CanSat 2015
Critical Design Review (CDR)

Team# 1001

Raven Knights

Presentation Outline

Section	Presenter
Systems Overview	Akshay Puli
Sensor Subsystem Design	Jonathan Goldnau-Vogt
Descent Control Design	Kyle Conway
Mechanical Subsystem Design	Kyle Conway
Communication and Data handling Subsystem Design	Jonathan Goldnau-Vogt
Electrical Power System Design	Jonathan Goldnau-Vogt
Flight Software Design	Jonathan Goldnau-Vogt
Ground Control System Design	Jonathan Goldnau-Vogt
CanSat Integration and Test	Kyle Conway
Mission Operations & Analysis	Akshay Puli
Requirement Compliance	Akshay Puli
Management	Akshay Puli

Team Organization

- **Akshay Puli** – 4th Year – Team Lead
  - **Kyle Conway** – 4th Year – Mechanical Design Lead
    - **Giuliana Velarde** – 3rd Year – Mechanical Design
    - **Graham Blackport** – 4th Year – Mechanical Design
    - **Bradley Kuiack** – 3rd Year – Mechanical Design
    - **Aman Sunesara** – 3rd Year – Mechanical Design
  - **Jonathan Goldnau-Vogt** – 2nd Year – Electrical Systems Lead
    - **Alok Deshpande** – 3rd Year – Electrical Design
    - **Erik Johnson** – 3rd Year – Software Design
    - **Maytham Sabbagh** – 3rd Year – Software Design

Faculty Advisor
Steve Ulrich

Acronyms

Acronym	Meaning
A	**A**nalysis
ACK	**Ack**nowledgement
ADC	**A**nalog-to-**D**igital **C**onverter
ALT	**Alt**itude
API	**A**pplication **P**rogram **I**nterface
ASC	**ASC**ent FSW state
AT	**At**tention
BIN	**Bin**ary file
CanSat	**Can**-sized **Sat**ellite
CMOS	**C**omplementary **M**etal **O**xide **S**emiconductor
CSV	**C**omma **S**eparated **V**alues
CURC	**C**arleton **U**niversity **R**obotics **C**lub
CONOPS	**Con**cept **o**f **Op**eration**s**
D	**D**emonstration
dBi	**D**ecibel (**I**sotrophic)
DSP	**D**igital **S**ignal **P**rocessing
EEPROM	**E**lectrically **E**rasable **P**rogrammable **R**ead-**O**nly **M**emory
FAT	File Allocation Table
FIFO	First In, First Out
FSW	**F**light **S**oft**w**are
FTDI	**F**uture **T**echnologies **D**evice **I**nternational
G	**G**-force
GCS	**G**round **C**ontrol **S**ystem
GPRMC	Recommended Minimum Specific GPS/Transit Data
GPS	**G**lobal **P**ositioning **S**ystem
GS	**G**round **S**tation
GUI	**G**raphical **U**ser **I**nterface
I	**I**nspection
I/O	**I**nput/**O**utput

Acronyms

Acronym	Meaning
I2C	**I**nter-**I**ntegrated **C**ircuit
ID	**Id**entifier
ISR	**I**nterrupt **S**ervice **R**outine
JPEG	**J**oint **P**hotographic **E**xperts **G**roup
LAT	**Lat**itude
LED	**L**ight **E**mitting **D**iode
LONG	**Long**itude
LNC	**L**au**NC**h FSW state
LND	**L**a**ND**ed FSW state
MCU	**M**icro**c**ontroller **U**nit
MUX	**Mu**ltiple**x**er
NiMH	**Ni**ckel **M**etal **H**ydride
NMEA	**N**ational **M**arine **E**lectronics **A**ssociation
NTSC	**N**ational **T**elevision **S**ystem **C**ommission
PANID	**P**revious **A**ccess **N**etwork **Id**entifier
PC	**P**ersonal **C**omputer
PCB	**P**rinted **C**ircuit **B**oard
PDR	**P**reliminary **D**esign **R**eview
PDS	**P**re-**D**eployment of **S**cience Vehicle FSW state
PID	Proportional Integral Derivative
PWM	**P**ulse-**W**idth **M**odulation
RC	**R**adio **C**ontrolled
RSSI	**R**eceived **S**ignal **S**trength **I**ndication
SD	**S**ecure **D**igital
SMA	**S**ub **M**iniature Version **A**
SPI	**S**erial **P**eripheral **I**nterface
SVD	**S**cience **V**ehicle **D**escent FSW state
T	**T**est
TST	**T**e**ST**ing FSW state
TTL	**T**ransistor-**T**ransistor **L**ogic

Acronyms

Acronym	Meaning
UART	**U**niversal **A**synchronous **R**eceiver/**T**ransmitter
USART	**U**niversal **S**ynchronous-**A**synchronous **R**eceiver/**T**ransmitter
USB	**U**niversal **S**erial **B**us
UTC	**C**oordinated **U**niversal **T**ime
VM	**V**erification **M**ethod

System Overview

Akshay Puli

Mission Summary

Mission

- The main mission for 2015 CanSat is to launch a science vehicle that will return to earth safely using a passive auto-gyro mechanism

Objectives

- Design lightweight and durable blades to provide sufficient lift during auto-gyro descent
- Deploy payload at 500m to ensure sufficient descent time
- Control the descent of the container and payload to altitude-defined speeds
- Stabilize on-board camera during descent
- Transmit telemetry from CanSat to ground station
- Avoid damage to the egg during the mission

Mission Summary

Bonus Objective:

- Using 3-axis accelerometer
  - The accelerometer provides critical data needed for the on-board system to stabilize the CanSat and thus the camera module

Managerial objectives:

- Obtain funding for the project including a travel budget for all team members to attend the competition
- Promote the CanSat project at Carleton and around Ottawa
- Perform extensive wind-tunnel testing to ensure adequate functionality of the descent mechanism
- Complete and test the final product by early May
- Perform a simulated run of CanSat preparation for launch

Summary of Changes Since PDR

Subsystem	Component	Design at PDR	Design at CDR	Reason for change
Descent Control	**Rotor blades**	Wire blades	Foam blades	Foam blades are lighter and actually produce lift, slowing the descent more than wire blades
Descent Control	**Rotor Hub**	No angle of attack for blades set	Angle of attack set to 2.5 degrees	Further wind tunnel testing showed that the rotor blades provided the most lift at an angle of attack of 2.5 degrees
Descent Control	**Rotor Hinge**	Hinge not designed to open to a specific angle	Hinge redesigned to open blades to 0 degree dihedral angle	The previous hinges did not constrain the dihedral angle for the blades
Mechanical	**Egg protection**	Spray foam insulation	Off the shelf urethane egg protector	More reliable and easier to work with
CDH	**RTC**	DS1338	DS1307	Same interface, same features and was available on campus from previous years
Electrical Power	**Capacitor in battery protection circuit**	Not present in circuit	Added to circuit	The added capacitor prevents overcurrent protection during release mechanism operation.
Electrical Power	**Release mechanism circuit**	2 release mechanism circuits in design	3 release mechanism circuits in design	The extra release mechanism was added just in case.
GCS	**Antenna**	RF Solutions Yagi Antenna	Custom built patch antenna	Cheaper and easier to acquire and transport.

System Requirement Summary

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SYS-01	Total mass of the CanSat (Container and Science Vehicle) shall be 600 grams +/- 10 grams.	Competition Requirement	High		MEC-08, MEC-09	X	X	X	
SYS-02	The Science Vehicle shall be completely contained in the Container	Competition Requirement	High		MEC-01	X			
SYS-03	The Container shall fit in the envelope of 125 mm x 310 mm including the Container passive descent control system	Competition Requirement	High		MEC-10	X			
SYS-04	The Container and Science Vehicle shall use a passive descent control system	Competition Requirement	High		DCS-01 DCS-02	X	X	X	
SYS-05	The CanSat (Container and Science Vehicle) shall deploy from the rocket payload section	Competition Requirement	High		FSW-01	X			
SYS-06	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.	Competition Requirement	High		FSW-02 SEN-7	X	X		X
SYS-07	The Science Vehicle shall use a auto-gyro descent mechanism	Competition Requirement	High		MEC-05	X			
SYS-08	All descent control device attachment components shall survive 50 Gs of shock	Competition Requirement	High		DCS-03 DCS-04			X	
SYS-09	All structures shall survive 50Gs of shock and 15Gs of acceleration	Competition Requirement	High					X	
SYS-10	During descent, the Science Vehicle shall collect and telemeter air pressure (for altitude determination), outside and inside air temperature, flight software state, battery voltage, and bonus objective data (accelerometer data and/or rotor rate).	Competition Requirement	High		FSW-02 SEN-1 EPS-01 CDH-01	X			X
SYS-11	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.	Competition Requirement	High		CDH-04 CDH-02 CDH-05 FSW-03	X	X		

System Requirement Summary

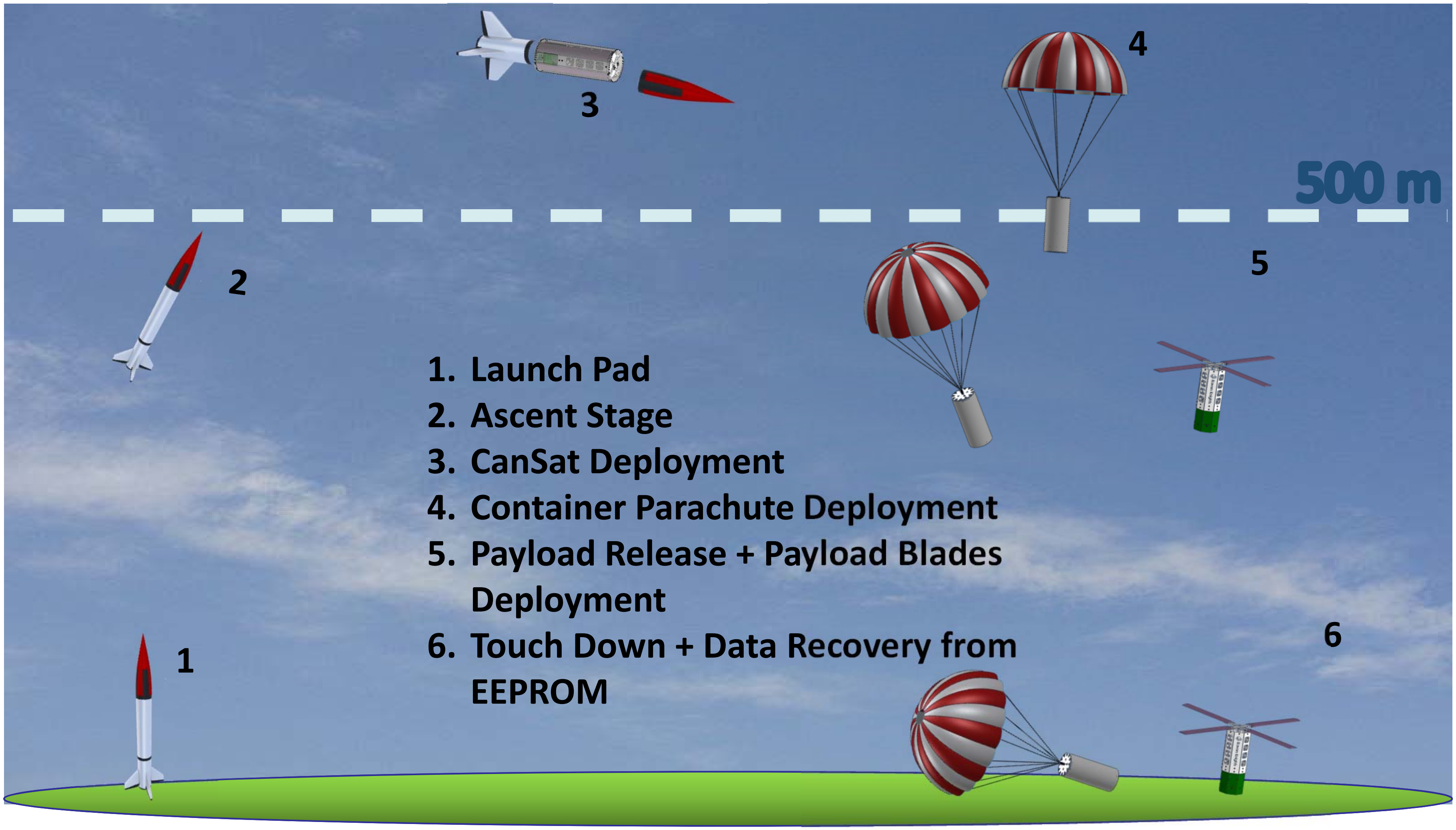
ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SYS-12	XBEE radios shall not use broadcast mode.	Competition Requirement	High		CDH-06	X		X	
SYS-13	The Science Vehicle shall have a video camera installed and recording the complete descent from deployment to landing. The video recording can start at any time and must support up to one hour of recording.	Competition Requirement	High		SEN-08	X		X	X
SYS-14	The descent rate of the Science Vehicle shall be less than 10 meters/second and greater than 4 meters/second.	Competition Requirement	High		MEC-06	X	X	X	
SYS-15	Cost of the CanSat shall be under $1000	Competition Requirement	High			X			X
SYS-16	Each team shall develop their own ground station	Competition Requirement	High		GCS-01 GCS-02 GCS-03 GCS-04		X		X
SYS-17	The Science Vehicle shall hold one large raw hen's egg which shall survive launch, deployment and landing.	Competition Requirement	High			X	X		
SYS-18	The CanSat flight software shall maintain its operating state even with a processor reset	Competition Requirement	High		FSW-07	X		X	X
SYS-19	The Science Vehicle and Container must be subjected to Environmental Testing Requirements document	Competition Requirement	High					X	

System Concept of Operations

Pre Launch Responsibilities:

- **Mission Control Officer**
  – Obtain egg and rocket from CanSat Officials
- **CanSat Crew**
  – Place egg in CanSat and CanSat in rocket
  – Power on CanSat
- **Ground Station Crew**
  – Check radio link
  – Begin monitoring ground station
- **Recovery Crew**
  – Take positions

System Concept of Operations

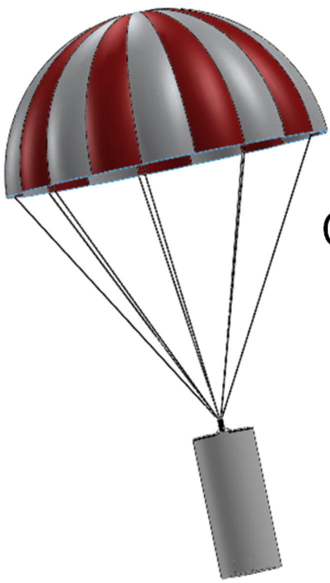


1. Launch Pad
2. Ascent Stage
3. CanSat Deployment
4. Container Parachute Deployment
5. Payload Release + Payload Blades Deployment
6. Touch Down + Data Recovery from EEPROM

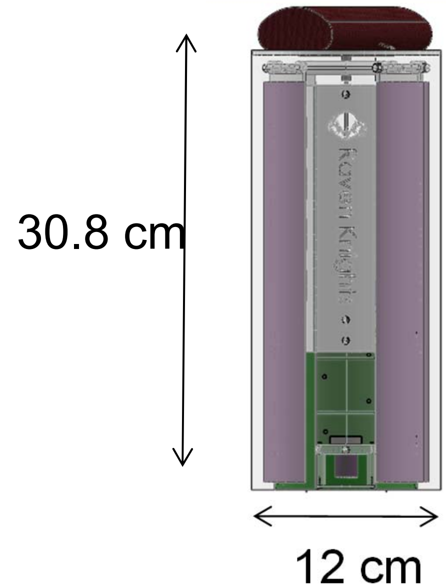
Post Launch Responsibilities:

- **Recovery Crew**
  - Retrieve Payload and Container after landing
  - Confirm status of egg with judges
  - Return Payload to Ground Station
- **Ground Station Crew**
  - Retrieve data from EEPROM
  - Give raw data to judges
- **All team members**
  - Prepare and analyze data for Post Flight Review

Physical Layout



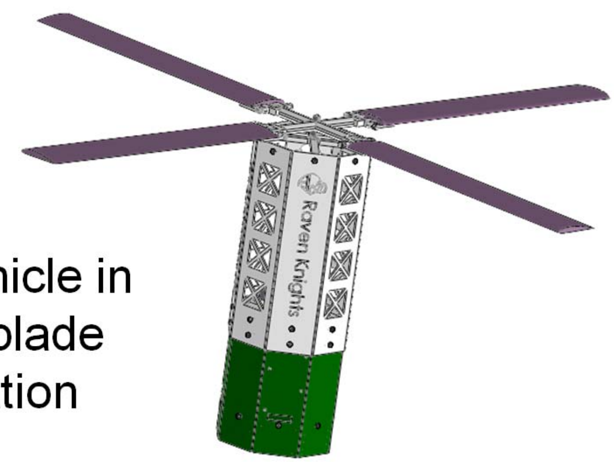
Container with parachute



Science vehicle with folded blades inside container, folded parachute on top

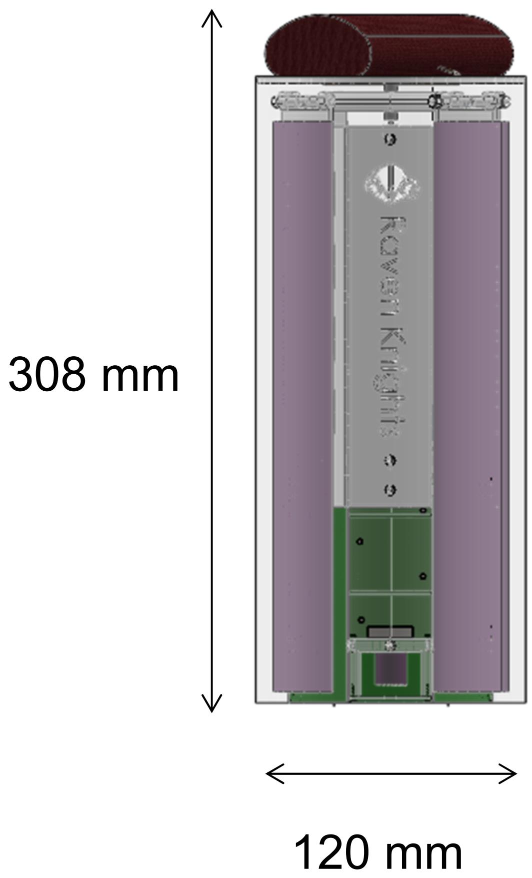
Science vehicle in folded blade configuration

Science vehicle in deployed blade configuration



Launch Vehicle Compatibility

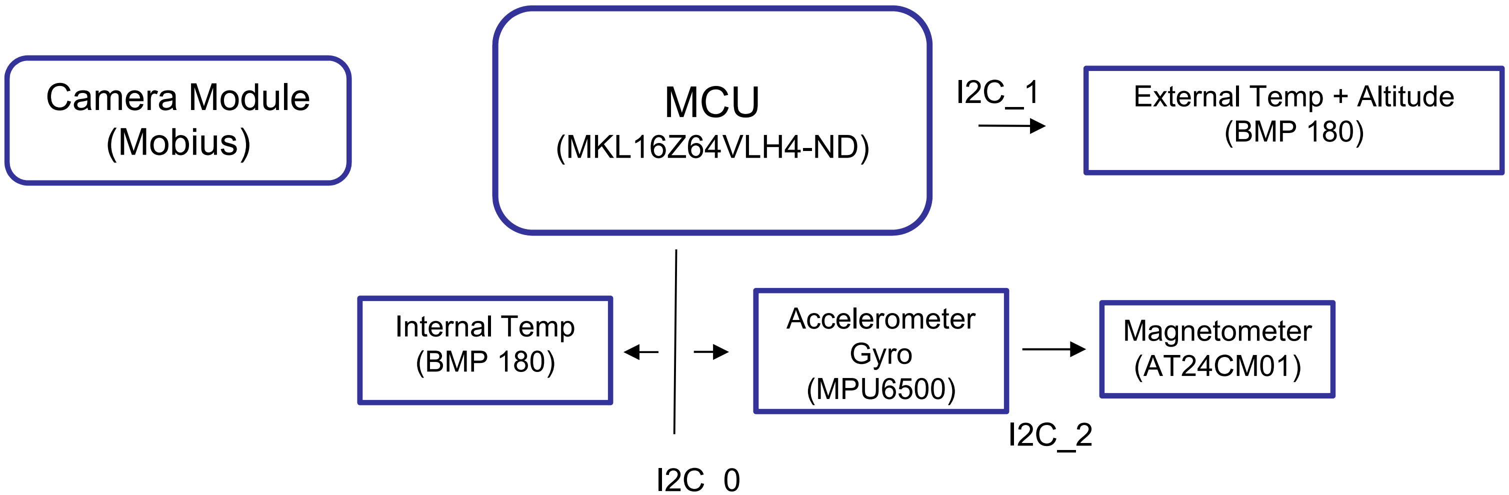
- The science vehicle and its auto-gyro descent mechanism fit inside the container as shown in the diagram
  - The autogyro blades fold between the outside of the science vehicle and the inside of the container
  - Based on measurements of the current prototype, the container has 5 mm diameter clearance and 2 mm vertical clearance in the rocket payload section
  - Rocket payload section compatibility will be verified by ensuring entire CanSat is smaller than given dimensions for rocket payload



Sensor Subsystem Design

Maytham Sabbagh

Sensor Subsystem Overview



- Camera Module: Used for recording the descent
- Internal Temp (BMP180): Used to record the internal temperature of the science vehicle
- External Temp + Altitude (BMP180): Used to record the external temperature and the pressure which is used for altitude calculations
- Accelerometer + Gyro (MPU6500): Used for the bonus flight objective
- Magnetometer (AT24CM01): Used for the stabilization of the science vehicle (which will allow for a stabilized video)

Sensor Changes Since PDR

– No changes made to sensor system design since PDR

Sensor Subsystem Requirements

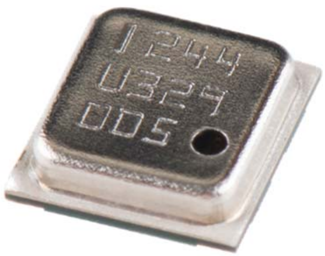
ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SEN-1	During descent, the Science Vehicle shall collect and telemeter air pressure (for altitude determination), outside and inside air temperature, flight software state, battery voltage, and bonus objective data (accelerometer data and/or rotor rate).	Competition Requirement	High	SYS-10		X			x
SEN-2	The sensors must be I2C compatible for the ease of using one protocol	Optional Requirement	Medium			X	X		X
SEN-3	The container and payload shall maintain a mission time	Competition Requirement	Medium			X			X
SEN-4	The container shall acknowledge the deployment of the payload	Optional Requirement	Low			X		X	X
SEN-5	The payload shall include an external umbilical power connection to allow for testing and safety checks when not harvesting energy.	Competition Requirement	Medium				X		
SEN-6	The Container shall descend at 12 m/s after release	Competition Requirement	High			X			X
SEN-7	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.	Competition Requirement	High	SYS-06		X	X		X

Sensor Subsystem Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SEN-8	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.	Competition Requirement	High	SYS-13		X		X	X

Altitude Sensor Summary

Bosch BMP180



- I^2C interface simplifies flight software design
- Temperature sensor included
- Acceptable range, resolution and accuracy to take good samples
- Easily obtainable

Specifications:

- Range: 300 – 1100 hPa
- Resolution: 0.01 hPa
- Accuracy: +/- 3 hPa
- Interface: I^2C

Data Processing:

- The pressure values will be sampled and the altitude conversion will be done by the FSW.
- Altitude calibration are based on the pressure data and the base altitude of the Launchpad before the mission.
- Altitude will be transmitted to GS in 16 bit signed integer format

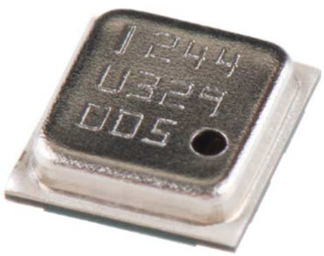
$$Altitude\ (m) = 44330 * \left(1 - \left(\frac{p}{p_o}\right)^{\frac{1}{5.255}}\right) \qquad p_0 = \frac{p}{\left(1 - \left(\frac{altitude}{44330}\right)\right)^{5.255}}$$

where p_o = pressure (hPa) at sea level, p = measured pressure (hPa)

$$Relative\ Altitude\ (m) = Abs.Altitude\ (m) - Base\ Altitude\ (m)$$

Air Temperature Sensor Summary

Bosch BMP180



- I^2C Interface simplifies flight software design
- Pressure sensor bundle allows for better system integration
- Acceptable range, resolution and accuracy to take good samples

Specifications:

- Range: -40 - +80 °C
- Resolution: 0.1 °C
- Accuracy: +/- 2 °C
- Interface: I^2C

Data Processing:

- The temperature samples are sampled and then transmitted to GS in 16 bit signed integer format
- Samples are converted to Celsius scale by the FSW software based on equations from the datasheet and calibration data.

Camera Summary

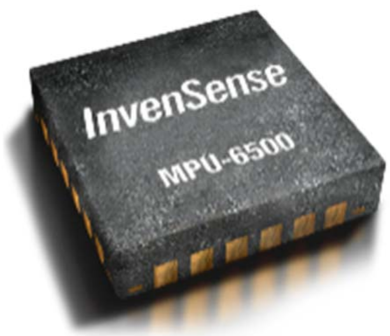
Mobius Camera with camera extension cable

- Camera module extension cable allows for flexible placement
- High resolution and framerate is a bonus for post-flight analysis of mission
- Camera powered from main Li-Ion flight battery
- Camera buttons and status lights modified to be accessible from outside of CanSat

Weight	Timestamp	Resolution (px)	Frames/Second	Extra Features
38 g	Yes	1080x1920 720x1280 320x480	30 60 60	Resolution, bitrate, field of view settings. Camera extension cable available

3-Axis Accelerometer Sensor Summary

MPU-6500



- Large sensitivity range convenient for measuring launch and parachute deployment acceleration
- I^2C interface simplifies interface with microcontroller
- Pin-compatible with MPU-9250 which includes a compass as well
- Programmable to have a compass (magnetometer) connected through it

Accelerometer accuracy	Accelerometer sensitivity range	Interface	Extra Features
±3%	±2 to ±16 g	I^2C	Gyro built in MPU-9250 pin compatible

Descent Control Design

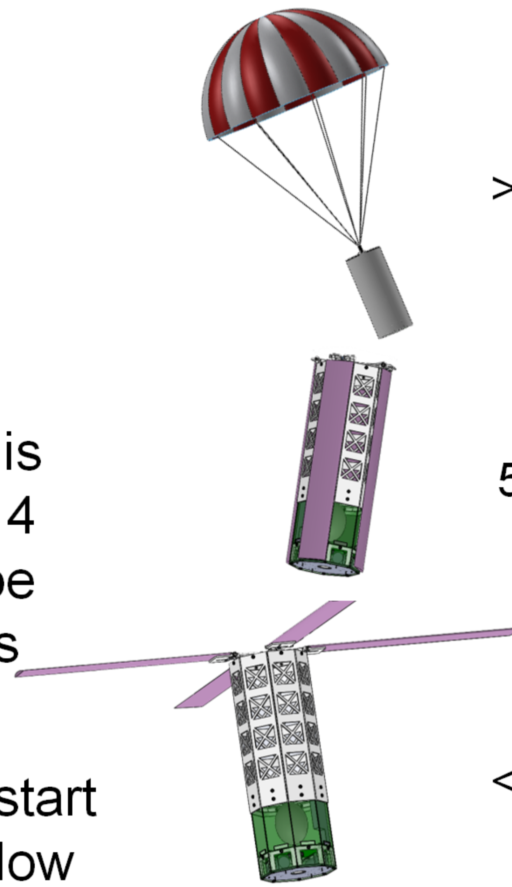
Kyle Conway

Descent Control Overview

- The descent of the container is controlled with a parachute.
- Once the payload is released, rotor blades slow the descent of the science vehicle

Outline

1. When the CanSat is dropped, the parachute will open
2. At an altitude of 500 m, the payload is released from the container and the 4 blades, initially folded inwards, will be deployed using spring-loaded hinges
3. As the payload falls, the blades will start rotating resulting in lift and drag to slow down its descent



>500 m

500 m

<500 m

Descent Control Changes Since PDR

Component	Design at PDR	Design at CDR	Reason for change
Rotor blades	Wire blades	Foam blades	Foam blades are lighter and actually produce lift, slowing the descent more than wire blades
Rotor Hub	No angle of attack for blades set	Angle of attack set to 2.5 degrees	Further wind tunnel testing showed that the rotor blades provided the most lift at an angle of attack of 2.5 degrees
Rotor Hinge	Hinge not designed to open to a specific angle	Hinge redesigned to open blades to 0 degree dihedral angle	The previous hinges did not constrain the dihedral angle for the blades

Descent Control Requirements

ID	Requirement	Rationale	Priority	Parent	Children	VM			
						A	I	T	D
DCS-01	The containers shall use a passive descent control system. It cannot free fall. A parachute is allowed and highly recommended. Included a spill hole to reduce swaying	Mission requirement	High	SYS-04		X		X	X
DCS-02	The Science Vehicle shall use a helicopter recovery system, The blades must rotate. No fabric or other materials are allowed between the blades.	Mission requirement	High	SYS-04			X	X	X
DCS-03	All descent control device attachments shall survive 50 Gs of shock	Hardware requirement	High	SYS-08			X	X	X
DCS-04	All descent control devices shall survive 50 Gs of shock	Hardware requirement	High	SYS-08			X	X	X
DCS-05	The descent rate of the Science Vehicle shall be less than 10 meter/second and greater than 4 meter/second	Mission requirement	High	SYS-14		X		X	X
DCS-06	The container shall feature fluorescent colours	Mission requirement	Medium				X		X
DCS-07	The descending mechanism must not use flammable materials	Hardware requirement	Low			X			
DCS-08	The Nichrome wire shall release the payload from the CanSat container	Mission requirement	High		FSW-01	X	X	X	X

Container Descent Control Hardware Summary

Descent Control Component	Material	Colour Selection	Component Sizing	Shock Force Survivability
Parachute	The parachute is made of 1.1oz rip stop nylon. It features 8 gores, and a reinforced spill hole.	Red and White	15’’ diameter	The purchased parachute is designed for high power rockets, and therefore designed to survive shock.
Cords	The cords are 330lb braided nylon shroud lines, connected to a 3/8’’ tubular nylon bridle and protected by heat shrink tube. The nylon bridle is attached to a barrel swivel.	The small size of these components render colour selection unimportant due to low visibility regardless of colour.	17’’ length shroud lines, nylon bridle and barrel swivel sized for appropriate use of parachute as specified by manufacturer	The shroud lines, bridle and barrel swivel are included in the parachute purchase, they are also designed for high power rockets.
Attachment	Nylon parachute cord will be looped through the eye of the parachute’s barrel swivel, looped through holes on the top of the container, then tied with a secure knot such as a Zeppelin’s Bend.	The placement (top of the container) of this component renders colour selection unimportant due to low visibility.	1/8” diameter nylon parachute cord	The parachute cord due to its high tensile strength under shock will be sufficient for the shock forces experienced.

Preflight Review Testability:

The CanSat will be tested through a drop test, following the specifications and requirements as outlined in the CanSat 2015 Environmental Testing Requirements document. The CanSat will be fully functional and conform to all size and mass restrictions for the preflight review.

Key Design Considerations:

The purchased parachute features a spill hole, desired in order to reduce sway of the container. It’s smaller size (15’’ diameter) was chosen to minimize drifting. The attachment point of the shroud lines to the parachute are reinforced with nylon ribbing, additionally the attachment seams are sewn twice to further reinforced the shroud line and parachute attachment points. To prevent parachute twisting, the chosen parachute features a barrel swivel.

Payload Descent Control Hardware Summary

Descent Control Component	Material	Colour Selection	Design Considerations	Component Sizing
Blades	Polystyrene foam	Pink	Polystyrene foam was chosen for its manufacturability and weight	Blade length of 255 mm. Constrained by height of science vehicle and space in container
Hub and Brackets	ABS plastic and stainless steel torsion springs	The placement (inside of science vehicle) of these components renders colour selection unimportant due to low visibility.	The hub was designed to allow the blades to fold into the container	Inner diameter of springs must be larger than 4.3 mm so that bolts can fit through them. Edges of hub have been designed to have a minimum 2 mm clearance from the side of the container
Shaft and Bearing	Stainless Steel	The placement (inside and on top of science vehicle) of these components renders colour selection unimportant due to low visibility.	The shaft and bearing were chosen to minimize weight	Bearing is 2 mm inner diameter with a 6 mm outer flange. It fits into a 3d printed support bracket. A 2 mm diameter shaft fits through the bearing.
Release Mechanism	Nickel-Chromium Wire and Fishing line	The placement (inside of science vehicle) of this component renders colour selection unimportant due to low visibility.	Fishing line must be strong enough to withstand shock of deployment.	40 lb fishing line

Active Components:
The nichrome wire burning is activated by data collected from the Bosch BMP180 altitude sensor. The accuracy of this sensor is +/- 3 hPa. It sends data in the ground station in a 16 bit signed integer format. Pressure values are sampled, altitude conversion is completed by the flight software. The calibration is done with pressure data and base altitude of the Launchpad. Once the container reaches an altitude of 500m, current is put through the nichrome wire, burning through the fishing line and releasing the blades.

Descent Rate Estimates

Descent rates calculated using terminal velocity equation

$$v = \sqrt{\frac{2mg}{\rho A C_D}}$$

$g = 9.81\ m/s^2$

$\rho = 1.205\ kg/m^3$

Assuming friction drag is negligible compared to pressure drag

Container + Science Vehicle:

- Drag coefficient of dome parachute is 1.5
- Area of 0.073 m^2
- Mass of 660 g (CanSat + egg)
- Predicted descent rate: 9.9 m/s

Descent Rate Estimates

Science Vehicle:

- Calculations done with drag and lift combined since they act in the same direction
- Drag/Lift coefficient experimentally determined as 6
- Area of 0.059 m^2
- Mass of 537 g
- Predicted descent rate: 5 m/s

Container:

- Drag coefficient of dome parachute is 1.5
- Area of 0.073 m^2
- Mass of 123 g
- Predicted descent rate: 4.75 m/s

Mechanical Subsystem Design

Kyle Conway

Mechanical Subsystem Overview

Category	Components	Material	Usage
Container	Cylindrical plastic casing	HDPE Sheet	Protects science vehicle
Science Vehicle – Container interface	Fishing line	Nylon	Fishing line secures the science vehicle to the inside of the container
Release Mechanism	Nichrome wire	Nichrome	Nichrome wire is used to burn through the fishing line, separating the science vehicle from the container
Container Descent Control	Parachute	Rip stop Nylon	Used to control the descent of the container
Science Vehicle Descent Control	Auto-gyro blades Hinges	Aluminum wire with packing tape covering ABS plastic hinges	Blades are folded in container and then released using nichrome wire and fishing line; rotating blades are used to slow the descent of the science vehicle
Science Vehicle	Support structure PCB structure	Acrylic with ABS plastic brackets FR-4 Fiberglass	Encloses and protects egg and electrical components
Egg Protection	Foam egg protector	Urethane foam	Protects the egg from impact forces

Mechanical Subsystem Changes Since PDR

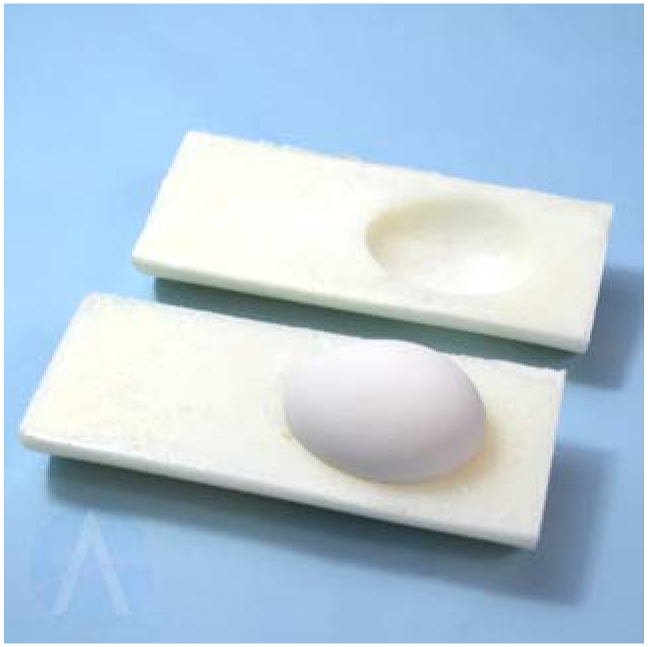
Component	Design at PDR	Design at CDR	Reason for change
Egg protection	Spray foam insulation	Off the shelf urethane egg protector	More reliable and easier to work with

Mechanical Sub-System Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
MEC-01	The casing shall protect internal components	Hardware requirement	High	SYS-02	MEC-03		X		X
MEC-02	The materials selection shall minimize cost, volume, and weight	Mission requirement	Medium			X			X
MEC-03	The casing shall protect internal components successfully, while having minimal weight and size	Hardware requirement	Medium	MEC-01		X	X		X
MEC-04	The electronics components shall be easily accessed	Human Interface requirement	Medium				X		X
MEC-05	Descent mechanism shall control descent speed	Mission requirement	High	SYS-07		X	X	X	X
MEC-06	The structure shall protect the egg on impact at up to 10 m/s	Hardware requirement	Medium	SYS-14		X	X	X	X
MEC-07	The separation mechanism shall separate both modules reliably within 2 seconds	Hardware requirement	High		FSW-01 EPS-02 EPS-03	X	X	X	
MEC-08	The CanSat shall weigh more than 590g	Mission requirement	Medium	SYS-01		X	X		X
MEC-09	The CanSat shall weigh less than 610g	Mission requirement	Medium	SYS-01		X	X		X
MEC-10	The CanSat shall measure no more than 120 mm diameter and 310 mm length	Hardware requirement	High	SYS-03			X		X
MEC-11	The protection system shall allow easy access to the egg	Human interface requirement	Low				X		X
MEC-12	The attach points shall support a load 30 times the CanSat weight	Hardware requirement	High			X	X	X	X

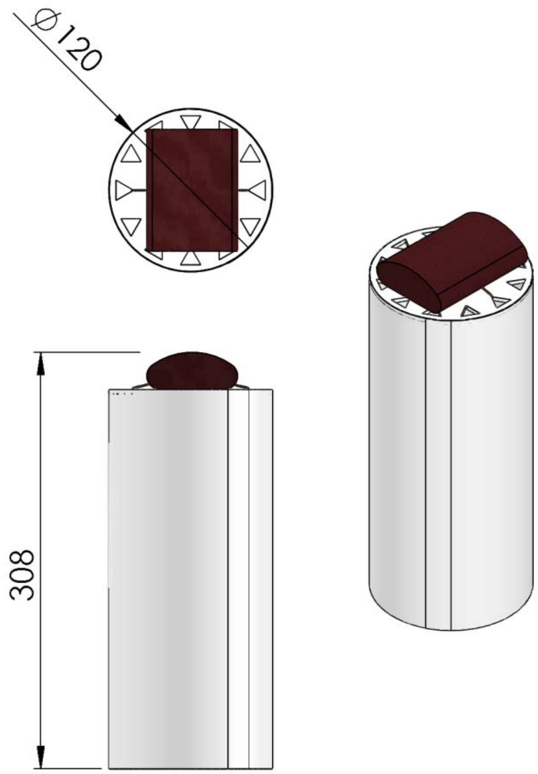
Egg Protection Overview

- **The egg protection is a molded flexible urethane foam protector**
- **Fits snuggly around egg to distribute pressure evenly**
- **Off the shelf egg protector is well tested and proven to work**
- **The two half cylinders make inserting the egg easy on launch day**

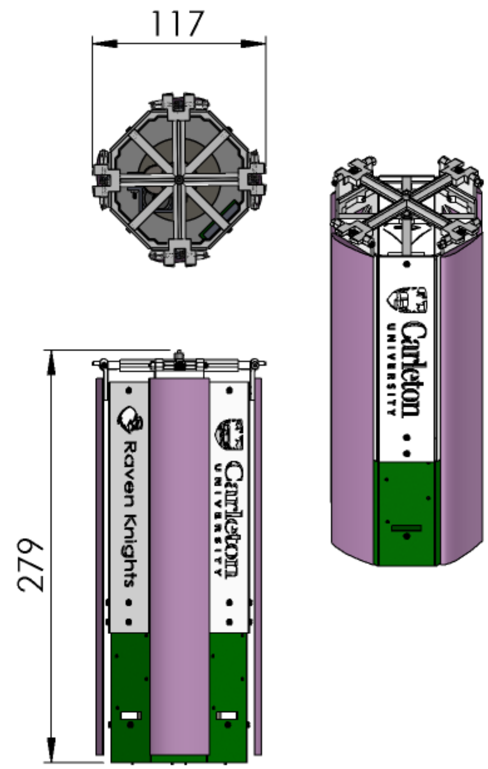


Reference:
https://www.apogeerockets.com/Building_Supplies/Payload_Protection/Vertical_Egg_Protector_BT-70_size

Mechanical Layout of Components

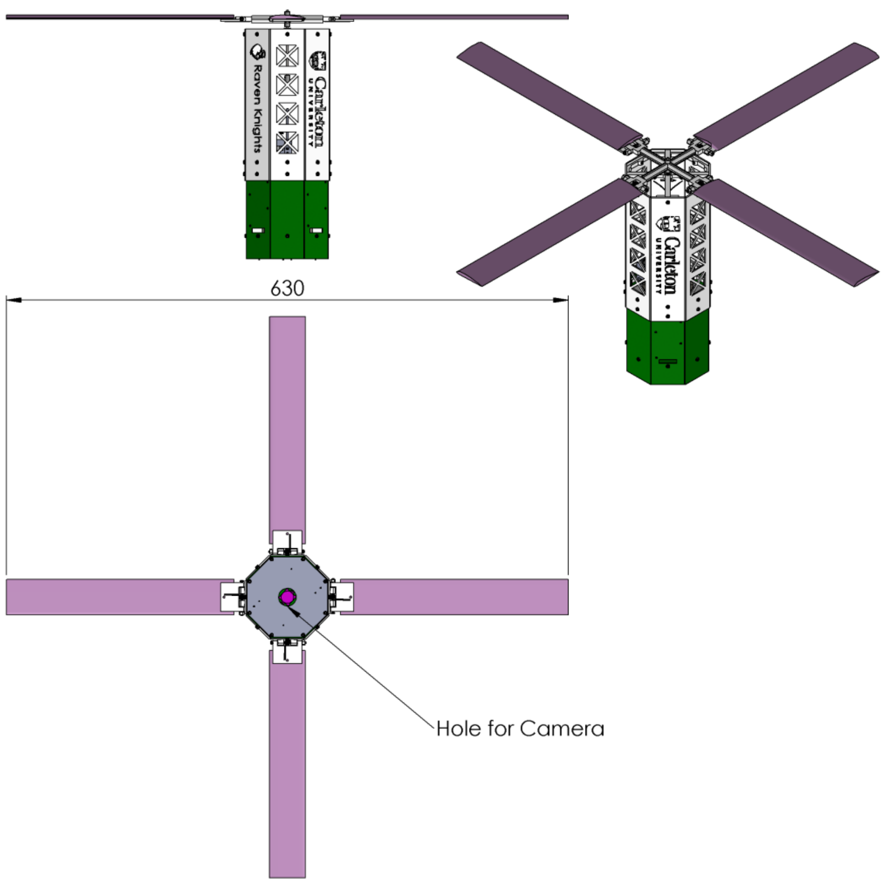


Container with Folded Parachute

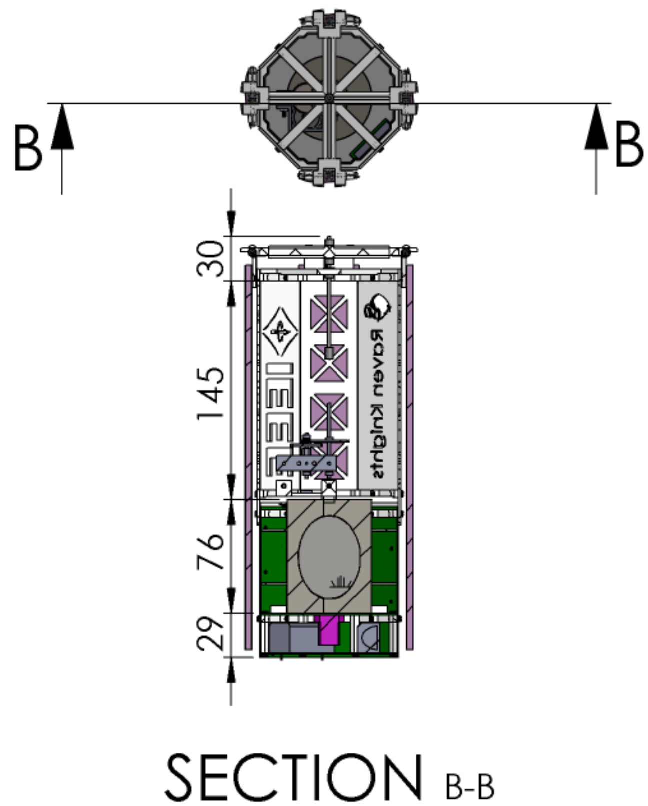


Science Vehicle with Blades Folded

Mechanical Layout of Components

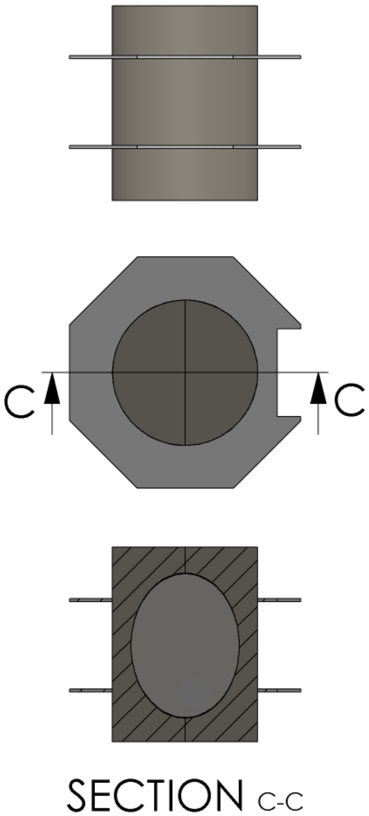


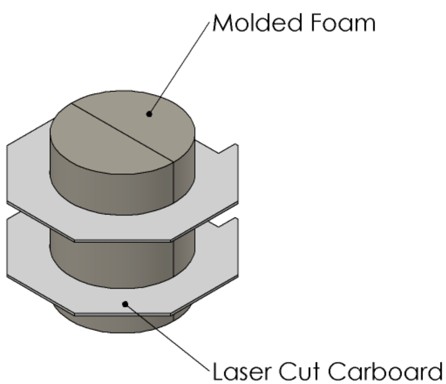
Science Vehicle with Blades Unfolded



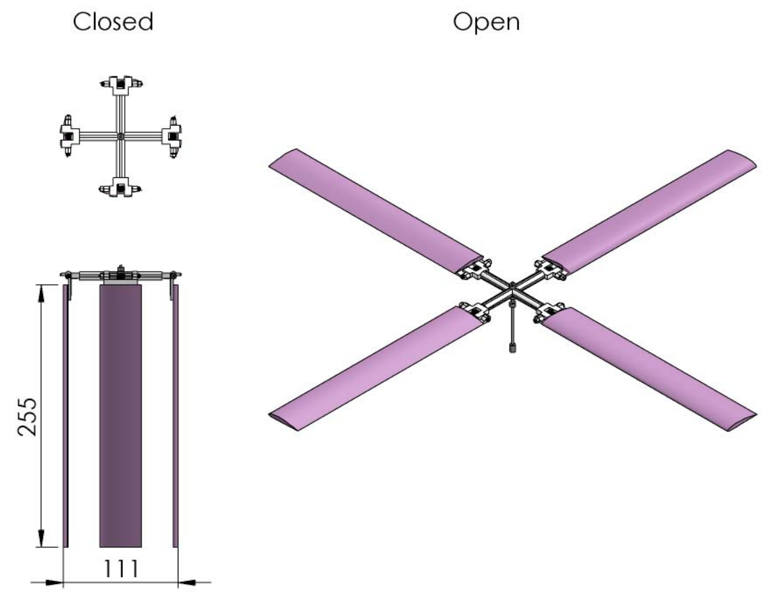
Science Vehicle Cross-Section

Mechanical Layout of Components





Egg Support Assembly



Hub, Hinge, and Blade Assembly

Material Selections

- **Descent control mechanism release**: Fishing line and Nichrome wire due to strength and the fact that the fishing line melts at low temperature making it easy to cut with Nichrome wire

- **Auto-gyro Deployment Hinge**: ABS due to light weight and unique geometry of part making 3D printing the most cost efficient option

- **Auto-gyro Blades:** Light weight foam wrapped with plastic sheeting to increase strength

Material Selections

- **Science Vehicle Exterior:** PCB on the bottom half due to strength, rigidity and ease of mounting electrical components both inside and outside the science vehicle. Acrylic on the top half, laser cut to remove material and reduce weight. The team contact information will also be laser cut into the acrylic.

- **Container:** Top is made of acrylic which is available in thin sheets that can be laser cut. Acrylic is both strong and light. The team contact information will be laser cut into the acrylic

- **Parachute:** Made of lightweight rip stop nylon as per the CanSat construction guide.

Container - Payload Interface

- **Science vehicle is affixed to the inside of the container using fishing line with auto-gyro blades folded in the "storage position"**
  - Auto-gyro blades are held down using separate fishing line

- **Science vehicle and container are separated by using Nichrome wire to melt fishing line connecting the top bracket of the payload to the holes in the top of the container**
  - When the science vehicle descent mechanism is activated, the auto-gyro blades are released by melting the second fishing line using Nichrome wire

Structure Survivability

Structure Survivability	Criteria			
	Mass	**Strength**	**Construction**	**Mounting**
PCB External Structure (FR4)	Light weight	Fiber Glass is a high strength material that can with stand 30g of shock	Fabrication of specific shapes and ease of repeatability	Planes attached to 3D Printed skeleton using screws
Electronics Components	Very light weight	N/A	N/A	All components are soldered onto the PCB boards. Large components have additional support using zip ties.
Plastic External Structure		Strong structural strength, allows for use of thin material	Laser cutting the material allows for fast construction and ease of repeatability	Laser cut holes allow for mounting of material to 3D printed skeleton using screws
ABS Plastic for 3D printing	Light weight	Use of industrial 3D printers to ensure high strength parts	Ease of constricting variety of specialized parts e.g. hinges for blades and skeleton structure	Screw mounts incorporated into the structure allows for attachment of other parts
Epoxy	Negligible	High strength adhesive	Used to attach different materials e.g. 3D printed hinges to the rotary blades.	N/A

The CanSat has been designed to be light weight and durable. To achieve this different material and fabrication processes were used e.g. 3D printed parts, laser-cut plastics, PCB panels etc.

Mass Budget

Payload:

Component	Mass [g]	Source	Tolerance [g]
Descent Mechanism Deployment System	5	Estimated	3
Egg	60	Estimated	N/A
Structure (including brackets, fasteners,	182	Measured	10
Molded Foam	11	Measured	1
Electrical Components and PCB (excluding structural PCB)	20	Estimated	10
Battery x2	16	DS	5
Camera	30	Measured	5
Motor Assembly (including gears)	30	Measured	1
Hub Assembly (including 4 autogyro blades, hub, hinges, bearings, shaft, shaft collar, shaft coupler)	52	Measured	5
Ballast	131	Arithmetic	N/A
Totals	537		

Mass Budget

Container:

Component	Total Mass [g]	Source	Tolerance [g]
Parachute	43	Measured	1
Structure	80	Measured	1
Total	123		

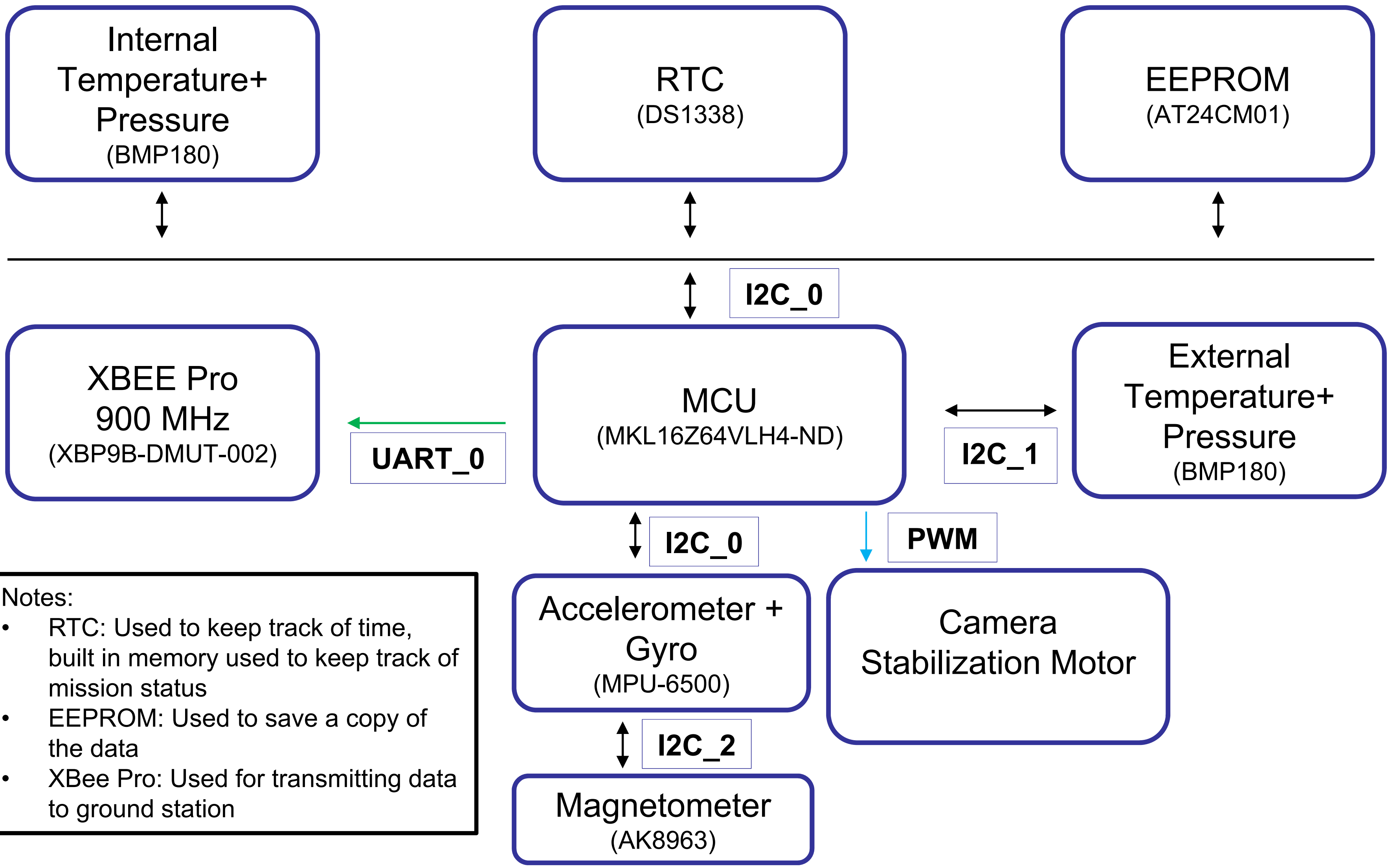
Structure	Mass [g]
Payload	537
Container	123
CanSat (including egg)	660
CanSat (no egg)	600

Note: Still within mission requirements with a margin of +/- 10g, this will be maintained by adjusting the ballast for any possible changes.

Communication and Data Handling Subsystem Design

Alok Deshpande

CDH Overview



Notes:
- RTC: Used to keep track of time, built in memory used to keep track of mission status
- EEPROM: Used to save a copy of the data
- XBee Pro: Used for transmitting data to ground station

CDH Changes Since PDR

Component	Used in PDR	Selected at CDR	Reason for change
RTC	DS1338	DS1307	Easier to obtain. Same interface, same features and was available on campus from previous years.

CDH Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
CDH-01	Science Vehicle shall collect and telemeter air pressure, outside and inside air temperature, flight software state, battery voltage and bonus objective data during the descent state	Telemetry collection and transmission required by the competition	High	SYS-10	FSW-02		X	X	
CDH-02	Science Vehicle shall transmit telemetry at 1 Hz rate	Transmission rate required by the competition	High	SYS-11	FSW-03		X		
CDH-03	Telemetry shall include mission time with one second or better resolution	Mission time is required by the competition	High				X		
CDH-04	2.4 GHz Series 1 and 2, and 900 MHz XBEE radios are allowed	XBEE requirement as indicated by the competition	Medium	SYS-11		X	X		
CDH-05	XBEE radio's NETID/PANID shall be set to team number (decimal)	Requirement by the competition	High	SYS-11		X			
CDH-06	XBEE radios shall not use broadcast mode	Requirement by the competition	Medium	SYS-12		X	X		
CDH-07	The Science Vehicle microcontroller shall have at least one ADC channel	Team requirement for battery level	Medium			X	X		
CDH-08	The Science Vehicle microcontroller shall have at least one I2C port	Team requirement for sensor and memory connection	Medium			X	X	X	
CDH-09	All sensor samples shall be logged as a backup	Team requirement	Medium		FSW-08		X		

Processor & Memory Selection

Processor: Freescale MKL16Z64VLH4

- At least 2 UART interfaces as required by the design
- At least 2 I^2C interfaces as required by the design
- Available in 64 pin TQFP format.
- Low power requirements

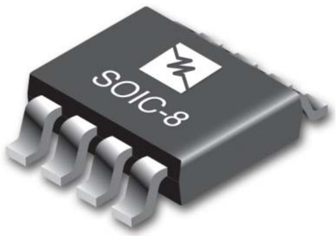
Speed and Memory	Data interfaces	Power Requirement	Board Type
Speed: 48MHz @3.3V Flash : 64KB RAM: 16KB EEPROM: N/A	I^2C – 2 UART – 3 SPI – 2 I2S – 1 Analog – 24 PWM – 3	> 40 µA/MHz	Custom Designed Board

Memory: Atmel AT24CM01

- Using existing I^2C bus with other peripherals
- Only needs 2 wires for I^2C instead of 3 for SPI
- 1 Mbit /32 byte packet = 4096 packets capacity
- At 1 Hz storing rate; able of storing 4096 seconds worth of packets, therefore can save 1 hour and 8 minutes worth of data

Size	Data interface	Type
1MBit	I^2C	EEPROM

Real-Time Clock



DS1307

- DS1307 was chosen over DS1338 because it was pin compatible, program compatible, has the same features, and was already available on campus
- Battery backed using 3V Coin Cell Battery
- The RTC will not reset if the power to the controller is lost

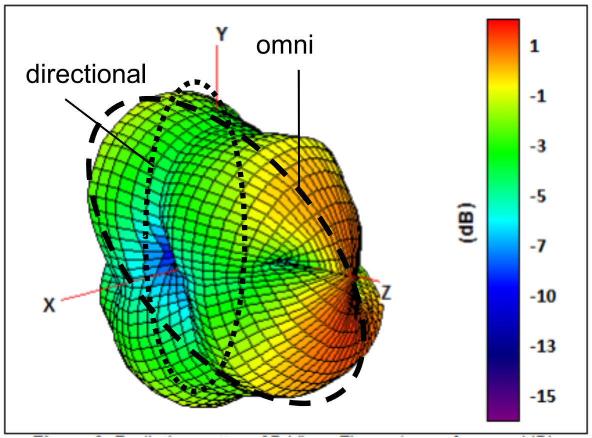
Interface	Voltage	RAM availability	Package Type
I^2C	4.5 V – 5.5 V	56B Battery-Backed	SOIC-8

- The DS1307 RTC is used to keep track of time in seconds since power up.
- FSW resets the RTC time on initial none POR power up.
- FSW queries the time and includes it with telemetry.
- RTC is powered by an external coin cell battery.
- RTC's 56B Battery-Backed memory will be used to keep track of current-state, last EEPROM save address, and other important information that has to be backed by battery

Antenna Selection

<u>Selected Payload and Container Antenna:</u> <u>Taoglas FXP290</u>

- **This antenna directs XBee transmission output towards the ground station**
- Printed circuit antenna, appropriate frequency range (902-928 MHz)
- Flexible, can fit inside CanSat's interior dimensions
- Has a low weight (1.5g) which fits the mass budget
  - U.FL connection, as opposed to other (lightweight + connector found to survive vibrations)
- Sufficiently low VSWR (<2:1 over band, meaning > 89% efficiency)
- Small: 75 mm x 45 mm x 0.1 mm
- Not too directional, as required (peak gain: 1.5 dBi)
- Matched at standard 50 Ohm impedance for 915 MHz (no need for extra impedance matching circuitry)



Radio Configuration

General Configuration

- We use the X-CTU software utility to configure the radio
  - Firmware is manually loaded onto each radio prior to testing (using AT commands)
  - For each radio:
    - We set the configuration parameter PANID to our team ID (ATID1001)
    - The transmit/receive rate is set to 1 Hz (ATIR3E8)
    - Broadcast mode is not enabled (use ATDL<u>any value except 0xFFFF</u>)

- We then use XBee API mode for communication in an 3 node wireless mesh network (see slide GCS Overview for connectivity diagram, and slide Telemetry Format for packet structure)

CanSat (Container and Science Vehicle) Radio Configuration

- We configure both the science vehicle and container radio with XBEE Pro 900HP DIGIMESH firmware (and destination address of GS radio)

Ground Station Radio Configuration

- We configure the ground station radios with same firmware (and destination address of CanSat radio)

Radio Configuration

Transmission Control

- The ground station software identifies packets from container and payload by analyzing the received telemetry packet
  - Each packet contains a source identification bit (see next slide)
  - A checksum is in place to see if any errors present
  - A packet count field indicates if any packets dropped
- The flight software maintains the state of the CanSat in flight, and accordingly, the on-board MCU alters packet transmission via its UART
- Data packets are sent to the GS. One-way communication throughout the length of the flight (all mission phases).
  - Design choice that communicating back to the CanSat not needed (should be self-sufficient in case of link failure)
- Upon landing (final state as defined in the FSW section), transmission will be ended

Telemetry Format

XBee API Frame

Start Delimiter
Length Bytes
API ID
API Frame ID
64-bit Destination Address
16-bit Destination Address
Broadcast radius
Option Byte
Data Packet
Checksum

Subtotal : 45 bytes

NB: commas between fields are ASCII-encoded (one extra byte/field)

Total : 28 bytes (17 excluding commas)

CanSat Telemetry Packet

Field Description

CanSat Telemetry Packet	Range	Bytes	Format
Team ID (xxxx)	1001	2	Simple Hex
Mission Time (tttt)	0-3600 (s)	2	Simple Hex
Altitude (hhh)	Max. ~999 (m)	2	Simple Hex
Outside Air Temperature (TT)	Max ~99 (°C)	1	Simple Hex
Internal Temperature (TT)	Max ~99 (°C)	1	Simple Hex
Flight Software State (X)	1-6	1	Simple Hex
Power Source Voltage (v.v)	Max ~9.9 (V)	3	ASCII-encoded
Accelerometer x-value (aa)	Max ~±16 (m/s^2)	1	Simple Hex
Accelerometer y-value (aa)	Max ~±16 (m/s^2)	1	Simple Hex
Accelerometer z-value (aa)	Max ~±16 (m/s^2)	1	Simple Hex
Packet Count (cccc)	Max ~3600	2	Simple Hex

Telemetry Format

- Data is sent continuously at the specified rate (1 Hz)
- The telemetry data is transmitted according to the Digimesh Transmit Request API data packets (API ID=0x10)
- Note: use ASCII → supplying power not a constraint; use Hex → aim to minimize field size (< errors)
- The presented format matches that of the competition requirements

Sample packet (values in HEX)

NB: commas between fields are ASCII-encoded (0x2C values)

7E 00 29 10 01 00 13 A2 00 40 C0 C5 F1 FF FE 01 00 **Header**

Start Delimiter	7E
Length (41 bytes)	00 29
API ID	10
Frame ID	01
64-bit Destination Address	00 13 A2 00 40 C0 C5 F1
16-bit Destination Address	FF FE
Broadcast radius (1 hop)	01
Option byte	00

03 E9 2C 00 01 2C 00 01 2C 19 2C 19 2C 06 2C 33 2E 33 **Data Packet**

Team ID	03 E9
Mission Time	00 01
Altitude (1m)	00 01
External temp (25C)	19
Internal temp (25C)	19
State (6)	06
3.3V Voltage (in ASCII format v.v)	33 2E 33

2C 0A 2C 00 2C 00 2C 00 01 **Data Packet (cont.)**

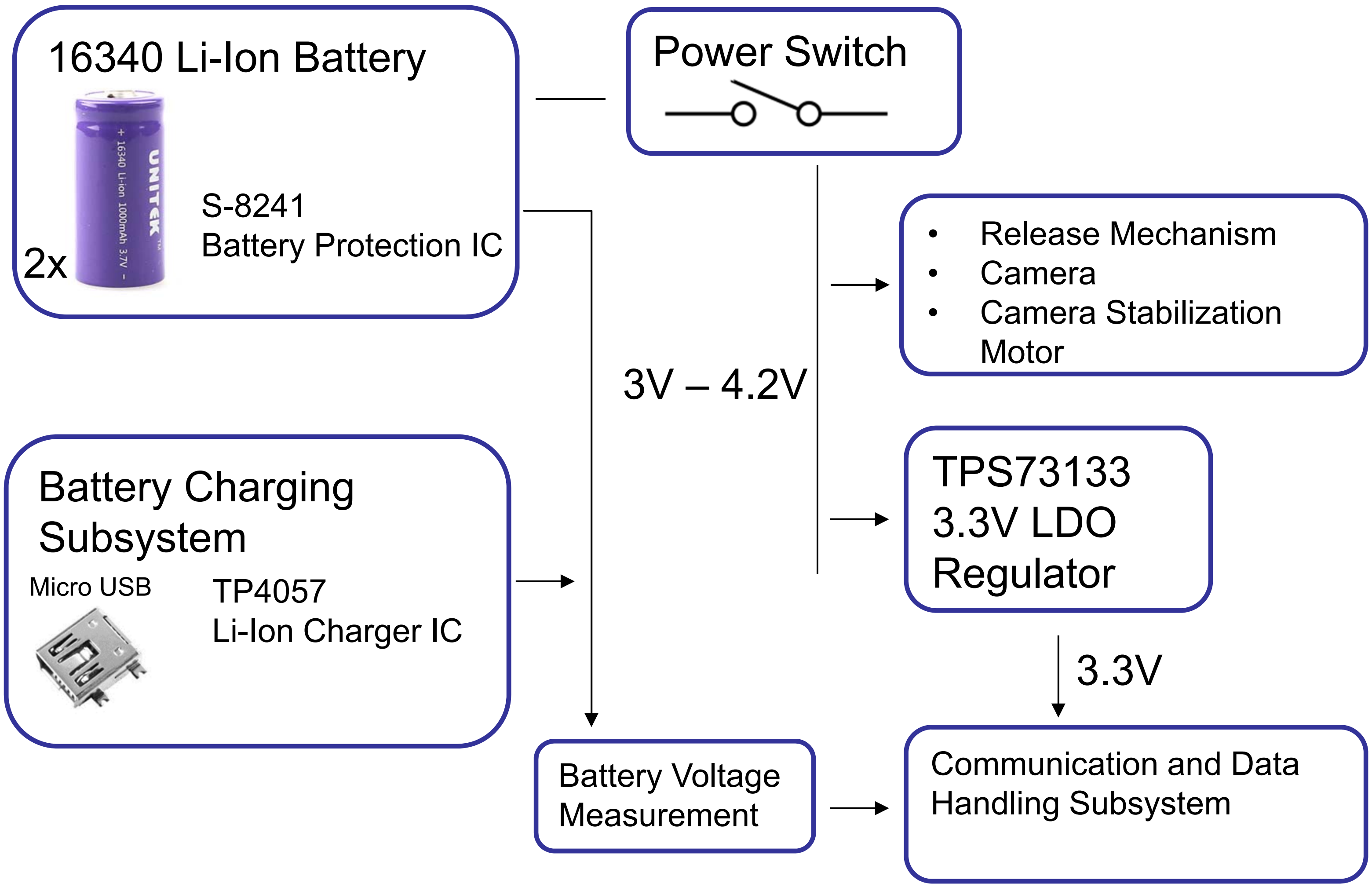
Acceler. -x=10	0A
-y=0	00
-z=0	00
Packet count (1)	00 01

09 **Checksum** (0xFF minus least significant byte of sum of other bytes in frame)

Electrical Power Subsystem Design

Jonathan Goldnau-Vogt

EPS Overview



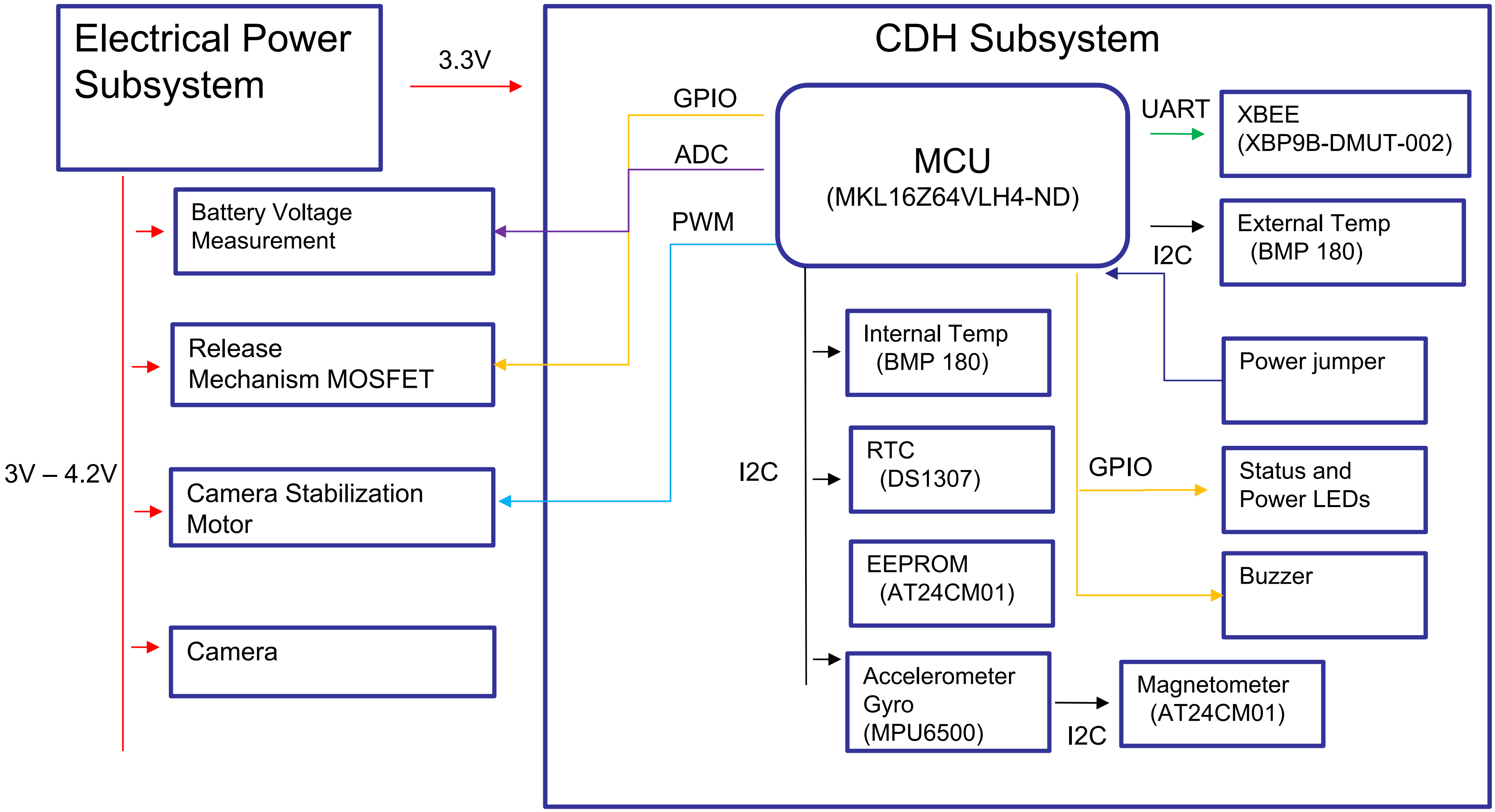
EPS Changes Since PDR

Component	Design at PDR	Design at CDR	Reason for change
Capacitor in battery protection circuit	Not present in circuit	Added to circuit	The added capacitor prevents overcurrent protection during release mechanism operation, ensuring enough current is provided to the nichrome wire.
Release mechanism circuit	2 release mechanism circuits in design	3 release mechanism circuits in design	The extra release mechanism was added just in case.

EPS Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
EPS-01	The payload power supply shall provide a regulated 3.3V to MCU and Sensors	System Requirement	High	SYS-10			x	x	
EPS-02	The batteries shall also be used to activate the release mechanism	System Requirement	High	MEC-07			x		
EPS-03	The batteries shall be able to supply 1A current for at least 1 s	System Requirement	High	MEC-07			x	x	
EPS-04	The batteries shall last for a least 1 hour	Mission Requirements	High			x	x		
EPS-05	The batteries shall either Alkaline, Ni-MH, lithium ion or Ni-Cad	Mission Requirements	Medium				x		

Electrical Block Diagram



Payload Power Source Selection and Design

Studied Power Source	Criteria				
	Typical Energy density at 25 C	Rechargeable?	Cell voltage	Internal Resistance	Notes:
Alkaline battery	400 W·h/L	No	1.5 V Nominal (1.0 V -1.6 V)	Typically Medium	One time use
Lithium-Ion	420 W·h/L	Yes	3.7 V Nominal (3.0 V – 4.2 V)	Typically Low	Permanently damaged by over discharge (<2.8 V)
Ni-MH	250 W·h/L	Yes	1.2 V Nominal (0.9V - 1.5 V)	Typically Low	Difficult to charge properly. Trickle charging damages battery over time

Selected Power Source: Lithium-Ion Battery form factor 16340 (3.7 V Nominal, 2x1000 mAh in parallel)

- Highest energy density for weight constrained CanSat
- Total weight 32 g for 7.2 Wh
- Low internal resistance means high current capability for release mechanism
- TPMICRO TP4057 IC onboard CanSat for charging over USB
- Seiko S-8241 IC onboard CanSat provides protection against:
    - Over discharge
    - Over charge
    - Over current (short circuit condition)

Power Budget

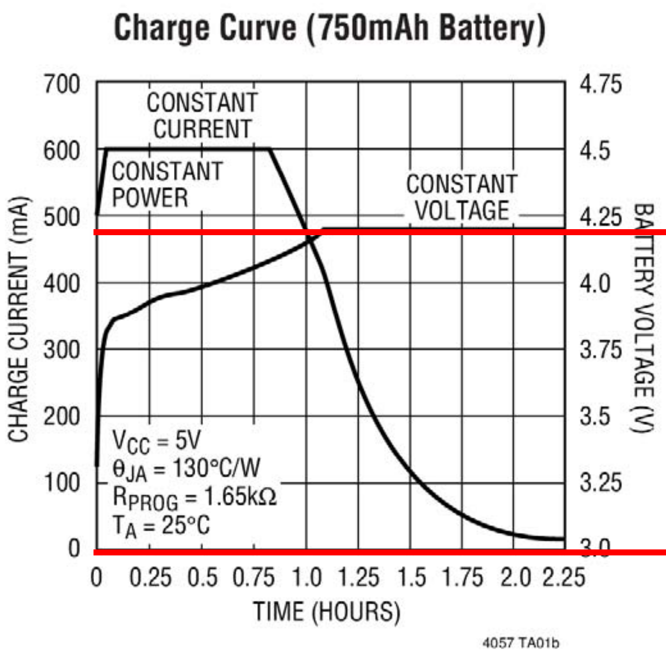
Component	Current (mA)	Voltage (V)	Power (mW)	Usage (sec)	Total Energy Consumed (mAh)	Source
Maxim DS1338 RTC	0.11	3.3	0.363	3600	0.11	DS
BMP085 T/P Sensor	0.003	3.3	0.0099	60	5.00×10^{-5}	DS
Freescale MKL16 MCU	6	3.3	19.8	3600	6	DS
XBee-PRO (S2B)	205 (TX)	3.3	676.5	60	3.4	DS
Atmel EEPROM	3.0	3.3	9.9	60	0.05	DS
Buzzer	60	3.3	198	3600	60	DS
MPU-6500 Gyro/Accel	3.4	3.3	0.09	3600	0.015	DS
3.3 V Regulator TPS73133	150	4.2	630	3600	150	DS
AK8963 Compass	0.28	3.3	0.924	3600	0.28	DS
Mobius Camera	200	~3.7	~740	3600	200	Web
Separation Mechanisms	~600	~3.7	~2200	~ 1	0.61	Measured

Battery Source	Power (mAh)
Available	2000
Total Consumed	420
Margin	1580

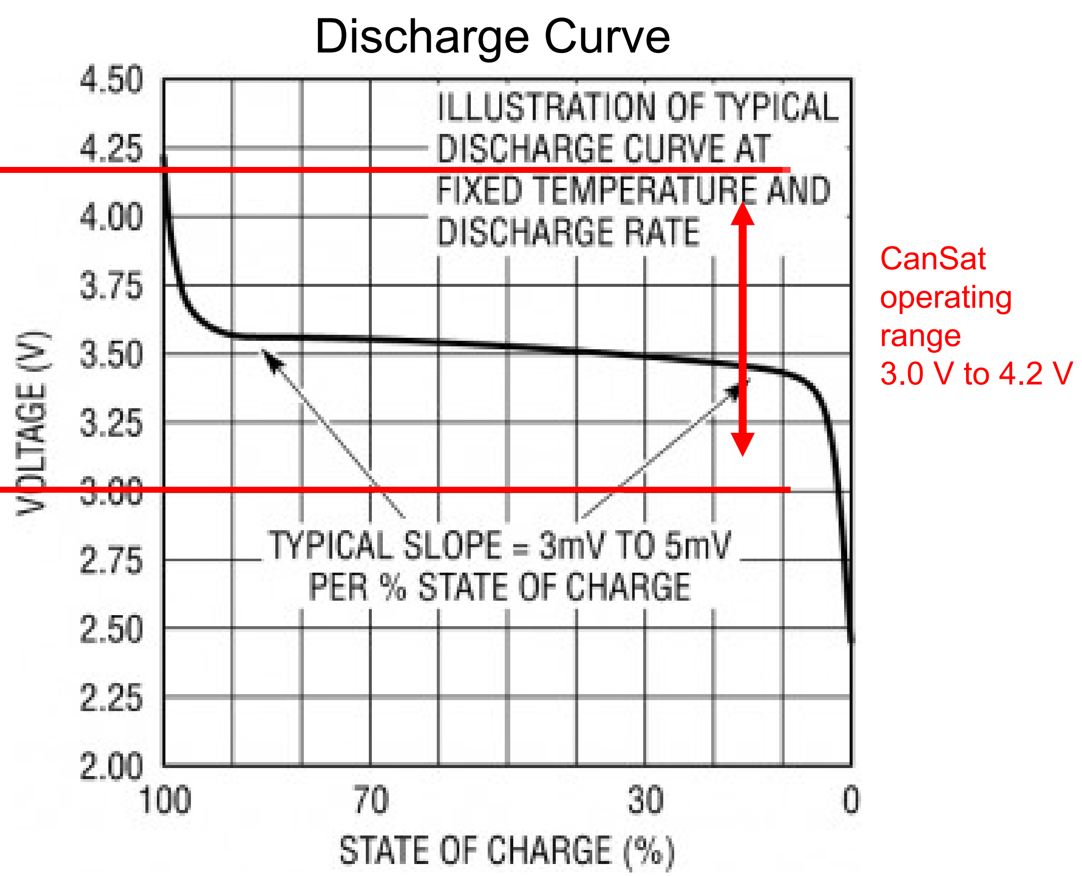
Battery Source	Power (mW)
Available	2800
Total Consumed	1227
Margin	1573

Note: Margin is sufficient for 1 hour wait on launch pad

Lithium-ion Battery Charge/Discharge



From: LTC4057 Datasheet



From: Bixmart.com

Power Bus Voltage Measurement

- Voltage is measured by 16-bit Analog to Digital Converter (ADC) on microcontroller
- ADC VREF is set to 2.5 V by precision shunt reference (±0.5%) see figure 2.
- Resistor divider scales battery voltage maximum 4.2 V to 2.308 V using RVD1 = 8.2K, RVD2 = 10K (±1%) see figure 1.

Figure 1 – Voltage divider

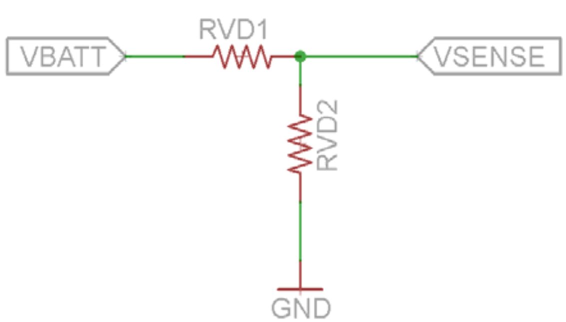
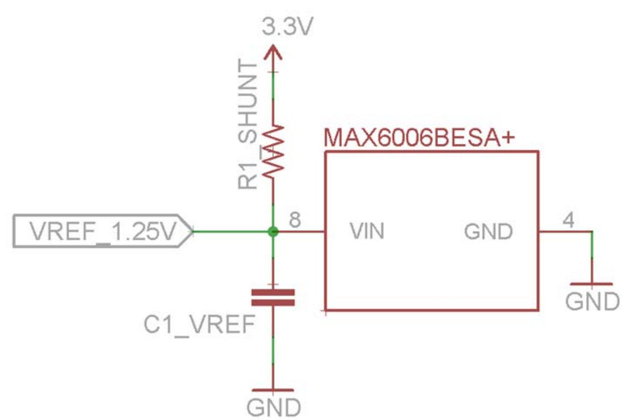


Figure 2 – Precision reference



Flight Software (FSW) Design

Erik Johnson

FSW Overview

- **Development and Deployment**
  – Written in C using the CodeWarrior Development Studio®
- **Software Architecture**
  – Software will consist of:
    - I^2C device interface driver for:
      – AT24CM01 (EEPROM memory device)
      – BMP180 (pressure/temperature sensor)
      – MPU6500 (accelerometer/gyroscope)
      – AK8963 (magnetometer)
      – DS1307 (accurate to 1 second or better RTC)
    - UART communication driver for interface with:
      – Host PC
      – Xbee
    - Main processing loop with ISR to handle timed periodic events (sampling sensors, saving data, transmitting data)

FSW Changes Since PDR

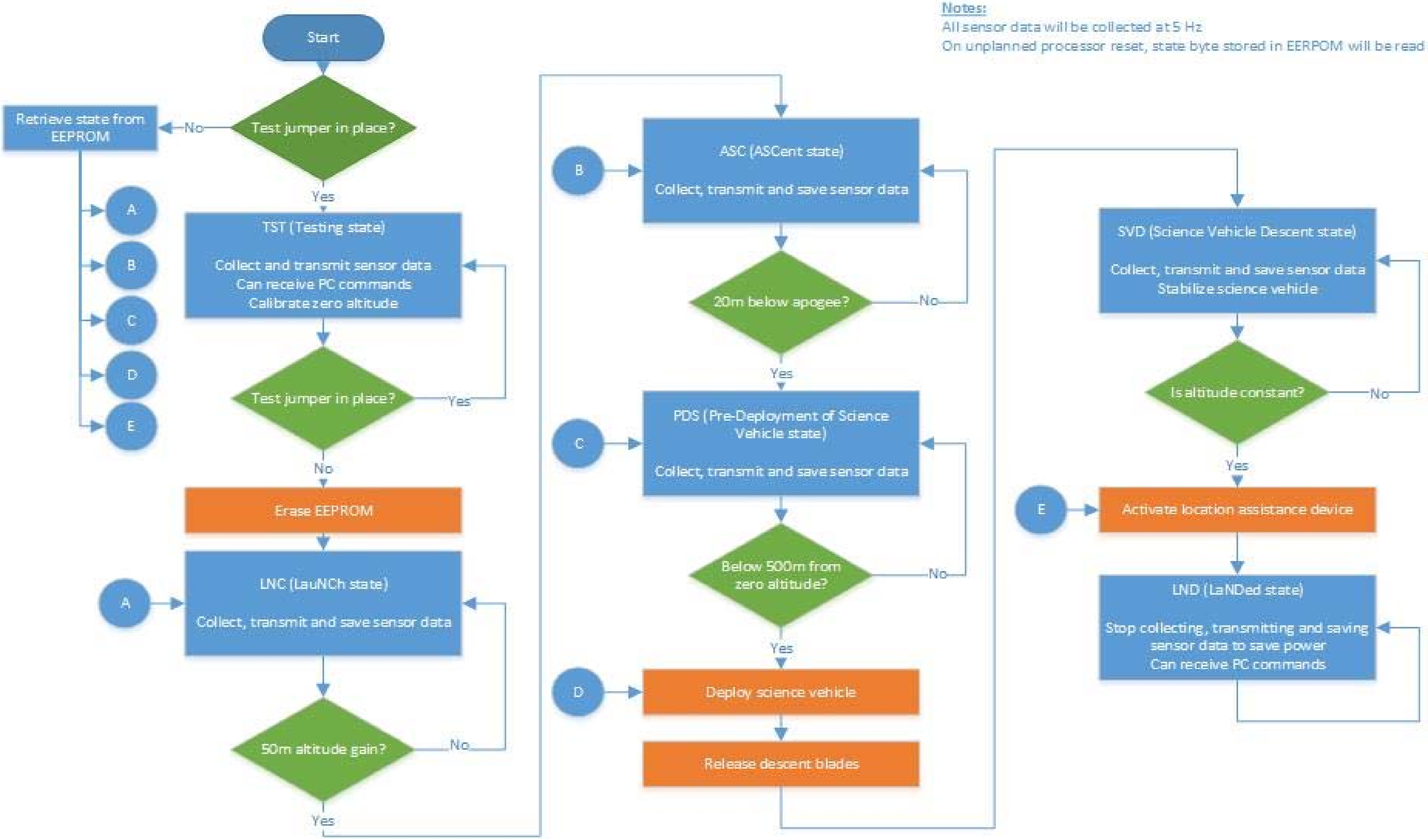
– No changes were made to the FSW design since PDR

FSW Requirements

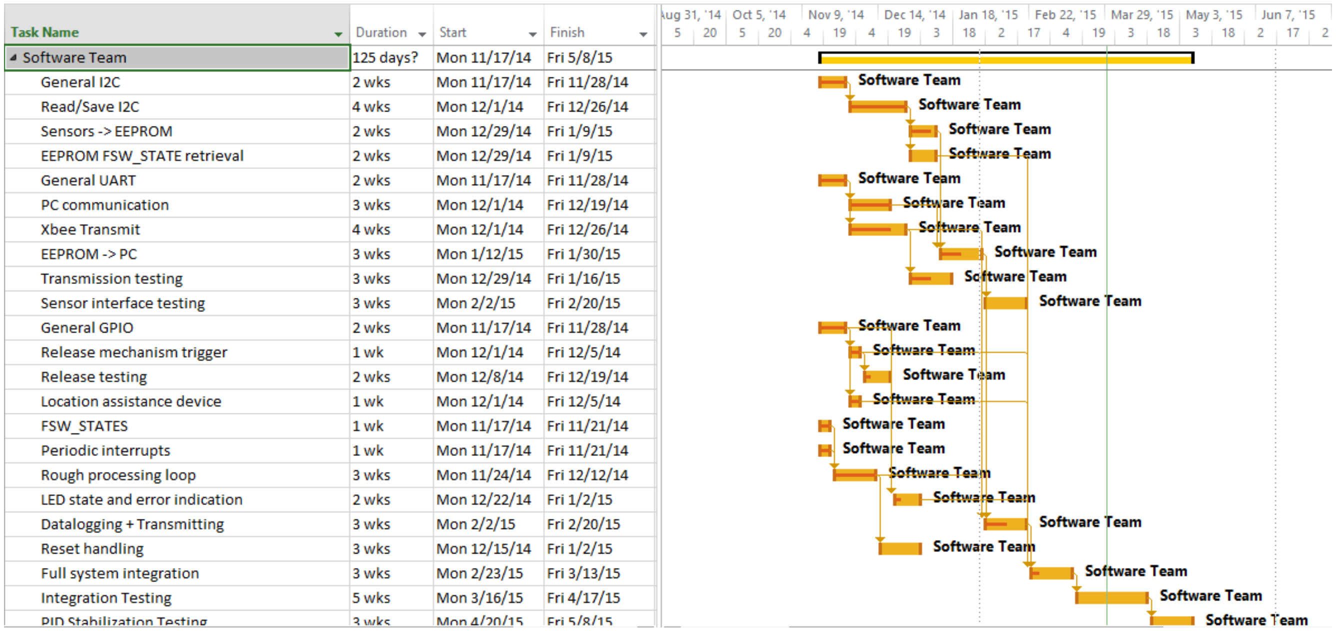
ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
FSW-01	FSW must deploy the science vehicle to allow for a descent of more than 300m	Mission Base Requirement	High	MEC-07, DCS-08, SYS-05				X	X
FSW-02	Telemetry data must be collected during descent	Mission Base Requirement	High	CDH-01, SYS-06, SYS-10			X		
FSW-03	Telemetry data must be transmitted at a rate of 1Hz throughout the mission	Mission Base Requirement	High	CDH-02 SYS-11			X		X
FSW-04	Video camera image must not rotate during descent	Mission Base Requirement	High			X		X	
FSW-05	FSW must keep track of its state and include the state in the telemetry data	Mission Base Requirement	High					X	X
FSW-06	Upon landing, transmission must cease and the audio beacon must be activated	Mission Base Requirement	High					X	X
FSW-07	FSW must recover from momentary power loss or unexpected processor reset	Mission Base Requirement	High	SYS-18		X		X	
FSW-08	Telemetry data shall be saved and should allow it to be extracted after landing	Derived Requirement	Medium	CDH-09				X	
FSW-09	Accelerometer data shall be included in telemetry	Mission Optional Requirement	Low					X	

CanSat FSW State Diagram

Notes:
All sensor data will be collected at 5 Hz
On unplanned processor reset, state byte stored in EERPOM will be read



Software Development Plan



Task Name	Duration	Start	Finish
Software Team	125 days?	Mon 11/17/14	Fri 5/8/15
General I2C	2 wks	Mon 11/17/14	Fri 11/28/14
Read/Save I2C	4 wks	Mon 12/1/14	Fri 12/26/14
Sensors -> EEPROM	2 wks	Mon 12/29/14	Fri 1/9/15
EEPROM FSW_STATE retrieval	2 wks	Mon 12/29/14	Fri 1/9/15
General UART	2 wks	Mon 11/17/14	Fri 11/28/14
PC communication	3 wks	Mon 12/1/14	Fri 12/19/14
Xbee Transmit	4 wks	Mon 12/1/14	Fri 12/26/14
EEPROM -> PC	3 wks	Mon 1/12/15	Fri 1/30/15
Transmission testing	3 wks	Mon 12/29/14	Fri 1/16/15
Sensor interface testing	3 wks	Mon 2/2/15	Fri 2/20/15
General GPIO	2 wks	Mon 11/17/14	Fri 11/28/14
Release mechanism trigger	1 wk	Mon 12/1/14	Fri 12/5/14
Release testing	2 wks	Mon 12/8/14	Fri 12/19/14
Location assistance device	1 wk	Mon 12/1/14	Fri 12/5/14
FSW_STATES	1 wk	Mon 11/17/14	Fri 11/21/14
Periodic interrupts	1 wk	Mon 11/17/14	Fri 11/21/14
Rough processing loop	3 wks	Mon 11/24/14	Fri 12/12/14
LED state and error indication	2 wks	Mon 12/22/14	Fri 1/2/15
Datalogging + Transmitting	3 wks	Mon 2/2/15	Fri 2/20/15
Reset handling	3 wks	Mon 12/15/14	Fri 1/2/15
Full system integration	3 wks	Mon 2/23/15	Fri 3/13/15
Integration Testing	5 wks	Mon 3/16/15	Fri 4/17/15
PID Stabilization Testing	3 wks	Mon 4/20/15	Fri 5/8/15

Risk mitigation for effects of late software development:

- Software is behind the ambitious schedule laid out in PDR
- Focus is being placed on ensuring functionality of highest importance components
- Tests have been planned to validate the FSW state transitions and data transmission

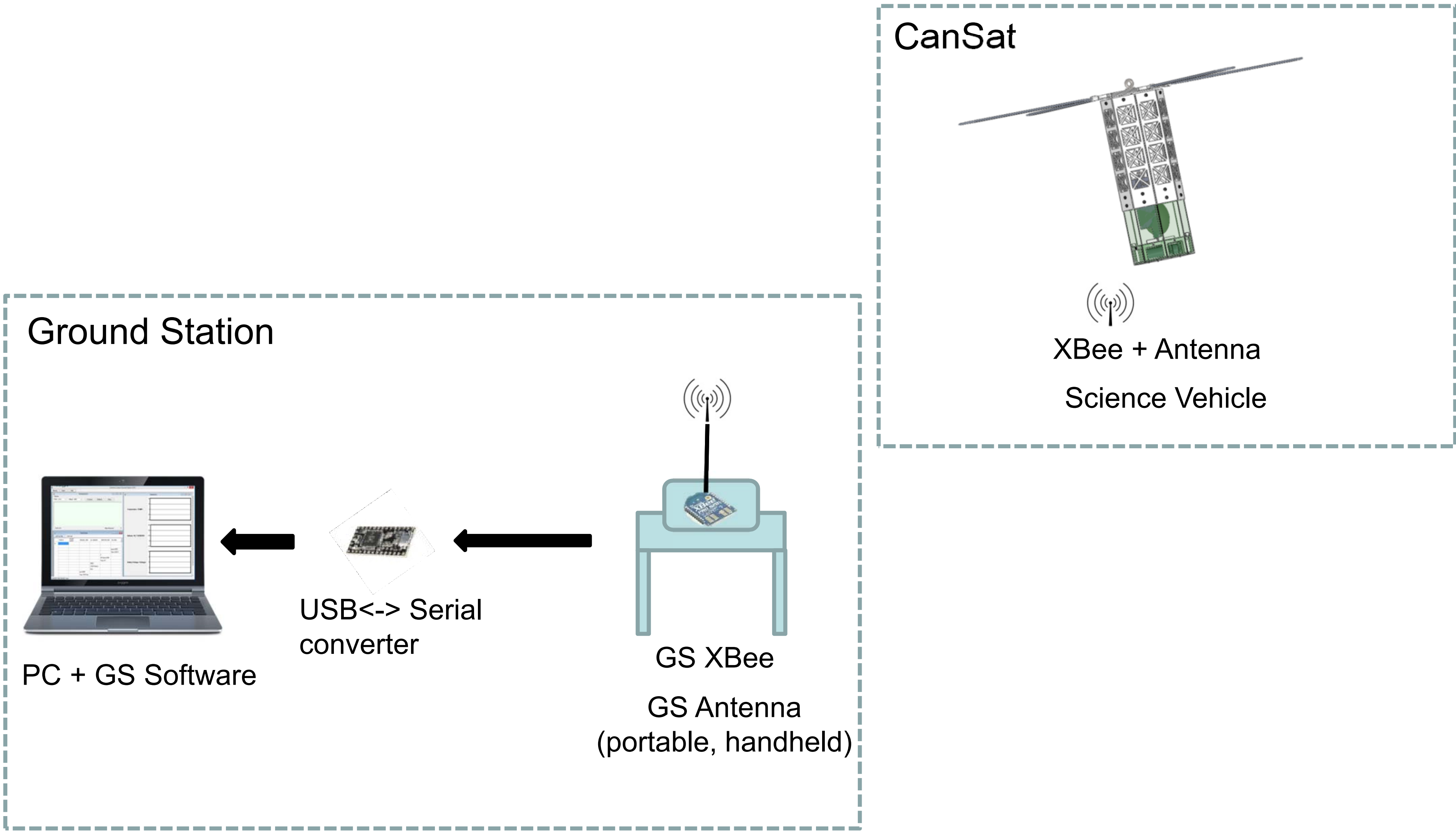
Software Development Plan

- **Progress since PDR**
  - All sensors can now be read with verified values
  - EEPROM can be written into and read from
  - FSW state transitions are theoretically functional, but not yet tested
  - Both a PC and the Xbee can now be communicated with
  - Timing for the release from the canister and the blade release are now implemented

Ground Control System (GCS) Design

Alok Deshpande

GCS Overview



GCS Changes Since PDR

Component	Design at PDR	Design at CDR	Reason for change
Antenna	RF Solutions ANT-GSM-YAGI11 (Yagi Antenna)	Custom built patch antenna	Cheaper and easier to acquire and transport.

GCS Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
GCS-01	The ground control system shall be able to receive and log packets that conform to the protocol .	Mission requirement	High	SYS-16				X	X
GCS-02	The antenna for the GCS shall be placed high enough for radio communications	Mandatory for radio communications	High	SYS-16			X		X
GCS-03	The GCS shall use a personal computer.	Ease of programming and cheaper in cost.	Medium	SYS-16			X		
GCS-04	The GCS analysis software shall be able to parse Science Vehicle packets.	System Requirement	Low	SYS-16					X

GCS Antenna

Selected GS Antenna: Custom-built patch antenna

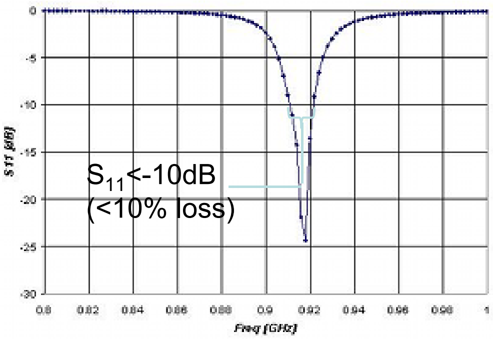
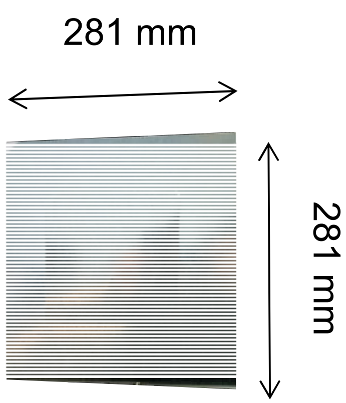


Fig. 1: Antenna input return loss (inversely correlated with efficiency), measured using vector network analyzer



- **This antenna maximizes reception of signal at GS**
- High gain (6.8 dBi), better than many other commercial antennae viewed
- Lowest cost option: $26.50 (materials cost)
- Frequency range generally matched: best for band of 910-920 MHz
- Sufficiently low return loss: >90% efficiency across band (provide graph)
- Directional in both planes (and ~ -5dBi in back lobes)

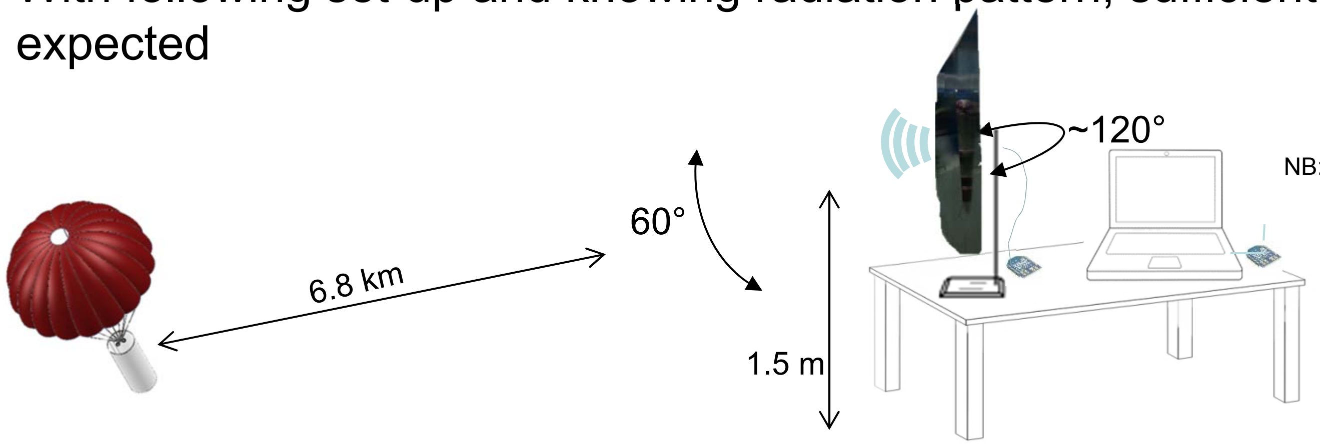
Antenna Construction

- Antenna is pre-built, so no additional assembly required
- Given the high gain of the antenna, portability not needed (but possible)
  - Eliminates any potential vibrations (and poor link) associated with hand-held antennae
- In addition to table at the Ground Station, small “retort”-type stand to be used as mount for table-top antenna
  - Total height of 1.5m determined to be sufficient for full antenna gain down to final 50m

GCS Antenna

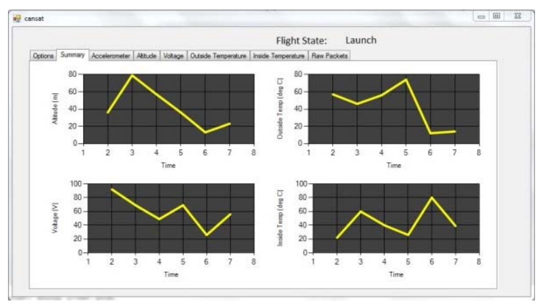
Placement/Coverage

- With following set-up and knowing radiation pattern, sufficient coverage expected



Distance link prediction: <u>calculated to be 6.8 km</u> [3] → **margin of ~1.8 km**

GCS Software operation

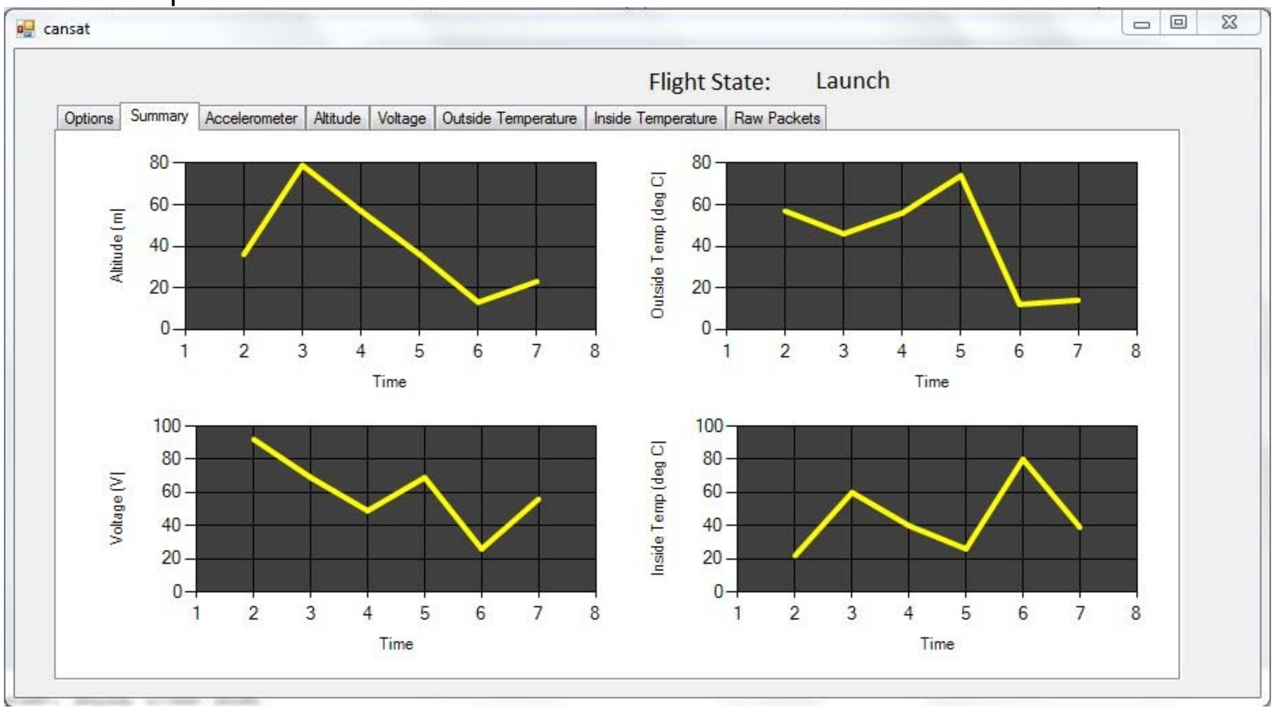


[3] Source: based on following calculator utility: http://www.afar.net/rf-link-budget-calculator/

GCS Software

- **No COTS software used**
- **Software written in C# using the SharpDevelop IDE**

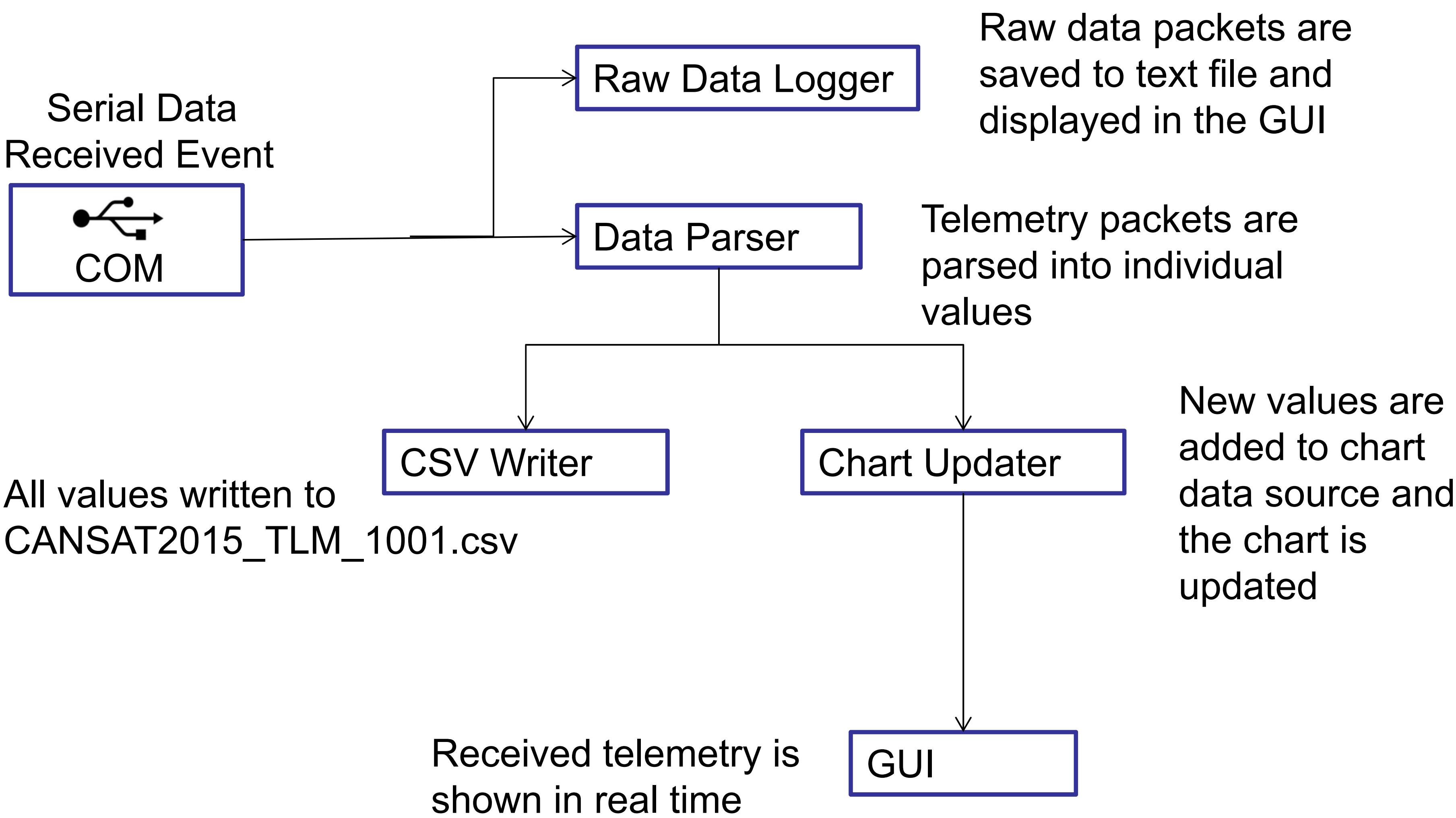
GUI Example:



CSV Example:

Team ID	Time	Altitude	Outside	Inside T	Voltage	State	Xaccel	Yaccel	Zaccel
1001	484	300	23	22	5	1	3	1	4
1001	485	300	23	22	5	1	3	1	4

GCS Software



GCS Software

- **Progress since PDR**
  - Changed plot colours to be easier to see in natural light
  - Started printing all raw data to a text file as well as to the GUI to make debugging easier
  - Added options to dump EEPROM data as well as change baud rate into the GUI
- **Testing**
  - Using an arduino to send sample data packets to the serial port, the functionality of the following was verified
    - Data parsing
    - Real time plots
    - Printing to CSV

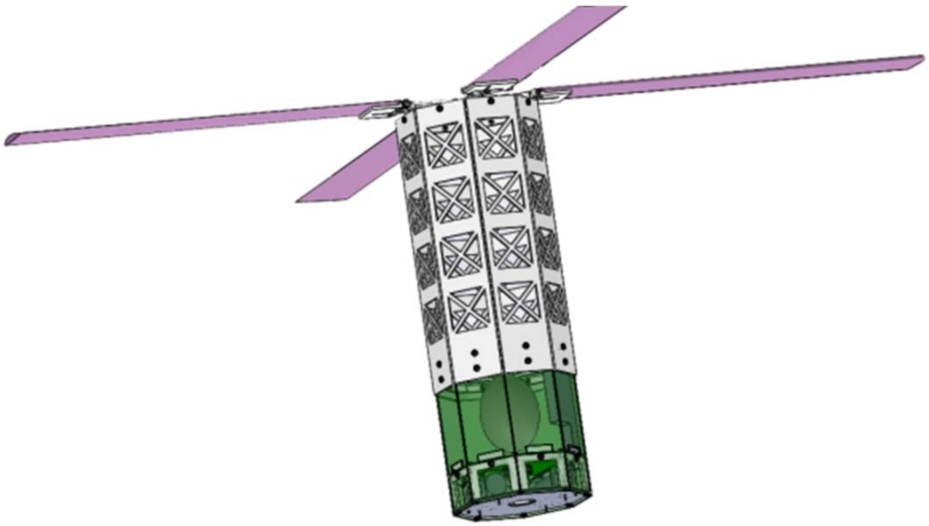
CanSat Integration and Test

Kyle Conway

CanSat Integration and Test Overview

– Assembly

- build prototype including electronic components

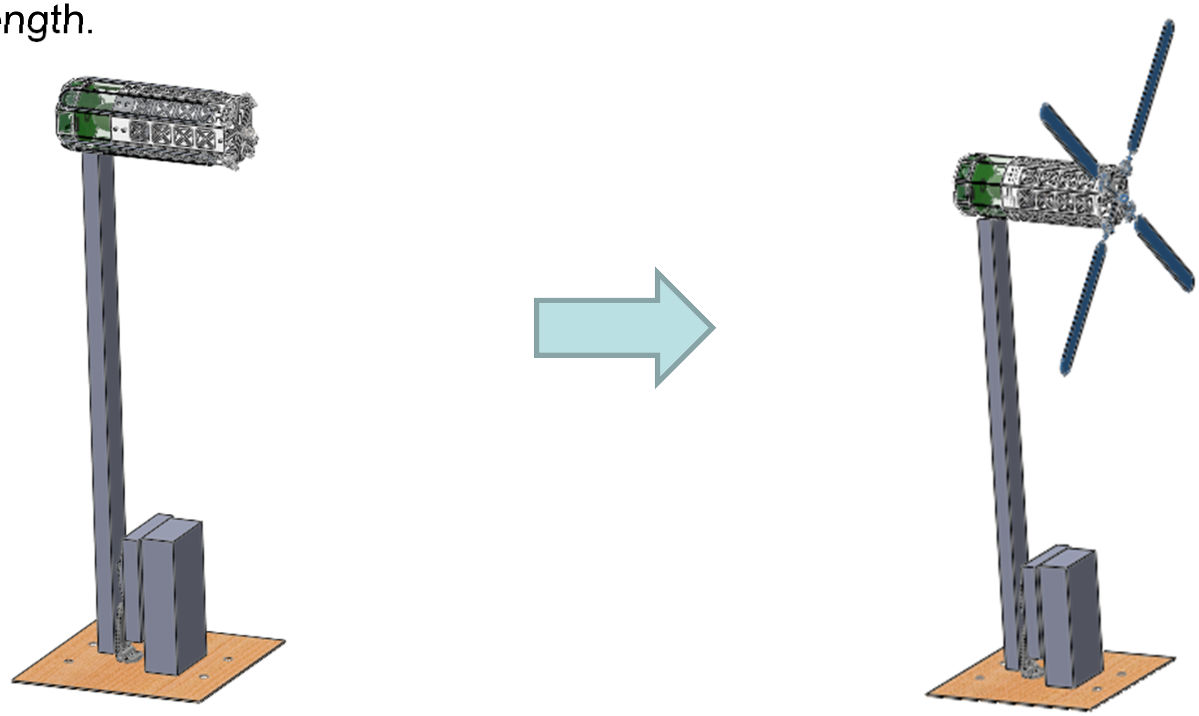


PCB with electronics is integrated in to the rest of the structure by screwing it to the top portion of the science vehicle which is made of acrylic.

CanSat Integration and Test Overview

– **Blade deployment testing**

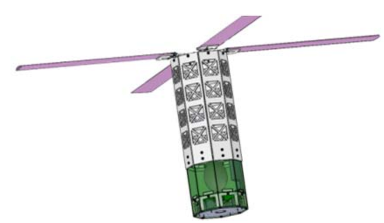
The science vehicle will be mounted in the wind tunnel, with the blades tied with fishing line. The wind speed will be increased to the estimated drop speed of the container with parachute (10 m/s). The fishing line will be melted through to release the blades. This will test the deployment mechanism, test the hinges and blade strength.



CanSat Integration and Test Overview

Science vehicle deployment testing

The CanSat will be dropped from an RC plane or a balloon to test integration of electrical components, deployment of the parachute, and deployment of the Science Vehicle from the container.



Sensor Subsystem Testing Overview

	Temperature Sensor Testing
Purpose	Ensure that temperature readings from the temperature sensor are accurate. Accurate temperature readings correspond to known temperature values for different situations and locations.
Constraints	• The process of reading the temperature from the sensor must be tested and confirmed • MCU and temperature sensor connections must be done correctly by ensuring the traces are placed correctly • Testing equipment (laptops, oven, fridge, cables, and debugging tools) must be working correctly • I^2C protocol and software must be operating correctly
Pass-Fail Criteria	• Indoor temperature reading correspond to known indoor temperature (~24°C) with a tolerance of ±0.5°C • Outdoor temperature reading correspond to known outdoor temperature with a tolerance of ±0.5°C (Known temperature is calculated using certified and manufacture tested temperature equipment) • Ensure that temperature reading is correct when the CanSat is placed in either a high temperature location (warm oven), or a low temperature location (fridge) • Ensure that the sensitivity and the time it takes to correctly adjust to the temperature change correspond to the values indicated on the datasheet

Sensor Subsystem Testing Overview

	Altitude Sensor Testing
Purpose	Ensure that altitude readings from the altitude sensor are accurate. Accurate altitude readings correspond to known altitude difference between a reference height and another set point at a higher altitude
Constraints	• The process of reading the pressure from the sensor must be tested and confirmed and that the process of converting the pressure to altitude is accurate • MCU and altitude sensor connections must be done correctly by ensuring the traces are placed correctly • Testing equipment (laptops, cables, and debugging tools) must be working correctly • I^2C protocol and software must be operating correctly
Pass-Fail Criteria	• Pressure at ground is close to the known ground pressure in Ottawa, Canada (101.5 kPa ± 5.0 kPa) • Confirm that the altitude measured by the sensor corresponds to known altitude between different altitude levels (levels in a building) • Ensure that the sensitivity and the time it takes to correctly adjust to the altitude change correspond to the values indicated on the datasheet

Sensor Subsystem Testing Overview

	Magnetometer Sensor Testing
Purpose	Ensure that the magnetometer readings from the sensor are consistent and agree to the expected values from the datasheet
Constraints	• The process of reading the magnetometer data from the sensor must be tested and confirmed and that the process of adjusting the magnetometer data is correct • MCU and magnetometer sensor connections must be done correctly by ensuring the traces are placed correctly • Testing equipment (laptops, cables, and debugging tools) must be working correctly • I^2C protocol and software must be operating correctly
Pass-Fail Criteria	• Confirm that the magnetometer's magnetic vector is pointing in the same direction for all orientations of the device at the same location • Confirm that the magnetometer's readings correspond to the datasheet values ($-200<x<200$, $-200<y<200$, and $-3200<z<-800$) • Confirm that when no magnetic field is applied, the magnetic vector measured from the magnetometer is always pointing to the magnetic north • Confirm that the magnetic vector measured from the magnetometer is pointing in the same direction as any applied magnetic field (applied magnetic field is done by placing a magnet with known polarities close to the magnetometer)

3-Axis Accelerometer Testing

	3-Axis Accelerometer Testing
Purpose	Ensure that the data read from the sensor are consistent and correspond to the values indicated on the datasheet, confirm the sensitivity of the sensor is similar to that in the datasheet
Constraints	• The process of reading the 3-axis data from the accelerometer is working correctly and that data can be read • MCU and accelerometer connections must be done correctly by ensuring the traces are placed correctly • Testing equipment (laptops, cables, and debugging tools) must be working correctly • I^2C protocol and software must be operating correctly
Pass-Fail Criteria	• Confirm that when placed on a flat surface, the magnitude of the axis pointing downwards (pointing towards ground) is 1g which corresponds to the gravitational acceleration g • Confirm that for all orientations, the magnitude of the axis pointing towards ground is 1g, this can be done by rotating the CanSat and reading the sensor data • Manually accelerate the CanSat and confirm that the accelerometer data shows an increase in the reading as the CanSat is accelerated at a faster rate

DCS Subsystem Testing Overview

	Payload Descent Control Wind Tunnel Testing	Container Descent Control Wind Tunnel Testing
Purpose	Verify that descent control system can produce enough lift/drag to achieve a terminal velocity from 4 – 10 m/s as outline in the mission requirements.	Verify that descent control will slow the container enough to have safe deployment of payload (desired velocity of ~10m/s)
Constraints	Prototype assembled (complete) Bracket to hold prototype in wind tunnel (complete) Testing assembly (complete)	Parachute (purchased) Testing assembly (complete)
Pass-Fail Criteria	Lift generation of 540 g (weight of science vehicle plus egg) in wind tunnel for a wind speed between 4 m/s and 10 m/s	Lift generation of 660 g (weight of container and science vehicle plus egg) in wind tunnel for a wind speed of 10 m/s

Mechanical Subsystem Testing Overview

	Blade Deployment Testing	Drop Testing
Purpose	Verify that rotor blades open properly and can survive shock from opening while the CanSat is falling	Verify separation, blade deployment and shock force survivability/egg protection.
Constraints	Need bracket to hold CanSat in wind tunnel without being in the way of the blades.	Need high enough place to drop from. (planning on using a balloon or RC plane)
Pass-Fail Criteria	All blades need to fully deploy (open ~90 degrees) Blades can't break.	Container and payload fully separate. Blades fully open (~90 degrees). Egg survives.

CDH Subsystem Testing Overview

	I^2C Testing
Purpose	Ensure that the I^2C protocol is working correctly. Ensure that sensors are being accessed and can be read and written into.
Constraints	• The I^2C initialization must be done correctly • MCU and sensor connections must be done correctly by ensuring the traces are placed correctly • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• Confirm that the sensors and peripherals connected to the I^2C bus lines can be accessed • Confirm that reading and writing to and from the I^2C connected devices is done correctly by having correct data read from the devices • Confirm that the I^2C bus lines are connected and operating correctly

CDH Subsystem Testing Overview

	UART Testing
Purpose	Ensure that the UART ports that will be used in the science vehicle are functional with the correct communication settings.
Constraints	• MCU and output headers must be connected by ensuring the traces are placed correctly • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• Confirm that the output headers connected to the UART ports in use receive the sent message at 9600 baud with 1 stop bit and no parity • Confirm that the PC can receive the message through the FTDI device with settings of 9600 baud with 1 stop bit and no parity

CDH Subsystem Testing Overview

	EEPROM Testing
Purpose	Ensure that saved data in the EEPROM is retrievable. Ensure that data written at different locations in the EEPROM is retrievable.
Constraints	• The processes of writing and reading to and from the EEPROM are tested and confirmed • MCU and EEPROM connections must be done correctly by ensuring the traces are placed correctly • Testing equipment (laptops, cables, and debugging tools) must be working correctly • The "I^2C Testing" has been performed and passed • A development board has been developed and populated
Pass-Fail Criteria	• Confirm that the data written to the EEPROM at different locations is retrievable and exactly the same • Confirm that the process of writing multiple bytes to the EEPROM is working • Confirm that the process of reading multiple bytes from the EEPROM is working

CDH Subsystem Testing Overview

	PWM Testing
Purpose	Ensure that the PWM signal used to operate the stabilization motors is working
Constraints	• MCU and output headers must be connected by ensuring the traces are placed correctly • Testing equipment (laptops, oscilloscopes, cables, and debugging tools) must be working correctly
Pass-Fail Criteria	• Confirm that the width of the PWM signal outputted from the MCU and checked with an oscilloscope corresponds to that set by the software with a tolerance of ±1% • Confirm that the frequency of the PWM signal outputted from the MCU and checked with an oscilloscope corresponds to that set by the software with a tolerance of ±1% • Confirm that the peak voltage of the outputted PWM signal is 3.3 V

CDH Subsystem Testing Overview

	TX data integrity testing	Selective reception testing
Purpose	Determine if data sent of correct formatting and transmission frequency	Confirm if data not being received by any other radio apart from GS
Constraints	• Presence of RF link • Availability of GS serial terminal for reading received data (HEX/ASCII-parsed readout)	• Presence of RF link • Availability of GS serial terminal for reading received data (HEX/ASCII-parsed readout) • Availability of alternate ground-station set up
Pass-Fail Criteria	Arbitrary sensor data (correctly formatted) received exactly as sent at serial port, with proper frequency i.e. correct reception of the sample data packet on slide regarding Telemetry Format	No data packets received at serial port of alternate ground station (i.e. no values displayed in terminal of the arbitrary data)

EPS Testing Overview

	High current test	LDO test	Endurance test	Rattle test
Purpose	To verify the ability for the battery, wires and FETS to deliver current to release mechanisms.	To verify LDO voltage stability with all dependent electrical systems at full load	To verify equipment operation exceeds hour long endurance requirement.	To verify connectors and solder joints are reliable and strong.
Constraints	Test activated by software	EPS, CDH and Sensor systems implemented	EPS, CDH and sensor systems implemented	EPS, CDH and sensor systems implemented
Pass-Fail Criteria	Pass: 4 A delivered for 5 seconds with battery voltage above 3.5 V	Pass: 3.3 V supply within 0.1 V during all testing conditions	Cansat and camera operational after 1.5 hour	Cansat fully operational during and after vibration testing with no resets

FSW Testing Overview

	CDH and Sensor Subsystem Integration Testing
Purpose	Ensure that the FSW can acquire data from sensors, perform any necessary calculations and send the data to the correct communication port with the correct communication settings.
Constraints	• The sensor subsystem (along with the necessary calculations) must be functional • All sensor subsystem tests have been performed and passed • The “UART Testing” has been performed and passed • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• Sensor data is seen on the UART communication port that will be used for transmitting data at 9600 baud with 1 stop bit and no parity • Each type of sensor’s data will be checked for the pass/fail criteria as presented in the sensor subsystem testing overview slides • The format of the packets sent to the UART communication port that will be used for transmitting data is identical to that desired (as presented in this document)

FSW Testing Overview

	FSW Transmission Testing
Purpose	Ensure that the FSW can form correctly structured packets and send them through the Xbee to a computer attached to another Xbee.
Constraints	• The “CDH and Sensor Subsystem Integration Testing” has been performed and passed • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• Sensor data is seen on the PC communication port that the second Xbee is attached to • Each type of sensor’s data will be checked for the pass/fail criteria as presented in the sensor subsystem tests • The packet structure must match the desired packet structure presented in the document

FSW Testing Overview

	FSW EEPROM Logging Test
Purpose	Ensure that the FSW will log sensor data to the EEPROM and then retrieve it to an attached computer. Each saved record will include a counter and a known number of packets will be saved.
Constraints	• The "EEPROM Testing" has been performed and passed • The "UART Testing" has been performed and passed • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• The sensor data stored in EEPROM is extracted successfully to the computer • Each type of sensor's data will be checked for the pass/fail criteria as presented in the sensor subsystem testing overview slides • The packet structure extracted to the computer must be identical to that saved and every packet saved must be extracted

FSW Testing Overview

	FSW State Transition Testing
Purpose	Ensure that the FSW makes the correct steps through the state machine with the correct data. This test will also verify the correct timing for the releases of the science vehicle from the container and of the auto-gyro blades.
Constraints	• The “UART Testing” has been performed and passed (as this will be the method for noticing state transitions) • The set points for the state transitions will have to be modified to accommodate the possible altitude gain of the elevator • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• The FSW transitions between states in the desired fashion (as presented on the slide “CanSat FSW State Diagram”) • The timing of the releases are 1 second (+/- .2 second) and .5 second (+/- .1 second) respectively

FSW Testing Overview

	PID Blade Stabilization Testing
Purpose	Ensure that the PID blade stabilization method is functional. The science vehicle will be affixed by the blades and they will be rotated at the calculated descent rate.
Constraints	• The “Magnetometer Sensor Testing” has been performed and passed • The “Payload Descent Control Wind Tunnel Testing” has been performed and passed (this determines the rotation rate of the blades during descent) • Testing equipment (laptops, cables, and debugging tools) must be working correctly • A development board has been developed and populated
Pass-Fail Criteria	• The science vehicle maintains a constant orientation (+/- 30°) while applying disturbance torques

GCS Testing Overview

	Range test
Purpose	Confirming that RF link sufficiently long to allow for continuous connection between CanSat and GS
Constraints	• Presence of short-distance RF link • Ability to measure distance between CanSat and GS
Pass-Fail Criteria	Reception of data packets (viewed as correct values appearing in serial terminal of GCS) as distance between CanSat and GS-laptop is increased, up to at least expected distance stated in GS antenna section (5 km)

Mission Operations & Analysis

Akshay Puli

Overview of Mission Sequence of Events

Preparation (CanSat Crew)

1. Arrive at Launch site and check-in with flight line judge

Preparation begins

2. Setup ground station and assemble CanSat
3. Request the egg and put it in the CanSat egg protection envelope
4. Conduct equipment startup test
5. Conduct container power level check

Powel level check passes

6. Initiate telemetry link to GS

Telemetry link success

Launch demonstration (Mission Control Officer)

7. Request a rocket

Rocket is Acquired

8. Place CanSat in rocket and launch pad when requested

Rocket Launch

9. Demonstrate real time telemetry to judges

CanSat deploys from rocket, starts to descend

500m container releases payload

10. Monitor decent of payload and container

Payload and container Impact

Recovery (Recovery Crew)

11. Locate Payload and Container impact location
12. Check in with field judge for permission to retrieval

Recover of Payload and CanSat

13. Analyze logged data and compare with telemetry

Launch demonstration ends

14. Remove ground station equipment from field location

Field Safety Rules Compliance

- The Mission Operations manual will be developed based on the provided competition mission operations manual
- The Mission Operations manual will include the following:
  - Ground Station configuration
  - CanSat preparation
  - CanSat rocket integration
  - Launch preparation
  - Launch procedure
  - Removal procedure
- The Mission Operations manual will be used in pre launch rehearsal activities.
- The first draft of Mission Operations manual is currently being prepared
- Two copies will be present at the Flight Readiness Review

CanSat Location and Recovery

Container and Payload recovery:

- We position recovery crew in strategic location at the launch field to spot the payload and the container as they decend and recover them.

Color Selection:

- We paint the body of both the container and payload with orange color for good visibility.

CanSat Address Labeling:

- We use the following to label both the container and payload modules

CanSat Competition 2015

Team Name: RavenKnights
Team ID: 1001
Contact Phone #: 1-613-915-5566
Contact Email: cansat@carletonrobotics.com

Carleton University

Mission Rehearsal Activities

- **Ground System Radio Link Check:**

CanSat Crew

1. Check if XBee radio on CanSat is placed properly in the socket
2. Check if GS XBee is connected to PC and attached to Antenna
3. Launch GS Software and connect to serial port with correct baud rate
4. Confirm the receipt of telemetry and proper behavior of CanSat
5. Check status of RSSI LED
6. Confirm integrity and correctness of telemetry
7. Radio Link Check Pass

- **Loading Egg in Payload:**

Mission Control Officer

1. Request Egg from field judge
2. Make sure egg is numbered and bring to CanSat Crew

CanSat Crew

1. Open egg protector
2. Carefully place egg in egg protector
3. Close and secure egg protector
4. Load egg protector into payload

- **Powering On/Off the CanSat:**

CanSat Crew

1. Remove CanSat power on jumper to supply power to the CanSat
2. Make sure power source is properly connected to the correct terminals and the connection is secured
3. Connect debug board and confirm CanSat is getting power and operational
4. Remove debug board
5. Remove test state jumper to exit test state and start the mission
6. CanSat power on is a success

Mission Rehearsal Activities

- **Launch Configuration Preparation**

Mission Control Officer

1. Request and get rocket
2. Coordinate with launch officer and confirm launch time window

Recovery Crew

1. Take positions
2. Notify when ready

CanSat Crew and GS Crew

1. Place the egg in the payload
2. Power on the CanSat
3. Check radio link
4. Check all electrical and mechanical connections are secured
5. Notify Mission Control Officer that CanSat is ready

Mission Rehearsal Activities

- **Telemetry processing, archiving, and analysis:**

CanSat Crew and GS Crew

1. Confirm of both raw and valid telemetry log files are created by GS Software
2. During mission demonstrate real time data reception to field judges
3. After recovery, read the logged data from the onboard EEPROM. And submit to judges.
4. Cross check logged data with received data
5. Conduct analysis of data for PFR

Mission Rehearsal Activities

- **Recovery**

Recovery Crew

1. Take positions before launch
2. Track rocket and CanSat visually. Use binoculars.
3. Find location of impact, check with field judge to confirm status of egg, before recovery.
4. Recover both modules
5. Bring to ground station for logged data retrieval

Requirements Compliance

Akshay Puli

Requirements Compliance Overview

- Requirements have all been complied with, except the environmental testing requirements.
- Tests for the environmental requirements have been planned and are indicated in yellow in the following slides.

Requirements Compliance Overview

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
1	Total mass of the CanSat (Container and Science Vehicle) shall be 600 grams +/- 10 grams not including the egg.	Comply	Mass Budget	
2	The Science Vehicle shall be completely contained in the Container. No part of the Science Vehicle may extend beyond the Container.	Comply	Physical Layout	
3	The Container shall fit in the envelope of 125 mm x 310 mm including the Container passive descent control system. Tolerances are to be included to facilitate Container deployment from the rocket fairing.	Comply	Launch Vehicle Compatibility	
4	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	Physical Layout, Container Descent Control Strategy Selection and Trade	
5	The Container shall not have any sharp edges to cause it to get stuck in the rocket payload section.	Comply	Physical Layout, Launch Vehicle Compatibility	
6	The Container shall be a florescent color, pink or orange.	Comply	Physical Layout, Launch Vehicle Compatibility	Container will be spray painted fluorescent pink
7	The rocket air frame shall not be used to restrain any deployable parts of the CanSat.	Comply	Physical Layout, Launch Vehicle Compatibility, Container – Payload Interface	All Deployable parts fit inside the container
8	The rocket air frame shall not be used as part of the CanSat operations.	Comply	Launch Vehicle Compatibility	
9	The CanSat (Container and Science Vehicle) shall deploy from the rocket payload section.	Comply	Launch Vehicle Compatibility	

Requirements Compliance Overview

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
10	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. It is up to the team to determine appropriate conditions for releasing the Science Vehicle.	Comply	CDH Overview	
11	The Science Vehicle shall use a helicopter recovery system. The blades must rotate. No fabric or other materials are allowed between the blades.	Comply	Physical Layout, Descent Control Overview, PDCSS&T	
12	All descent control device attachment components shall survive 50 Gs of shock.	Comply	Structure Survivability Trades	
13	All descent control devices shall survive 50 Gs of shock.	Comply	Structure Survivability Trades	
14	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	Structure Survivability Trades	
15	All structures shall be built to survive 15 Gs acceleration.	Comply	Structure Survivability Trades	
16	All structures shall be built to survive 30 Gs of shock.	Comply	Structure Survivability Trades	
17	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	Structure Survivability Trades	
18	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	Structure Survivability Trades	

Requirements Compliance Overview

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
19	Mechanisms shall not use pyrotechnics or chemicals.	Comply		No pyrotechnics or chemicals are used in the design of the CanSat.
20	Mechanisms that use heat (e.g., nichrome wire) shall not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.	Comply	Container – Payload Interface	
21	During descent, the Science Vehicle shall collect and telemeter air pressure (for altitude determination), outside and inside air temperature, flight software state, battery voltage, and bonus objective data (accelerometer data and/or rotor rate).	Comply	CanSat FSW State Diagram	
22	The Science Vehicle shall transmit telemetry at a 1 Hz rate	Comply	Telemetry Format	
23	Telemetry shall include mission time with one second or better resolution, which begins when the Science Vehicle is powered on.	Comply	FSW Overview	
24	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	CDH Overview	
25	XBEE radios shall have their NETID/PANID set to their team number (decimal).	Comply	Radio Configuration	
26	XBEE radios shall not use broadcast mode.	Comply	Radio Configuration	
27	The Science Vehicle shall have a video camera installed and recording the complete descent from deployment to landing. The video recording can start	Comply	Camera Summary	

Requirements Compliance Overview

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
28	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	Camera Summary	
29	The descent rate of the Science Vehicle shall be less than 10 m/s	Comply	Descent Rate Estimates	
30	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	3-axis Accelerometer Trade Selection	
31	Cost of the CanSat shall be under $1000. Ground support and analysis	Comply	CanSat Budget	
32	Each team shall develop their own ground station.	Comply	GCS System Overview	
33	All telemetry shall be displayed in real time during descent.	Comply	GCS Software	
34	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	GCS Software	
35	Teams shall plot data in real time during flight on the ground station computer.	Comply	GCS Software	
36	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	GCS System Overview	

Requirements Compliance Overview

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
37	The ground station shall be portable so the team can be positioned at the ground station operation site along the flight line. AC power will not be available at the ground station operation site.	Comply	GCS System Overview	
38	The Science Vehicle shall hold one large raw hen's egg which shall survive launch, deployment and landing.	Comply	Physical Layout	Space for egg is shown in picture in bottom right
39	Both the Container and Science Vehicle shall be labeled with team contact	Comply	Material Selections	
40	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. Example states include: PreFlightTest(0),LaunchWait(1), Ascent(2), RocketDeployment(3), Stabilization(4),Separation(5), Descent(6), and Landed(7).	Comply	CanSat FSW State Diagram	
41	No lasers are allowed.	Comply		No lasers will be used on the CanSat
42	The Science Vehicle shall include an easily accessible power switch which does not require removal from the Container for access. An access hole or panel in the Container is allowed.	Comply	Electrical Block Diagram	
43	The Science Vehicle must include a battery that is well secured.. (Note: a common cause of failure is disconnection of batteries and/or wiring during launch.)	Comply	Payload Power Source Trade Study	

Requirements Compliance Overview

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
44	Lithium polymer cells are not allowed due to being a fire hazard.	Comply	Payload Power Source Trade Study	
45	Alkaline, Ni-MH, lithium ion built with a metal case, and Ni-Cad cells are allowed. Other types must be approved before use.	Comply	Payload Power Source Trade Study	
46	The Science Vehicle and Container must be subjected to the drop test as described in the Environmental Testing Requirements document.	Partial		Tests planned
47	The Science Vehicle must be subjected to the vibration testing as described	Partial		Tests planned
48	CanSat Science Vehicle and Container must be subjected to the thermal test as described in the Environmental Testing Requirements document.	Partial		Tests planned
49	Environmental test results must be documented and submitted to the judges at the flight readiness review.	Partial		Tests planned

Management

Akshay Puli

Status of Procurements

- All sensors procured including spares
- All components procured including spares
- Ground station equipment procured and manufactured
- Hardware changes made after testing will require additional procurement
- Flight circuit boards procured. Revisions will be made if time allows, otherwise hardware will be modified if needed

CanSat Budget – Hardware

Electrical	Qty.	Total	Considerations
Barometer - BMP180	2	$10.00	actual
Microcontroller - MKL16Z64VLH4	1	$4.00	actual
Accel/Gyro - MPU-6500	1	$15.00	actual
xBee	2	$60.00	actual
Magnetometer - AK8963	1	$10.00	actual
Misc passive componets + led	1	$50.00	actual
Electromechanical (e.g motor, switches)	1	$50.00	actual
Breakout boards	1	$40.00	actual
Battery, Lithium -ion	2	$20.00	actual
Mobius camera	1	$80.00	actual
Mobius camera extension cable	1	$10.00	actual
micro-SD Card	1	$15.00	actual
Total Electrical Budget		**$394.00**	

CanSat Budget – Hardware

Mechanical	Qty.	Total	Considerations
Materials	n/a	$ 80.00	estimated
Fasteners	n/a	$ 50.00	estimated
Manufacturing	n/a	$ 100.00	estimated
3D Printing	n/a	$ 50.00	estimated
PCB Fabrication	10	$ 200.00	estimated
Egg protection casing	n/a	$ 20.00	estimated
Total Mechanical Budget		**$ 500.00**	

Total Budget	Total
Electrical Budget	$ 394.00
Mechanical Budget	$ 500.00
Total CanSat Budget	**$ 894.00**

Margin: $106 under budget set by mission requirements

CanSat Budget – Other Costs

Additional Costs	Amount	Considerations
Eggs for testing	$ 20.00	Estimated
Computers	University Provided	
Test facilities and equipment	University Provided	
Ground station Antenna + Cable	$ 75.00	Estimated
Ground Station Xbee	$ 35.11	Actual
Travel	$ 10,000.00	Projected
Total	**$ 10,130.11**	

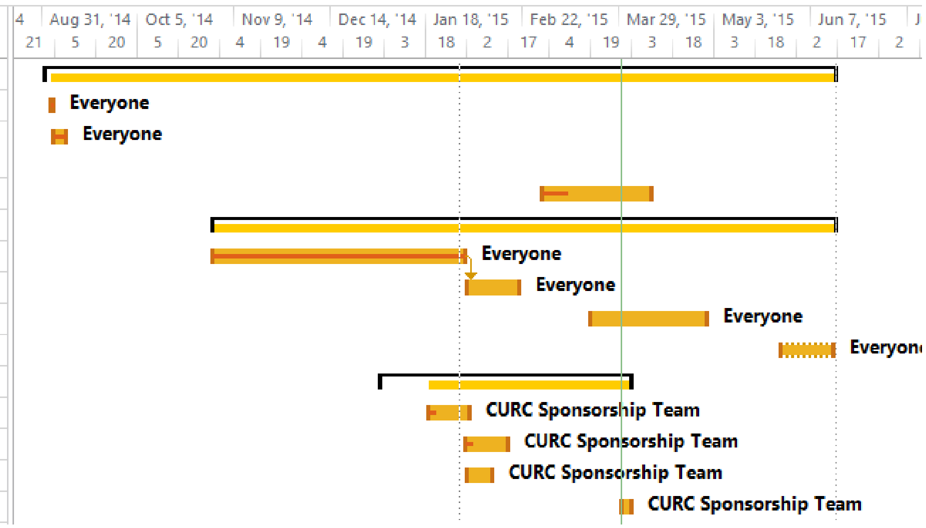
Sources Of Income	
Carleton University Robotics Club (CURC)	$ 1,500.00
Fundraising (?)	TBD
Sponsors(?)	TBD
Shortfall	**$ 8,630.11**

- Projected travel is based on all 10 team members travelling to Texas calculated based on today's rates. However, only 3 members are required to be in Texas.
- Electrical and Hardware budget to be covered by CURC. The rest will need to have fundraising or sponsorship.
  - Suggested Sources:
    - Corporate T-shirt and website logo sponsorships
    - On campus promotion tables

Program Schedule

Administrative Tasks

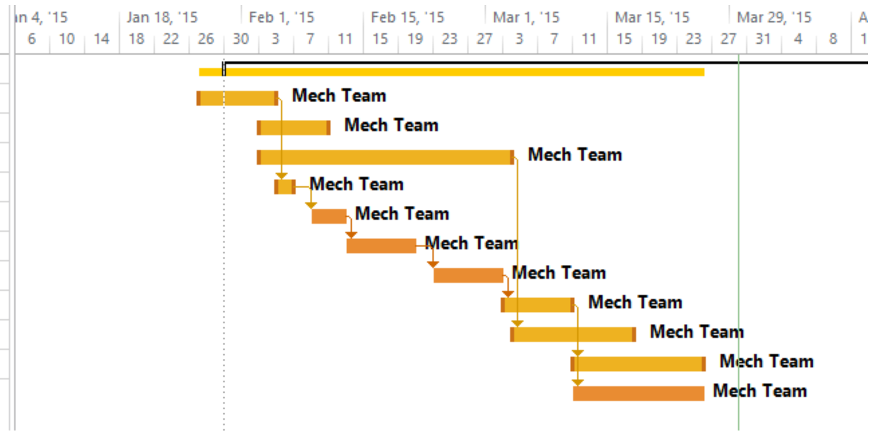
Task Name	Duration	Start	Finish	Marked
Administration	206 days	Mon 9/1/14	Mon 6/15/15	Yes
Attend CURC General Body Meeting	1 day	Wed 9/3/14	Wed 9/3/14	Yes
Hold First CanSat Meeting and Select Team Leads	3 days	Thu 9/4/14	Mon 9/8/14	Yes
Travel Preperations	30 days	Sun 3/1/15	Thu 4/9/15	Yes
Deliverables	162 days	Sat 11/1/14	Mon 6/15/15	Yes
PDR	67 days	Sat 11/1/14	Sat 1/31/15	Yes
PDR Review	15 days	Mon 2/2/15	Fri 2/20/15	Yes
CDR	30 days	Thu 3/19/15	Wed 4/29/15	Yes
PFR	14 days	Wed 5/27/15	Sun 6/14/15	Yes
Sponsorship	66 days	Thu 1/1/15	Thu 4/2/15	Yes
Sponsorship Package	11 days	Mon 1/19/15	Mon 2/2/15	Yes
RavenKnights Website	12 days	Sun 2/1/15	Mon 2/16/15	Yes
Contact Cemetrix	7 days	Mon 2/2/15	Tue 2/10/15	Yes
IEEE Board Meeting	4 days	Mon 3/30/15	Thu 4/2/15	Yes



Program Schedule

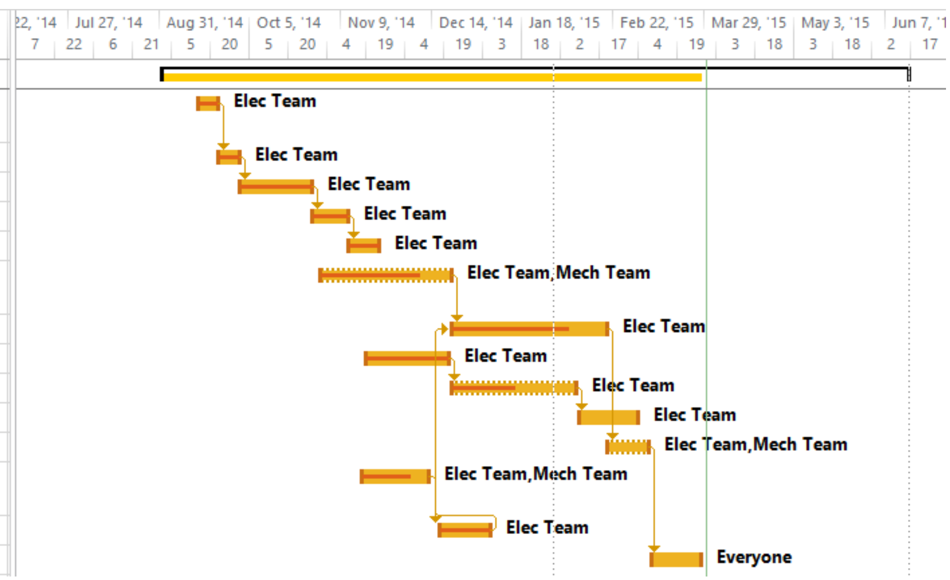
Mechanical Team

Task Name	Duration	Start	Finish	Marked
Mechanical Team	97 days	Fri 1/30/15	Mon 6/15/15	Yes
Blade Testing	7 days	Tue 1/27/15	Wed 2/4/15	Yes
Build Container	6 days	Tue 2/3/15	Tue 2/10/15	Yes
Design System for Testing Rotation Control	21 days	Tue 2/3/15	Tue 3/3/15	Yes
Complete Hinge Design	2 days	Thu 2/5/15	Fri 2/6/15	Yes
3D Print Parts for 2nd Prototype	4 days	Mon 2/9/15	Thu 2/12/15	Yes
Assemble Complete Prototype	6 days	Fri 2/13/15	Fri 2/20/15	Yes
Test Blade Deployment	6 days	Mon 2/23/15	Mon 3/2/15	Yes
Environmental Testing	6 days	Tue 3/3/15	Tue 3/10/15	Yes
Rotational Control Testing	10 days	Wed 3/4/15	Tue 3/17/15	Yes
High Drop Tests	11 days	Wed 3/11/15	Wed 3/25/15	Yes
Integration Tests of Container and Science Vehicles	11 days	Wed 3/11/15	Wed 3/25/15	Yes



Electrical Team

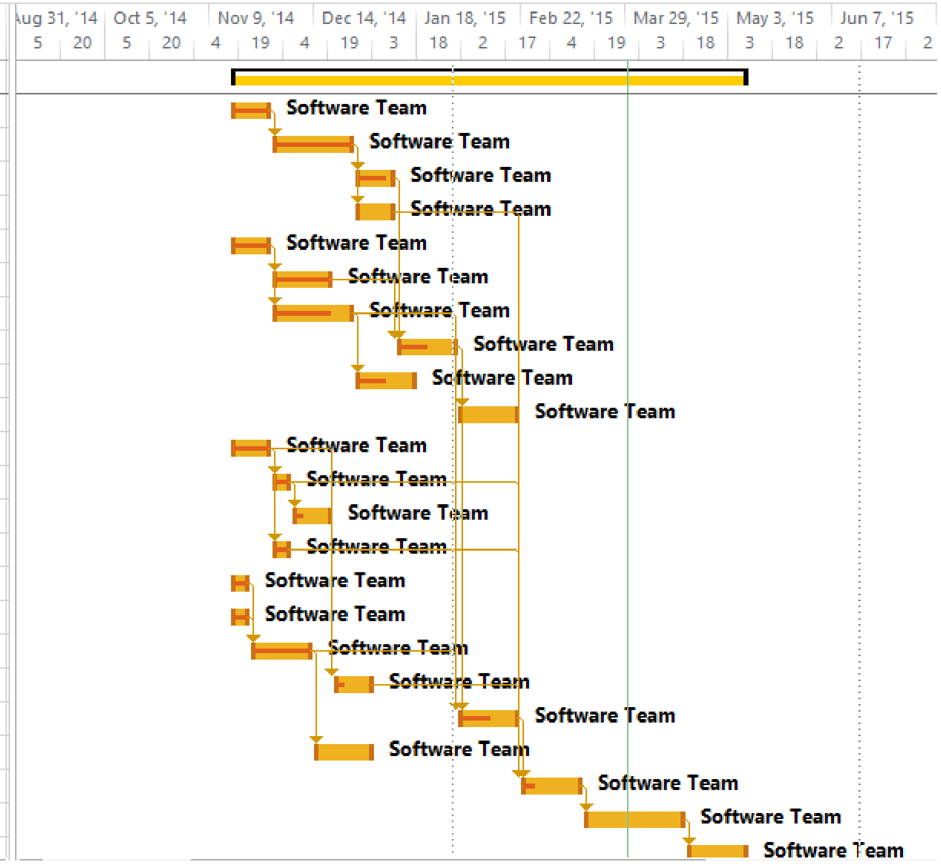
Task Name	Duration	Start	Finish
Electrical Team	206 days	Mon 9/1/14	Mon 6/15/15
Review Mission Guide and Document Requirments	6 days	Mon 9/15/14	Mon 9/22/14
Select Required Sensors and Microcontroller	6 days	Tue 9/23/14	Tue 9/30/14
Design Prototyping PCB	20 days	Wed 10/1/14	Tue 10/28/14
Solder Components onto PCB	10 days	Wed 10/29/14	Tue 11/11/14
Test PCB and Hand over to Software Team	9 days	Wed 11/12/14	Sun 11/23/14
Colobrate with mech team on PCB Structure Design	37 days	Sat 11/1/14	Sun 12/21/14
Design and Fabricate CanSat PCB	44 days	Mon 12/22/14	Thu 2/19/15
Choose Xbee and Purchase Parts	24 days	Wed 11/19/14	Sat 12/20/14
Design antenna for wireless communication	36 days	Mon 12/22/14	Sat 2/7/15
Range Test Wireless Communications	17 days	Mon 2/9/15	Tue 3/3/15
Construct PCB Structure and Integrate PCB	12 days	Fri 2/20/15	Sat 3/7/15
Colobrate with Mech Team to Design Camera Stabilization	20 days	Mon 11/17/14	Fri 12/12/14
Implement Camera Stabilizationon PCB	14 days	Wed 12/17/14	Mon 1/5/15
Test Prototype 1	15 days	Mon 3/9/15	Fri 3/27/15



Program Schedule

Software Team

Task Name	Duration	Start	Finish
Software Team	125 days?	Mon 11/17/14	Fri 5/8/15
General I2C	2 wks	Mon 11/17/14	Fri 11/28/14
Read/Save I2C	4 wks	Mon 12/1/14	Fri 12/26/14
Sensors -> EEPROM	2 wks	Mon 12/29/14	Fri 1/9/15
EEPROM FSW_STATE retrieval	2 wks	Mon 12/29/14	Fri 1/9/15
General UART	2 wks	Mon 11/17/14	Fri 11/28/14
PC communication	3 wks	Mon 12/1/14	Fri 12/19/14
Xbee Transmit	4 wks	Mon 12/1/14	Fri 12/26/14
EEPROM -> PC	3 wks	Mon 1/12/15	Fri 1/30/15
Transmission testing	3 wks	Mon 12/29/14	Fri 1/16/15
Sensor interface testing	3 wks	Mon 2/2/15	Fri 2/20/15
General GPIO	2 wks	Mon 11/17/14	Fri 11/28/14
Release mechanism trigger	1 wk	Mon 12/1/14	Fri 12/5/14
Release testing	2 wks	Mon 12/8/14	Fri 12/19/14
Location assistance device	1 wk	Mon 12/1/14	Fri 12/5/14
FSW_STATES	1 wk	Mon 11/17/14	Fri 11/21/14
Periodic interrupts	1 wk	Mon 11/17/14	Fri 11/21/14
Rough processing loop	3 wks	Mon 11/24/14	Fri 12/12/14
LED state and error indication	2 wks	Mon 12/22/14	Fri 1/2/15
Datalogging + Transmitting	3 wks	Mon 2/2/15	Fri 2/20/15
Reset handling	3 wks	Mon 12/15/14	Fri 1/2/15
Full system integration	3 wks	Mon 2/23/15	Fri 3/13/15
Integration Testing	5 wks	Mon 3/16/15	Fri 4/17/15
PID Stabilization Testing	3 wks	Mon 4/20/15	Fri 5/8/15



Shipping and Transportation

- **CanSat Container and Science Vehicle**
  - Look into getting a case with a custom molded foam insert
  - Transport CanSat with carry on luggage
    - Ensure everything complies with regulations of airline

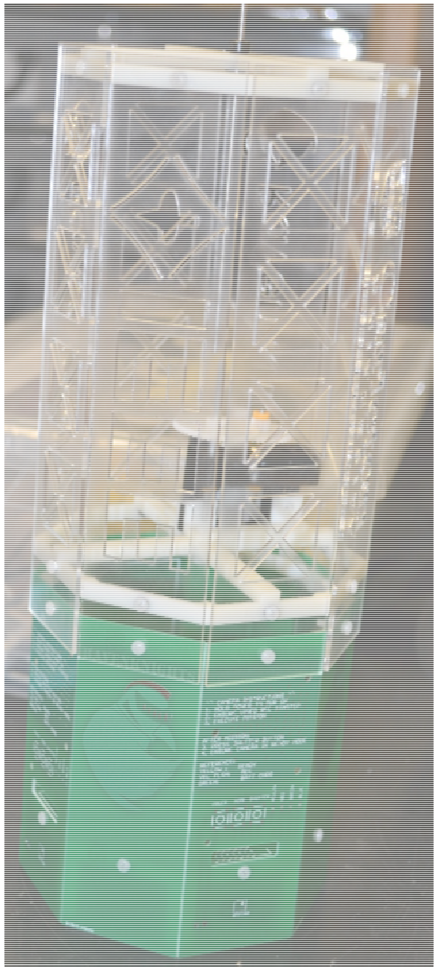
- **Antenna mast**
  - Table top mast should easily fit in carry on luggage

- **Tools and equipment**
  - Only transport tools which cannot be easily purchased locally

http://www.productioncase.com/category/custom-cnc-foam-inserts-214.aspx

Conclusions

- **Progress to date**
  - Tested descent control
  - Assembled prototypes of both payload and container
  - Drivers to implement CDH have be development and implemented
  - All onboard sensors have been tested and configured
  - Prototype camera stabilization test bed has been built
  - Ground station antenna has been constructed
  - Completed implementation of FSW



Conclusions

- **Work to be completed**
  - Test payload and container separation
  - Make payload container interface
  - Test communications and ground station
  - Test camera stabilization
  - Test ground station with live data from payload