015
26	PFR	6/14/2015	0	6/14/2015



Shipping and Transportation

Plans For Shipping / Transporting The Cansat Hardware

- We are planning to transport the CanSat hardware by air with us in June.
- We have decided to first dismantle everything into smaller subsystems and then pack each subsystem carefully, so that possibility of damage is minimized. At the launch site ,all the subsystems will be reassembled.
- We will inquire from and request airlines travelling to the States before booking our tickets about making special arrangements for our team since we will carry a lot of delicate components and quite a lot of electronics which might not be allowed under normal circumstances. We will prepare/show necessary documents if required.
- We will hire a mini-van for transporting our hardware from the airport to the hotel and from the hotel to the launch site. More than one van might be required.

Other Options For Shipping

- Water Transportation – It’s a good option and relatively inexpensive and less complicated but generally takes a lot of time .We will use this as our back up option and consider shipping by water if air shipping is not possible.

Shipping and Transportation

Carry-on Restrictions:

- There is a weight limit to the check in baggage in airlines. Materials exceeding the weight limit might not be allowed or extra fee may be required (depending on the airlines).
- Materials having large volumes might also not be allowed, so we are planning to dismantle the CanSat hardware into smaller subsystems for shipping.
- Transportation of sophisticated electronic components may not be allowed. We might need to obtain special permission from airline companies for carrying electronic components and other large parts.

Shipping Of Tools And Equipment

- Parts like antenna mast will be dismantled into smaller parts. All tools and equipment which might come in handy during reassembly will be carried. Special security permission might be needed for carrying some tools and equipment.
- All inquires will be made and all decisions regarding the mode of shipping will be finalized beforehand.

Conclusions

The Critical Design Phase is complete and now we are ready to begin with the final fabrication. All major decision points have been accomplished and a detailed list of the finished and unfinished tasks is given below:

- **MAJOR ACCOMPLISHMENTS:**
  - Physical design and material for CanSat body has been finalized.
  - Release mechanism has been finalized and tested.
  - Descent Control mechanism has been finalized and tested and is undergoing final fabrication.
  - Most of the electronic components have been purchased and tested.
  - Egg safety mechanism has been finalized and tested.
  - Programming and logic of the electronic circuits have been completed.

Conclusions

- **MAJOR UNFINISHED WORK:**
  - Flight software has been tested with two sensors. Integration of all sensors and their testing will be complete by the second week of April.
  - Mission Operations Manual building is underway and should be completed in less than a week.
- **TESTING TO COMPLETE:**
  - To ensure that the egg is saved, further, and more rigorous testing will be performed in this month.
  - Two more balloon tests are scheduled for the final model to ensure the survival and data transmission.
  - Flight software tests incorporating all sensors is yet to be done.
- **FLIGHT SOFTWARE STATUS:**
  - Data acquisition from two sensors has been tested with reset mechanism with two independent states namely, HIGH and LOW, using AtMega 328.
  - The ground station GUI has been developed and tested using two sensors. It will be completed by the mid of April.

Questions?

Thank You for your Attention.