CanSat 2014
Critical Design Review (CDR)

Team # 2305

RavenKnights

Presentation Outline

Section	Presenter
Systems Overview	Amente/Jayant
Sensor Subsystem Design	Amente
Descent Control Design	Graham
Mechanical Subsystem Design	Jayant
Communication and Data handling Subsystem Design	David
Electrical Power System Design	David
Flight Software Design	Amente
Ground Control System Design	Amente
CanSat Integration and Test	David/Graham
Requirement Compliance	Jayant
Management	Jayant

Team Organization

- Amente Bekele
  3rd Year
  Team Lead
  - Jayant Sachdev
    4th Year
    Mechanical Design Lead
    - Jesse Mahussier
      4th Year
      Mechanical Design
    - Graham Blackport
      4th Year
      Mechanical Design
    - Rohan Garnik
      2nd Year
      Mechanical Design
    - Omar Mohammed
      3rd Year
      Mechanical Design
  - David Yao
    3rd Year
    Electrical Systems Lead
    - Alok Deshpande
      2nd Year
      Electrical Design
    - Akshay Puli
      3rd Year
      Electrical Design
    - Paul Mushubi
      2nd Year
      Electrical Design

Faculty Advisor
Cheryl Schramm

Acronyms

Acronym	Meaning
A	Analysis
ACK	ACKnowledgement
ADC	Analog-to-Digital Converter
ALT	ALTitude
API	Application Program Interface
AT	ATtention
BIN	BINary file
CanSat	Can-sized Satellite
CMOS	Complementary Metal Oxide Semiconductor
CSV	Comma Separated Values
CURC	Carleton University Robotics Club
CONOPS	Concept of Operations
D	Demonstration
dBi	Decibel (Isotrophic)
DSP	Digital Signal Processing
EEPROM	Electrically Erasable Programmable Read-Only Memory
FAT	File Allocation Table
FIFO	First In, First Out
FSW	Flight SoftWare
FTDI	Future Technologies Device International
G	G-force
GCS	Ground Control System
GPRMC	Recommended Minimum Specific GPS/Transit Data
GPS	Global Positioning System
GS	Ground Station
GUI	Graphical User Interface
I	Inspection
I/O	Input/Output
I2C	Inter-Integrated Circuit

Acronyms (Continued)

Acronym	Meaning
ID	IDentifier
ISR	Interrupt Service Routine
JPEG	Joint Photographic Experts Group
LAT	Latitude
LED	Light Emitting Diode
LONG	Longitude
MCU	Microcontroller Unit
MUX	MUltipleXer
NiMH	Nickel Metal Hydride
NMEA	National Marine Electronics Association
NTSC	National Television System Commission
PANID	Previous Access Network IDentifier
PC	Personal Computer
PCB	Printed Circuit Board
PDR	Preliminary Design Review
PWM	Pulse-Width Modulation
RC	Radio Controlled
RSSI	Received Signal Strength Indication
SD	Secure Digital
SMA	SubMiniature version A
SPI	Serial Peripheral Interface
T	Test
TTL	Transistor-Transistor Logic
UART	Universal Asynchronous Receiver/Transmitter
USART	Universal Synchronous-Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
UTC	Coordinated Universal Time
VM	Verification Method

System Overview

Amente

Mission Summary

Mission:

The mission for the 2014 CanSat competition is to design, build and launch an “Environmentally Powered Atmospheric Probe”.

Objectives

- Harvest energy from the environment to power the Payload.
- Collect telemetry from both Container and Payload at a minimum of 1HZ and transmit it to Ground Station.
- Control the descent of the Container and Payload to altitude-defined speeds.
- Deploy the payload at 500m.
- Keep the egg intact through out the whole trip.

Mission Summary

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Summary of Changes Since PDR

- **Sensor Subsystem**
  - No changes
- **Descent Control**
  - No changes
- **Mechanical Subsystem**
  - Separation mechanism was changed to a simpler connection between Nichrome wire and fishing line.

Summary of Changes Since PDR

- **CDH Subsystem**
  - XBee radios on Payload and Container to be configured with End-Device firmware instead of Router
- **EPS Design**
  - Use 8600mF Capacitor instead of 4700mF as reservoir
  - Use 9V Energizer battery to power container
- **FSW Design**
  - Added Temperature and Altitude calculation
- **GCS Design**
  - Use additional custom designed ISP programmer with debugging capabilities

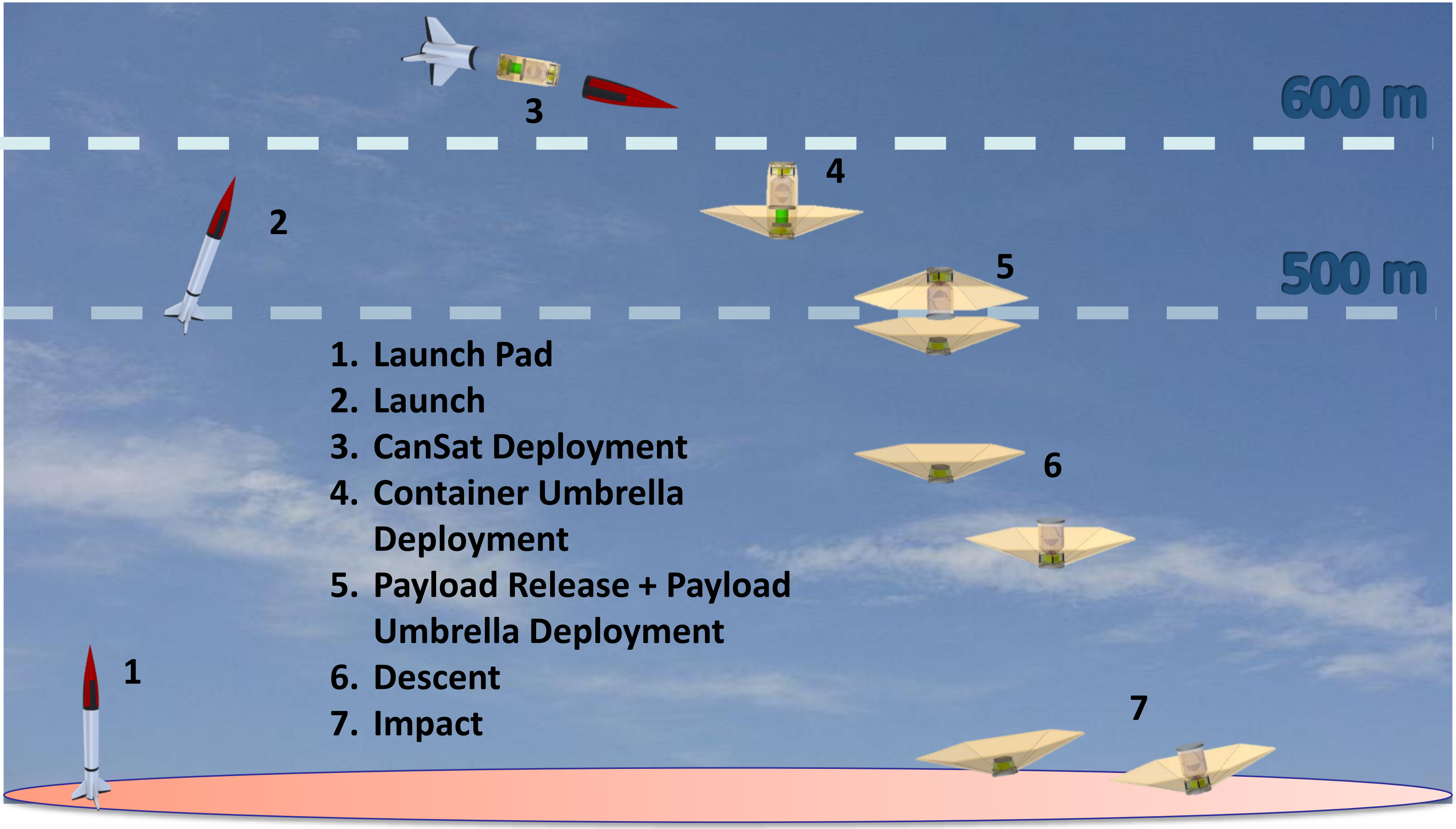
System Requirement Summary

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SYS-01	CanSat shall consist of two modules, container and payload module	Competition Requirement	High				x		
SYS-02	The payload shall contain and protect the egg from cracking or breaking during flight through landing.	Competition Requirement	High						
SYS-03	Total mass of the CanSat (container and payload) shall be 600 grams +/- 10 grams without the egg	Competition Requirement	High						
SYS-04	Container shall fit in the envelope of 125 mm x 310 mm including the container passive descent control system.	Competition Requirement	High						
SYS-05	The CanSat (container and payload) shall deploy from the rocket fairing section.	Competition Requirement	High						x
SYS-06	CanSat shall use no flammable or pyrotechnic devices	Competition Requirement	High				x		
SYS-07	Container shall use alkaline batteries	Competition Requirement	High				x		
SYS-08	CanSat and Operation shall comply with field safety regulations	Competition Requirement	High						x
SYS-09	XBee radios shall be used for telemetry.	Competition Requirement	High				x		x
SYS-10	XBee radios shall have their NETID/PANID set to their team number	Competition Requirement	High						
SYS-11	XBee radios shall not use broadcast mode.	Competition Requirement	High						
SYS-12	Both the container radio and payload radio shall use the same NETID/PANID	Competition Requirement							
SYS-13	CanSat electronics shall be enclosed	Competition Requirement	High				x		
SYS-14	When released, the payload shall have a descent rate of less than 10 m/s	Competition Requirement	High						
SYS-15	The container shall use a passive descent control system.	Competition Requirement	High			x		x	
SYS-16	All structures shall be built to survive 30 Gs of shock and 15 Gs of acceleration	Competition Requirement	High						
SYS-17	Cost of the CanSat shall be under $1000	Competition Requirement	Medium						

System Requirement Summary

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SYS-18	All telemetry shall be displayed in real time during descent	Competition Requirement	High						x
SYS-19	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets.	Competition Requirement	High						
SYS-20	The container and payload shall maintain a mission time	Competition Requirement	Medium						
SYS-21	The container shall acknowledge the deployment of the payload	Optional Requirement	Low						
SYS-22	The payload shall include an external umbilical power connection to allow for testing and safety checks when not harvesting energy.	Competition Requirement	Medium						
SYS-23	The Container shall descend at 12 m/s after release	Competition Requirement	High						
SYS-24	The Container and Payload shall separate at 500m +/- 10m	Competition Requirement	High			x		x	x

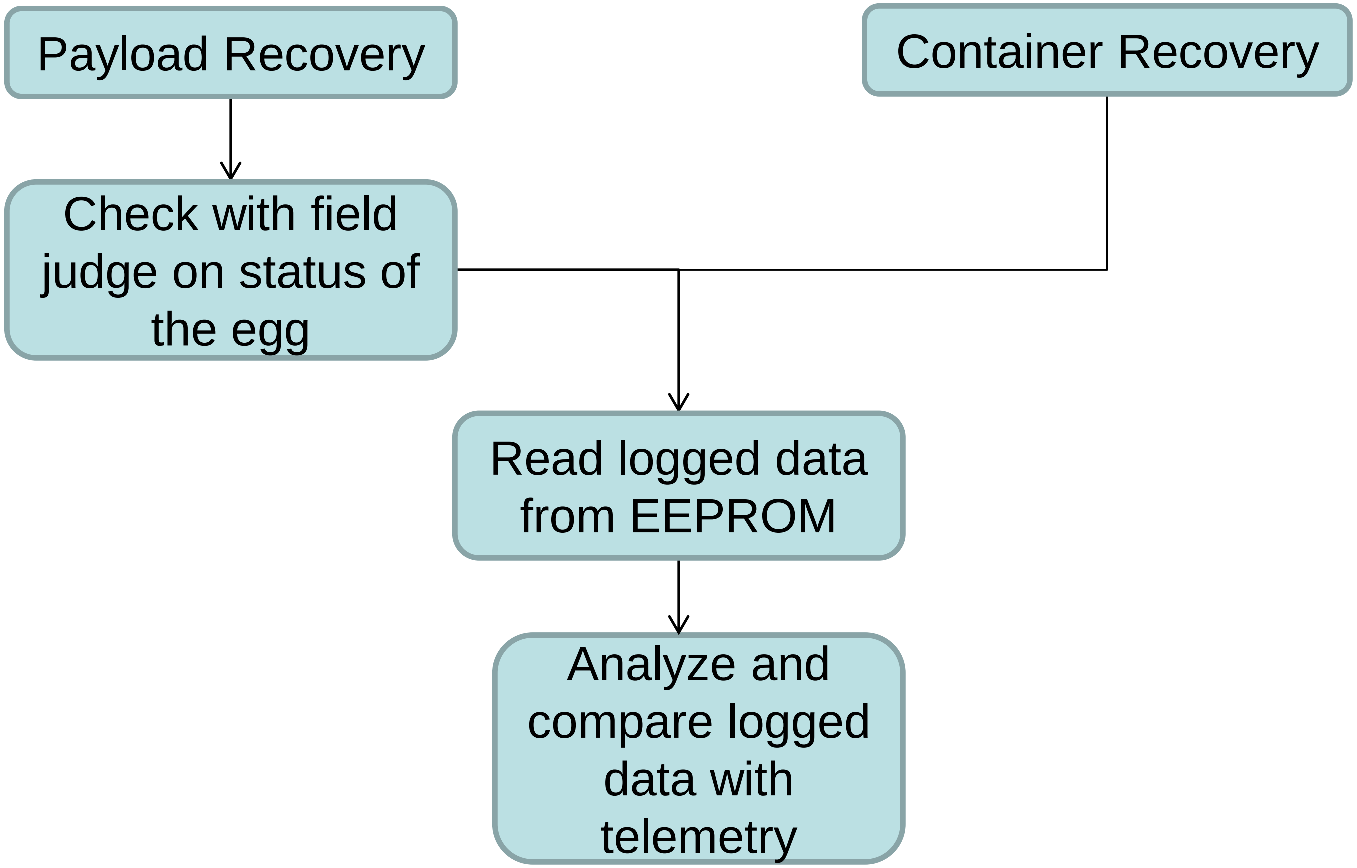
System Concept of Operations



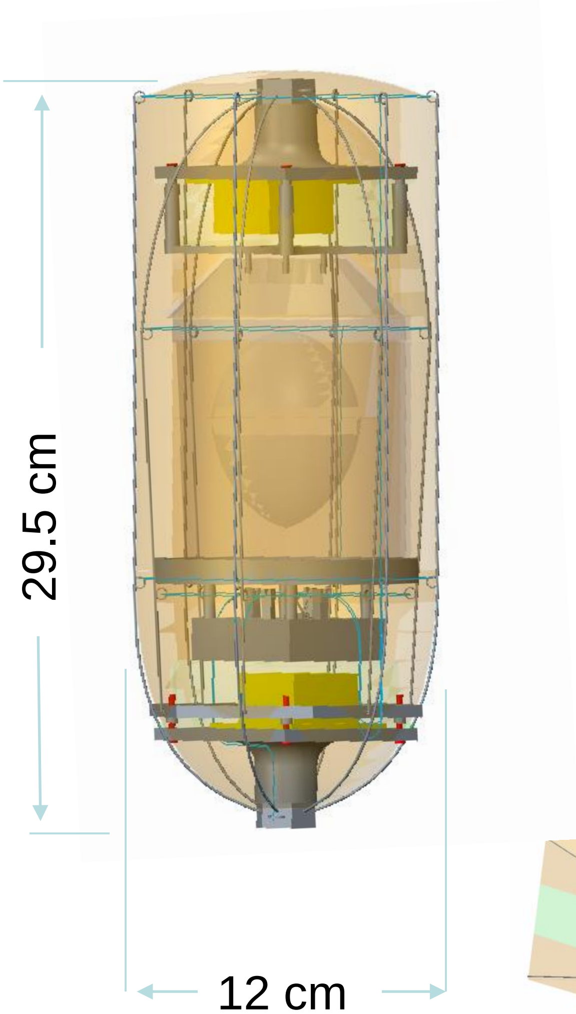
1. Launch Pad
2. Launch
3. CanSat Deployment
4. Container Umbrella Deployment
5. Payload Release + Payload Umbrella Deployment
6. Descent
7. Impact

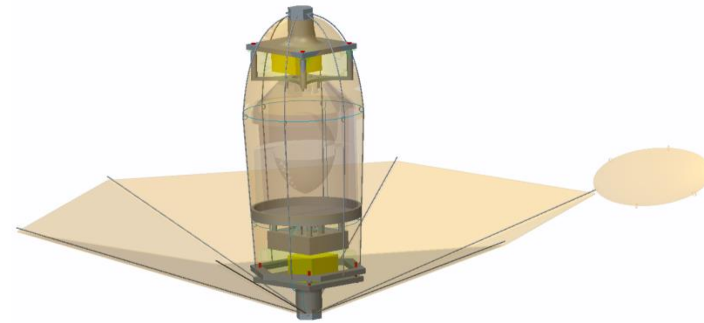
System Concept of Operations

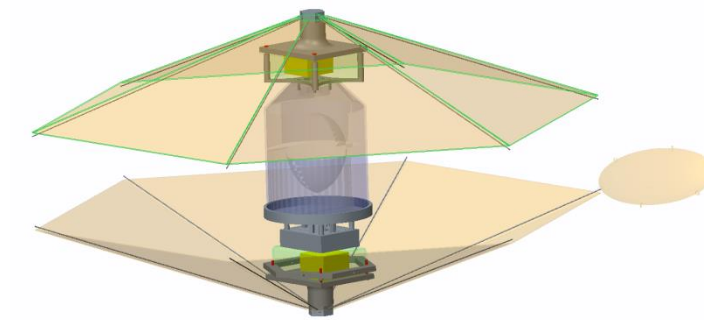
Post-launch recovery and data reduction

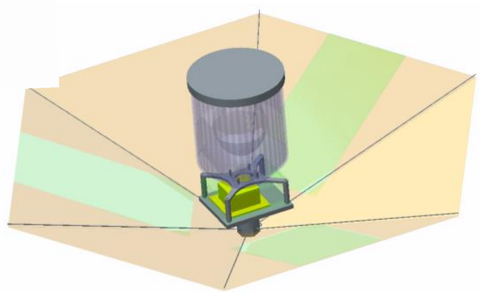


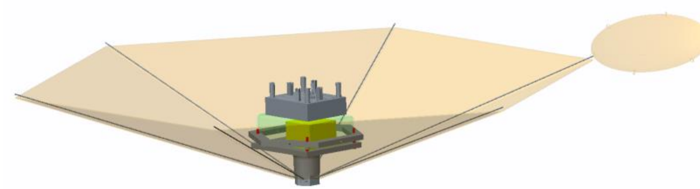
Physical Layout







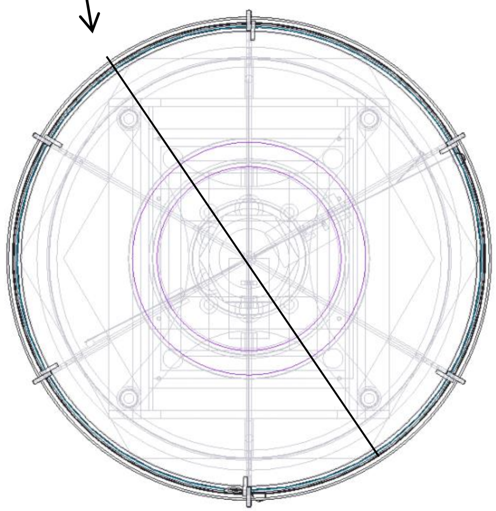




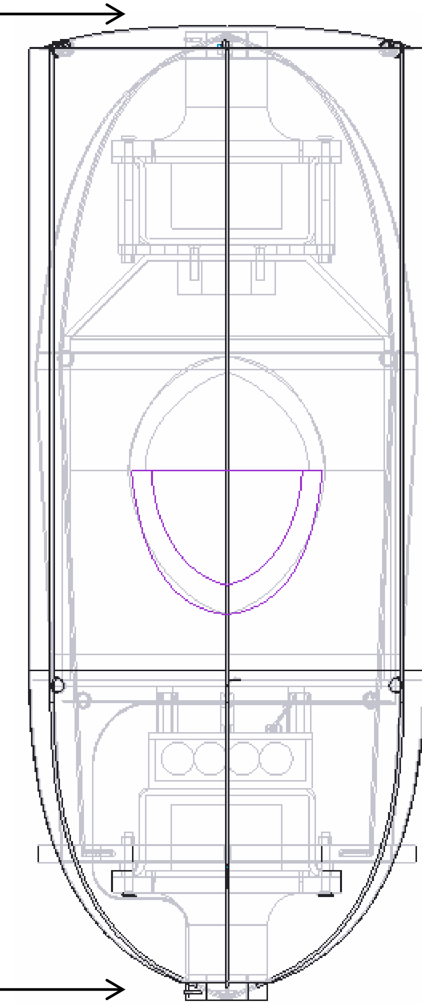
Launch Vehicle Compatibility

Dimensions are measured from Prototype

12 cm
.25 cm clearance
in all directions



29.5 cm
(.5 cm clearance)

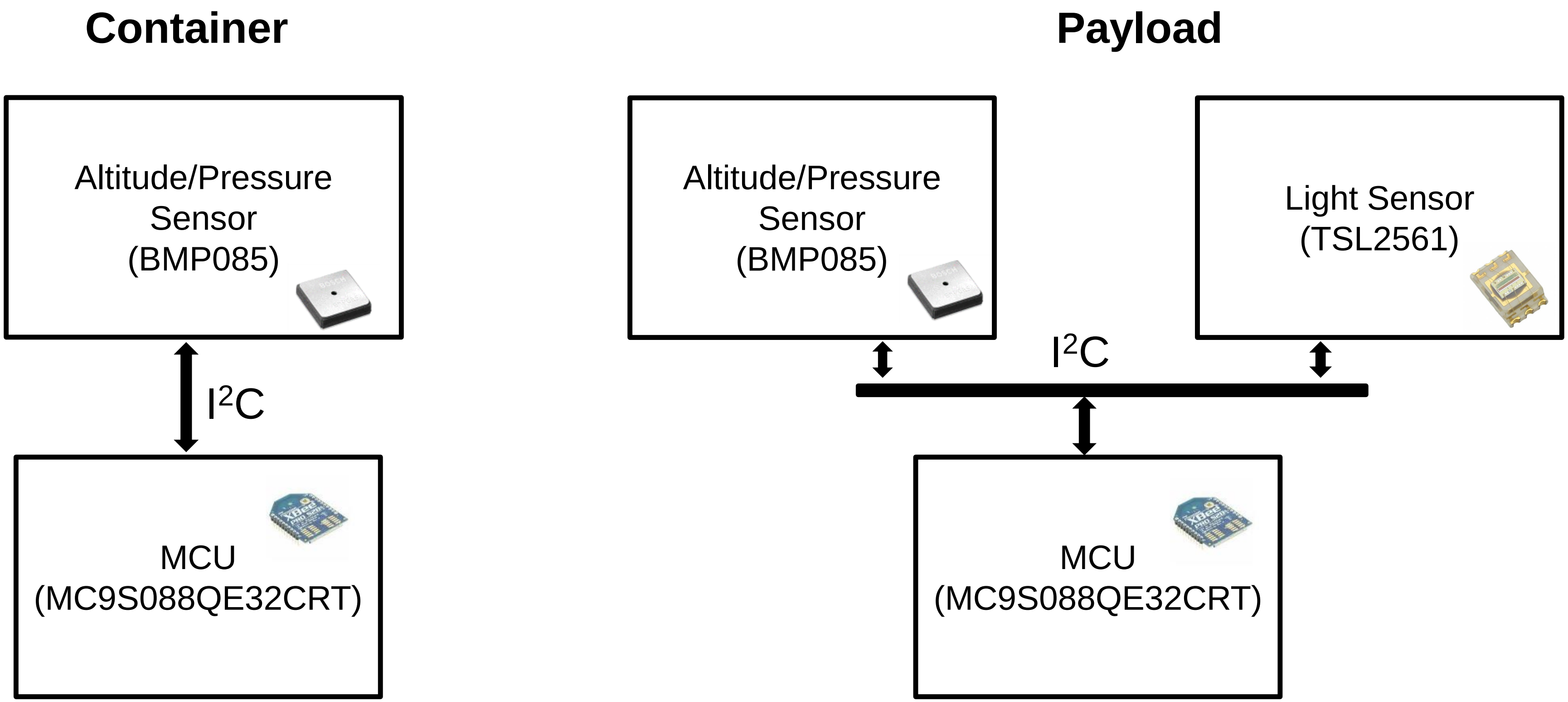


Fabric
will cover

Sensor Subsystem Design

Amente

Sensor Subsystem Overview



Sensor Changes Since PDR

- **Overview of the CanSat sensor system changes since PDR**
  - No Changes

Sensor Subsystem Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
SS-01	Telemetry shall be collected at a minimum of 1Hz	Competition Requirement	High			X			x
SS-02	Altitude sample shall be included with telemetry	Competition Requirement	High			X			X
Ss-03	Temperature sample shall be included with telemetry	Competition Requirement	Medium			X			X
SS-04	Light sensor data shall be included with telemetry	Optional Requirement	Low			X		X	X

Altitude Sensor Summary

Bosch BMP085 (Both Payload and Container)

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

Specifications

Range: 300 – 1100hPa
Resolution: 0.01hPa
Accuracy: +/- 2.5hPa
Interface: I^2C

<u>Data processing:</u>

- Pressure sample values will be sampled and transmitted to GS in 16bit integer format
- Altitude conversion calculations are done by the FSW.
- Altitude will be calibrated based on the pressure data and base altitude of the launchpad before mission

Absolute Altitude:

$$Abs.Altitude\ (m) = 44330 \cdot \left(1 \cdot \left(\frac{p}{p_o}\right)^{\frac{1}{5.255}}\right)$$

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

Altitude relative to ground:

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

Air Temperature Sensor Summary

Bosch BMP085 (Both Payload and Container)

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

Specifications

Range: -40 ºC – +85 ºC
Accuracy: +/- 2 ºC
Interface: I^2C

Data processing:

- The temperature samples are taken transmitted to GS in 16 bit signed integer format
- Samples are converted to Celsius scale by the GS software based on equations from Datasheet

Light Sensor Camera

AMS-TAOS TSL2561

- I^2C Interface simplifies flight software design
- Measures light intensities in both visible and infrared spectrum

Specifications

Operating Temp Range:- 30 ºC – 80 ºC
Dynamic range (Lux) : - 0.1 – 40000
Interface: I^2C

Data processing:

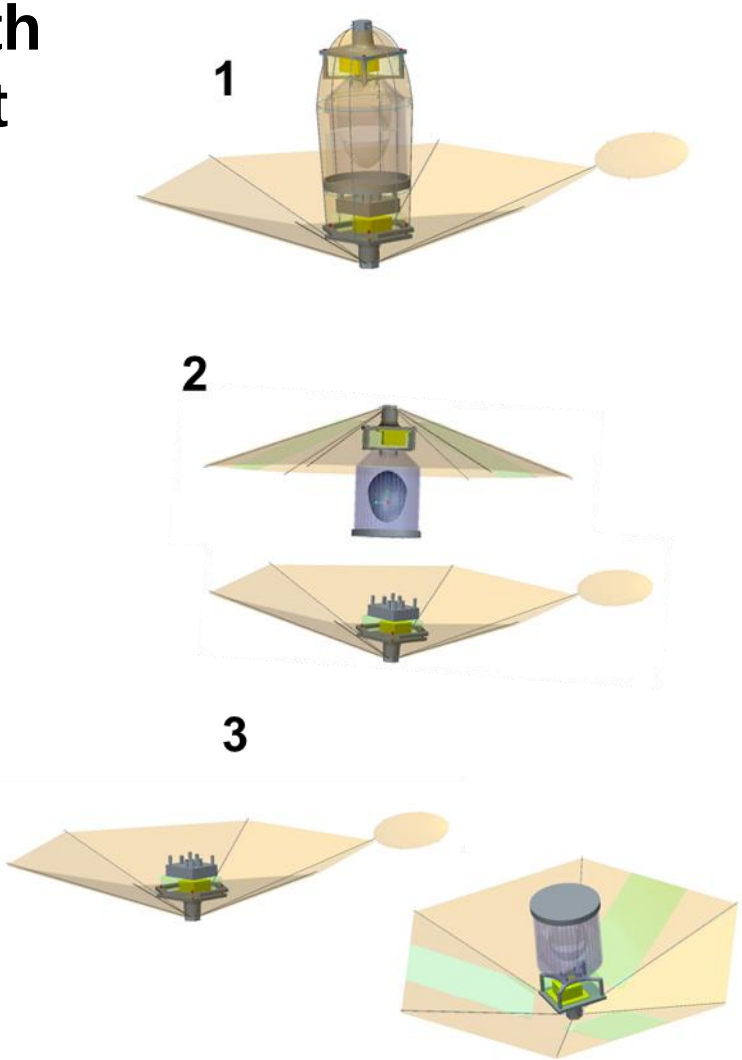
- The light sensor samples are taken in 16 bit unconverted format
- Samples are converted LUX and mw/m^2 for infrared by the GS software based on equations from Datasheet

Descent Control Design

Graham

Descent Control Overview

- **Umbrella-like surfaces made with steel spring wire and RC aircraft Koverall used to create drag**
- **Outline:**
  1. After CanSat is released, container umbrella opens
  2. At 500 m altitude, payload umbrella opens, slowing the payload more than the container, causing separation
  3. Payload flips over naturally



Descent Control Changes Since PDR

- **Changes since the PDR**
  - No changes

Descent Control Requirements

ID	Requirement	Rationale	Priority	Parent	Children	VM			
						A	I	T	D
DCS-01	The descent rate of the container shall be 12 m/s above 500 meters.	Mission requirement	High	SYS-23		x		x	x
DCS-02	The descent rate of the payload shall be less than 10 m/s below 500 meters.	Mission requirement	High	SYS-14		x		x	x
DCS-03	All descent control device attachments shall survive 30 G's of shock	Hardware requirement	High	SYS-16		x			
DCS-04	The decent mechanism folding method shall prevent entanglement and minimize volume	Hardware requirement	High				x		x
DCS-05	The container shall feature fluorescent colours	Mission requirement	High				x		x
DCS-06	The descending mechanism must not use flammable materials	Mission requirement	High				x		x
DCS-07	The Nichrome wire actuator shall release the payload from the CanSat container	Mission requirement	High			x	x	x	x

Container Descent Control Hardware Summary

- **Steel spring wires used in descent control provide shock absorption**
- **Length and angle of steel spring wire determined in descent rate calculations in order to meet DCS-001**
  - 27 cm at an angle of 40° allows for sufficient drag from umbrella structure to meet mission requirements
- **Orange fabric across steel spring wire for optimal visibility**
  - Fabric is RC aircraft Koverall for it’s versatility
- **Successful test of prototype from a height of 106 m has been completed**

Payload Descent Control Hardware Summary

DCS deployment trigger and mechanism

- Umbrella deployment mechanism uses Nichrome wire to cut through a fishing line in tension which holds steel spring wires tied together.
- Deployment trigger uses a GPIO pin on the microcontroller unit which drives an N-channel MOSFET switch to allow current through the Nichrome wire from decent control triggering power source.

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  - 27 cm at an angle of 40° allows for sufficient drag from umbrella structure to meet mission requirements
- **Orange fabric across steel spring wire for optimal visibility**
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Descent Rate Estimates

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

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

$v = terminal\ velocity$

$C_D = drag\ coefficient$

$A = frontal\ area$

$\rho = air\ density$

$m = mass$

- Descent control surface approximated as a cone to obtain drag coefficients using $C_D = 0.0112\theta + 0.162$
  - Payload: $C_D = 0.442$
  - Container: $C_D = 0.386$
- Assuming pressure drag >> friction drag
- Geometry was calculated based on velocities given in mission requirements

Descent Rate Estimates

- **Frontal area required to achieve desired velocities:**
  - Payload: A = 0.175 m^2
  - Container: A = 0.199 m^2
- **Using these values and the formula we calculate the following results:**
  - Container + Payload velocity: 12.0 m/s
  - Container velocity: 6.6 m/s
  - Payload velocity: 10.0 m/s

Mechanical Subsystem Design

Jayant

Mechanical Subsystem Overview

Category	Components	Material	Usage
Shell	Cylindrical casing	Thermoplastic	Protects the CanSat components, allows access to electronics
Payload-container interface	Fishing line	Fishing line	Fishing line holds the payload and container together
Release Mechanism	Fishing line Nichrome wire	Fishing line Nichrome wire	Nichrome wire is used to burn through the fishing line releasing separating the payload and container
Descent control	Upside down umbrella	Fabric Steel spring wire	Controls the speed of descent
Egg protection	Foam Non-Newtonian fluid	Corn starch Water	Prevents the egg from breaking due to impact

Mechanical Subsystem Changes Since PDR

- **Mechanical changes since PDR**
  - Separation mechanism was changed to a simpler connection between Nichrome wire and fishing line.

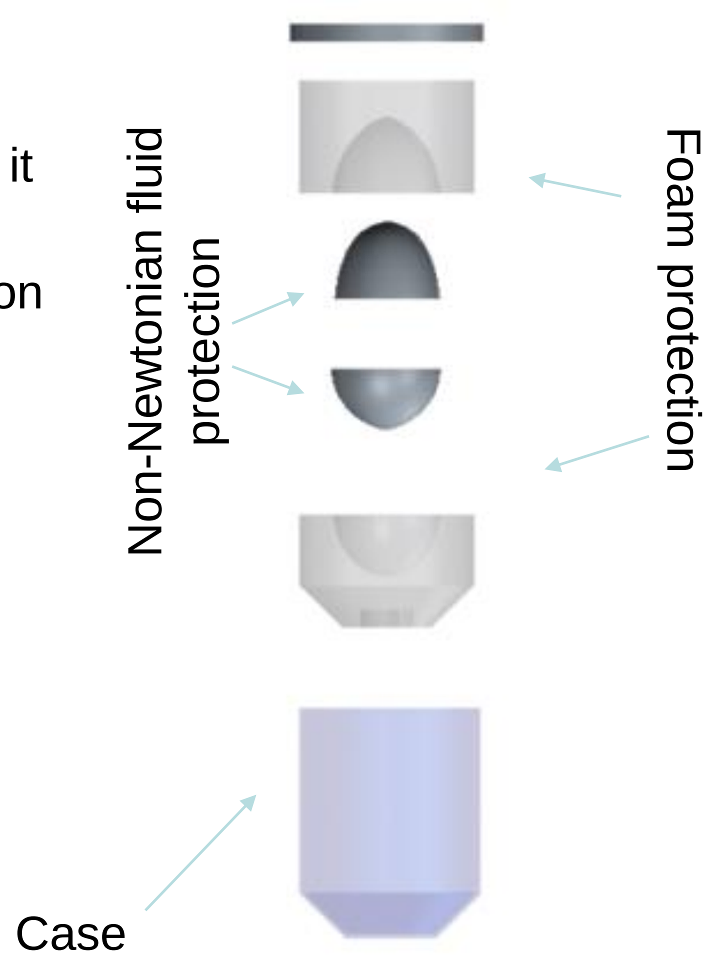
Mechanical Sub-System Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
MEC-01	The casing shall protect internal components	Hardware requirement	High	SYS-13			x		x
MAT-01	The materials selection shall minimize cost, volume, and weight	Mission requirement	Medium			x			x
MAT-02	The casing shall protect internal components successfully, while having minimal weight and size	Hardware requirement	Medium			x	x		x
MAT-03	The electronics shall be hard mounted using proper casing, screws and bolts	Mission requirement	Medium				x		x
MEC-02	Descent mechanism shall control descent speed	Mission requirement	High			x	x	x	x
MEC-03	The structure shall protect the egg on impact at 10 m/s	Hardware requirement	Medium	SYS-14		x	x	x	x
MEC-04	The separation mechanism shall separate both modules reliably within 2 seconds	Hardware requirement	High			x	x	x	
MEC-05	The CanSat shall 600g +/- 10g	Mission requirement	Medium			x	x		x
MEC-06	All Structures shalll be built to survive 30G of shock	Mission requirement	Medium			x	x	x	x
MEC-07	The CanSat shall measure no more than 120 mm diameter and 300 mm length	Hardware requirement	High	SYS-04			x		x
MEC-08	All Structures shall be designed to survive 15g of Acceleration	Mission requirement	Medium			x	x	x	x
MEC-09	The construction cost shall not exceed $1000	Mission requirement	High	SYS-17		x			x
MEC-10	The attach points shall support a load 30 times the CanSat weight	Hardware requirement	High	SYS-16		x	x	x	x
MEC-11	The Container and Payload shall separate at 500m +/- 10m	Mission requirement	High	SYS-24		x		x	x

Egg Protection Overview

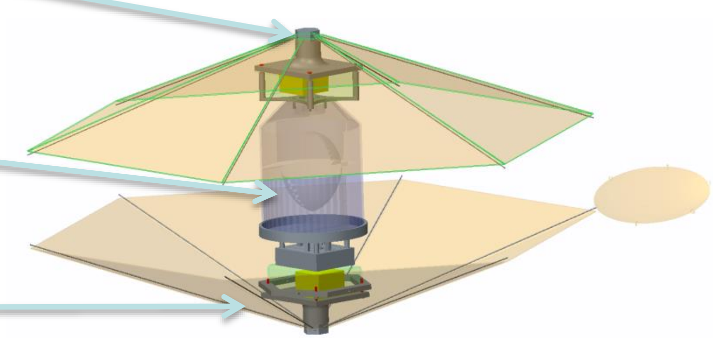
Used Materials

- **Corn starch** solution provides **best protection** (tested up to 14 m/s), however it is very heavy
- **Memory foam** provides good egg protection up to 7.5 m/s
- Design includes memory foam cut out to surround egg, coated with corn starch solution to maximize weight and egg protection efficiency



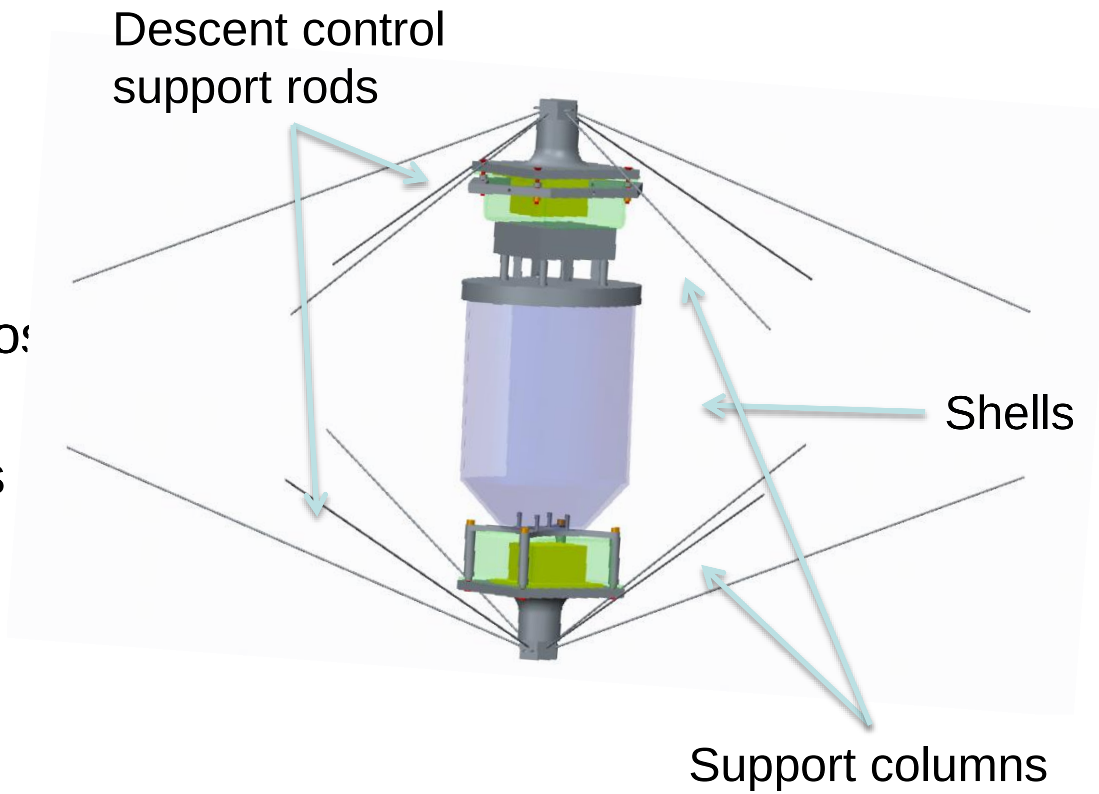
Mechanical Layout of Components

- **Main Layout**
  - Within size constraints
  - Volume remaining for system growth



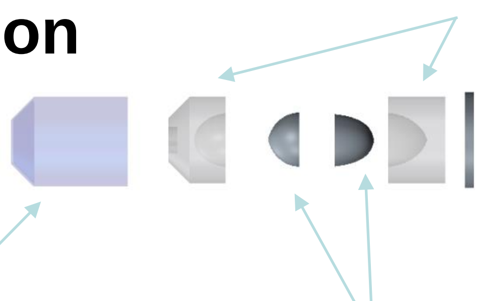
Mechanical Layout of Components

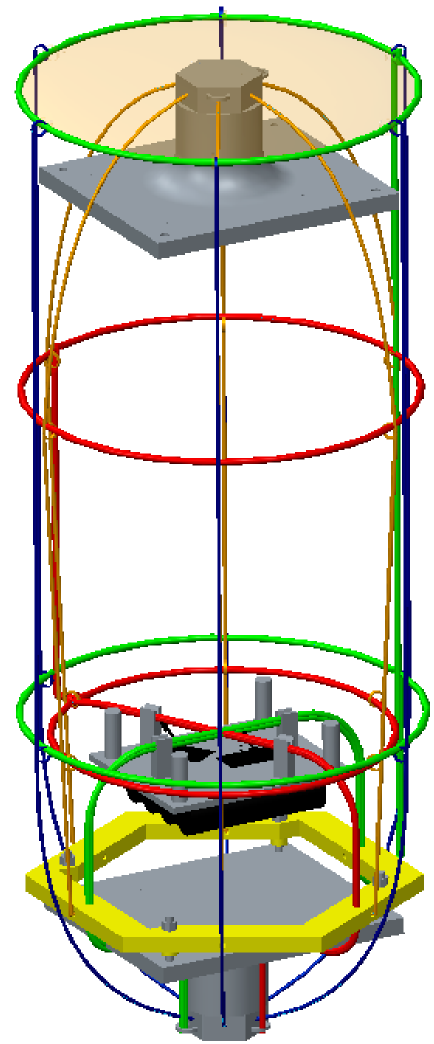
- **Shells**
  - Protect and contain internal components
  - Payload
    - Thermoplastic/thermos shells
    - Sheet metal brackets
    - Riveted assembly
- **Support Columns**
  - Absorb shock
  - Provide structural support



Mechanical Layout of Components

- **Release mechanism**
  - Fishing wire (green) opens container decent mechanism (blue)
  - Fishing wire (red) releases the payload from the container (yellow) and opens the payload decent mechanism (orange)
  - Battery (black) to heat Nichrome wire (black) and cut fishing wire
- **Egg protection**





Material Selections

- **Payload Container and Release Mechanism Materials**

- **Selected materials:**
  - Shell: Thermoplastics due to their toughness
  - Support Rods: Metal due to its forming capabilities and high strength
  - 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
  - Connectors (i.e. rivets and bolts): Metal by design

Materials Selections

- **Descent Control Mechanism and Egg Protection Materials**
- **Selected materials:**
  - **Descent control structure**: Steel Spring wire because its flexible and can be bent a large amount without plastic deformation
  - **Descent Control mechanism**: Koverall Fabric since it is strong and has an ability to stretch
  - **Egg protection**: mostly foam with some cornstarch solution to optimize egg protection and weight saving.

Container - Payload Interface

- Payload umbrella deployment also detaches payload from container.
- Mechanism uses Nichrome wire to cut through a fishing line in tension which holds payload and container together and also the steel spring wires that make up the payload umbrella..
- Deployment trigger uses a GPIO pin on the microcontroller unit which drives an N-channel MOSFET switch to allow current through the Nichrome wire from decent control triggering power source.

N-channel MOSFET: NTD4906N Power MOSFET
30 V, 54 A, Single N−Channel

Fishing Line: Spiderwire EZ BRAID ,
Nylon Microfiber ~220°C melting point

Nichrome wire: 30AWG thickness, needs ~0.875A current to heat up and cut the fishing line

Structure Survivability

- **Internal Structure**
  – Electronic components are secured in a different compartment at the bottom of the payload protected by additional foam to survive 30g's of shock
  – The PCB boards are attached to another support board using screws to hold them in place during flight
  – Electrical connections and pin sockets will be secured using zip ties to hold them in place
- **External Structure**
  – The frame contains steel spring wires which help support the payload and the umbrella structure

Mass Budget

Payload:

Component	Mass [g]	Source	Total Mass [g]	Tolerance [g]
Steel Spring Wire (x6)	5	Data Sheet	30	± 5
Koverall	2	Data Sheet	2	± 1
Corn Starch Fluid	60	Design	60	± 5
Structure	50	Estimate	50	± 5
Support Column	30	Estimate	30	± 3
Descent Control Structure	30	Estimate	30	± 3
Egg	67	Measured	67	± 5
Solar Panels (x3)	28	Data Sheet	84	± 3

Total Payload Mass (Without Egg): 286g
Total Payload Mass (including egg): 353 g

Mass Budget

Container:

Component	Mass [g]	Source	Total Mass [g]	Tolerance [g]
Steel Spring Wire (x6)	5	Data Sheet	30	± 5
Koverall	2	Data Sheet	2	± 1
Structure	50	Estimate	50	± 5
Support Column	30	Estimate	30	± 3
Descent Control Structure	30	Estimate	30	± 3
Battery (x4)	7	Data Sheet	28	± 1
Battery Holder	25	Estimate	25	± 3
Electrical Components and PCB	120	Estimate	120	± 5

Total Container Mass: 315 g

Total CanSat Mass (with egg): 668 g

Total CanSat Mass (without egg) 601 g

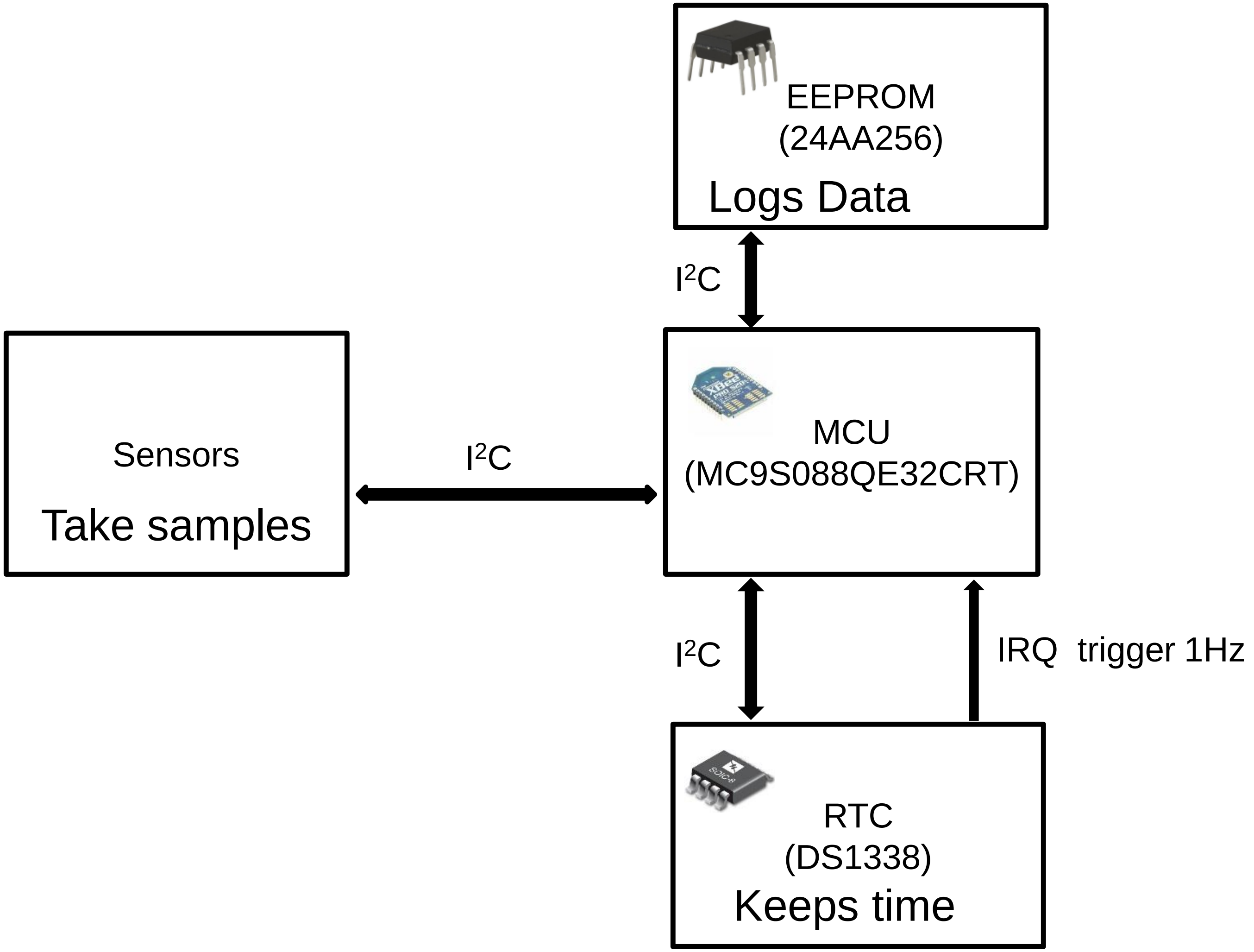
Competition Requirement: 600 +/-10 g

Margin: 9 g

Communication and Data Handling Subsystem Design

David

CDH Overview



CDH Changes Since PDR

- **Changes to the CDH since PDR**
  - Xbee radios on both payload and container are now configured using the ZIGBEE ROUTER AT firmware

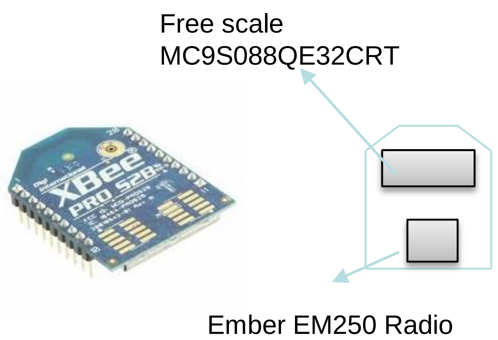
CDH Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
CHD-01	The container and payload shall use XBee transceivers for communication	Mission Requirement	High				x		
CDH-02	The payload microcontroller shall have at least one ADC channel	System Requirement	Medium				x		
CDH-03	The payload microcontroller shall have at least one I2C port	System Requirement	Medium				x		
CDH-04	The payload RTC chip shall have a small amount of memory	System Requirement	Low				x		
CDH-05	The NETID of the payload and container radio's shall be set to the team id	Mission Requirement	High				x		x
CDH-06	The container microcontroller shall have at least one ADC channel	System Requirement	Medium				x		
CDH-07	The container microcontroller shall have at least one I2C port	System Requirement	Medium				x		
CDH-08	The payload and container shall use the same RTC and EEPROM devices	Design Requirement	Low				x		
CDH-09	All sensor samples shall be logged	System Requirement	Medium				x		x

Processor & Memory Selection

Selected Payload and Container Processor: Freescale MC9S088QE32CRT

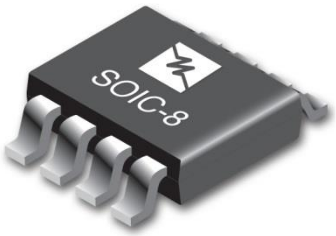
Speed and Memory	Data interfaces	Power Requirement	Board Type
Speed: 48MHz @3.3V Flash : 32KB RAM: 2KB EEPROM: N/A	I^2C – 1 UART – 2 SPI – 1 Analog – 3	15mA additional when bundled with XBee	Bundled with Programmable XBee



- By using the already available MCU on the Programmable variant of XBee radio module (XBP24BZ7UITB003), we minimize our overall system power consumption and save the additional cost of a dedicated MCU.

Real-Time Clock

Payload and Container RTC: DS1338

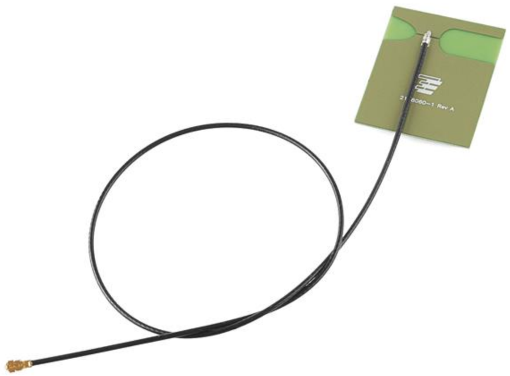


Interface: I^2C
RAM Availability: 56B
Package Type: SOIC-8
Recovery at Power-Up: 2ms Max

- The DS1338 RTC is used to keep track of the time in seconds since power up.
- The FSW on the MCU resets the RTC time on initial none POR power up.
- The FSW queries the time every second and includes it with telemetry sample.
- The RTC us powered by an external coin cell battery to remain powered on in case of power interruption
- It is also configured to send out a 1Hz square wave once it is enabled. The wave is fed into a GPIO IRQ pin on the MCU so that it can be interrupted at a 1-second interval.
- The interrupt wakes the MCU up from a low power sleep which it then begins to collect sensory data and sends them out via the XBee.
- This also lets us count uptime and number of packets. At last, the MCU is put back into sleep again to await for the next interrupt and the cycle continues.
- The DS1338 also has ability to store 56 bytes of arbitrary data.

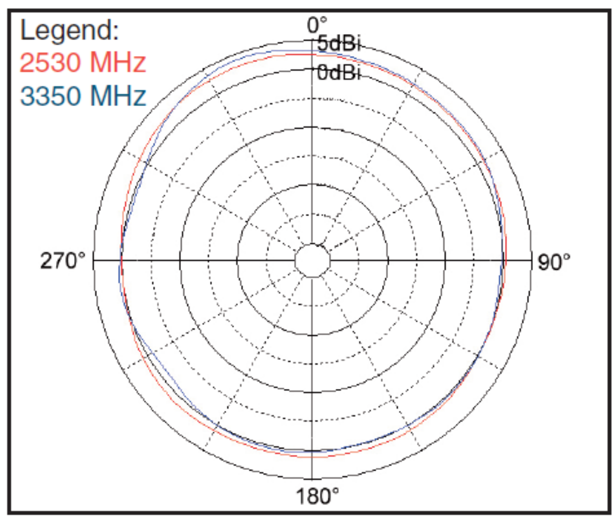
Antenna Selection

Payload and Container Antenna: TE Connectivity 2118059- 1

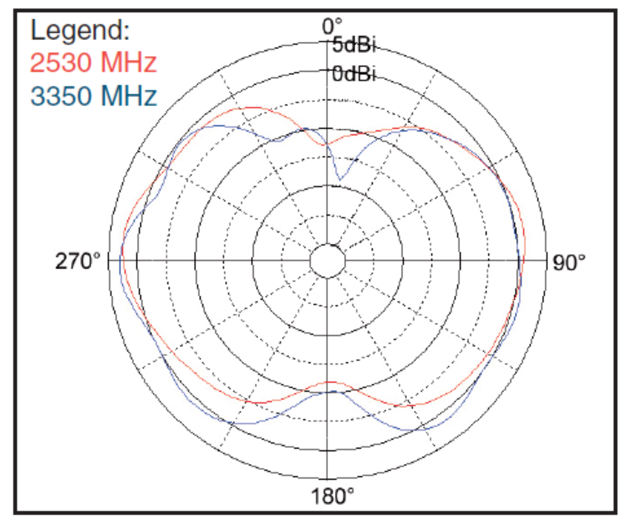


Frequency: 2.3GHz – 3.8 GHz
Peak-gain:4dBi (+1.85dBd)
Dimensions: 30.60 mm x 36.85 mm x 0.304mm

Azimuth



Elevation



- The antenna boosts XBee transmission output in the direction of the ground station
- Has a low mass (< 3.3 g) which fits the mass budget
- Adhesive mounting saves space

Radio Configuration

General Configuration

- We use X-CTU Software to configure the radio
- We use XBee API mode for communication in a three node wireless mesh network

CanSat (Payload and Container) Radio Configuration

- We configure both payload and container radio with ZIGBEE ROUTER AT firmware. ROUTER firmware can be configured to avoid radio cyclic sleep. AT mode makes FSW programming simpler.
- We set the configuration parameter NETID to our team ID

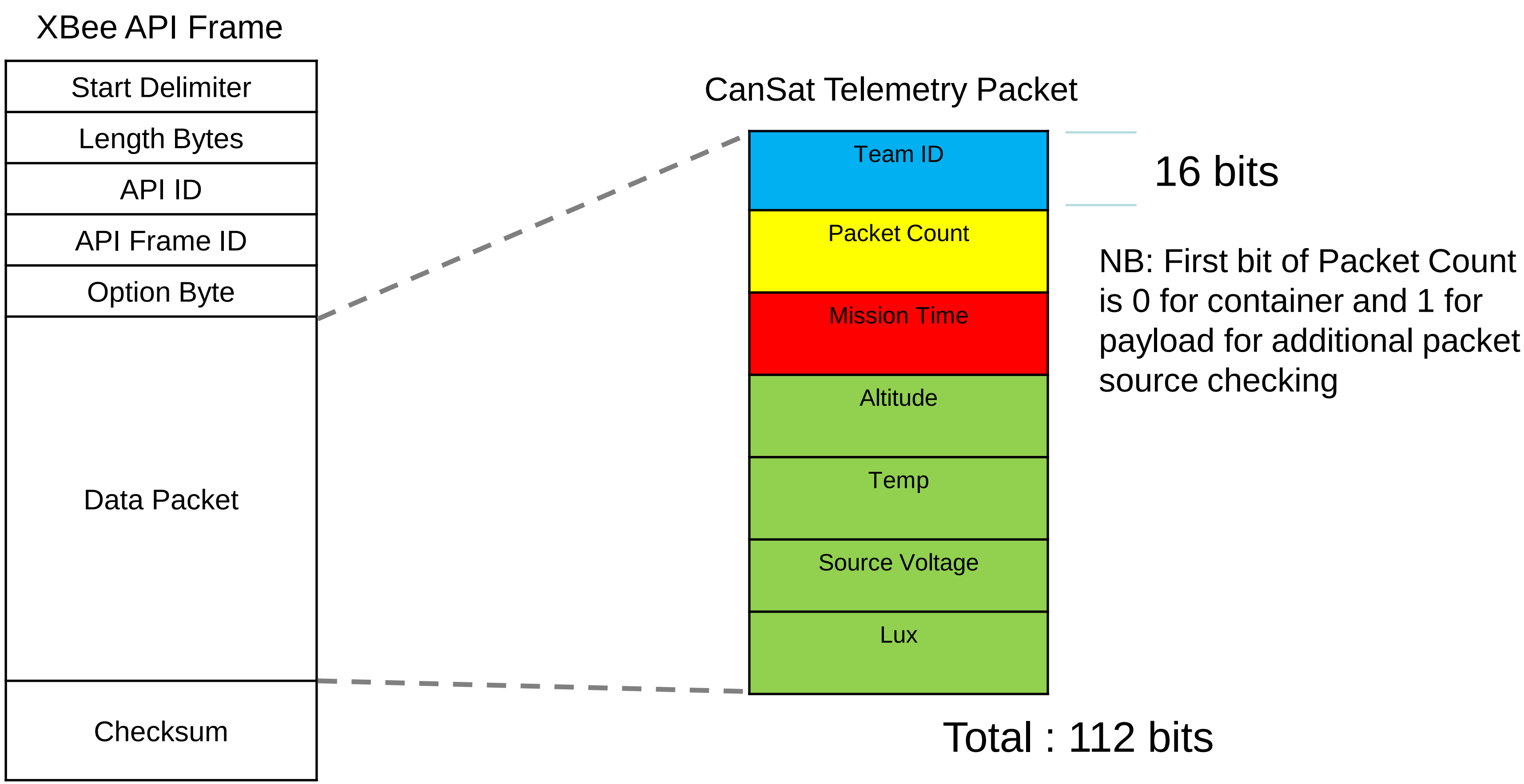
Ground Station Radio Configuration

- We configure the ground station radio with ZIGBEE COORDINATOR API firmware.
- GS Xbee will receive API packets even if Payload and Container radio have AT firmware.
- We set the configuration parameter NETID to our team ID

Transmission Control

- The ground station software identifies packets from container and payload by parsing the source address from the received telemetry packet

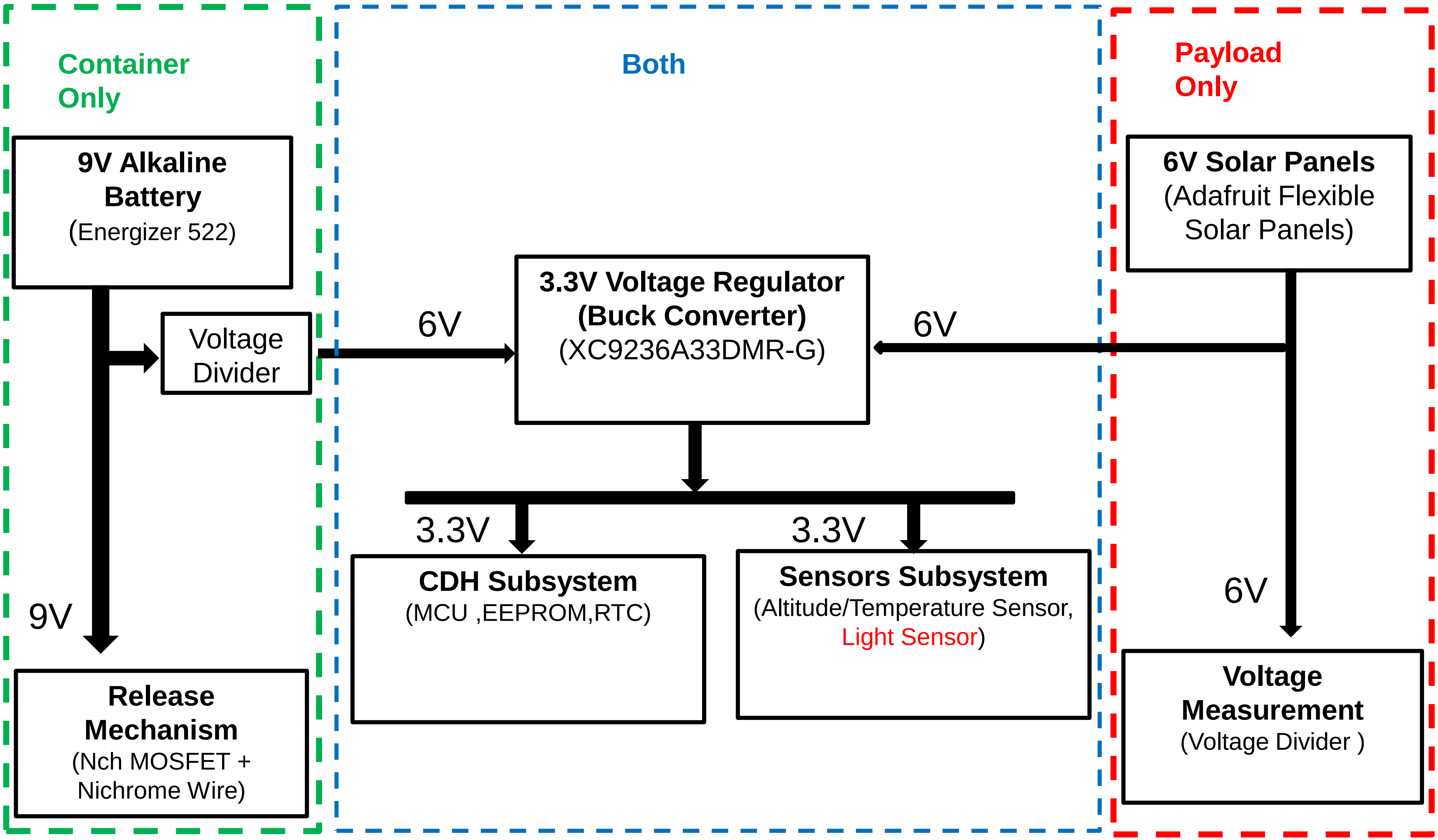
Telemetry Format



- The telemetry data is transmitted as XBee API Packet frame data packet. The FSW puts transmission requests to Xbee radio on continuous 1Hz interval. The packets may arrive on GS continuously or in bursts.

Electrical Power Subsystem Design

David


Container Only
Both
Payload Only
9V Alkaline Battery (Energizer 522)
Voltage Divider
9V
Release Mechanism (Nch MOSFET + Nichrome Wire)
6V
3.3V Voltage Regulator (Buck Converter) (XC9236A33DMR-G)
6V
3.3V
3.3V
CDH Subsystem (MCU ,EEPROM,RTC)
Sensors Subsystem (Altitude/Temperature Sensor, Light Sensor)
6V Solar Panels (Adafruit Flexible Solar Panels)
6V
Voltage Measurement (Voltage Divider)

EPS Changes Since PDR

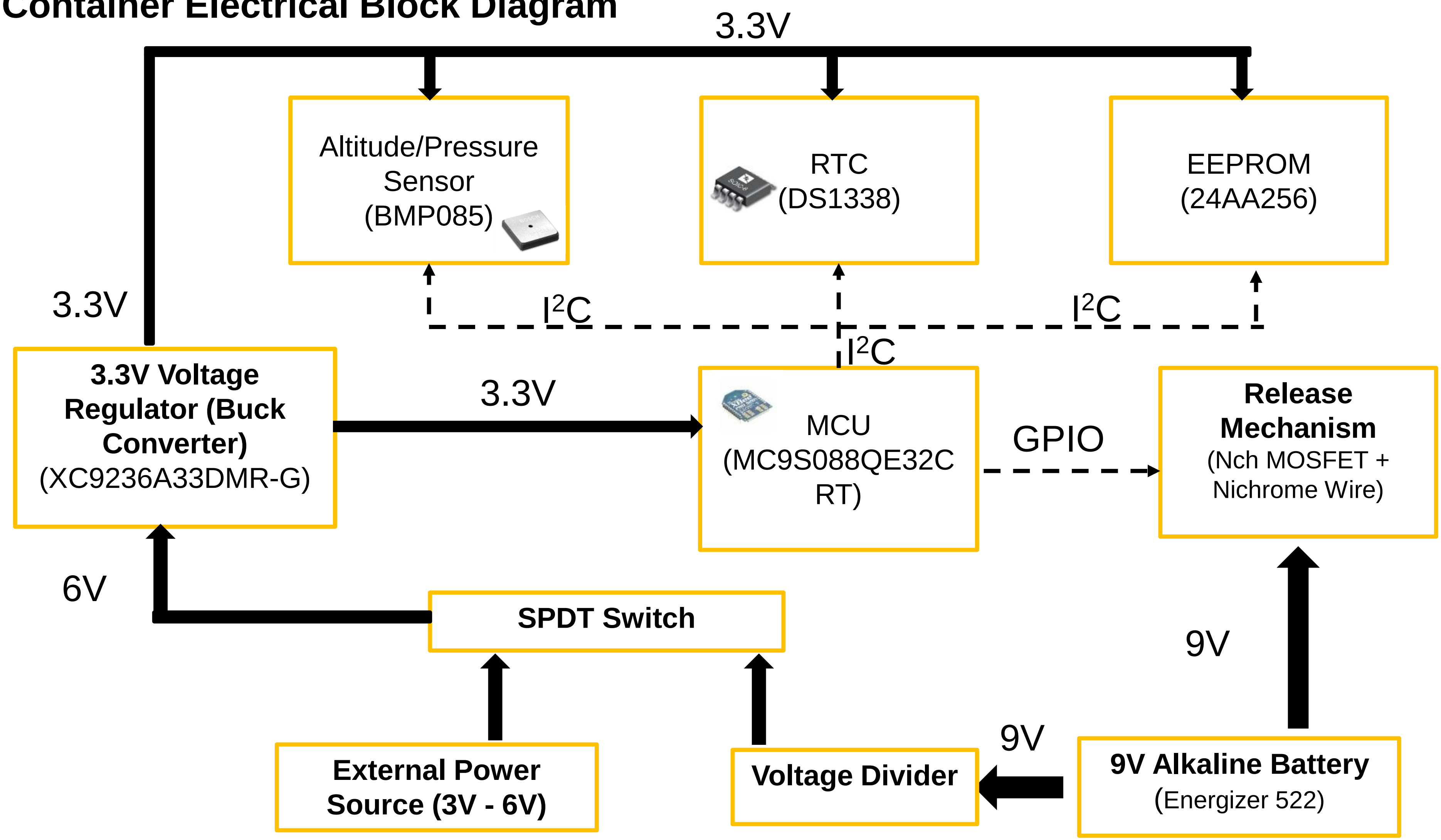
- **List changes to the EPS subsystem since PDR**
  - Container is powered using Energizer 522 9V batteries.

EPS Requirements

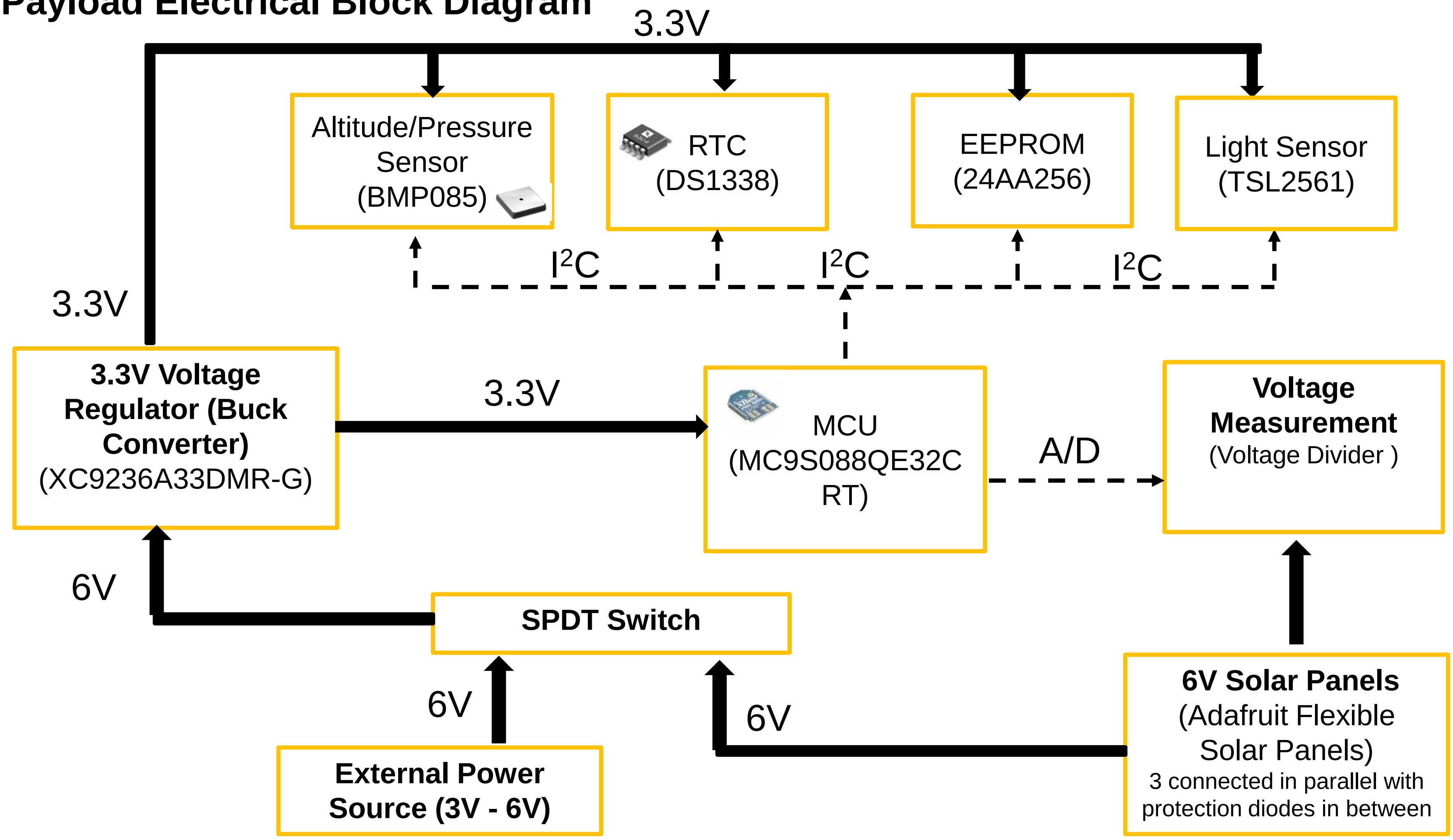
ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
EPS-01	The container power supply shall provide a regulated 3.3V to MCU and Sensors	System Requirement	High				x	x	
EPS-02	The payload power supply shall provide a regulate 3.3V to MCU and Sensors	System Requirement	High				x	x	
EPS-03	The payload power supply shall limit the voltage from the solar panels with in a safe input range of the regulator	System Requirement	High				x	x	
EPS-04	The container power supply shall 9V energizer alkaline batteries.	System Requirement	High				x		
EPS-05	The payload power supply shall provide an attachment point for solar panel voltage measurement	System Requirement	High				x		
EPS-06	The batteries in the container shall also be used to activate the release mechanism	System Requirement	High				x		
EPS-07	The batteries in the container shall be able to supply 1A current for at least 500ms	System Requirement	High				x	x	

Electrical Block Diagram

Container Electrical Block Diagram

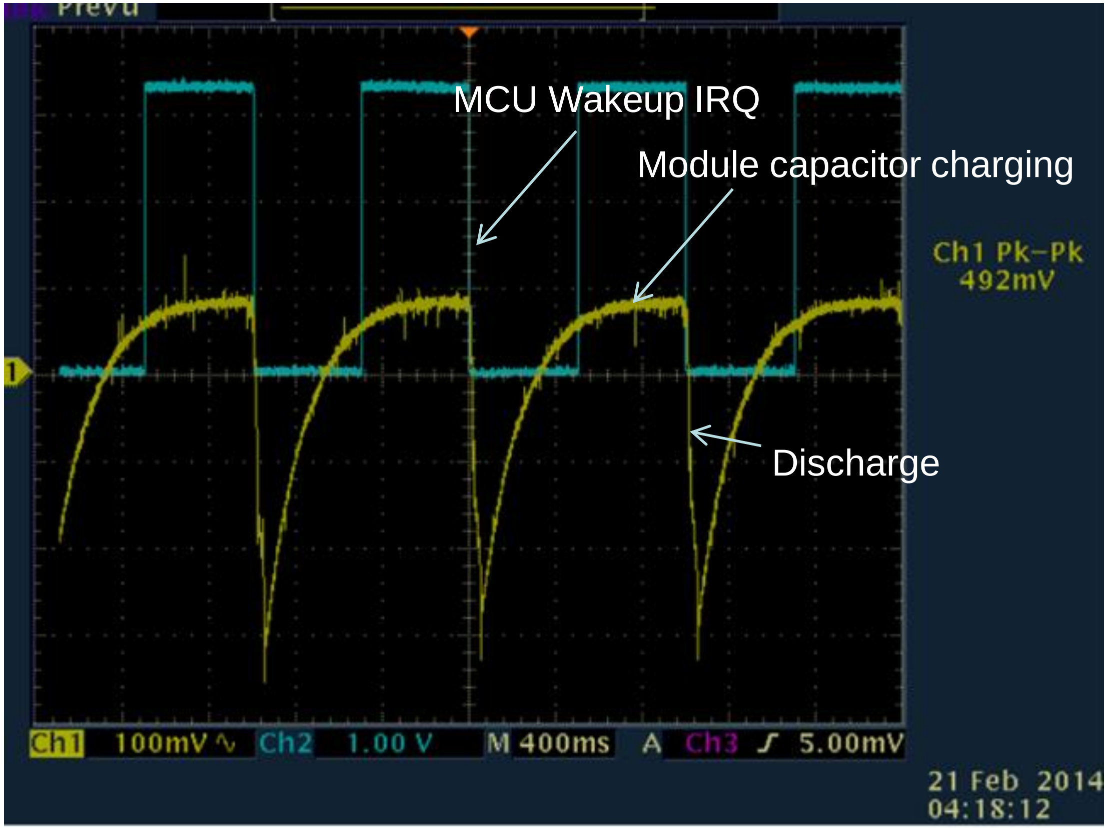


Payload Electrical Block Diagram



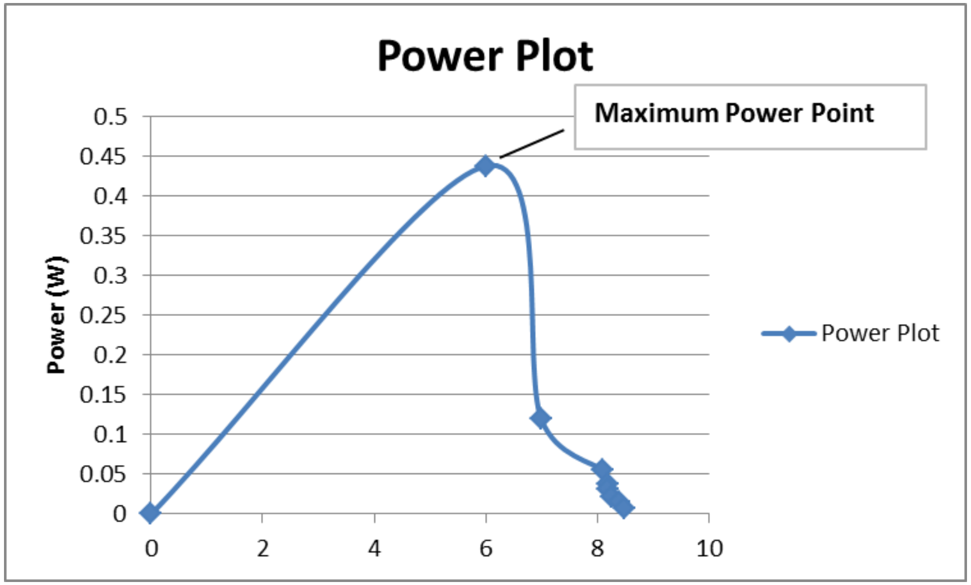
Payload Energy Harvesting Strategy

- **Power source**
  - Payload is powered by three Adafruit 6V 1W solar panels
- **Energy storage**
  - A single 4700µF electrolytic capacitor (C8) acts as an energy reservoir to help the buck converter maintain its output voltage



Payload Energy Harvesting Strategy

- **Packet Transmission**
  - The capacitor spends the majority of the time charging when the demand for current is relatively low and releases its charge when the XBee is transmitting
  - Transmission lasts approximately 4ms



Container 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
MC9S08QE32CRT MCU	15	3.3	49.5	3600	15.00	DS
XBee-PRO (S2B)	205 (TX)	3.3	676.5	60	3.4168	DS
Microchip 24AA256 EEPROM	3.0	3.3	9.9	60	0.05	DS
TAOS TSL2561	0.24	3.3	0.792	60	0.004	DS
Separation Mechanism	~600	6.0	3600	~ 0.5	0.08333	Measured
Buck Converter	0.015	6.0	0.09	3600	0.015	DS

Battery Source	Power (mAh)
Total Consumed	18.928
Available	1000.0
Margin	981.072

Battery Source	Current(mA)
Max Current	823.368
Available	1000.0
Margin	176.632

Payload Power Budget

Component	Current (mA)	Voltage(V)	Power (mW)	Usage (min)	Total Energy Consumed (mAh)	Source
Maxim DS1338 RTC	0.11	3.3	0.363	3600	0.11	DS
XBee-PRO (S2B)	205 (Tx)	3.3	676.5	60	3.4168	DS
MC9S08QE32CRT MCU	15	3.3	49.5	3600	15.00	DS
Microchip 24AA256 EEPROM	3.0	3.3	9.9	60	0.05	DS
Buck Converter	0.015	6.0	0.09	3600	0.015	DS

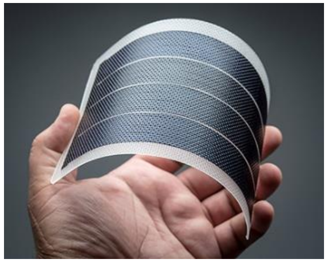
Solar Panel Source	Current(mA)
Max Current	223.125
Available	300.0
Margin	76.875

Power Source Summary

Alkaline 9V batteries for the container:

For the container we are using Energizer Alkaline 9V Battery. It gives us enough current to use it both as a release mechanism power source and to power the MCU.

Solar panels for the payload:

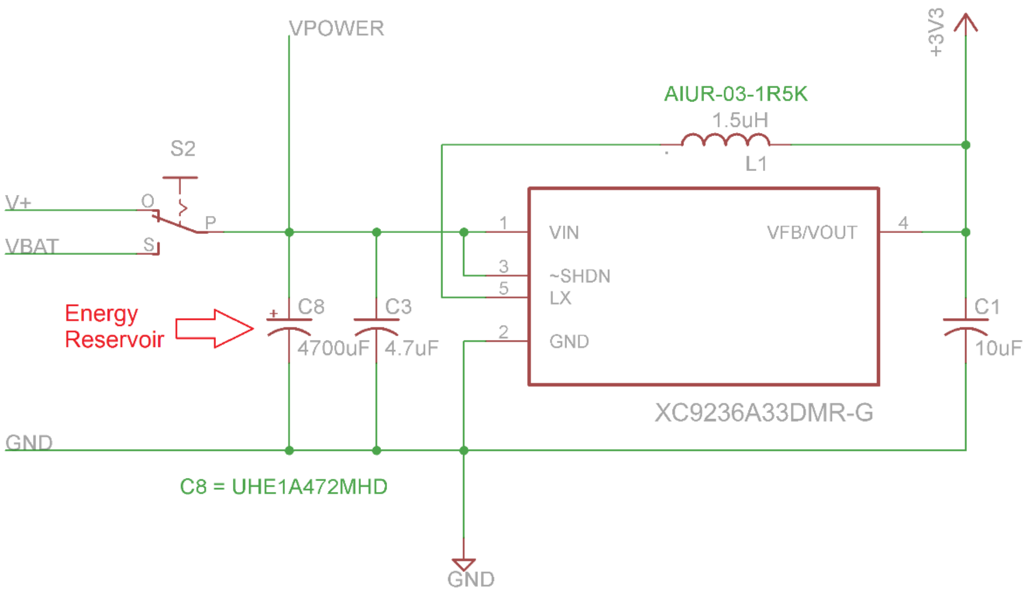


For our environmentally powered payload, we decided to use solar panels because they were the easiest to implement from a mechanical perspective while costing the least amount in the mass budget.

Power Source Connections: We use screw terminals for power source connections to the PCB's. We provide a selection switch and external source socket for easy testing.

Power Storage Summary

- A single 4700µF electrolytic capacitor (C8) acts as an energy reservoir to help the buck converter maintain its output voltage
- The capacitor spends the majority of the time charging when the demand for current is relatively low and releases its charge when the XBee is transmitting



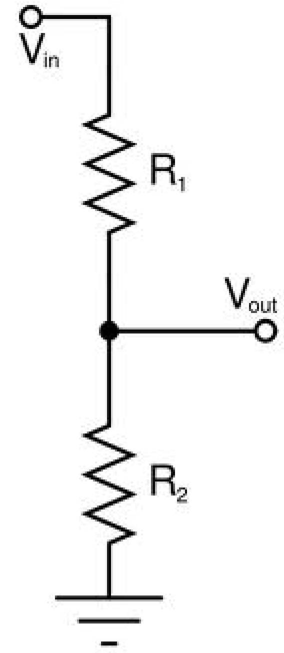
Power Bus Voltage Measurement

We measure the solar panel's voltage by reading the measurement from the ADC, which is located on the microcontroller. The ADC takes in a continuous quantity signal, which is then converted to a discrete digital time representation.

Since the MCU uses a typical input voltage of 3.3V, it is important to make sure that the ADC does not receive more than 3.3V. In order to adjust the solar panel's voltage to the measurement range (assumed to be from 0V to 3.3V), we use a voltage divider to divide the input voltage by 1/3 to keep it in the measurement range.

The ADC resolution bits of the microcontroller used are 12 bits; from this value, we find there are 4096 quantization levels. Then we calculate that the ADC voltage resolution is 3.3V / 4096 = 0.8mV.

We chose R1 to be 6k while R2 is 3k.



$$Vout = Vin\left(\frac{R2}{R1+R2}\right)$$

Flight Software (FSW) Design

Amente

FSW Overview

- **Development Environment**
  - CodeWarrior Development Studio® with Programmable XBee SDK from Digi®
- **Programming Language** – C (gcc cross compiler to HC08)
- **Software Architecture**
  - Individual drivers with routines for each sensor and device
    - I^2C driver
      - EEPROM
      - RTC
      - Altitude/Temperature sensor
      - Light Sensor
    - XBee Radio API
  - Main routine including IRQ timed ISR's.
- In both Payload and Container **FSW**, 1Hz timed IRQ from DS1338(RTC chip) triggers ISR to read sensor values and assemble a telemetry packet to transmit

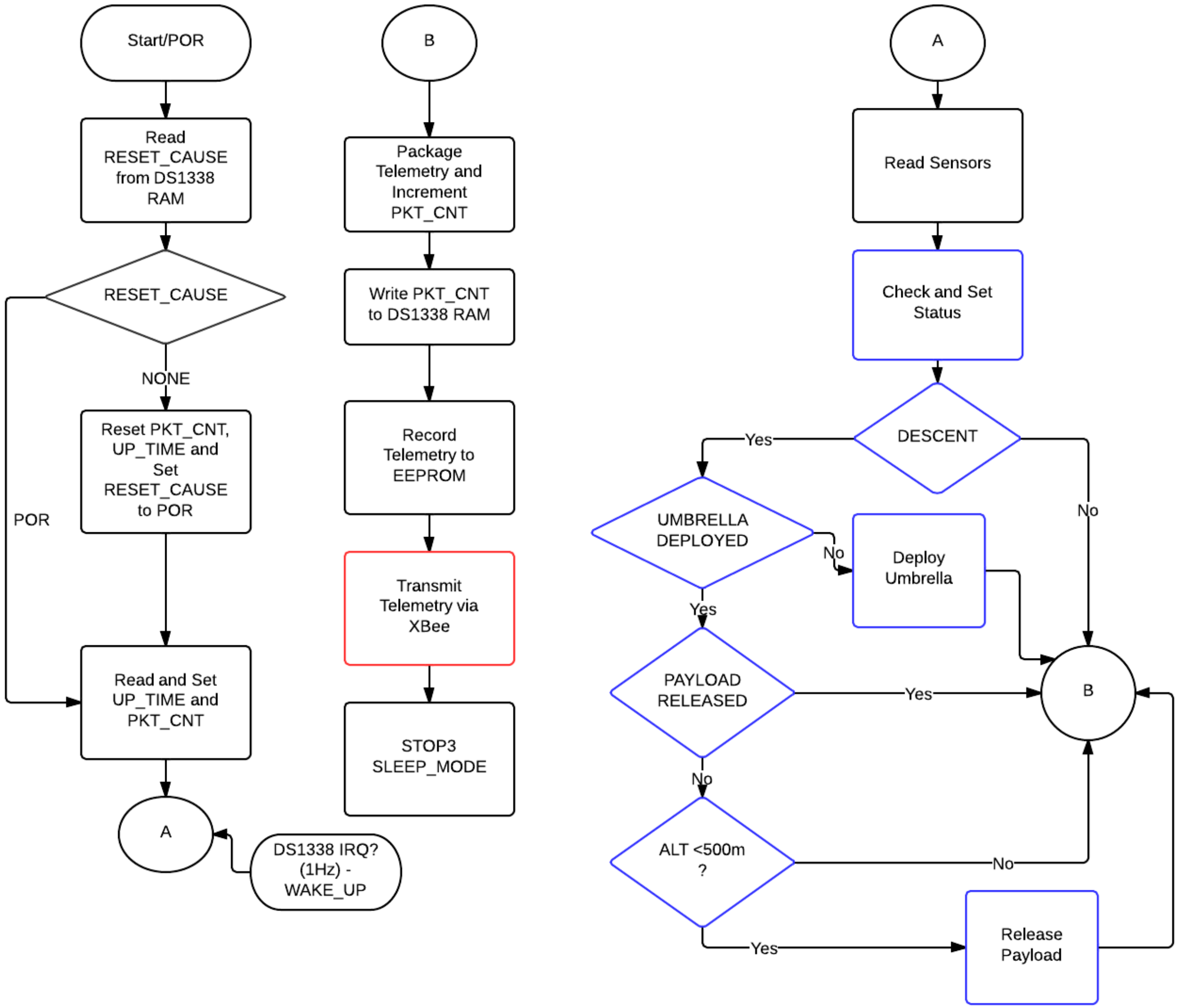
FSW Changes Since PDR

- **FSW changes since the PDR**
  - Added Temperature and Altitude calculation
  - Reorganized code as FSM with states

FSW Requirements

ID	Requirement	Rationale	Priority	Parent(s)	Children	VM			
						A	I	T	D
FSW-1	The container FSW shall sample altitude and temperature values from the altitude and temperature sensor	Mission Requirement	High			X			
FSW-2	The container FSW shall activate the release mechanism at around 500m +/- 1m altitude	Mission Requirement	High				X	X	X
FSW-3	The container FSW shall count the number of transmitted packet	Mission Requirement	High			X		X	
FSW-4	The container FSW shall keep track of mission time	Mission Requirement	High				X	X	
FSW-5	The container FSW shall restore its state in case of a processor reset	Mission Requirement	High			X		X	
FSW-6	The payload FSW shall sample altitude and temperature values from the altitude and temperature sensor	Mission Requirement	High					X	
FSW-7	The payload FSW shall sample light intensity values from both infrared and visible light spectrum from the light sensor .	Bonus Requirement	High					X	
FSW-8	The payload FSW shall sample sensors at a minimum rate of 1Hz	Mission Requirement	High			X		X	
FSW-9	The container FSW shall sample sensors at a minimum rate of 1Hz	Mission Requirement	High			X		X	
FSW-10	The payload FSW shall restore its state in case of a processor reset	Mission Requirement	High				X		
FSW-11	The container FSW shall log sampled data on to the EEROM for backup.	Mission Requirement	High				X		
FSW-12	The Payload FSW shall log sampled data on to the EEPROM for backup	Mission requirement	High			X		X	
FSW-13	The container FSW shall deploy the container umbrella when the cansat is released from the rocket	System Requirement	High			X	X	X	

CanSat FSW State Diagram



Key

Container only

Maximum power

Status

RESET_CAUSE
- NONE – Clean Reset
- POR – Power On Reset

PKT_CNT
- Count of telemetry samples

UP_TIME
- Elapsed time since clean reset

SLEEP_MODE
- Put MCU into low power mode

WAKE_UP
- 1HZ IRQ wake up trigger

DESCENT
- CanSat released from rocket

UMBRELLA_DEPLOYED
- Container umbrella deployed

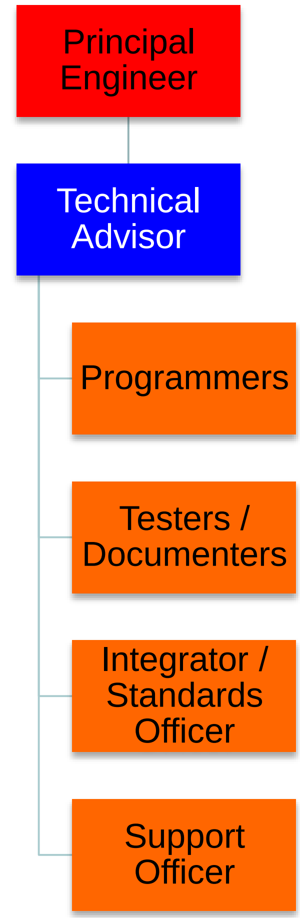
PAYLOAD_RELEASE
- Container releases payload

ALT
- Currently read altitude value

Software Development Plan

- **Prototyping environments:**
  - Revision Control - Use hosted Git service (www.bitbucket.com)
  - Configure payload and container builds from the same source code. Use C macros to separate code that should go only on the payload FSW.
- **General Testing methodology:**
  - Testing subsequent sensors individually with predefined test scripts
  - Testing individually developed functions with the tested sensors
    - Signal Integrity/Termination, I/O
  - Testing combined functions in generic application
  - Testing whole firmware together
  - Debugging firmware
  - Releasing firmware as beta
  - Finalizing firmware
- **Progress Since PDR:** FSW beta released and currently being tested

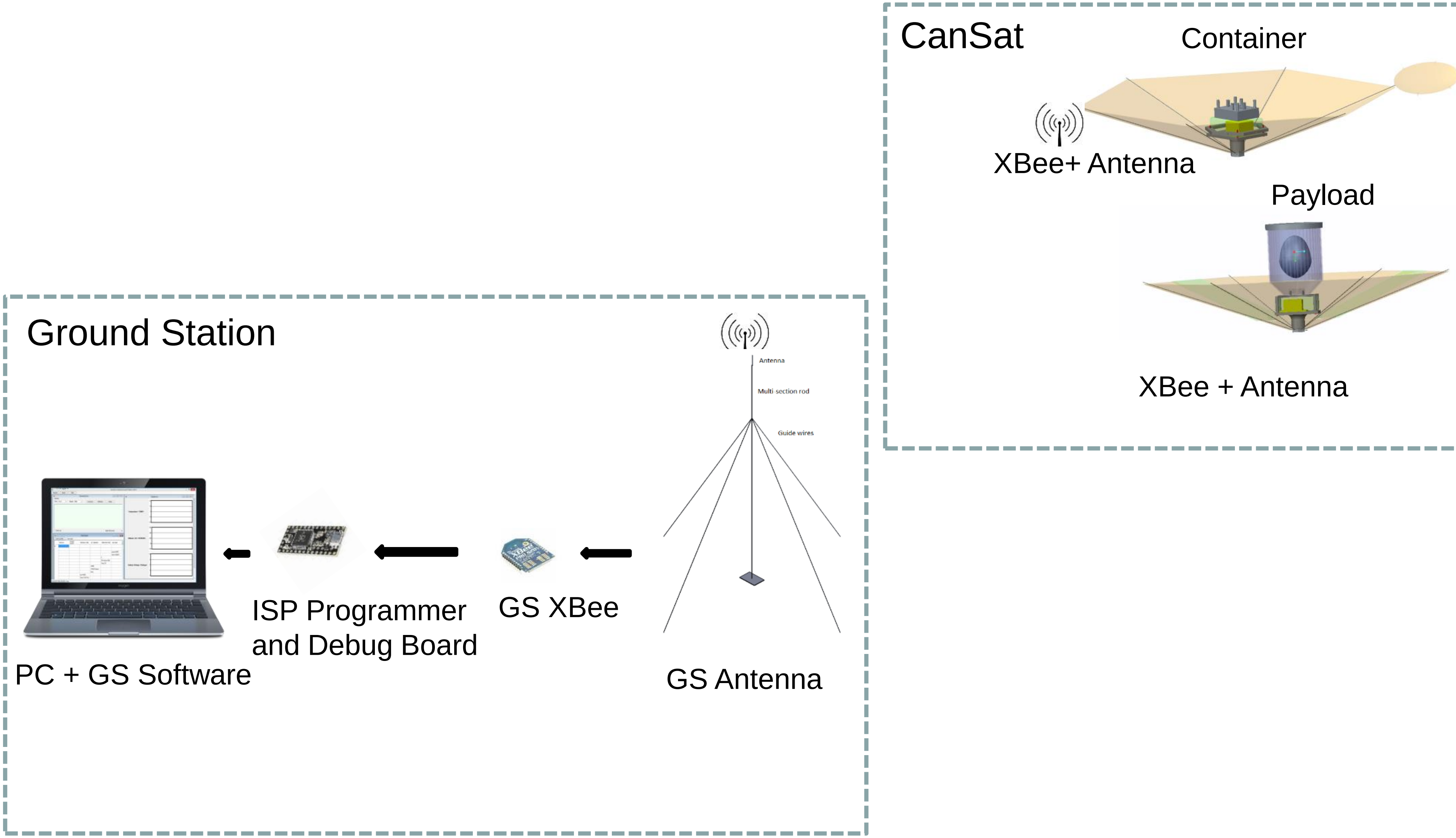
Development Teams



Ground Control System (GCS) Design

Amente

GCS Overview



GCS Changes Since PDR

- **Changes to the GCS subsystem since PDR.**
  - Removed sensor data conversion from GS software

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					X	X
GCS-02	The antenna for the GCS shall be placed at least 3.5 m off the ground, within line of sight to CanSat.	Mandatory for radio communications	High				X		X
GCS-03	The GCS shall use the FTDI to USB adapter to interface with the XBee.	Interface requirement	Low				X		X
GCS-04	The GCS shall be able to command the CanSat to start transmitting telemetry.	Ease of control	Low				X	X	X
GCS-05	The GCS shall use a personal computer.	Ease of programming and cheaper in cost.	Medium				X		
GCS-06	The GCS software will be programmed in C# programming language using Visual Studio.	Ease of programming and cheaper in cost.	Medium			X		X	X
GCS-07	The GCS analysis software shall be able to parse container and payload packets.	System Requirement	Low						X

GCS Antenna

Selected antenna: TP-LINK TL-ANT2415D

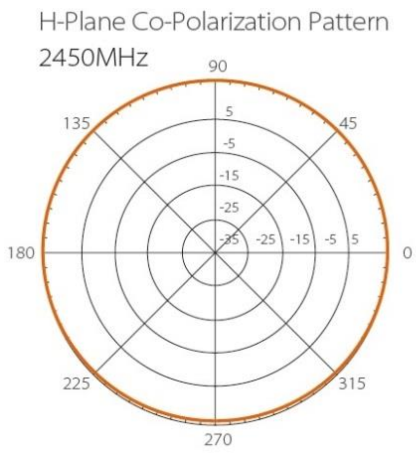
Provides better gain and directivity

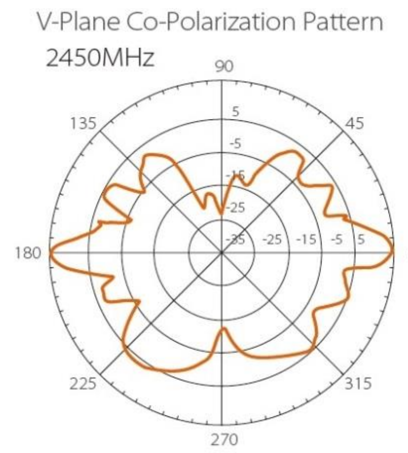
Antenna placement: 3.5m above the ground

Maximum radio distance: 5.25 km

Predicted link distance: 1.75 km

Margin: 4 km





- We assemble a multi-section rod mast on a steel platform and use guy wires to mount the antenna in place.

GCS Software

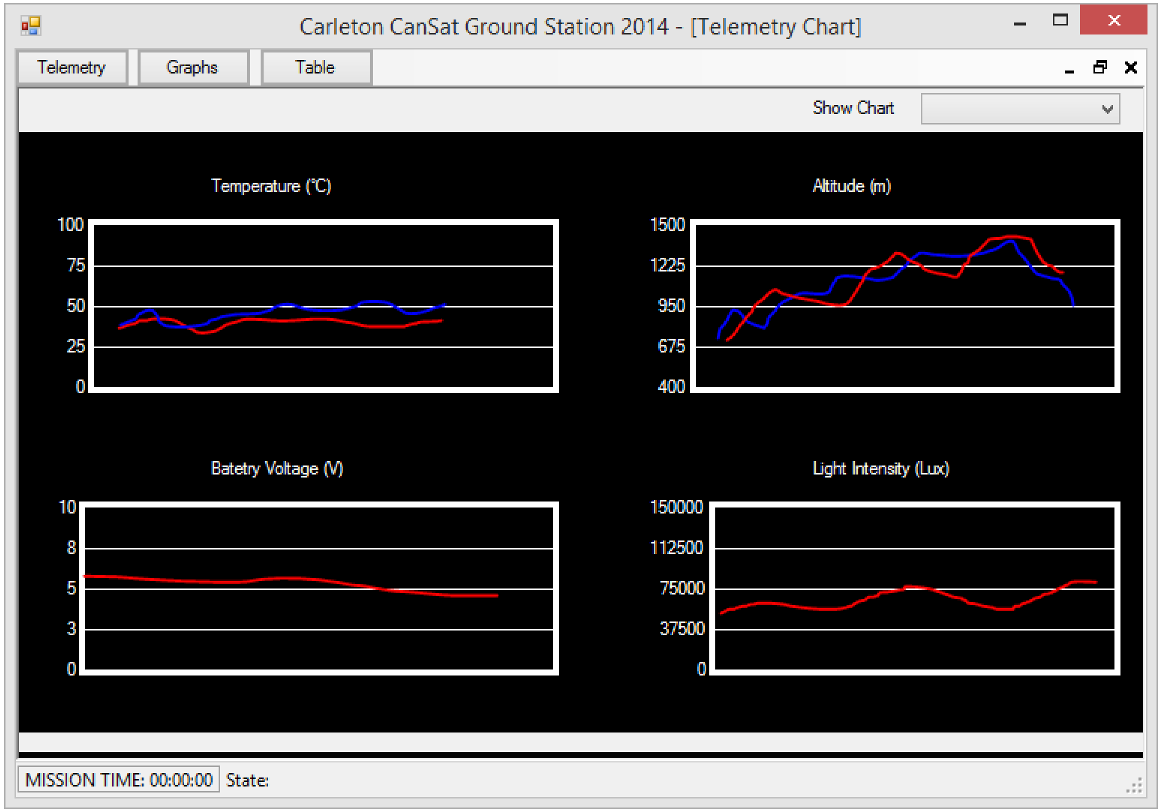
Development

- Programming Language**: C#**
- No COTS software is used

Progress Since PDR

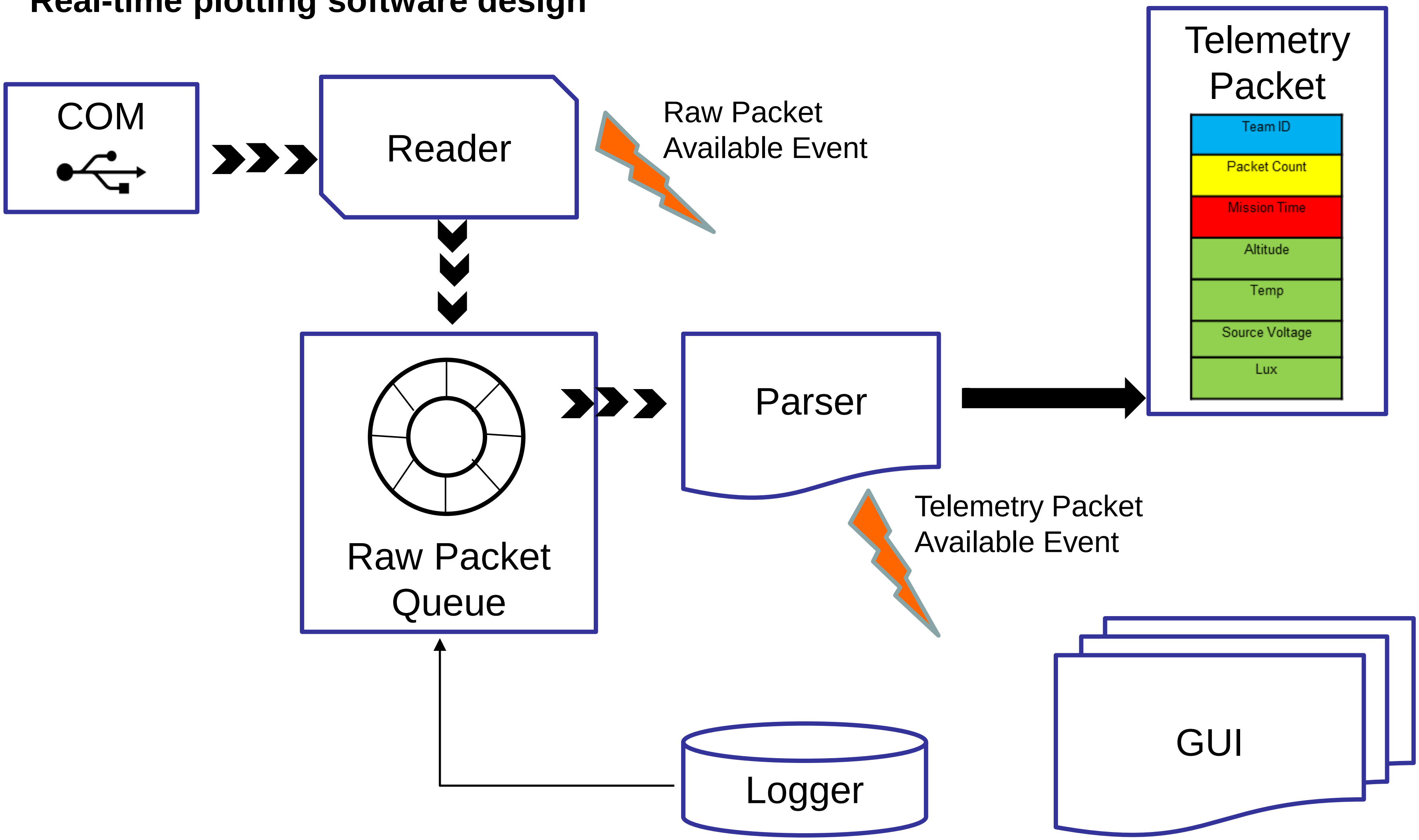
- Telemetry parsing is implemented
- Logging functionality is implemented
- GUI is improved

Telemetry Display Chart



GCS Software

Real-time plotting software design



CanSat Integration and Test

Amente & Graham

CanSat Integration and Test Overview

- **CanSat Subsystem Integration**
  - Sequence
    1. Mechanical Subsystem
    2. Decent Control Subsystem
    3. Sensor Subsystem
    4. Communication and Data Handling Subsystem
    5. FSW
    6. Ground Control Station
- **Test Equipment and Environment**
  - Digital Oscilloscope, Multi-meter, Logic Analyzer for electrical subsystem testing
  - Large field and RC plane to conduct drop tests.

Sensor Subsystem Testing Overview

	Temperature Sensor	Altitude Sensor	EEPROM
Purpose	Make sure correct values are obtained in all possible altitude and temperature ranges and data logging is consistent and accurate		
Constraints	FSW , MCU and testing equipment work as expected		
Pass-Fail Criteria	Indoor readings conform to room temperature 24 °C , outdoor reading conform to readings by other devices	Reading conforms to known altitude values.	Writing to EEPROM is successful and written data can be retrieved after CanSat power is reset.

Light Sensor Testing Overview

Purpose

- Confirm sensitivity and detection ranges provided by the datasheet.

Constraints

- FSW , MCU and testing equipment work as expected

Pass/Fail Criteria

- Can get readings of both infrared and visible light spectrum values.
- Threshold readings as expected minimum for complete dark and maximum for bright light
- Correlation exists between light sensor readings and the power obtained from solar panels.

DCS Subsystem Testing Overview

Purpose

- To make sure both container and payload descent speed meet competition requirements.

Constraints

- Umbrella deployment mechanism works as expected, altitude and time readings can be obtained from CanSat to know descent speed.

Pass/Fail Criteria

- Payload and container attain terminal velocity less then 12 m/s before impact
- CanSat has a stable orientation during descent

Mechanical Subsystem Testing Overview

	Umbrella Deployment and Release Testing	Survivability Testing	Egg Protection Testing
Purpose	Make sure CanSat meets acceleration/shock requirements. Make sure the egg protection mechanism protects the egg from maximum height drop.		
Constraints	Deployment and release trigger work as expected		
Pass-Fail Criteria	Container umbrella opens when triggered. Container releases payload at the defined altitude. Payload separates from container.	All structural materials and electronic components survive the impact.	The egg remains intact.

CDH Subsystem Testing Overview

	MCU Testing	RTC Testing	XBee Antenna Testing
Purpose	Make sure the subsystem consistently handles collected sensor data and telemetry transmission.		
Constraints	Sensors function as expected.		
Pass-Fail Criteria	FSW runs properly on MCU.	Clock time is maintained when power source is interrupted.	Antenna orientation based radiation pattern obtained from datasheet gives optimum link

EPS Testing Overview

	Power generation testing	Power distribution testing
Purpose	Ensure power sources supply adequate voltage and current for 60 min; account for variability	Ensure proper timing of power delivery for efficiency
Constraints	• Implementation of: - voltage limiter circuit (LDO) - power amplification (op-amps) - voltage dividers • Access to digital readout meter • Attachment point for solar panel voltage measurements	• Access to digital readout meter (oscilloscope) • Integration with voltage sensor (for payload)
Pass-Fail Criteria	<u>Payload</u>: provide - voltage in the range of 3.75V-6V to the LDO -15.2 at 3.3 V to power it, RTC, MCU <u>Container</u>: same supply requirement as latter	- Voltage sensor able to detect over range of all variations <u>Payload</u>: provide 225 mA for 60s <u>Container</u>: provide - 1A at 6V for 0.5s (release mechanism) - 250 mA for 60s (other subsystems)

FSW Testing Overview

Purpose

- To make sure FSW functions as expected.

Constraints

- CDH and Sensor subsystem pass their respective test

Pass/Fail Criteria

- CanSat operates as expected. Telemetry format is consistent and all sensor samples are included. Release mechanism and Umbrella deployment are properly triggered.

GCS Testing Overview

Purpose

- To make sure GS software displays received telemetry and plots in real time.
- To make sure GS software records received telemetry using correct format.

Constraints

- All other CanSat subsystems function properly

Pass/Fail Criteria

- Telemetry is plotted accurately and consistently.
- Recorded data can be exported to correct format as per competition requirement.

Mission Operations & Analysis

Jayant

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 antenna 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

   Launch window opens, rocket launched

9. Demonstrate receipt of 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

    Field judge permits to recover modules

13. Analyze logged data and compare with telemetry. Deliver data to field judge

    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

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 2014

Team Name: RavenKnights
Team ID: ______________
Contact Phone #: _______________
Contact Email: _________________

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. Connect debug board and check status of RSSI LED
6. Confirm integrity and correctness of telemetry
7. Radio Link Check Pass

Mission Rehearsal Activities

ANNUAL CANSAT COMPETITION

- **Loading the Egg Payload:**

Mission Control Officer		CanSat Crew	
1	Request Egg from field judge	1	Open egg protection envelope and make sure protection materials are in place
2	Make sure egg is numbered and bring to CanSat Crew	2	Carefully place egg in envelope
		3	Close envelope lid properly and make sure it is secured
		4	Egg Payload Loading success

Powering On/Off the CanSat:

CanSat Crew

1. Remove Coin Cell Battery to completely reset the CanSat
2. Make sure power source is properly connected to the correct terminals and the connection is secured
3. Toggled power selection switch to internal power source
4. Connect debug board and confirm CanSat is getting power.
5. CanSat Power On success

- **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 Ready!

CanSat Crew and GS Crew

1. Place the Egg payload
2. Power On CanSat
3. Check Radio Link
4. Check all electrical and mechanical connections are secured
5. Notify CanSat Ready!

Mission Rehearsal Activities

- **Loading CanSat into launch Vehicle**

CanSat Crew and GS Crew

1. Confirm all components are included.
2. Confirm all connections are secured
3. Confirm CanSat is powered on
4. Confirm Radio Link
5. Carefully put CanSat in launch vehicle
6. Notify Launch Vehicle ready!

Mission Control Officer

1. Wait until Launch vehicle is ready
2. When launch window opens take launch vehicle to launch pad.

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.
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 CanSat crew for logged data retrieval

Requirements Compliance

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Requirements Compliance Overview

- The current design is compliant to all mission requirements
- **Compliance Overview**
  - Total mass under mass limit requirement
  - Container fully contains payload
  - CanSat fits in envelope of 125 mm x 310 mm
  - No pyrotechnic devices or lithium batteries used
  - Electronics well enclosed and protected
  - CanSat designed to meet descent rate requirements
  - CanSat contains all required sensors
  - Xbee radios configured according to requirements
  - External Power connection is available

Requirements Compliance (multiple slides, as needed)

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 payload) shall be 600 grams +/- 10 grams without the egg.	Comply	45	
2	The payload shall contain and protect the egg from cracking or breaking during flight through landing. The egg will weigh not more than 67 grams.	Comply	36	
3	The payload shall be completely contained in the container. No part of the payload may extend beyond the container.	Comply	37	
4	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	15	
5	The container shall use a passive descent control system. It cannot free fall.	Comply	27	
6	The container shall not have any sharp edges to cause it to get stuck in the rocket fairing section.	Comply	15	
7	The container shall be a florescent color, pink or orange.	Comply	27	
8	The rocket airframe shall not be used to restrain any deployable parts of the CanSat.	Comply	15	
9	The rocket airframe shall not be used as part of the CanSat operations.	Comply	15,12	
10	The CanSat (container and payload) shall deploy from the rocket fairing section.		12	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
11	The descent control systems shall not use any flammable or pyrotechnic devices.	Comply	**28**	
12	The descent rate of the CanSat shall be 12 m/s above 500 meters.	Comply	28	
13	When the CanSat reaches 500 meters, the payload shall be released from the container.	Comply	36,12,13	
14	When released, the payload shall have a descent rate of less than 10 m/s	Comply	28	
15	All descent control device attachments shall survive 30 Gs of shock.	Comply	28	
16	All descent control devices shall survive 30 Gs of shock.	Comply	28	
17	All electronic components shall be enclosed and shielded from the environment with the exception of sensors.	Comply	36	
18	All structures shall be built to survive 15 Gs acceleration.	Comply	36	
19	All structures shall be built to survive 30 Gs of shock.	Comply	36	
20	All electronics shall be hard mounted using proper mounts such as standoffs, screws, or high performance adhesives.	Comply	36	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
21	All mechanisms shall be capable of maintaining their configuration or states under all forces.	Comply	36	
22	Mechanisms shall not use pyrotechnics or chemicals.	Comply	11,40	
23	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	40	
24	No batteries shall be allowed in the payload. Batteries are allowed only in the container to support releasing the payload.	Comply	57	
25	The container shall only use alkaline type batteries.	Comply	57	
26	The container shall collect and store data at a 1 Hz rate from launch to the moment of landing.	Comply	55	
27	The container shall transmit its altitude data at a 1 Hz rate during from launch time to landing.	Comply	55	
28	The payload shall harvest energy from the environment during descent.	Comply	57	
29	During descent, the payload shall collect air pressure, air temperature and power source voltage once per second.	Comply	55	
30	During descent, the payload shall transmit all telemetry. The number of telemetry data transmitted shall be scored. The payload shall not generate telemetry at greater than 1 Hz rate.	Comply	55	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
31	Telemetry shall include payload mission time with one second or better resolution, which begins when the payload is powered on. Mission time shall be maintained in the event of a processor reset during the launch and mission.	Comply	52,55	
32	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	54,55	
33	XBEE radios shall have their NETID/PANID set to their team number	Comply	54	
34	XBEE radios shall not use broadcast mode	Comply	54	
35	Both the container radio and payload radio shall use the same NETID/PANID. Teams are allowed to determine how to coordinate communications between the container, payload and ground station	Comply	54	
36	The payload shall include an external umbilical power connection to allow for testing and safety checks when not harvesting energy.	Comply	65	
37	The external power connection shall be a sturdy connector that is easily accessible when the payload is stowed in the container. Loose wires are not allowed.	Comply	65	
38	Cost of the CanSat shall be under $1000. Ground support and analysis tools are not included in the cost.	Comply	11	
39	Each team shall develop their own ground station.	Comply	79	
40	All telemetry shall be displayed in real time during descent.	Comply	82	

Requirements Compliance

Rqmt Num	Requirement	Comply / No Comply / Partial	X-Ref Slide(s) Demonstrating Compliance	Team Comments or Notes
41	All telemetry shall be displayed in engineering units (meters, meters/sec, Celsius, etc.)	Comply	82	
42	Teams shall plot data in real time during flight.	Comply	82	
43	The ground station shall include an antenna mast of 3.5 meters height, which is to be measured from the ground to the tip of the antenna structure.	Comply	79,80	
44	The ground station mast shall be free standing. The antenna mast cannot be attached to provided tent or other structures.	Comply	80	
45	The ground station mast shall be properly secured as to not fall over under any conditions with surface winds up to 30 mph.	Comply	80	
46	If guy wires are used to support the ground station antenna mast, the guy wires shall be made visible for safety.	Comply	80	
47	Both the container and payload shall be labeled with team contact information including email address.	Comply	93	
48	The flight software shall maintain a count of packets transmitted, which shall increment with each packet transmission throughout the mission. The value shall be maintained through processor resets	Comply	73	
49	The container and payload shall maintain a mission time which is the number of seconds since each vehicle is powered on. The mission time shall be maintained in the event of a power loss or processor reset. The time may be maintained by software or by hardware real-time clock. If a hardware real-time clock is used, a separate, dedicated power source may be used to power the clock; however, this power source may not be used to power any other vehicle functions.	Comply	52	

Management

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Status of Procurements

- **Sensor and component procurements**
  - All sensors and components including backups have been purchased and have arrived
  - PCB boards Rev.2 have been finished and are currently on processing at board house
  - Structural prototype parts have been 3D printed. CAD drawings are currently being finalized for printing final product

CanSat Budget – Hardware

Electrical	Qty.	Total	Considerations
Temp/Alt sensor breakout (Adafruit BMP085)	2	$ 39.90	actual
Xbee PRO S2B	2	$ 70.22	actual
Antenna (TE Connectivity 2118059- 1)	2	$ 13.08	actual
PCB Manufacturing	10	$ 15.00	actual
Crystal (32.768KHz 12.5PF)	2	$ 3.84	actual
RTC chip (DS1338Z)	2	$ 7.42	actual
EEPROM chip (24AA256)	2	$ 2.26	actual
Voltage Regulator (XC9236A33DMR-G)	2	$ 1.30	actual
Light Sensor breakout (Adafruit TSL2561)	1	$ 7.95	actual
Msc. Headers and Connectors	n/a	$ 20.00	estimated
Batteries	4	$ 12.11	estimated
Solar Panels (Adafruit Flexible Solar Panel)	4	$ 100.00	actual
Msc. Resistors and Capacitors	n/a	$ 20.00	estimated
TOTAL ELEC		**$ 313.08**	

Mechanical	Qty.	Total	Considerations
3D Printing	n/a	$ 300.00	estimated
Koverall	3	$ 32.97	actual
Nichrome Wire	n/a	$ 6.50	actual
Electronic mounting brackets	1	$ 10.00	estimated
Egg protection casing	n/a	$ 20.00	estimated
TOTAL MECH		**$ 369.47**	
OVERALL TOTAL		**$ 682.55**	
COMPETITION REQUIRMENT		**$ 1,000.00**	
DIFFERENCE		**$ 317.45**	

CanSat Budget – Other Costs

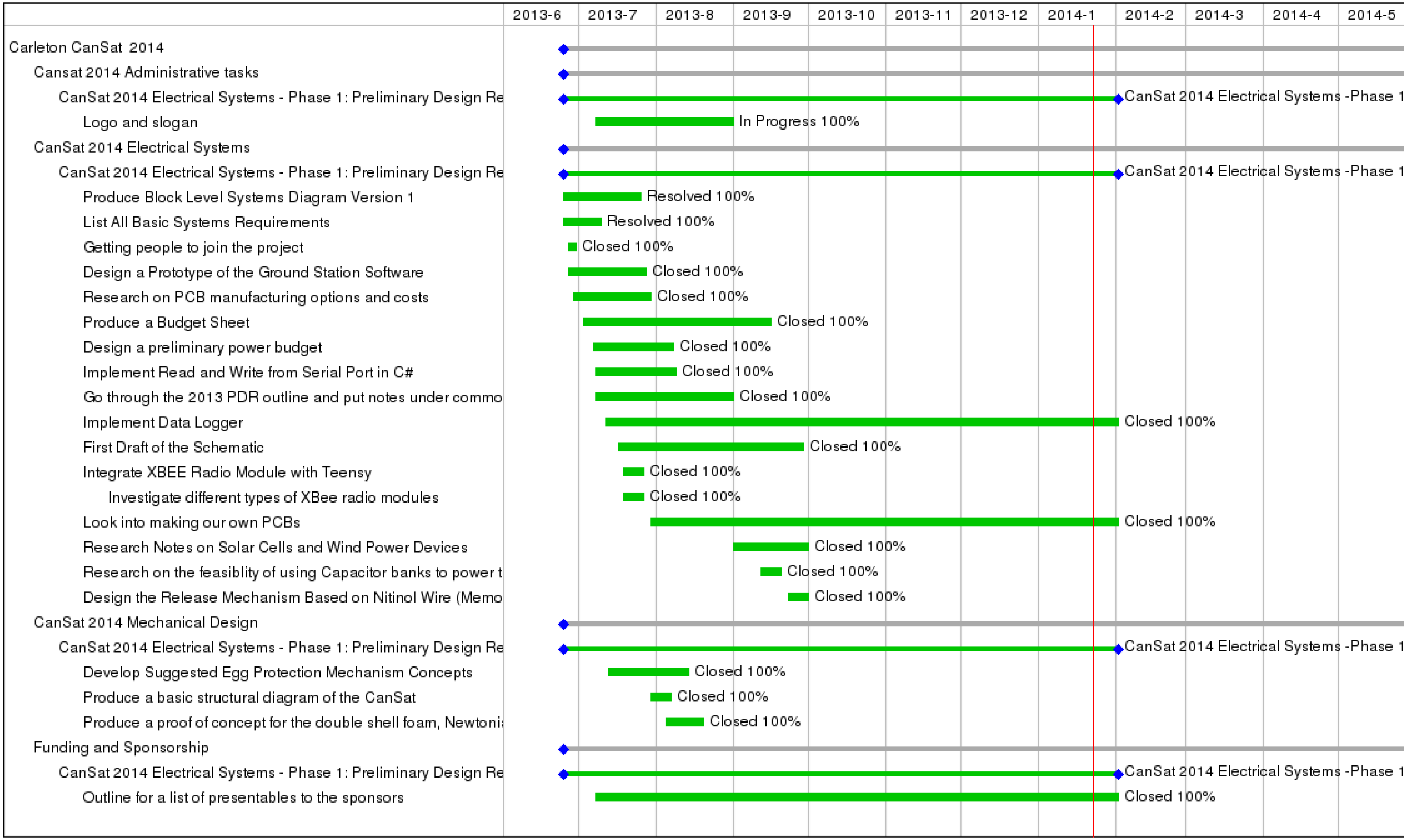
Additional costs	Amount	Considerations
Eggs for testing	$ 20.00	Estimated
Computers	university provided	
Test facilities and equipment	university provided	
Ground station Antenna + Cable	$ 75.00	Estimated
Ground station Xbee	$ 35.11	Actual
Travel	$ 10,000.00	Projected
TOTAL	**$ 10,130.11**	

Sources of income	
Carleton University Robotics Club (CURC	$ 1,500.00
Fundraising (?)	TBA
Sponsors (?)	TBA
Shortfall	**$ 8,630.11**

- Projected travel based on all 10 team members taking flights purchased at today's rate. However, only 3 people must go to complete mission.
- Electrical and hardware budget to be covered by Carleton University Robotics Club CURC through funding provided by CUSEF (Carleton University Student Engineering Fund). The rest will need to have fundraising or sponsorship.
    - ❖ Suggested sources:
        - Corporate T-shirt and website logo sponsorships
        - Launch local crowd funding campaign

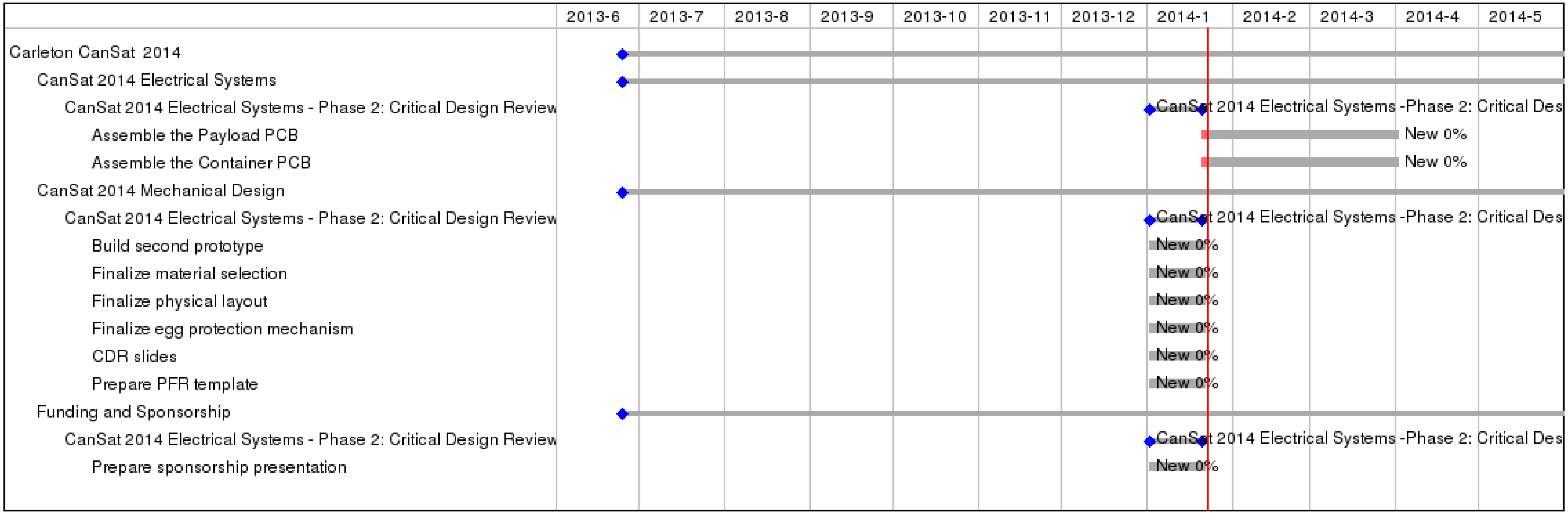
Program Schedule

Target tasks before CDR



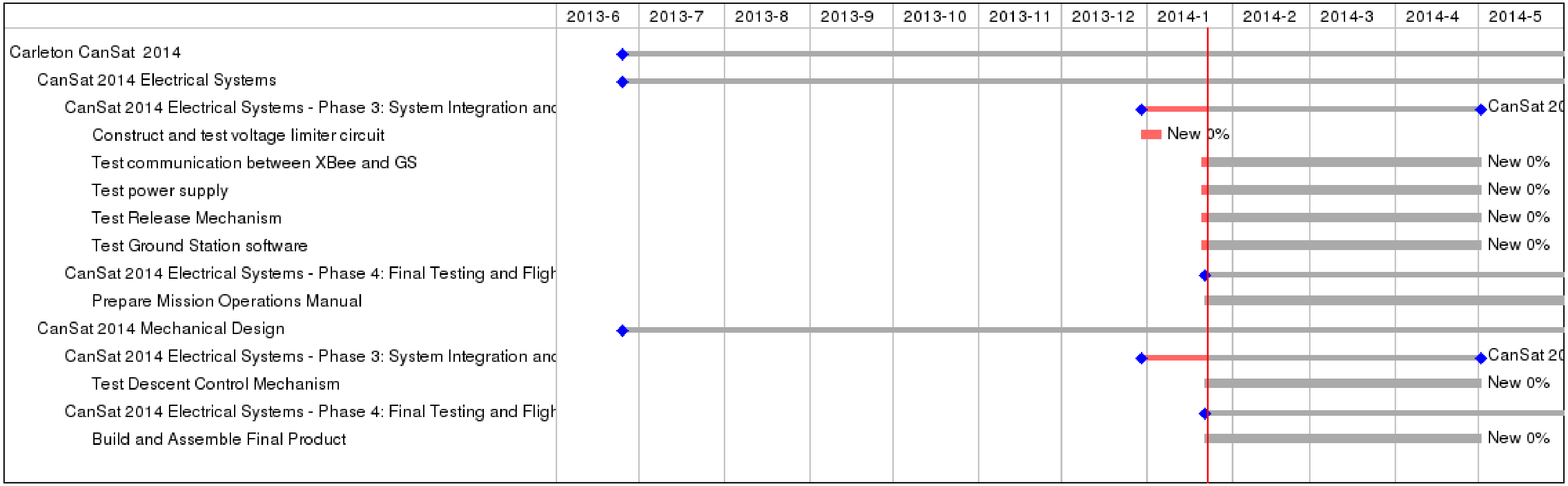
Program Schedule

Target tasks for CDR



Program Schedule

Target tasks after CDR until final launch demonstration



Shipping and Transportation

- **Plans for shipping/transporting the CanSat hardware to the launch site**

  - Transport CanSat with carry on luggage. Disassemble the steel spring wires to allow for easy inspection at security.

- **Shipping/transportation of tools and equipment**

  - Antenna mast is designed to be constructed and assembled from local parts purchased in Abilene.

  - Only transport tools which can not be purchased locally.

Conclusions

- **System Design Simplicity and Elegance**
  - System design of payload is symmetric with that of container, including Mechanical Subsystem, Electrical Subsystem, CDH, FSW and GCS software. This simplifies integration and testing.
- **Progress to date**
  - Mechanical team
    - Designed and tested descent mechanism and egg protection
    - Finalizing design of release mechanism
    - Completed 3D printing of prototype structural parts
  - Electrical team:
    - Interfaced all sensors with microcontroller on radio module
    - Ground station software has been developed
    - Rev.1 payload and container PCB’s have been fabricated and tested.
    - Radio link, release mechanism and solar panels have been tested
    - Power supply design have been completed. PCB is currently being fabricated.
    - Rev.2 PCB designs have been completed and sent out for fabrication

Conclusions

- **Work to be completed**
  - Mechanical team
    - Finish testing of structural materials
    - Conduct more drop tests from higher altitude
    - Conduct umbrella deployment and release mechanism test while on descent
    - 3D Print final structural parts
  - Electrical team
    - Conduct more test on power supply and solar panels
    - Conduct more test on Radio Link
    - Conduct more test on FSW and GS Software