CanSat 2013
Critical Design Review (CDR)

#1000
Demolishor
University of Alabama in Huntsville
Space Hardware Club
Presentation Outline

• Provide a simple outline of the presentation
• If possible, indicate the team member(s) who will be presenting each section
• Terms:
  – *Container* refers to the *Re-entry Container* component of the CanSat
  – *Payload* refers to the *Science Payload* component of the CanSat

**IMPORTANT PRESENTATION GUIDELINE FOR CANSAT 2013:**
Teams should focus on charts with this star icon during the presentation. Other charts are to be skipped to save time; they will be reviewed by the judges off line. **Do not remove the star icon from the slides.**
Presentations are to be 30 minutes in length.
Team Organization

Team Lead
Mason Manning

Faculty Advisor
Dr. Francis Wessling

Sensor Subsystem
Mason Manning

Descent Control
Eric Becnel

Mechanical Subsystem
Eric Becnel

CDH Subsystem
Mason Manning

EPS Subsystem
Mason Manning

Flight Software
Mason Manning

Ground Control
Matt Rodencal

CanSat 2013 CDR: Team #1000 Demolishor
Acronyms

- CDH – Communications and Data Handling
- EPS – Electrical Power Subsystem
- FSW – Flight Software
- GCS – Ground Control Subsystem
- ODR – Output Data Rate
- LSB – Least Significant Byte
- LSB – Least Significant Bit
- MSB – Most Significant Byte
- MSB – Most Significant Bit
- dps – Degrees Per Second
- USART – Universal Synchronous/Asynchronous Receive/Transmit
- SPI – Serial Peripheral Interface bus
- I2C – Inter-Integrated Circuit
- TWI – Two Wire Interface
- TTL – Transistor-Transistor Logic
- NTC – Negative Thermal Coefficient
- PTC – Positive Thermal Coefficient
- PCB – Printed Circuit Board
- FOS – Factor of Safety
The purpose of this section is to introduce the reviewer to the overall requirements and configuration of the CanSat. This provides a basis for the details presented in the subsystem sections.

System Overview

Eric Becnel
Mission Summary

- **Primary Mission Objective**
  - Successful delivery of a simulated science payload to Earth’s surface after deployment from a rocket at near-apogee

- **Secondary Mission Objective**
  - Measure the impact force of the lander with the ground at a sampling rate of at least 100 samples per second, storing the data on board

- **Personal Mission Objective**
  - Measure the 3-axis rotational stability of the CanSat during descent and transmit the data alongside the normal telemetry
Summary of Changes Since PDR

• Overview design changes since PDR
  – Mechanical
    • Primary frame
      – Plastic with composite base changed to composite with plastic hinges

• Details of the changes are discussed in subsequent sections
Mechanical Changes

Old Frame
• Plastic ring
• Composite lower shield

• Pros:
  – Simple to fabricate

• Cons:
  – Heavier 34 grams
  – Rapid prototyping cost a lot
  – Machining would take a while

New Frame
• Composite full frame
• Plastic hinge points

• Pros:
  – Lighter 21 grams
  – Low cost to injection mold

• Cons
  – More complex
Mission Summary

- **Primary Mission Objective**
  - Successful delivery of a simulated science payload to Earth’s surface after deployment from a rocket at near-apogee

- **Secondary Mission Objective**
  - Measure the impact force of the lander with the ground.
    - Selected for simplicity and minimal required additional hardware

- **Personal Mission Objectives**
  - Measure the 3-axis rotational stability of the CanSat during descent and transmit the data alongside the normal telemetry
  - Operate a parallel off-band communications system to evaluate effects of Zigbee network traffic.

Presenter: Eric Becnel
System Requirement Summary

- **Overall System Requirements**
  - The total mass of the system shall be 700 g, ±10 g
  - Total system cost, excluding ground support and analysis tools shall be under $1000 (USD)

- **Container Requirements**
  - The CanSat shall be installed in a container to protect it during launch and deployment near apogee
    - Fit inside a cylindrical envelope of 130 x 250 mm
    - Have a controlled descent
    - Have no sharp edges
    - The container must be a fluorescent color
    - The rocket airframe can not be used to restrain any deployable parts of the CanSat
System Requirement Summary

- **CanSat Descent Control & Recovery Requirements**
  - The system shall not use any pyrotechnic devices
  - No exposed nichrome wire
  - Meet the following descent rates
    - Container with Payload descend at 20 +/- 1 m/s (670 to 400m)
    - Payload below 20 m/s (400 to 0m) using aero-breaking structure
  - An audible beacon, rated above 80 dB must be included on the CanSat (payload and container), capable of operating for at least three hours
  - All descent control devices must be capable of surviving 30 G of shock
System Requirement Summary

• **Payload Requirements**
  
  – **Communication Requirements**
    • The CanSat shall not transmit telemetry until commanded by the ground station
    • The CanSat communications radio shall be the XBEE radio S1 or S2
    • The XBEE radio shall not transmit in broadcast mode
    • The XBEE radio will have its NETID set to the team number
    • The ground station antenna shall be elevated at least 3.5 m off the ground and secured from falling
  
  – **Power Requirements**
    • An external power control and power indicator is required
    • The CanSat shall have battery capacity to support a one hour wait on the launch pad, in addition to flight operations and 3 hour buzzer.
    • The CanSat shall not use Lithium Polymer batteries

*Prior permission has been obtained to use an alternate radio of the team’s choice*
• **Payload Requirements (continued)**
  
  – Flight Software Requirements
    
    • The CanSat shall maintain and transmit the current software state
      
      – In the event of a software reset, the CanSat shall be able to determine the correct state
    
    • The CanSat shall transmit the following data at least every two seconds:
      
      – GPS data (UTC time, latitude, longitude, mean sea level altitude, number of satellites tracked)
      
      – Altitude in meters above sea level (non-GPS measured)
      
      – Air temperature
      
      – Battery Voltage
      
      – Flight software state
      
      – Flight software maintained mission time
System Requirement Summary

• **Payload Requirements (continued)**
  – **Structure Requirements**
    • All electronics must be enclosed and shielded from the environment
    • Support 10 G acceleration
    • Survive 30 G acceleration
    • Circuit boards must be hard mounted
    • Identification on the payload
  – **Mechanical Requirements**
    • Maintain state under all forces
    • No pyrotechnics or chemicals
    • All hot wires are not exposed
System Requirement Summary

• **Ground Control Requirements**
  – Save in CSV format as specified
    • Named properly
  – Xbee mounted over 3.5 meters high
  – Visualize data in real time
Secondary Mission Requirements

- The CanSat must measure the force of impact with the ground
- The event must be sampled with a rate of at least 100 samples per second
- The collected data must be stored on-board the CanSat for later retrieval
## Overview of Mission Sequence of Events

<table>
<thead>
<tr>
<th>Event</th>
<th>Responsible Crew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrive</td>
<td></td>
</tr>
<tr>
<td>Set up ground station</td>
<td>Ground Station Crew</td>
</tr>
<tr>
<td>• Ground Station Crew</td>
<td></td>
</tr>
<tr>
<td>CanSat Functional Test</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Perform weigh-in</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Assemble CanSat</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Select egg</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Verify tower height</td>
<td>Ground Station Crew</td>
</tr>
<tr>
<td>• Ground Station Crew</td>
<td></td>
</tr>
<tr>
<td>Perform fit-check</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Integrate with rocket</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Launch pad integration</td>
<td>CanSat Crew</td>
</tr>
<tr>
<td>• CanSat Crew</td>
<td></td>
</tr>
<tr>
<td>Initiate mission when instructed</td>
<td>Mission Control Officer</td>
</tr>
<tr>
<td>• Mission Control Officer</td>
<td></td>
</tr>
<tr>
<td>Verify communications</td>
<td>Ground Station Crew</td>
</tr>
<tr>
<td>• Ground Station Crew</td>
<td></td>
</tr>
<tr>
<td>Retrieve CanSat</td>
<td>Recovery Crew</td>
</tr>
<tr>
<td>• Recovery Crew</td>
<td></td>
</tr>
<tr>
<td>Deliver telemetry</td>
<td>Ground Station Crew</td>
</tr>
<tr>
<td>• Ground Station Crew</td>
<td></td>
</tr>
<tr>
<td>Score the mission</td>
<td></td>
</tr>
<tr>
<td>Perform mission</td>
<td></td>
</tr>
</tbody>
</table>

CanSat 2013 CDR: Team #1000 Demolishor

Presenter: Eric Becnel
Physical Layout

- Lower payload integration
- Tapered integration
- 120 deg decelerator
Physical Layout (Canister)

- Parasheet
- Upper electronics ring
- Fiberglass structure
  - Painted orange
- Name plate
- Elastic ejection strap
- Bottom payload storage
Physical Layout (Payload)

- Decelerator
- Torsion spring
- Electronics
- Frame
- Power switch
- Impact foam

Name plate
Egg
Egg container
Shock mount
Launch Vehicle Compatibility

- **Geometry**
  - Diameter 0.126m
    - 2mm radial clearance
  - Height 0.240m
    - 10mm vertical clearance
  - Parasheet in upper volume
    - Compressible

- **Position in rocket**
  - Bottom in image is in the bottom of the payload bay
Sensor Subsystem Design

Mason Manning
Sensor Subsystem Overview

- **Accelerometer: ADXL345**
  - Used to measure impact force with the ground
  - Maximum ODR of 3200 Hz
  - Maximum sensitivity of 3.5 mG/LSb
  - SPI and I2C capabilities

- **Gyroscope: L3GD20**
  - Used to measure stability of the CanSat during descent
  - Maximum ODR of 760 Hz
  - Maximum sensitivity of 8.75 mdps/LSb
  - SPI and I2C capabilities

- **Pressure Sensor: MS5611**
  - Used to measure altitude above sea level
  - Resolution: 1.2 Pa
  - SPI communication

- **GPS: M10382-A1**
  - Used to measure position
  - USART communication

- **Temperature: NTC Thermistor**
  - Used to measure air temperature
## Sensor Subsystem Requirements

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Requirement(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS Module</td>
<td>• Capable of sampling at a rate of at least 0.5 Hz (once every two seconds)</td>
</tr>
<tr>
<td>Altitude Sensor</td>
<td>• Capable of measuring altitude differences of at least 0.1 m</td>
</tr>
<tr>
<td></td>
<td>• Capable of sampling at a rate of at least 0.5 Hz</td>
</tr>
<tr>
<td>Temperature Sensor</td>
<td>• Capable of measuring temperature differences of at least 1 °C</td>
</tr>
<tr>
<td></td>
<td>• Capable of sampling at a rate of at least 0.5 Hz</td>
</tr>
<tr>
<td>Impact Force Sensor</td>
<td>• Capable of measuring the maximum acceleration experienced upon impact</td>
</tr>
<tr>
<td></td>
<td>• Capable of sampling at a rate of at least 100 Hz</td>
</tr>
<tr>
<td>Rotational Sensor</td>
<td>• Capable of measuring rate of rotation on all 3 axes</td>
</tr>
<tr>
<td></td>
<td>• Capable of sampling at a rate of at least 100 Hz</td>
</tr>
</tbody>
</table>
Sensor Changes Since PDR

- No sensor subsystem changes since PDR
Antenova M10382-A1

- **Data Format:**
  - NMEA 0183 (2.3, compatible to 3.0) and/or UBX (u-blox Binary)
  - Output via USART, SPI, or I2C

- **Accuracy:**
  - Horizontal Position: 2.5 meters
  - Velocity: 0.1 meters per second
  - Heading: 0.5°

- **Antenna tuning capability:**
Non-GPS Altitude Sensor Summary

• Measurement Specialties MS5611-01BA01
• Data Format
  – 24 bit ADC value
  – Output via I2C or SPI
• Accuracy
  – 1.2 Pa, maximum
  – 10 cm altitude resolution possible
  – 0.1 °C integrated temperature sensor
Non-GPS Altitude Sensor Summary

- **Calculate Temperature**
  - Difference between actual and reference temperature
    - \( dT = D2 - T_{REF} = D2 - C5 \times 2^8 \)
  - Actual temperature (-40…85°C with 0.01°C resolution)
    - \( TEMP = 20°C + dT \times TEMPSENS = 2000 + dT \times C6/2^{23} \)

- **Calculate Temperature Compensated Pressure**
  - Offset at actual temperature
    - \( OFF = OFF_{T1} + TCO \times dT = C2 \times 2^{16} + \frac{C4 \times dT}{2^7} \)
  - Sensitivity at actual temperature
    - \( SENS = SENS_{T1} + TCS \times dT = C1 \times 2^{15} + \frac{C3 \times dT}{2^8} \)
  - Temperature compensated pressure (10…1200 mbar with 0.01 mbar resolution)
    - \( P = D1 \times SENS - OFF = (D1 \times SENS/2^{21} - OFF)/2^{15} \)
Air Temperature Summary

NTC Thermistor

- Data Format
  - 12 bit voltage ADC value

- Accuracy
  - ~0.5 mV ADC resolution
  - Corresponds to ~0.02 °C temperature resolution

- Temperature Calculation
  
  \[ R_{NTC} = \frac{33000}{TEMP_{ADC}} - 10000 \]

  \[ T = \frac{B}{\ln\left(\frac{R_{NTC}}{R_0 e^{-\frac{B}{T_0}}}\right)} \]

  B = 3375 K (characteristic parameter)
  \( R_0 = 10 \, k\Omega \)
  \( T_0 = 298.15 \, K \)
**Impact Force Sensor Summary**

**Analog Devices ADXL345**
- Maximum sampling rate of 3200 Hz
- Shock survivability of 10000 G

**Data Format**
- 13 bit ADC measurement
- Output via I2C or SPI

**Accuracy**
- 3.5 mG/LSb, maximum

**Force Calculation**
- $a = data \times sensitivity$
- $F = m \times a$

data: ADC value returned by the device
sensitivity: mG/LSb at the selected sampling rate
m: mass of the CanSat Payload

Presenter: Mason Manning
Descent Control Design

Eric Becnel
Canister w & w/o payload

- Parasheet for container
- 0.197m diameter
- 20 m/s
- 670 m to ground

Payload

- Decelerator
- 16.5 in diameter
- 120 deg
- 400 m to ground
Descent Control Changes Since PDR

• There are no changes from the PDR
• Our Prototype testing will occur on 4/6 or 4/20
  – Local High Powered Rocket launch dates
Descent Control Requirements

- **CanSat Descent Control & Recovery Requirements**
  - 3.1-The system shall not use any pyrotechnic devices
  - 10.3-No exposed nichrome wire
  - Meet the following descent rates
    - 3.2-Container with Payload descend at 20 +/-1 m/s (670 to 400m)
    - 3.3-Payload below 20 m/s (400 to 0m) using aero-breaking structure
  - 3.4-An audible beacon, rated above 80 dB must be included on the CanSat (payload and container), capable of operating for at least three hours
  - 3.5/6-All descent control devices must be capable of surviving 30 G of shock
Container Descent Control
Hardware Summary

• **Payload interfaces from bottom**
  – Secured with monofilament strap with >30g rating to payload weight (114N ~ 26lbf)
  – Deployments restrained by female tapered payload bay of the container
  – Deployment triggered by Payload
  – Buzzer will be activated at launch manually

• **Colors**
  – Canister – Bright orange (easy to find in field)

• **Connection to parasheet**
  – Direct Kevlar line tied to upper fiberglass tie-off point (FOS of 24)

• **Preflight review testability**
  – Pull test between upper parasheet and payload
Payload Descent Control Hardware Summary

- The separation will be triggered by the Payload
  - Hot wire
  - Pressure based altitude determination
- Color
  - Parasheet – Red (easy to find in the sky)
- Payload decent control deployment upon ejection from Container
- Active components
  - SPI communication to pressure sensor
    - High speed, reliable, resistant to noise
  - Altitude will be calculated from sensor temperature and pressure
  - Hot wire actual will release payload
The decent rates are a function of altitude.

Decent rates:
- Canister + payload
  ~ 20 m/s
- Payload
  ~ 8.3 m/s
- Canister
  ~ 12 m/s
Air speed calculations

Lander decent rates
CanSat 2013 A
UAHuntsville

\[
\text{Temp}_{\text{std}} := 288.15 \text{K} \\
L_{\text{temp}} := 0.0065 \frac{\text{K}}{\text{m}} \\
\text{Pres}_{\text{std}} := 101325 \text{Pa} \\
g = 9.807 \frac{\text{m}}{\text{s}^2} \\
M_{\text{air}} := 0.0289644 \frac{\text{kg}}{\text{mole}} \\
R_{\text{ugc}} := 8.31447 \frac{\text{J}}{\text{mole} \cdot \text{K}}
\]

\[
\text{Temp}(h) := \text{Temp}_{\text{std}} - L_{\text{temp}} \cdot h \\
\text{Pres}(h) := \text{Pres}_{\text{std}} \left( \frac{\text{Temp}(h)}{\text{Temp}_{\text{std}}} \right) \\
\rho(h) := \frac{M_{\text{air}} \cdot \text{Pres}(h)}{R_{\text{ugc}} \cdot \text{Temp}(h)}
\]
Air speed calculations

Forward Drag Device

\[ \text{Angle} := \frac{120\text{deg}}{2} = 60\text{deg} \]
\[ \text{Diameter}_{FDD} := 16.5\text{in} \]
\[ \text{Cd}_{FDD} := 0.8 \]
\[ \text{Area}_{FDD} := \left(\frac{\text{Diameter}_{FDD}}{2}\right)^2 \cdot \pi \]
\[ \text{mass}_{Payload} := 0.45\text{kg} \]
\[ \text{speed}_{FDD}(1750\text{ft}) = 8.291 \frac{\text{m}}{\text{s}} \text{ at landing} \]

Parasheet

\[ \text{Diameter}_{Parasheet} := 7.75\text{in} \]
\[ \text{Cd}_{Parasheet} := 1.0 \]
\[ \text{estimate for a hexagon parasheet} \]
\[ \text{Area}_{Parasheet} := \left(\frac{\text{Diameter}_{Parasheet}}{2}\right)^2 \cdot \pi \]
\[ \text{mass}_{container} := 0.25\text{kg} \]
\[ \text{speed}_{container}(1750\text{ft} + 670\text{m}) = 20.348 \frac{\text{m}}{\text{s}} \]
\[ \text{speed}_{container}(1750\text{ft} + 400\text{m}) = 20.079 \frac{\text{m}}{\text{s}} \]

This drag model only incorporates the parasheet contribution. The CanSat will add additional drag.

\[ \text{speed}_{empty}(h) := \sqrt{\frac{\text{g} \cdot (\text{mass}_{container})^2}{\rho(h) \cdot \text{Area}_{Parasheet} \cdot \text{Cd}_{Parasheet}}} \]
Air speed calculations

\[ h_{\text{ground}} := 1750 \text{ft} = 533.4 \text{m} \quad h_{\text{separation}} := h_{\text{ground}} + 400 \text{m} \quad h_{\text{apogee}} := h_{\text{ground}} + 670 \text{m} \]

\[ h_{\text{range}} := h_{\text{ground}}, h_{\text{ground}} + 50\text{ft} \ldots h_{\text{apogee}} \]

mission altitude range

\[ h_{\text{cp}} := h_{\text{separation}}, h_{\text{separation}} + 50\text{ft} \ldots h_{\text{apogee}} \]

container + payload altitude range

\[ h_{\text{p}} := h_{\text{ground}}, h_{\text{ground}} + 50\text{ft} \ldots h_{\text{separation}} \]

payload altitude range

\[ h_{\text{c}} := h_{\text{ground}}, h_{\text{ground}} + 50\text{ft} \ldots h_{\text{separation}} \]

container altitude range

\[ \frac{h_{\text{range}}}{\text{m}} \]

\[ \text{Temp}\left(\frac{h_{\text{range}}}{\text{K}}\right) \]

\[ \frac{h_{\text{range}}}{\text{m}} \]

\[ \text{Pres}\left(\frac{h_{\text{range}}}{\text{kPa}}\right) \]
Air speed calculations

\[
\begin{align*}
\text{hp} & \quad \text{m} \\
\text{speed}_{\text{FDD}}(h_p) & \quad \text{m/s} \\
\text{range} & \quad \text{m} \\
\text{rho}(h_{\text{range}}) & \quad \text{kg/m}^3 \\
\text{h}_{\text{cp}} & \quad \text{m} \\
\text{speed}_{\text{container}}(h_{\text{cp}}) & \quad \text{m/s} \\
\text{h}_c & \quad \text{m} \\
\text{speed}_{\text{empty}}(h_c) & \quad \text{m/s}
\end{align*}
\]
Air speed calculations

The speed of the parts of the system will change as we decrease through the atmosphere. The decent rate will be initially around 20m/s until the separation altitude of 400m above the ground. At this point, the payload and container should separate and descend individually. The mass of the assembly is fixed, defining the performance of the container drag device. Upon separation of the payload, planned to be from the bottom of the container, the container will fall faster than the payload causing a potential separation issue. A forced ejection should be used to ensure operation.
Mechanical Subsystem Design

Eric Becnel
Mechanical Subsystem Overview

- **Decelerator (rip-stop nylon)**
  - Arm Deployed by simple torsion spring
    - Nitinol wire and carbon fiber arms
  - Deployment retained by canister
  - Tapered interface reduces snagging
  - Elastic canister rejection strap
  - Egg protection container
    - Fiberglass
  - Shock mounted egg
    - R/C truck shocks
  - Front impact foam (closed cell phone)
  - PCB epoxied to compositeframe
  - Monofilament strap to retain in container
  - Concealed nichrome hot-wire release

- **Container**
  - Fiberglass container
  - RF transparent
  - Bottom access to payload for power up
  - Simple parasheet (rip-stop nylon)
  - Kevlar parasheet cords
# Mechanical Subsystem Changes Since PDR

## Mechanical – PDR
Plastic frame with composite lower cover

- **Pros:**
  - Simple to fabricate

- **Cons:**
  - Heavier 34 grams
  - Rapid prototyping cost a lot
  - Machining would take a while

## Mechanical – CDR
All composite frame with plastic hinge points

- **Pros:**
  - Lighter 21 grams
  - Low cost to injection mold

- **Cons:**
  - More complex
Mechanical Sub-System Requirements

• **Structure Requirements**
  – All electronics must be enclosed and shielded from the environment
  – Support 10 G acceleration
  – Survive 30 G acceleration
  – Circuit boards must be hard mounted
  – Identification on the payload

• **Mechanical Requirements**
  – Maintain state under all forces
  – No pyrotechnics or chemicals
  – All hot wires are not exposed

• **Competition requirement 3.1 sections 2, 3, 9 and 10**
Egg Protection Overview

• Three levels of protection
  
  – Foam encapsulation
  
  – Hydraulic damped springs with >2cm travel
  
  – Front impact foam
Mechanical Layout of Components

- Egg container on shocks
- Drag device
- Electronics
- Impact foam

Units in mm
Material Selections

- **Decelerator and parasheet**
  - Kevlar cord for parasheet
  - Rip-stop nylon for low mass, tough fabric
- **Canister**
  - Fiberglass layed up on custom mold
- **Egg holder**
  - Fiberglass cup supported by aluminum ring for bolting interface to the springs
- **Decelerator arms**
  - Carbon fiber deployment arms with foam core for extra strength
- **Frame**
  - Fiberglass frame
- **Hinges**
  - Injection molded or rapid prototyped plastic
Container - Payload Interface

• **Storage**
  – Tapered bottom hole holding payload un-deployed

• **Connected**
  – Monofilament strap (black lines show path)
  – Can meet 30G shock force
  – Path connects both structures

• **Cut down**
  – PCB mounted hot wire

• **Ejection force**
  – Elastic strap pulls payload out (white line shows path)
Structure Survivability (Payload)

• **Electronic component division**
  – Top interacts with human or environment
    • Pressure, GPS, Battery
  – Bottom components are conformal coated
  – Power switch on bottom

• **Frame**
  – Protects top
  – Encloses bottom
  – Glued to rim
Structure Survivability (Payload)

- **Egg rides on suspension**
  - Take off
  - Landing

- **Direct load path**
  - All forces are applied to the frame
Structure Survivability (Canister)

• Payload hangs from strap routed to the top
• Direct load path
  – All forces are applied to the parasheet attachment point
• Canister battery
  – Will be secured with either zip-tie or similar battery restraint
• PCB is glued to upper bulkhead
## Mass Budget

### Container

<table>
<thead>
<tr>
<th>Part</th>
<th>Mass</th>
<th>Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>35 g</td>
<td>modeling</td>
</tr>
<tr>
<td>• Pcb</td>
<td>+/-10</td>
<td></td>
</tr>
<tr>
<td>• Battery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Container</td>
<td>200 g</td>
<td>modeling</td>
</tr>
<tr>
<td></td>
<td>+/-20</td>
<td></td>
</tr>
<tr>
<td>Parasheet</td>
<td>22 g</td>
<td>modeling</td>
</tr>
<tr>
<td>Total</td>
<td>257 g</td>
<td></td>
</tr>
</tbody>
</table>

### Payload

<table>
<thead>
<tr>
<th>Part</th>
<th>Mass</th>
<th>Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronics</td>
<td>118 g</td>
<td>modeling</td>
</tr>
<tr>
<td>• Pcb</td>
<td>+/-20</td>
<td></td>
</tr>
<tr>
<td>• Battery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• parts</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frame</td>
<td>21 g</td>
<td>modeling</td>
</tr>
<tr>
<td></td>
<td>+/-5</td>
<td></td>
</tr>
<tr>
<td>Decelerator</td>
<td>24 g</td>
<td>modeling</td>
</tr>
<tr>
<td>Egg holder</td>
<td>52 g</td>
<td>modeling</td>
</tr>
<tr>
<td></td>
<td>+/-5</td>
<td></td>
</tr>
<tr>
<td>Shocks</td>
<td>108 g</td>
<td>measured</td>
</tr>
<tr>
<td></td>
<td>+/-5</td>
<td></td>
</tr>
<tr>
<td>Impact foam</td>
<td>22 g</td>
<td>modeling</td>
</tr>
<tr>
<td></td>
<td>+/-5g</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>345 g</td>
<td></td>
</tr>
</tbody>
</table>

**Cansat: 602 g**

**Margin: 98 g**

(ballast Canister to meet 700g)

**Egg: 60g**
Communication and Data Handling Subsystem Design

Mason Manning
CDH Overview

- **Microcontroller: Atmel ATxmega128A1U**
  - Command and data processing
  - Payload control
- **Data Storage: Atmel AT45DB642D**
  - Storage of data gathered in-flight
  - Storage of impact acceleration data
- **Antenna:**
  - 2.4 GHz whip, ½ wave, SMA, 50 Ω
    - XBEE communications
  - 433 MHz whip, ¼ wave, SMA, 50 Ω
    - Off-band communications via CC1100 module
- **Radio:**
  - XBEE SMT: 2.4 GHz communications
  - CC1100 Module: 433 MHz communications
CDH Changes Since PDR

- No CDH subsystem changes since PDR
# CDH Requirements

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirement(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller</td>
<td>• Capable of interfacing with all selected sensors</td>
</tr>
<tr>
<td></td>
<td>• Capable of gathering and transmitting all telemetry data at a rate of 0.5 Hz</td>
</tr>
<tr>
<td>Data Storage</td>
<td>• Capable of storing all impact force data</td>
</tr>
<tr>
<td></td>
<td>• Minimum of ~2 KB, assuming a 10 second record time</td>
</tr>
<tr>
<td>Antenna</td>
<td>• Capable of providing sufficient gain between the CanSat and ground station</td>
</tr>
<tr>
<td>Radio</td>
<td>• Capable of transmitting/receiving data to/from the CanSat from/to the ground station</td>
</tr>
<tr>
<td>Telemetry</td>
<td>• Must contain the following data: “CANSAT”, TEAM_ID, MISSION_TIME, GPS_TIME,</td>
</tr>
<tr>
<td></td>
<td>GPS_LONG, GPS_ALT, GPS_SAT, ALT_SENSOR, TEMP, BAT_V, STATE, ROTATION</td>
</tr>
<tr>
<td>Audible Locating Device</td>
<td>• Must be rated above 80 dB</td>
</tr>
<tr>
<td></td>
<td>• Capable of operating for at least three hours</td>
</tr>
</tbody>
</table>
Processor & Memory Selection

• **Processor: Atmel ATXmega128A1U**
  – Max Speed: 32 MHz
  – 128 kilobytes program flash, 8 kilobytes SRAM, 2 kilobytes EEPROM
  – USB – 1
  – SPI – 12
  – TWI (I2C) – 4
  – USART – 8
  – ADC Channels – 16
  – Analog Comparators – 4
  – DAC Channels – 4
  – Temperature Sensor – 1
  – External Bus Interface – 1
  – Timers – 8
  – Output Compare Channels – 24
  – Input Capture Channels – 24
  – PWM Channels – 24
  – 32 KHz RTC – 1
  – Calibrated RC Oscillator – 1
  – Watchdog Timer – 1

• **Memory: Adesto Technologies AT45DB642D**
  – 64 Megabits of dataflash storage
  – Accessed via SPI interface
  – Sufficient for predicted ~2 KB storage necessary to record acceleration data
Antenna Selection

- **Linx Technologies ANT-2.4-CW-QW-RPS**
  - Specifications
    - Center frequency: 2.45 GHz
    - Wavelength: ½ Wave
    - VSWR: <1.9 typically, at center frequency
    - Impedance: 50 Ω
    - Connector: RP-SMA
    - Mass: Not specified
  - Features
    - Low cost
    - Omni-directional radiation pattern
    - Fully weatherized

- **Linx Technologies ANT-433-CW-QW-SMA**
  - Specifications
    - Center frequency: 433 MHz
    - Wavelength: ¼ Wave
    - VSWR: <1.9 typically, at center frequency
    - Impedance: 50 Ω
    - Connector: SMA
    - Mass: Not specified
  - Features
    - Low cost
    - Omni-directional radiation pattern
    - Fully weatherized
Radio Configuration

• **XBEE will be configured in a P2P mode**
  – PAN ID will be set to the team number (1000)
  – Broadcast mode will be disabled (DL != 0xFFFF)
    • The destination address will be set to that of the ground station
  – These settings can be configured with serial commands on assembly via the X-CTU program or via the Xmega on power-on.

• **Transmission Control**
  – No transmissions will be sent from the CanSat until the appropriate command has been received from the ground station
  – Hardware flow control (request to send, clear to send) signals used to ensure no buffer overflow to XBEE module
Telemetry Format

• **Included Data**
  - The fixed string “CANSAT”
  - `<TEAM_ID>`
  - `<MISSION_TIME>` - Time as maintained by the MCU
  - `<GPS_TIME>` - UTC time returned by GPS module
  - `<GPS_LAT>` - Latitude
  - `<GPS_LONG>` - Longitude
  - `<GPS_ALT>` - Altitude as returned by GPS module
  - `<ALT_SENSOR>` - Altitude as returned by non-GPS sensor
  - `<TEMP>` - Air temperature
  - `<BAT_V>` - Battery voltage
  - `<STATE>` - Current flight software state
  - `<ROTATION>` - Rate of rotation on all three axes
  - Terminating carriage return

• **Example Packet**
```
CANSAT,1000,354,125120.45,7516.24,16245.61,342,05,342.1,15.0,9.0,MAIN_DESCENT,162.4,425.2,312.6\r
```

• **Packet Data Rate**
  - 9600 bits per second
Activation of Telemetry Transmissions

• The command will be via Xbee radio
• API packet with start command code
Locator Device and Labeling

• **Audible Beacon**
  - Activated by applying 3.3 V via one of the microcontroller IO pins
  - Deactivated upon recovery by turning off the CanSat payload via the accessible power switch

At 3.3 V, sound level is just above 80 dB, whereas the requirement is 80 dB.

Both the CanSat payload and container will be identifiable via adhesive labels containing Team Number, email address, and a phone number.
Electrical Power Subsystem Design

Mason Manning
EPS Overview

• **Power Source**
  – 3 CR123 batteries in series
  – 9 – 12 volt DC power jack

• **Power Switch**
  – Power enable switch for entire EPS

• **Ideal Diode Controller**
  – Back-current protection and multiple power source switching

• **DC-DC Converter(s)**
  – Efficient power regulation for 3.3 and 5.0 volt rails

• **Current Limit(s)/Load Switch**
  – Limit current passing through nichrome hotwires to 1.5 A
  – MCU controlled switch to enable current flow to hotwires
EPS Changes Since PDR

• No EPS changes since PDR
EPS Requirements

• The CanSat shall have an external power control and some indication of being turned off
• The CanSat shall have a battery capacity to support up to a one hour wait on the launch pad, plus flight operations
• The CanSat shall not use lithium polymer batteries
## Power Budget

<table>
<thead>
<tr>
<th>Component</th>
<th>Power Consumption (mW)</th>
<th>Duty Cycle</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADXL345</td>
<td>0.462</td>
<td>100%</td>
<td>Datasheet</td>
</tr>
<tr>
<td>L3GD20</td>
<td>20.13</td>
<td>100%</td>
<td>Datasheet</td>
</tr>
<tr>
<td>Xmega128A1U</td>
<td>66</td>
<td>30%</td>
<td>Datasheet</td>
</tr>
<tr>
<td>DC-DC 3.3 V</td>
<td>10.8</td>
<td>100%</td>
<td>Estimate</td>
</tr>
<tr>
<td>DC-DC 5.0 V</td>
<td>10.8</td>
<td>100%</td>
<td>Estimate</td>
</tr>
<tr>
<td>MS5611</td>
<td>4.62</td>
<td>100%</td>
<td>Datasheet</td>
</tr>
<tr>
<td>M10382-A1</td>
<td>171.6</td>
<td>100%</td>
<td>Estimate</td>
</tr>
<tr>
<td>CC1100 module</td>
<td>1200</td>
<td>20%</td>
<td>Estimate</td>
</tr>
<tr>
<td>XBEE</td>
<td>330</td>
<td>20%</td>
<td>Estimate</td>
</tr>
<tr>
<td>CM-1240</td>
<td>29.7</td>
<td>20%</td>
<td>Datasheet</td>
</tr>
<tr>
<td>AT45DB642D</td>
<td>82.5</td>
<td>100%</td>
<td>Datasheet</td>
</tr>
<tr>
<td>Ideal Diode Controller</td>
<td>0.234</td>
<td>100%</td>
<td>Estimate</td>
</tr>
</tbody>
</table>

- Worst Case Total Power Consumption: 1.93 W
- Battery Capacity: 1500 mAh
- Worst Case System Lifetime: 6.3 hours
Power Source Summary

• Two available power sources to the EPS
  – 3 CR123 batteries in series: 9 V DC
    • Lithium Ion Batteries
    • 1500 mAh capacity
  – 5 mm barrel jack: 12 V DC
    • Used for bench-top testing and debugging
    • Automatically disconnects the batteries when plugged in
Battery Voltage Measurement

- Measured via the microcontroller’s on-board ADC through a voltage divider
  - Maximum range: 0 – 2.0625 V
  - 12 bit resolution yields ~0.5 mV resolution
  - Voltage divider brings maximum voltage within ceiling of ADC to maximize resolution

- Voltage Calculation
  - $BATT_{ADC} = ADC \times 0.0005V$
  - $BATT = BATT_{ADC} \times \frac{(R23+R24)}{R24}$

ADC: raw ADC value
$BATT_{ADC}$: signal to MCU
$BATT$: battery voltage
Flight Software Design

Mason Manning
FSW Overview

- Architecture comprised of two main sections
  - Main loop
    - Wake to read sensors, determine flight software state, and log telemetry
    - Transmit the telemetry
    - Go back to sleep
  - Impact Event
    - ADXL345 detects impact and notifies MCU
    - MCU continuously records acceleration data to capture impact
- Written in C using Atmel Studio 6 IDE
### FSW Changes Since PDR

<table>
<thead>
<tr>
<th>FSW – PDR</th>
<th>FSW – CDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>FSW States: Pre-launch, ascent, initial descent, main descent, impact, recovery</td>
<td>FSW States: Initialization, Pre-launch, ascent, initial descent, main descent, recovery</td>
</tr>
<tr>
<td></td>
<td>• Initialization state checks EEPROM for any previously saved state at each power-on or reset</td>
</tr>
<tr>
<td></td>
<td>• No need for Impact state</td>
</tr>
<tr>
<td></td>
<td>• Initial impact happens faster than the state can be written to EEPROM (on the order of milliseconds)</td>
</tr>
</tbody>
</table>
FSW Requirements

• The flight software shall maintain and telemeter an indicator of the CanSat flight software state
• In the event of a processor reset during the mission, the flight software shall be able to determine the correct state
Execution starts at Initialization.
At each state change, the new state is saved to EEPROM.
State transitions to Initialization represent a reset.
State transitions from Initialization, except to Pre-Launch on first power-on, represent a software recovery.

- Execution starts at Initialization.
- At each state change, the new state is saved to EEPROM.
- State transitions to Initialization represent a reset.
- State transitions from Initialization, except to Pre-Launch on first power-on, represent a software recovery.
CanSat FSW State Diagram

• **Initialization**
  – Configures all IO pins and internal hardware modules for operation
  – Reads EEPROM byte which indicates the correct software state
  – If no state value is present in EEPROM, state changes to Pre-Launch. Otherwise, the state changes to that stored in EEPROM

• **Pre-Launch**
  – Waiting for the initiate telemetry command from ground station

• **Ascent**
  – Telemetry initiated at once per second
  – Stores all sent telemetry on AT45DB642D
  – Monitors altitude for steady increase, then steady decrease to proceed to Initial Descent

• **Initial Descent**
  – Monitors altitude for 400 meter mark
  – At 400 meters, separates from container and proceeds to Main Descent

• **Main Descent**
  – Monitors ADXL345 for impact interrupt to proceed to Impact
  – Impact
    • Continuously records acceleration data for 5 seconds at 3200 samples/second
    • Stores in a .bin file on AT45DB642D
  – Monitors ADXL345 for rest interrupt to proceed to Recovery

• **Recovery**
  – Activates audible beacon
Software Development Plan

- **Concurrent Development**
  - Software is being developed directly alongside the electrical hardware
  - Combined with a bottom-up approach, this allows for simultaneous FSW development and electrical hardware verification

- **Bottom-up Approach to Development**
  - Low-level drivers for sensors/devices are developed first
  - High-level algorithms for deployment and state determination are developed last

- **Bench-top Prototyping Environment**
  - FSW is developed while having direct access to electrical hardware, minimizing the amount of errors encountered due to large amounts of code being written without hardware testing

- **FSW Testing**
  - Test new drivers/algorithms as they are written, allowing for a linear integration of software, piece by piece

- **Progress**
  - ADXL345 driver tested
  - L3GD20 driver tested
  - AT45DB642D Dataflash driver tested
  - CC1100 receive and transmit driver tested
Ground Control System (GCS) Design

Matt Rodencal
GCS Overview

- GCS initiates telemetry transmission
- Live data display; real time plot
- Written in Labview

CANSAT
Container shown
Telemetry transmits at 1Hz

Receiver must be elevated 3.5 meters

GCS

- Cansat will be recovered based on final GPS coordinates
GCS Requirements

• **Hardware Requirements**
  – The ground control station antenna shall be elevated a minimum of 3.5 meters (11.5 feet) from ground level to ensure adequate coverage and range.
  – It must be secured so it cannot fall.

• **Software Requirements**
  – All telemetry shall be displayed in real-time during launch and descent.
  – All telemetry shall be displayed in engineering units.
  – Teams shall plot data in real-time during flight.
  – The telemetry data file shall be named as follows:
    • `CANSAT2013_TLM_<TEAM_ID>_TEAM_NAME.csv`

**Additional Requirements**
- **2.4GHz Antenna must be pointed in the direction of the field and elevated 30°-60°**
- **Ground Station computer must have Labview and Excel**
GCS Antenna Selection

- **XBEE (63mW) and 70cm Ground Station (~500mW)**
  - The HG2408P patch antenna
    - 130° gain lobe
  - 70cm Tape Measure Dipole
    - Omni-directional

- **Antenna Tower**
  - Made up of tent poles and Rapid Prototyped End Caps
    - Light-weight
    - Allows for quick setup and is free standing
    - Xplained and radios are at top of tower and only wire sent down the tower is a USB cable
  - Distance link predictions (provided line of sight)
    - XBEE: >2-3 miles
    - 70cm: >50 miles
GCS Software

- Labview (computer) and Atmel Studios (embedded) are being used
- Real-time plotting will be done using Labview
  - Position will be done using a DirectX Google Earth plug-in for Labview
- Data from the CanSat is sent to a CVS and can be retrieved using Excel
- The start command is sent when the start button is pressed on the control window
- Progress since PDR
  - Labview
    - Serial Interface fully functional
    - Data archiving fully functional
  - Xplained
    - USART functional (not integrated)
    - Off band radio operational (not integrated)
CanSat Integration and Test

Eric Becnel
CanSat Integration and Test Overview

- **Subsystem testing**
  - **Electronics**
    - Full electronic functionality demonstrated
      - Power rails are functioning properly
      - Verify voltage under high current load of hot wire
    - Communications range test and ground station testing
      - Both radios
      - Tower to ground range like competition
      - Instigate network trouble to verify API packet mode functionality
    - Conformal coating of components which are not damaged or compromised through this process
      - Lower side of PCBs
CanSat Integration and Test Overview

• Subsystem testing
  – Mechanical
    • Decent rate verification
      – Testing methods being considered with mass simulator
      – Low altitude (~10m)
        » Parking Garage to barely reach steady state
        » Video Feedback
          » Works if acceleration is ~0 on video feedback
      – Higher altitude testing (~670m)
        » High powered rocket launch
        » CanSat electronics logging and transmitting
          » Works if altitude over time is within competition limits
CanSat Integration and Test Overview

• Integration
  – Build mechanical parts
  – Assemble PCBs
  – Assemble flight unit

• Testing
  – Practice flight sequence on amateur rocket or other means of achieving sufficient altitude as previously discussed
    • High powered rocket and launch field
  – Vacuum chamber test
    • Verify proper recognition of flight phases for pass
    • Verify reading correct pressure vs. calibrated chamber for pass
  – System drop test
    • Verify interrupt and sampling rate are sufficient to read un-aliased vibration curve
      – Pass/Fail via visual inspection of curve
Impact Force Sensor Testing

- **Low altitude testing**
  - Drop from parking garage
  - Achieve steady state for impact
  - Trigger recording with interrupt like competition
  - Raw byte storage with time stamp
    - 2 bytes/axis x 3 axis, 4 byte time stamp

<table>
<thead>
<tr>
<th>Sample Rate</th>
<th>3200</th>
<th>Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size</td>
<td>10</td>
<td>Bytes</td>
</tr>
<tr>
<td>Duration</td>
<td>5</td>
<td>Seconds</td>
</tr>
<tr>
<td>Total size</td>
<td>156.25</td>
<td>Kilobytes</td>
</tr>
</tbody>
</table>
DCS Subsystem Testing Overview

- Decent rate verification
  - Testing methods being considered with mass simulator
  - Low altitude (~10m)
    » Parking Garage to barely reach steady state
    » Video Feedback
      » Pass if acceleration is ~0 on video feedback
  - Higher altitude testing (~670m)
    » High powered rocket launch
    » CanSat electronics logging and transmitting
      » Pass if altitude slope over time is within competition limits
Mechanical Subsystem Testing
Overview

• **Pull test on assembly load test of attachments**
  – Pass is exceeds 30g
  – Software not needed

• **Fully functional flight test**
  – Pass if
    • Separation is a success
    • Load paths are maintained
    • Impact is handled
    • Egg protection is successful
CDH Subsystem Testing Overview

- Verify start command is recognized
  - Xbee
  - 70cm Ham radio
- Verify sensor sample rate is achieved
  - Log data and verify is associated frequency of data recording
EPS Testing Overview

• Full electronic functionality demonstrated
  – Power rails are functioning properly
  – Verify voltage under high current load of hot wire
FSW Testing Overview

• **Simulate test in vacuum chamber**
  – Sequence flight via pressure change
  – Pass if phases are detected correctly

• **Fully functional test flight**
  – Pass if full mission is achieved
GCS Testing Overview

• Communications range test and ground station testing
  – Both radios
  – Tower to ground range like competition
  – Instigate network trouble to verify API packet mode functionality
  – Pass if communication is successful
• Fully functional test flight
  – Pass if full mission is achieved and data is logged and displayed properly
Mission Operations & Analysis

Eric Becnel
Overview of Mission Sequence of Events

Arrive

Set up ground station
• Ground Station Crew

CanSat Functional Test
• CanSat Crew

Perform weigh-in
• CanSat Crew

Assemble CanSat
• CanSat Crew

Select egg
• CanSat Crew

Verify tower height
• Ground Station Crew

Perform fit-check
• CanSat Crew

Integrate with rocket
• CanSat Crew

Launch pad integration
• CanSat Crew

Initiate mission when instructed
• Mission Control Officer

Verify communications
• Ground Station Crew

Retrieve CanSat
• Recovery Crew

Deliver telemetry
• Ground Station Crew

Score the mission

Perform mission

Deliver telemetry
• Ground Station Crew

Score the mission

Perform mission
Mission Operations Manual
Development Plan

- Checklist will be developed upon a practice run of the flight day using the actual hardware/software
- 3 check lists
  - Ground station preparation
  - CanSat preparation
  - Rocket integration
- The launch preparation procedure, launch procedure and removal procedure will be added with the checklists
- Development status: To be completed
CanSat Location and Recovery

• **Container**
  – Buzzer
  – Bright orange body
  – Bright red parachute
  – Return address label

• **Payload**
  – Buzzer
  – Bright red decelerator
  – GPS position transmitted
    • 2 RF bands

• **Visible tracking**
  – Recovery team will visually watch both parts of CanSat
The purpose of this section is to summarize and cross reference the compliance to the CanSat Competition Mission Guide requirements.

Requirements Compliance

Eric Becnel,
Matt Rodencal,
Mason Manning
Requirements Compliance Overview

• State current design compliance to requirements
• Summarize content of the detailed slides that follow
• If the design does not comply to the requirements, that is a serious issue – why?
## Requirements Compliance (1 of 7)

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Requirement</th>
<th>Comply / No Comply / Partial</th>
<th>Slide(s) Demonstrating Compliance</th>
<th>Team Comments or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Base Requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1.1</td>
<td>Total mass of cansat, container, and all descent control devices shall be 700 grams. Mass shall not vary more than +/-10 grams.</td>
<td>Comply</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>3.1.2</td>
<td>The cansat must be installed in a container to protect it from deployment out of the rocket.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.1.2.1</td>
<td>The container shall fit inside the cylindrical payload section of the rocket defined by the cylindrical payload envelope of 130 mm x 250 mm length control system including the descent control system.</td>
<td>Comply</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>3.1.2.2</td>
<td>The container must use a descent control system. It cannot free fall.</td>
<td>Comply</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>3.1.2.3</td>
<td>The container shall not have any sharp edges that could cause it to get stuck in the rocket payload section.</td>
<td>Comply</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3.1.2.4</td>
<td>The container must be a fluorescent color, pink or orange.</td>
<td>Comply</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>3.1.2.5</td>
<td>No protrusions beyond the envelope defined are allowed while stowed in the rocket.</td>
<td>Comply</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3.1.2.6</td>
<td>The rocket airframe cannot be used to restrain any deployable parts of the cansat.</td>
<td>Comply</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3.1.2.7</td>
<td>The rocket airframe and payload section shall not be used as part of the cansat operations.</td>
<td>Comply</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3.1.2.8</td>
<td>The cansat shall deploy from the rocket payload section.</td>
<td>Comply</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

*Use the Green (Comply), Yellow (Partial Compliance), and Red (No Comply) color codes as shown in the examples above for each requirement*
## Requirements Compliance (2 of 7)

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Requirement</th>
<th>Comply / No Comply / Partial</th>
<th>Slide(s) Demonstrating Compliance</th>
<th>Team Comments or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.3</td>
<td>The Cansat shall comply with the following descent and recovery requirements.</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3.1.3.1</td>
<td>The descent control system shall not use any flammable or pyrotechnic devices.</td>
<td>Comply</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>3.1.3.2</td>
<td>The cansat descent rate shall be 20 meters per second +/- 1 meter per second after being deployed while 400 meters above the ground using a passive descent control device such as a parachute or streamer.</td>
<td>Comply</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>3.1.3.3</td>
<td>When the cansat goes below 400 meters, the cansat shall deploy aero-braking structure to reduce the descent rate to 20 m/s or less.</td>
<td>Comply</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>3.1.3.4</td>
<td>All cansats must include a audible locating device rated above 80 dB and operate for at least three hours. It may be activated at launch or at landing.</td>
<td>Comply</td>
<td>64, 35</td>
<td></td>
</tr>
<tr>
<td>3.1.3.5</td>
<td>All descent control device attachments must survive 30 Gees of shock.</td>
<td>Comply</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>3.1.3.6</td>
<td>All descent control devices must survive 30 Gees of shock.</td>
<td>Comply</td>
<td>91</td>
<td></td>
</tr>
</tbody>
</table>
## Requirements Compliance (3 of 7)

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Requirement</th>
<th>Comply / No Comply / Partial</th>
<th>Slide(s) Demonstrating Compliance</th>
<th>Team Comments or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.4</td>
<td>The Cansat shall comply with the following communications requirements</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3.1.4.1</td>
<td>The cansat communications radio shall be the XBEE radio series 1 or 2.</td>
<td>Comply</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>3.1.4.2</td>
<td>The XBEE radios shall have their NETID set to the team number.</td>
<td>Comply</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>3.1.4.3</td>
<td>The XBEE radio shall not use the broadcast mode.</td>
<td>Comply</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>3.1.4.4</td>
<td>The ground control station antenna shall be elevated a minimum of 3.5 meters (11.5 feet) from ground level to ensure adequate coverage and range. It must be secured so it cannot fall.</td>
<td>Comply</td>
<td>83</td>
<td></td>
</tr>
<tr>
<td>3.1.4.5</td>
<td>The cansat shall not transmit telemetry until commanded by the team ground station. Commanding can be executed while the cansat is in the rocket on the launch pad.</td>
<td>Comply</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>3.1.4.6</td>
<td>The XBEE radio can operate in any mode as long as it does not interfere with other XBEE radios.</td>
<td>Comply</td>
<td>61</td>
<td></td>
</tr>
<tr>
<td>Req ID</td>
<td>Requirement</td>
<td>Comply / No Comply / Partial</td>
<td>Slide(s) Demonstrating Compliance</td>
<td>Team Comments or Notes</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>------------------------------</td>
<td>-----------------------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>3.1.5</td>
<td>The cansat shall comply with the following power requirements:</td>
<td>Comply</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>3.1.5.1</td>
<td>The cansat shall have an external power control such as a power switch and some indication of being turned on or off. The idea is to keep teams from dis-assembling their cansat to turn it on or off which has led to many failures in the past.</td>
<td>Comply</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>3.1.5.2</td>
<td>The cansat shall have battery capacity to support up to a one hour wait on the launch pad plus time for flight operations.</td>
<td>Comply</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>3.1.5.3</td>
<td>The cansat shall not utilize lithium polymer (LiPo) batteries. Lithium Ion batteries, LiFePO4 cylindrical cells, NiMH, NiCd, and alkaline batteries are allowed. Other types must be approved before use.</td>
<td>Comply</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td>3.1.6</td>
<td>The cansat shall comply with the following flight software requirements:</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.6.1</td>
<td>The flight software shall maintain and telemeter an indicator of the cansat flight software state. An example set of states is 0 (BOOT), 1 (TEST_MODE), 2 (LAUNCH_PAD), 3 (ASCENT), 4 (ROCKET_DEPLOY), 5 (DESCENT), 6 (CANSAT_RELEASE), and 7 (IMPACT).</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.6.2</td>
<td>In the event of a processor reset during the mission, the flight software shall be able to determine the correct state.</td>
<td>Comply</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>3.1.6.3</td>
<td>The states shall be described in the PDR and CDR presentations.</td>
<td>Comply</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>
### Requirements Compliance (5 of 7)

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Requirement</th>
<th>Comply / No Comply / Partial</th>
<th>Slide(s) Demonstrating Compliance</th>
<th>Team Comments or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.7</td>
<td>The cost of the cansat flight hardware shall be under $1000 (USD). Ground support and analysis tools are excluded.</td>
<td>Comply</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>3.1.8</td>
<td>Each team shall develop and use their own ground station. All telemetry shall be displayed in real-time during launch and descent. All telemetry shall be displayed in engineering units (meters, meters per second, Celsius, etc.). Teams shall plot data in real-time during flight.</td>
<td>Comply</td>
<td>81</td>
<td></td>
</tr>
</tbody>
</table>
## Requirements Compliance (6 of 7)

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Requirement</th>
<th>Comply / No Comply / Partial</th>
<th>Slide(s) Demonstrating Compliance</th>
<th>Team Comments or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.9</td>
<td>Structure Requirements</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3.1.9.1</td>
<td>All electronics shall be enclosed and shielded from the environment. No electronics can be exposed except for sensors. There must be a structural enclosure.</td>
<td>Comply</td>
<td>51</td>
<td>--</td>
</tr>
<tr>
<td>3.1.9.2</td>
<td>The structure must support 10 Gees acceleration.</td>
<td>Comply</td>
<td>91</td>
<td>--</td>
</tr>
<tr>
<td>3.1.9.3</td>
<td>The structure must survive 30 Gees shock force.</td>
<td>Comply</td>
<td>91</td>
<td>--</td>
</tr>
<tr>
<td>3.1.9.4</td>
<td>Electronic circuit boards must be hard mounted using proper mounts such as standoffs and screws. High performance adhesives are acceptable.</td>
<td>Comply</td>
<td>51</td>
<td>--</td>
</tr>
<tr>
<td>3.1.9.5</td>
<td>Team number, email address and a phone number must be placed on the structure to aid in recovery.</td>
<td>Comply</td>
<td>19, 20</td>
<td>--</td>
</tr>
<tr>
<td>3.1.10</td>
<td>Mechanisms Requirements</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3.1.10.1</td>
<td>Mechanisms must be capable of maintaining their configuration or states under all forces such as acceleration and shock forces.</td>
<td>Comply</td>
<td>91</td>
<td>--</td>
</tr>
<tr>
<td>3.1.10.2</td>
<td>Mechanisms must not use pyrotechnics or chemicals.</td>
<td>Comply</td>
<td>50</td>
<td>--</td>
</tr>
<tr>
<td>3.1.10.3</td>
<td>Mechanisms that use heat (e.g. nichrome wire) must not be exposed to the outside environment to reduce potential risk of setting vegetation on fire.</td>
<td>Comply</td>
<td>50</td>
<td>--</td>
</tr>
</tbody>
</table>
## Requirements Compliance (7 of 7)

<table>
<thead>
<tr>
<th>Req ID</th>
<th>Requirement</th>
<th>Comply / No Comply / Partial</th>
<th>Slide(s) Demonstrating Compliance</th>
<th>Team Comments or Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1.11</td>
<td>During descent, the payload shall transmit the following telemetry data once every two (2) seconds:</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3.1.11.1</td>
<td>GPS data including UTC time, latitude, longitude, mean sea level altitude, and number of satellites tracked.</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.11.2</td>
<td>Altitude in meters above sea level via a non GPS sensor.</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.11.3</td>
<td>Air temperature.</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.11.4</td>
<td>Battery voltage in volts.</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.11.5</td>
<td>Flight software state.</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.1.11.6</td>
<td>Flight software maintained mission time.</td>
<td>Comply</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>3.2</td>
<td>Selectable Objective Requirements. Each team shall select one of the following options as part of their mission design:</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3.2.1</td>
<td>The Cansat shall measure the impact force with the ground. Data shall be collected at a rate of at least 100 samples/second and stored on board for post processing.</td>
<td>Comply</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>
Management

Mason Manning
Status of Procurements

• Composites: Procured
• Mechanical components: Procured
• Electrical components:
  – Most components procured
  – AT45DB642D dataflash module on order
  – 47 uF capacitors on order
    • Expected delivery by the week of April 8th at the latest
• Printed Circuit Boards: Not ordered
  – Currently in the purchasing process
  – Will be ordered by April 5
• Ground Station components: Not ordered
# CanSat Budget – Hardware

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Component</th>
<th>Cost - Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensor</td>
<td>ADXL345</td>
<td>$7.15</td>
</tr>
<tr>
<td>Sensor</td>
<td>L3GD20</td>
<td>$6.33</td>
</tr>
<tr>
<td>Sensor</td>
<td>M10382-A1</td>
<td>$29.89</td>
</tr>
<tr>
<td>Sensor</td>
<td>MS5611</td>
<td>$10.88</td>
</tr>
<tr>
<td>Sensor</td>
<td>NTC Thermistor</td>
<td>$0.66</td>
</tr>
<tr>
<td>CDH</td>
<td>ATxmega128A1U</td>
<td>$5.32</td>
</tr>
<tr>
<td>CDH</td>
<td>AT45DB642D</td>
<td>$5.62</td>
</tr>
<tr>
<td>CDH</td>
<td>2.4 GHz Antenna</td>
<td>$7.43</td>
</tr>
<tr>
<td>CDH</td>
<td>433 MHz Antenna</td>
<td>$7.49</td>
</tr>
<tr>
<td>CDH</td>
<td>XBEE</td>
<td>$33.50</td>
</tr>
<tr>
<td>CDH</td>
<td>CC1100 module</td>
<td>$15.00</td>
</tr>
<tr>
<td>CDH</td>
<td>CM-1240</td>
<td>$4.81</td>
</tr>
</tbody>
</table>
### CanSat Budget – Hardware

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Component</th>
<th>Cost – Actual unless otherwise noted</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS</td>
<td>2x DC-DC Converter</td>
<td>$16.94</td>
</tr>
<tr>
<td>EPS</td>
<td>Ideal Diode Controller</td>
<td>$3.18</td>
</tr>
<tr>
<td>EPS</td>
<td>2x Current Limit Switch</td>
<td>$1.48</td>
</tr>
<tr>
<td>EPS</td>
<td>Power Switch</td>
<td>$4.09</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Pivot Points</td>
<td>$7.16</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Shocks</td>
<td>$56.99</td>
</tr>
<tr>
<td>Mechanical</td>
<td>Composites</td>
<td>$50.00 – Estimate</td>
</tr>
<tr>
<td>Descent Control</td>
<td>Fabric</td>
<td>$15.00 – Estimate</td>
</tr>
<tr>
<td>Descent Control</td>
<td>Kevlar</td>
<td>$5.00 – Estimate</td>
</tr>
</tbody>
</table>

Allowed CanSat Hardware Budget: $1000.00  
Total Estimated Hardware Costs: $293.92
### CanSat Budget – Other Costs

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Component</th>
<th>Cost – Actual unless otherwise noted</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCS</td>
<td>XBEE</td>
<td>$33.50</td>
</tr>
<tr>
<td>GCS</td>
<td>CC1100 module</td>
<td>$15.00</td>
</tr>
<tr>
<td>GCS</td>
<td>Mounting hardware</td>
<td>$50.00 – Estimate</td>
</tr>
<tr>
<td>GCS</td>
<td>Antenna(s)</td>
<td>$25.00 – Estimate</td>
</tr>
<tr>
<td>Other</td>
<td>Travel Costs</td>
<td>$3000 – Estimate</td>
</tr>
</tbody>
</table>

Target Program Budget: Under $5000.00  
Total Other Program Costs: $3123.50

Total CanSat Budget: $3417.42
# Program Schedule

**Presenter:** Mason Manning

**CanSat 2013 CDR: Team #1000 Demolishor**

<table>
<thead>
<tr>
<th>Name</th>
<th>Begin Date</th>
<th>End Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preliminary Design Review</td>
<td>2/5/13</td>
<td>2/6/13</td>
</tr>
<tr>
<td>Initial Component Verification</td>
<td>2/5/13</td>
<td>2/26/13</td>
</tr>
<tr>
<td>Initial Software State Verification</td>
<td>2/5/13</td>
<td>2/26/13</td>
</tr>
<tr>
<td>Integrate Components with Software State</td>
<td>3/1/13</td>
<td>3/26/13</td>
</tr>
<tr>
<td>Initial Experimental Verification of System</td>
<td>4/17/13</td>
<td>5/6/13</td>
</tr>
<tr>
<td>Reliability Testing</td>
<td>5/7/13</td>
<td>6/19/13</td>
</tr>
<tr>
<td>Final Integration</td>
<td>6/2/13</td>
<td>6/8/13</td>
</tr>
<tr>
<td>Post Flight Review</td>
<td>6/12/13</td>
<td>6/14/13</td>
</tr>
<tr>
<td>Demonstration Flight</td>
<td>9/12/13</td>
<td>9/14/13</td>
</tr>
<tr>
<td>Flight Readiness Review</td>
<td>6/7/13</td>
<td>6/7/13</td>
</tr>
<tr>
<td>Fabricate Mechanical Components</td>
<td>3/1/13</td>
<td>4/1/13</td>
</tr>
<tr>
<td>Integrate Mechanical and Electrical Components</td>
<td>4/2/13</td>
<td>4/15/13</td>
</tr>
</tbody>
</table>
Shipping and Transportation

- CanSat and other hardware will be carried personally by the team en route to the launch location
  - Minimizes risk of losing the CanSat or other essential tools/hardware
  - Minimizes risk of damaging the CanSat or other essential tools/hardware
Conclusions

• Major Accomplishments
  – Begun fabrication of mechanical systems
  – Several device drivers have been tested
  – Electrical and PCB schematic finished
  – Majority of parts ordered and/or procured
  – Demo of Ground Station software completed

• Unfinished Work
  – Assemble electrical system, ground station hardware
  – Begin integrating software with the flight system
  – Integrate complete system and prepare for testing

• Testing to Complete
  – Descent control test
  – Electrical power test
  – Software state machine test
  – Integrated system test