T.B.D.
(The Boom Deployment)

Conceptual Design Review

University of Colorado Boulder

Zachary Asmussen, Anahid Blaisdell, Adam Boylston, Yohannese Gebremedhin, Nicholas Gentz, Jacob Grunwald, Nolan Ferguson, Joseph Frank, Rebekah Haysley, Ross Kloetzel, Jack Maydan, Ryan McCormick, Cassandra Noice, Virginia Nystrom

10.19.16
CoDR Presentation Content

- **Section 1: Mission Overview**
  - Mission Statement
  - Mission Objectives
  - Theory and Concepts
  - Concept of Operations
  - Expected Results

- **Section 2: Design Overview**
  - Science Design
  - Engineering Design
  - Functional Block Diagram
  - Payload Layout (sketches)
  - RockSat-X User’s Guide Compliance
CoDR Presentation Contents

• Section 3: Management
  – Team Organization
  – Schedule
  – Budget
  – Mentors (Faculty, industry)
  – Risks/Worries
  – Contact and Availability Matrices

• Section 4: Conclusions
Mission Overview
Mission Overview: Mission Statement

Successfully deploy a ROCCOR slit boom at an altitude of 150-170 km and characterize its deployment and viability as a space-weather antenna.
## Mission Overview: Mission Objectives

<table>
<thead>
<tr>
<th>Objective Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>Demonstrate a strain-energy deployment of two ROCCOR composite booms in the micro-g vacuum of space.</td>
</tr>
<tr>
<td>Primary</td>
<td>Collect video, rate of deployment, temperature, and other boom characterization data for use by ROCCOR.</td>
</tr>
<tr>
<td>Secondary</td>
<td>Integrate a space weather sensor onto two ROCCOR booms for proof of boom sensor integration.</td>
</tr>
<tr>
<td>Secondary</td>
<td>Collect space weather data for contribution to the space-weather community.</td>
</tr>
</tbody>
</table>
Minimum Success Criteria

• **Primary Mission Success**
  – Boom is deployed correctly according to ROCCOR standards
  – Determine rate of deployment data
  – Collect stress data throughout boom
  – Collect video of boom deployment
Main Overview: Theory and Concepts

**Primary Objective - ROCCOR Slit Boom:**

Research:
- Characterize deployment of composite boom never tested in space environment
- Complete 0g vacuum testing for ROCCOR

Variables:
- Speed
- Strain/Stress/Torsion/Shear
- Elasticity

Deployment/Retraction System:
- Characterize:
  - Retraction time
  - Impact on systems
  - Limitations

Methods:
- Develop restraint and release system
- Computer Vision with dual camera
- Sensors using embedded flex wire
- 9 Axis IMU
- Temperature Sensors
Mission Overview: Theory and Concepts

- High strain composite
- Multiple configurations
  - Coiled, Uncoiled, or Neutral available
  - Size based on application
  - Length rolled up smaller than circumference
- Test background
  - Documented bend test to be investigated
  - Prior flight test although unsuccessful
  - Issues with humidity to be investigated
Secondary Objective - Space Weather/Usability POC:

Research:
- Solar radiation & Geomagnetic Activity in D + E region of Ionosphere
- Prove boom’s viability as a research instrument

Variables:
- Ion Plasma disturbances (solar flare)
- EM Field disturbances and RF
- Long Range Upper Atmos Lightning
- Magnetosphere strength & variation

Methods:
- Langmuir Probe
- Dipole/other RF-based antenna
- Magnetometer + 9 Axis IMU
Mission Overview: Boom Expected Results

• Deployment Observation
  – Nominal deployment with no buckling
  – Safe release of boom

• Rate of Deployment
  – Controlled deployment rate
  – Based on boom chosen by ROCCOR

• Temperature Data
  – Temperature of boom during deployment

• Camera Data
  – 2 quality videos of boom deployed from different angles
Mission Overview: Space Weather Expected Results

**Broadband EM impulse from lightning**
- Capable of being picked up from 2000 km
- Short impact

**Celestial RF & Magnetosphere**
- RF Signals from nearby stars/emitting bodies
- Magnetosphere perturbations or variations to RF spectrum
- Moderate Impact

**Ionosphere Plasma Data**
- Sounding rocket flights with Langmuir probes flown in past
- Plasma Temp/Density/Voltage
- Strong extended impact
ConOps

- All systems on
- Begin data collection

\[ \text{t} = 0 \text{ min} \]
Altitude: 75 km

**Boom Deployment**

\[ \text{t} \approx 1.3 \text{ min} \]
Altitude: 75 km

**Apogee**

\[ \text{t} \approx 3.1 \text{ min} \]
Altitude: \( \approx 150 \text{ km} \)

End of Malemute Burn

\[ \text{t} \approx 0.6 \text{ min} \]
Altitude: 52 km

**Boom Release**

\[ \text{t} \approx 4.5 \text{ min} \]
Altitude: 75 km

\[ \text{t} \approx 15 \text{ min} \]
Splash Down

**ConOps**

Altitude

**t ≈ 7.5 min**
Chute Deploys

**t ≈ 15 min**
Boom Deployment

**t ≈ 3.1 min**
Apogee

**t ≈ 0.6 min**
End of Malemute Burn
Functional Flow Diagram

TOP LEVEL

1.0
Power On

3.0
Launch

4.0
Shell Release

5.0
Perform Mission Operations

6.0
Respin

7.0
Re-Entry and Splashdown

2.0
Begin Video

SECOND LEVEL

4.0 Ref.
Shell Release

5.1
Provide Electrical Power

5.2
Timer Event: Deploy Booms

5.3
Acquire payload data

5.4
Confirm Deployment

5.5
Contingency

6.0 Ref.
Respin

5.0
Transmit Payload Data

6.7
Timer Event: Release booms

CoDR 2017
Design Overview
Functional Block Diagram
Design Overview: Science
Design Overview: Science Design

• Characterization of ROCCOR deployable boom:
  • Rate of deployment
    – Using camera footage
  • Temperature of boom
    – IR Temperature Sensor

• Space Weather Measurement Options:
  • Langmuir probe
  • RF based EM disturbance detectors
# Design Overview: Instrumentation

<table>
<thead>
<tr>
<th>Boom Characterization Instruments</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Sensor</td>
<td>Measure temperature of composite material throughout strain energy deployment</td>
</tr>
<tr>
<td>Accelerometer</td>
<td>Rate of deployment, acceleration of boom, direction of forces during deployment</td>
</tr>
<tr>
<td>GoPro</td>
<td>High resolution video to characterize rate of deployment, provide usable images to ROCCOR, low-resolution video streamed through telemetry</td>
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<tr>
<td>TBD space-weather instrument (magnetometer, EM receiver, etc.)</td>
<td>Prove viability of integrating sensors into boom, collect scientific data</td>
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<table>
<thead>
<tr>
<th>Other Hardware</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>A/D Converter, high res/sample rate</td>
<td>Convert analog signals from the CDA to digital values.</td>
</tr>
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</table>
Design Overview: Structures
Design Overview: Payload Layout

SECTION A-A

Current weight estimate for enclosure 6 lbs
6061 Aluminum for enclosure
Boom Deployment System

• Mounted via clamp on back tab of composite
• 2 linear actuators collapsing linear bushing bearings
• Deploys coiled composite boom via stored strain energy
Design Overview: Avionics
Design Overview: Avionics Flowchart

![Diagram of avionics flowchart with various components and connections.]

Legend:
- Power
- Data
- Signals

Software Breakout:
- I2C/RS232: WiringPi Python Library
- Video Compression: FFmpeg

Components:
- WFF
- Power
- RS232
- Event Timer
- Parallel bits 1-3
- Buck 28V->5V Conversion
- Video Compression
- Raspberry Pi 3B
- Boom Release Actuator 2 (loaded)
- Sensor Suite: Strain Gauge Accelerometer
- Sensor Data
- I2C Bus
- SD Card (Data Logging)
- Boom retention status
- Video recording status
- Video
- Camera 1
- Boom Release Actuator 1 (unloaded)
- Camera 2
- Sensor Suite: Strain Gauge Accelerometer

2017 CoDR
# User Guide Compliance: Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
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<tr>
<td>Center of gravity in 1” plane of plate?</td>
<td>Worried about boom affecting COG</td>
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<tr>
<td>Weight 30.0 +/- 1.0 (15.0 +/- 0.5) lbs?</td>
<td>Estimating 8 ± 2 lbs, subject to change</td>
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<tr>
<td>Max Height &lt; 10.75” (5.13”)</td>
<td>Currently designed at 5”</td>
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<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>To be designed</td>
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<tr>
<td>Within Keep-Out Zone</td>
<td>Yes, see Design Overview: Payload Layout</td>
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<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>N/A</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
<td>Yes, 3 Lines</td>
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<tr>
<td>Using/Understand Asynchronous Line</td>
<td>N/A</td>
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<tr>
<td>Using X GSE Line(s)</td>
<td>Yes, GSE-1</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
<td>Yes, TE-1</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
<td>Yes, TE-R</td>
</tr>
<tr>
<td>Using &lt; 1 Ah</td>
<td>Unknown</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>Yes, &lt; 15 V</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>Not currently, may change</td>
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<tr>
<td>Using deployable?</td>
<td>Yes, but speed unknown</td>
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<tr>
<td>Whole team consists of US Persons</td>
<td>Yes</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
<td>No</td>
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</tbody>
</table>
Management
Team Organization

Nick Gentz
Co-Project Manager

Virginia Nystrom
Co-Project Manager

Ross Kloetzel
Systems Engineer

Ryan McCormick
Structures Lead

Anahid Blaisdell

Yohannese Gebremedhimg

Nick Gentz

Rebekah Haysley

Cassandra Noice
Avionics Lead

Zachary Asmussen

Nolan Ferguson

Jacob Grunwald

Virginia Nystrom

Joseph Frank
Science Lead

Adam Boylston

Ross Kloetzel

Jack Mayden
# Schedule

<table>
<thead>
<tr>
<th>Task</th>
<th>Deadline</th>
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<tbody>
<tr>
<td>CoDR</td>
<td>10/19</td>
</tr>
<tr>
<td>Tour of ROCCOR / Meeting with Contacts</td>
<td>Week of 10/24</td>
</tr>
<tr>
<td>Teleconference with ROCCOR &amp; ASTRA</td>
<td>Week of 10/24</td>
</tr>
<tr>
<td>Earnest Deposit Due</td>
<td>October</td>
</tr>
<tr>
<td>Finalize Mission Statement &amp; Objectives</td>
<td>10/21</td>
</tr>
<tr>
<td>Finalize Higher Level Mission Requirements</td>
<td>10/21</td>
</tr>
<tr>
<td>Finalize Minimum Success Criteria</td>
<td>10/21</td>
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<tr>
<td>Finalize Concept of Operations</td>
<td>10/28</td>
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<tr>
<td>Finalize Functional Block Diagram</td>
<td>10/28</td>
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<tr>
<td>Finalize Mechanical Sketches</td>
<td>10/28</td>
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<tr>
<td>PDR</td>
<td>11/2</td>
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## Schedule

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<tr>
<td>Finalize Lower Level Mission Requirements</td>
<td>11/18</td>
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<tr>
<td>Finalize Model of Science Design</td>
<td>11/18</td>
</tr>
<tr>
<td>Finalize Solid Mechanical Drawings</td>
<td>11/18</td>
</tr>
<tr>
<td>Finalize Electrical Schematics</td>
<td>11/18</td>
</tr>
<tr>
<td>Finalize Software Flow Chart</td>
<td>11/18</td>
</tr>
<tr>
<td>Finalize Weight Budget</td>
<td>11/18</td>
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<tr>
<td>Finalize Power Budget</td>
<td>11/18</td>
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<tr>
<td>Finalize Hardware List</td>
<td>11/18</td>
</tr>
<tr>
<td>Complete Interface Matrices</td>
<td>11/18</td>
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<tr>
<td>Complete Risk Matrices</td>
<td>11/25</td>
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<tr>
<td>Mechanical Manufacturing Plan</td>
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<tr>
<td>Electrical Manufacturing Plan</td>
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<tr>
<td>Software Development Plan</td>
<td>11/25</td>
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<tr>
<td>Prototyping Complete</td>
<td>11/25</td>
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<tr>
<td>Finalize Subsystem Testing Plan</td>
<td>11/25</td>
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<tr>
<td>Finalize System Testing Plan</td>
<td>11/25</td>
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<td>CDR</td>
<td>11/30</td>
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# Preliminary Budget

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<th>Expense</th>
<th>Cost</th>
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<td>Flight Cost</td>
<td>$14,000</td>
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<tr>
<td>Hardware</td>
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<tr>
<td>Labor</td>
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<td>Travel</td>
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<td><strong>$57,000</strong></td>
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<table>
<thead>
<tr>
<th>Source</th>
<th>Cost</th>
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<tbody>
<tr>
<td>COSGC</td>
<td>$39,000</td>
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<tr>
<td>UROP</td>
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<tr>
<td>EEF</td>
<td>$15,000</td>
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<tr>
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<td><strong>$57,000</strong></td>
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</table>

* Funding may also come from sponsors and grants
Mentors / Sponsorship

• **ROCCOR**
  - In contact with Bruce Davis, Tom Murphey, and Kamron Medina
    • Conference call with above and Mark Lake (VP of Operations)
  - Face to Face meeting at ROCCOR Week of 10/24
  - High level of interest from company shown

• **ASTRA (Atmospheric & Space Technology Research Associates)**
  - Contacted Marcin Pilinski
  - Mentorship for possible space weather sensors
  - Possible hardware donations
# Team Contact Matrix

## University of Colorado Boulder

### Fall 2016 RS-X Contact Matrix

<table>
<thead>
<tr>
<th>Role</th>
<th>Name</th>
<th>Day Phone</th>
<th>Cell Phone</th>
<th>Receive Texts?</th>
<th>Email</th>
<th>Citizenship</th>
<th>Add to mailing list?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Project Manager</td>
<td>Nicholas Gentz</td>
<td>719-505-2647</td>
<td>719-505-2647</td>
<td>Yes</td>
<td><a href="mailto:nige9413@colorado.edu">nige9413@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Co-Project Manager</td>
<td>Virginia Nystrom</td>
<td>303-829-8794</td>
<td>303-829-8794</td>
<td>Yes</td>
<td><a href="mailto:virginia.nystrom@colorado.edu">virginia.nystrom@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Systems Engineer</td>
<td>Ross Kloetzel</td>
<td>808-348-7405</td>
<td>808-348-7405</td>
<td>Yes</td>
<td><a href="mailto:ross.kloetzel@colorado.edu">ross.kloetzel@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Avionics Lead</td>
<td>Cassandra Noice</td>
<td>303-898-9141</td>
<td>303-898-9141</td>
<td>Yes</td>
<td><a href="mailto:cassandra.noice@colorado.edu">cassandra.noice@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Avionics Team</td>
<td>Zachary Asmussen</td>
<td>303-884-2002</td>
<td>303-884-2002</td>
<td>Yes</td>
<td><a href="mailto:zachary.asmussen@colorado.edu">zachary.asmussen@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Avionics Team</td>
<td>Nolan Ferguson</td>
<td>720-289-5349</td>
<td>720-289-5349</td>
<td>Yes</td>
<td><a href="mailto:nofe9992@colorado.edu">nofe9992@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Avionics Team</td>
<td>Jacob Grunwald</td>
<td>832-585-4297</td>
<td>832-585-4297</td>
<td>Yes</td>
<td><a href="mailto:jacob.grunwald@colorado.edu">jacob.grunwald@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Science Lead</td>
<td>Joseph Frank</td>
<td>303-801-8489</td>
<td>303-801-8489</td>
<td>Yes</td>
<td><a href="mailto:joseph.frank@colorado.edu">joseph.frank@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Science Team</td>
<td>Adam Boylston</td>
<td>303-720-9755</td>
<td>303-720-9755</td>
<td>Yes</td>
<td><a href="mailto:adam.boylston@colorado.edu">adam.boylston@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Science Team</td>
<td>Jack Maydan</td>
<td>203-617-5128</td>
<td>203-617-5128</td>
<td>Yes</td>
<td><a href="mailto:jackmaydan@gmail.com">jackmaydan@gmail.com</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Structures Lead</td>
<td>Ryan McCormick</td>
<td>303-704-1313</td>
<td>303-704-1313</td>
<td>Yes</td>
<td><a href="mailto:Rymc5125@colorado.edu">Rymc5125@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Structures Team</td>
<td>Anahid Blaisdell</td>
<td>719-685-6844</td>
<td>719-685-6844</td>
<td>Yes</td>
<td><a href="mailto:anahid.blaisdell@colorado.edu">anahid.blaisdell@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Structures Team</td>
<td>Yohannese Gebremedhin</td>
<td>720-436-4683</td>
<td>720-436-4683</td>
<td>Yes</td>
<td><a href="mailto:yoge0927@colorado.edu">yoge0927@colorado.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
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<tr>
<td>Structures Team</td>
<td>Rebekah Haysley</td>
<td>303-908-7906</td>
<td>303-908-7906</td>
<td>Yes</td>
<td><a href="mailto:rebekah.haysley@colorado.edu">rebekah.haysley@colorado.edu</a></td>
<td>U.S.</td>
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CoDR
**Team Availability Matrix**

### UNIVERSITY OF COLORADO BOULDER

#### CoDR RS-X Team Availability Matrix

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<thead>
<tr>
<th>Oct 10-14</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
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<td>8:00 AM</td>
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<td>9:00 AM</td>
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<td>10:00 AM</td>
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<td>5:00 PM</td>
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<td>2</td>
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</table>

Please use Mountain Time Zone Times.
Risks / Worries
Risks/Worries:

Science:

• **Boom**
  – Electrical coupling of boom with power on rocket
  – Integrating sensors to prevent interference with boom deployment

• **Space Weather Sensors**
  – Electromagnetic interference from rocket and other experiments
Risks/Worries:

Structures:

• Boom deployment mechanism (essential for mission success!)
• Maintaining a deployment rate of less than 1 in/sec
• Booms during re-entry (discarding vs. burning)
• Having enough space for two booms, two cameras, and the electronic equipment
Risks/Worries:

Avionics:
- RS232: Compressed Video
- Not getting the RS232 line
- Not being able to compress our video
- Hardware Sampling speed/ compatibility
Conclusion

• T.B.D. should fly because we are:
  • Testing a product never tested in a space environment
  • Seeking to contribute useful space weather data
  • Complying with (or requesting small exemptions from) all RocketSat-X requirements
Next Steps
Next Steps

Science:

• Find specific sensors (temperature/accelerometers/etc.) that will be integrated with the boom
• Finalize details with ROCCOR and Astra on what type of boom will be used and what space weather will be investigated
Next Steps

Structures:

- Deployment rate of boom
- Properties of the composite materials
- Overall dimensions of boom both rolled up and expanded
- Deployment options
- Material considerations
Next Steps

Avionics:
• Draft electrical schematics
• Draft software flow chart
• Draft avionics testing plan
• Power budget
References

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