RocketSat-11

R.E.X.-B.
(Rapid EXpandable-Boom)
Critical Design Review

University of Colorado Boulder
Zachary Asmussen, Anahid Blaisdell, Adam Boylston, Nolan Ferguson, Joseph Frank, Yohannese Gebremedhin, Nicholas Gentz, Jacob Grunwald, Rebekah Haysley, Leina Hutchinson, Ross Kloetzel, Jack Maydan, Ryan McCormick, Virginia Nystrom

12/9/2016
CDR Presentation Outline

• Section 1: Mission Overview
• Section 2: System Overview
• Section 3: Subsystem Design
• Section 4: Prototyping/Analysis
• Section 5: Manufacturing Plan
• Section 6: Testing Plan
• Section 7: User Guide Compliance
• Section 8: Project Management Plan
• Section 9: Appendix

Please hold questions until the end!
Past Project: XHD Video payload

- Senior Design and Space Grant project half payload to take video of all 4 sides of the rocket during flight
- REX-B will use and improve on legacy designs such as
  - Camera port seals
  - Wire harnessing and insulation
- REX-B will also work with proven components such as
  - Nema series stepper motors
  - Glenair connectors
  - GoPro Cameras
Past Project: RocketSat-10

- Sponsored by Air Force Research Laboratory to investigate the formation of an aluminum-iridium alloy in a 0-g environment
- REX-B will make use of legacy components such as
  - Gasket material for electronics box seal
    - Material has flown successfully at least twice on CU missions
  - Glenair connectors
1.0 Mission Overview
Mission Overview: Mission Statement

The **Rapid EXpandable-Boom** payload will successfully deploy a ROCCOR slit-tube boom and return characterization data to better understand the mechanics of strain-energy deployment in a micro-g vacuum environment.
## Mission Overview: Mission Objectives

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary Objective</td>
<td>Demonstrate a strain-energy deployment of a slit-tube boom in the micro-g vacuum of space</td>
</tr>
<tr>
<td>Primary Objective</td>
<td>Capture low resolution images of the entire boom deployment process</td>
</tr>
<tr>
<td>Primary Objective</td>
<td>Collect rate of deployment, deployment path, temperature, humidity, acceleration, and high resolution video data</td>
</tr>
<tr>
<td>Secondary Objective</td>
<td>Analyze the high resolution video using computer software to reconstruct the deployment process</td>
</tr>
</tbody>
</table>
# Top Level Requirements

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The payload shall be capable of deploying a ROCCOR slit-tube boom with no interference to the boom deployment path</td>
<td><strong>Demonstration Test</strong></td>
<td>Boom will be deployed and analyzed in ground testing to determine capabilities</td>
</tr>
<tr>
<td>The payload shall be capable of capturing and downlinking low-resolution still images of the entire boom deployment process</td>
<td><strong>Demonstration Test</strong></td>
<td>To be confirmed in system and integration testing</td>
</tr>
<tr>
<td>The payload shall be capable of collecting data necessary for characterization and reconstruction of the boom deployment process</td>
<td><strong>Analysis</strong></td>
<td>Test data to be analyzed to deem system and software ready for full post-flight analysis</td>
</tr>
<tr>
<td>The Rapid EXpandable Boom team shall comply with all requirements set forth by Wallops Flight Facility and Colorado Space Grant Consortium</td>
<td><strong>Analysis</strong></td>
<td>WFF testing and regular meetings</td>
</tr>
</tbody>
</table>
Mission Overview: Success Criteria

**Minimum Success Criteria:**
- Full deployment of the boom
- Low-resolution still images of the entire boom deployment
- Deployment time
- Graphs of position vs time
- Graph of velocity vs time

**Comprehensive Success Criteria:**
- Minimum success AND...
- High-resolution video of the entire boom deployment from 2 angles (for reconstruction)
- Accelerometer data from tip of boom
- Internal video of pre-deployed boom
- Environmental data (storage humidity, deployment conditions)
Mission Overview: Theory and Concepts

- Fully deploying and imaging a ROCCOR Slit Tube Boom in microgravity aboard a sounding rocket.
- Composite booms haven’t been tested extensively in space, so this represents a potential breakthrough in lightweight deployment mechanisms.
Mission Overview: Concept of Operations

- **T+200**: Timer Event 1 ON: Power on cameras
- **T+205**: Timer Event 2 ON: Boom deployment Spin Rate ~ 0.0 Hz
- **T+215**: Timer Event 1 OFF: Turn off cameras
- **T+265**: Timer Event 2 OFF: Boom Ejection
- **T+330**: Experiments Power off
- **T+460**: Chute deployment
- **T+900**: Splashdown
- **T=0 to T+5.2**: Terrier Burn Spin rate ~5-7 Hz
- **T+5.2 to T+17.4**: Malamute Burn
- **T+17.4 to T+29.1**: Nose and Shell separation Spin Rate ~0.3 Hz
- **T-210 to T=0**: Microcontroller begins power-up Internal camera begins recording Environmental data collection begins
Mission Overview: Functional Flow Diagram

**TOP LEVEL**

- 1.0: Power On Payload
- 2.0: Launch
- 3.0: Shell Release
- 4.0: Perform Mission Operations
- 5.0: Respin
- 6.0: Re-Entry and Splashdown

**SECOND LEVEL**

- 4.1: Acquire pre-deployment data
- 4.2: Timer Event 1 ON Deploy Boom
- 4.3: Timer Event 2 ON Deploy Boom
- 4.4: Acquire deployment data
- 4.5: Transmit Payload Data
- 4.6: Timer Event 1 OFF Turn off cameras x3
- 4.7: Timer Event 2 OFF Eject boom

**THIRD LEVEL**

- 4.1.1: Temperature sensor reading data
- 4.1.2: Internal camera recording
- 4.4.1: HD video recording
- 4.4.2: Accelerometer reading data
- 4.4.3: Low-res stills captured
- 4.5.1: Low-res stills downlinked
- 4.5.2: Accelerometer data downlinked
Functional Block Diagram

Electronics & Power Control Systems
- DC-DC Converter 3.3V
- DC-DC Converter 8V
- DC-DC Converter 12V
- Nema 8 (Deployment)
- Nema 11 (Ejection)

Science
- External Sensors
- Internal Sensors
  - Temperature (digital)
  - Triple-Axis Accel.
  - Pressure

Camera System
- OV7670 micro-camera
- Pin Headers

Command & Data Handling
- NUCLEO
  - OS Communication
  - Interrupt 1
  - Interrupt 2
- Timing
- SD Card
- RTC
- GoPro Session
- GoPro Hero 5
- MPU 6050 (9 DoF)
- Boom

Legend:
- GSE Power (28V)
- 3.3V
- 5V
- 12V
- Data
- Timer Event
- Interrupt Signal 1
- Interrupt Signal 2
Mission Overview: Expected Results

• Deployment of boom after door opening with no interference
  – No blossoming during launch
  – No buckling during deployment
  – Temperature not expected to affect boom

• Rate of deployment

• At least 2 high quality videos to be used for computer vision analysis
2.0 System Overview
2.1 Science System Overview

Adam Boylston, Joseph Frank, Ross Kloetzel, Jack Maydan
System Overview: Science Design Overview
System Overview: Science Design Overview

• Camera System
  – 4 camera suite to characterize the boom before and during deployment
    • Pre-flight conditions
    • Deployment path, rate
    • Forces (flexing, twisting, etc.)
    • 3D reconstruction of deployment
  – Changes from PDR
    • No range finder
    • New cameras chosen
System Overview: Science Design Overview

• Sensor System
  – Environmental Suite
    • Characterize conditions of rocket during flight
  – Boom Sensors
    • Temperature
      – Provide requested data to ROCCOR
    • 9 D.O.F. IMU
      – Provide data on deployment path
  – Changes from PDR
    • No humidity sensor
    • No space weather sensor attached to boom
## System Overview: Science Design Overview

<table>
<thead>
<tr>
<th>Data to be collected</th>
<th>How it will be collected</th>
<th>What it will be used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Still images of deployment</td>
<td>OV7670</td>
<td>Images will be downlinked to provide visual data in case of landing failure</td>
</tr>
<tr>
<td></td>
<td><em>Data will be downlinked</em></td>
<td></td>
</tr>
<tr>
<td>Video inside of boom container</td>
<td>OV7670</td>
<td>Show how rolled boom behaves under launch conditions and its state before deployment</td>
</tr>
<tr>
<td></td>
<td><em>Saved to SD card</em></td>
<td></td>
</tr>
<tr>
<td>HD video of deployment</td>
<td>GoPro Hero 5</td>
<td>Aid in characterization of deployment and provides data on torques and flexing</td>
</tr>
<tr>
<td></td>
<td><em>Saved locally to GoPro</em></td>
<td></td>
</tr>
<tr>
<td>Side view video of deployment</td>
<td>GoPro Session</td>
<td>Combined with HD video to enable 3D stereoscopic reconstruction</td>
</tr>
<tr>
<td></td>
<td><em>Saved locally to GoPro</em></td>
<td></td>
</tr>
</tbody>
</table>
## System Overview: Science Design Overview

<table>
<thead>
<tr>
<th>Data to be collected</th>
<th>How it will be collected</th>
<th>What it will be used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accelerometer and gyroscopic data of deployment</td>
<td>9 DOF IMU to be mounted on the end of the boom &lt;br&gt; <em>Data will be downlinked</em></td>
<td>Primary data for characterization of position and velocity of boom during deployment</td>
</tr>
<tr>
<td>Temperature of boom</td>
<td>Thermistor mounted on deployment mechanism and placed in contact with boom &lt;br&gt; <em>Saved to SD card</em></td>
<td>Provide requested data to ROCCOR to understand condition of boom before deployment</td>
</tr>
<tr>
<td>Environmental data (internal and external temperature, internal accelerometer, internal pressure)</td>
<td>Environmental suite of sensors &lt;br&gt; <em>Saved to SD card</em></td>
<td>Provides data to characterize flight conditions and sealing of containers</td>
</tr>
</tbody>
</table>
2.2 Mechanical System Overview

Anahid Blaisdell, Yohannese Gebremedhin, Nick Gentz
Rebekah Haysley, Ryan McCormick
System Overview: Mechanical Design Overview
System Overview: Mechanical Design Overview
System Overview: Mechanical Design Overview
System Overview: Mechanical Design Overview

Nema 8

Hero 5

OV7670

Nucleo

Hero Session

Nema 11

OV7670
System Overview: Mechanical Design Overview

PDR Changes

• Moved away from strap design
  – In favor door release

• Removed linear actuator
  – Replaced with linear stepper motor

• Provided more boom support
  – Guide rails with tight tolerances

• More modular camera boxes
  – Less material, easier construction and sealing
2.3 Avionics System Overview

Zachary Asmussen, Jacob Grunwald, Nolan Ferguson, Leina Hutchinson, Virginia Nystrom
System Overview: Electrical Design Overview

- 34V to 12V DC/DC
- 34V to 5V DC/DC
- Boom Characterization Hardware
- External Sensors:
  - Low Res Camera
  - Inertial Measurement Unit
  - 2x Temp Probe
  - 2x Go Pros
- Power
- WFF Input
- Data
- WFF
  - GSE1
  - Asynchronous (RS232)
  - Parallel 1:8
  - Event Timer
- 34V to 3.3V DC/DC
- MCU:
  - Power
  - RS232 Out
  - I2C In
  - I2C Out
  - Event Timer Interrupt
- Driver Circuits:
  - Driver Circuit 1
  - Driver Circuit 2
  - Driver Circuit 3
- Actuators:
  - Door Stepper Motor 1
  - Door Stepper Motor 2
  - Linear Actuator Stepper Motor
- Internal Sensors:
  - Temperature
  - Pressure
  - Accelerometer
  - Low Res Camera
System Overview: Electrical Design Overview

• Changes from PDR
  – GoPros now powered by rocket
  – PCB instead of perf board
  – Scheduled more revisions on PCB
System Overview: Software Design Overview

• **Software Objective**
  - Control boom deployment/release
  - Handle timer events
  - Format, store, downlink data

• **Software Handling**
  - Nucleo Microcontroller
  - Software written in C
System Overview: Software Design Overview

Rocket Event: GSE-1

- Bootup
- Begin Internal Timer

Check Interrupt
- If Interrupt
  - To Interrupt...

Else

1. Attempt Get Image
   - Compress Image
   - Convert Image to B&W
   - Downlink Image

2. Attempt Get Boom Temp
   - Format Data
   - Downlink Data

3. Attempt Get Boom Accel Data
   - Format Data
   - Downlink Data

4. Attempt Get Video
   - Format Video
   - Store Video

5. Attempt Get Sensor Data
   - Format Data
   - Store Data

Right Panel:
- Check/Aimpt
- Format
- Downlink
- Store

External Events:
- Rocket Event
- Internal Event
System Overview: Software Design Overview

From Main... If Interrupt → Check Interrupt Type

Rocket Event: TE-1 (H) → TE-1A Interrupt → Trigger Camera Power → Get Low-Res Image → Filter Low-Res Image → Store Low-Res Image

Rocket Event: TE-2 (H) → TE-2A Interrupt → Trigger Deploy Actuator

Rocket Event: TE-2 (L) → TE-2B Interrupt → Trigger Release Actuator

Rocket Event: TE-1 (L) → TE-1B Interrupt → Power Off Cameras

Sensor Interrupt → Collect Sensor Data → Store Sensor Data

Rocket Event

Check/Attempt
Format
Downlink
Store
Internal Event
Changes from PDR

• Final microcontroller decision - Nucleo
• Downlinking images instead of video
  – Determined how images will be sent down the RS232 line
• Grayscale photos instead of color photos
  – Increases rate of photo downlink by a factor of 3
System Overview: Description of Partnerships

Partnership with ROCCOR

- REX-B will collect:
  - Successful deployment of ROCCOR’s product in a 0-g environment
  - Video and data to characterize deployment
- REX-B team must:
  - Design deployment and release mechanism
  - Design camera system
  - Determine appropriate sensors
- ROCCOR will provide:
  - 1 full-size boom for flight
  - Sample booms for testing
- Point of contact: Kamron Medina
  - Brief weekly teleconferences
  - Defining requirements for characterization
• With camera constraints stereoscopic construction may be more difficult

• This is no longer a minimum criteria for mission success by ROCCOR so it may be a possible de-scope if needed
System Overview: Special Requests

- Faster telemetry
- More than 1 in. per second deployment
- RS-232
- Nitrogen purge on launch-pad
- Information about humidity conditions at launch and during storage
3.0 Subsystem Design
3.1 Science System Design
Camera System Chosen

- **Hero 5 Black:**
  - 240 FPS @ 720p Wide
  - Wide FOV: 118.2 - 122.9 degree Horizontal
  - Using the power-on-record function, 2 seconds to start

- **Hero Session:**
  - 120 FPS @ 720p Wide
  - Wide FOV: 122.4 degree Horizontal

- **OV7670 Micro Camera:**
  - 640X480 image, 30 images per second burst, 75 degree FOV
  - Direct interface with Nucleo board
  - Low light mode
### Camera Masses and Dimensions

<table>
<thead>
<tr>
<th></th>
<th>Mass</th>
<th>Dimensions</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hero 5 Black</strong></td>
<td>118 Grams</td>
<td>66x44.6x33.7 mm</td>
<td>$400</td>
</tr>
<tr>
<td><strong>Hero Session</strong></td>
<td>74 grams</td>
<td>38x38x38 mm</td>
<td>$200</td>
</tr>
<tr>
<td><strong>OV7670 Micro Camera</strong></td>
<td>15 grams</td>
<td>24x24x10 mm</td>
<td>(2) $20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>207 grams (0.46 Pounds)</td>
<td></td>
<td>$640</td>
</tr>
</tbody>
</table>
Computer Vision Camera Positions
New Field Of View Top Down Diagram

Key:

GoPro Hero Session FOV:

GoPro Hero 5 FOV:

Deploying Boom:

Area of stereoscopic coverage:
Camera Systems

• Better Quality
  – 2 cameras operating in HD 720p at 240 FPS

• Wider FOV
  – Position Flexibility
  – No compromise on coverage

• Internal Cameras
  – Medium Resolution with internal light source
  – Storage and deployment mechanisms
  – Pictures sent to earth
Camera System Tracking Objects Example
# Sensors

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Temp Range</th>
<th>Mass</th>
<th>Current</th>
<th>Data</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeywell 701 Thermistor</td>
<td>-70 to 500 C</td>
<td>14 mg</td>
<td>0.3 mA to 1 mA</td>
<td>Analog</td>
<td>$15.62</td>
</tr>
<tr>
<td>Digital Temperature DS18B20</td>
<td>-55 to 125 C</td>
<td>16.5 mg</td>
<td>1 to 1.5 mA</td>
<td>Digital</td>
<td>$3.95</td>
</tr>
<tr>
<td>High-G Triple Axis Accelerometer ADXL377</td>
<td>-55 to 125 C</td>
<td>1.27 g</td>
<td>300 μA</td>
<td>Analog</td>
<td>$24.95</td>
</tr>
<tr>
<td>Sparkfun Pressure MPL115A1</td>
<td>-40 to 105 C</td>
<td>1.7 g</td>
<td>5 μA</td>
<td>Digital</td>
<td>$12.95</td>
</tr>
<tr>
<td>Sparkfun IMU MPU-9250</td>
<td>-40 to 105 C</td>
<td>1.84 g</td>
<td>3.5 mA</td>
<td>I²C</td>
<td>$14.95</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5.12 g</td>
<td>5.1 to 6.3 mA</td>
<td></td>
<td>$72.42</td>
</tr>
</tbody>
</table>
SCI.RSK.1: No usable data can be retrieved IF cameras do not have correct focus, exposure, or lighting
SCI.RSK.2: No HD video will be collected IF camera data is unrecoverable
SCI.RSK.3: Not enough accelerometer data will be recorded IF the sensor does not stay attached to the tip in the high energy release
SCI.RSK.4: No data collected on temperature of boom IF conditions exceed operating range of sensor
Risk Mitigation Graph

- High Consequence:
  - SCI.RSK.3
  - SCI.RSK.1
- Moderate Consequence:
  - SCI.RSK.2
  - SCI.RSK.4
- Low Consequence:
  - SCI.RSK.4

- Possibility:
- SCI.RSK.3
- SCI.RSK.1

- Actions:
  - Cameras and sensors come off the shelf
  - Integration of tracking markers and boom sensors 1/23/17
  - Camera FOV Test 1/30/17
  - Accelerometer Reconstruction Code 2/27/17
  - Tracking Code 3/13/17
  - Stereoscopic Reconstruction Code 3/27/17
  - Science System DITL Test 4/1/17
3.2 Mechanical System Design
Final Deployment Mechanism

- Torsional Spring
- Boom
  - Roll Diameter: 2.23"
  - Spool Width: 3.85"
  - Thickness: 0.01"
- Nema Stepper
  - 0.79" X 0.79" X 1.1"
Final Deployment Mechanism:

- **Hardware:**
  - Nema 8 (x2)
  - Torsional spring
- **Power:**
  - 12-24 V for stepper motors (Current: 0.2 A)
- **Stepper motor:**
  - Movement triggered by timer event

- This subsystem design is subject to minor changes based on results of testing, but overall design is final.
Final Ejection Mechanism

1.10”

3.78”

4.56”
Final Ejection Mechanism
Final Ejection Mechanism

- **Hardware:**
  - Nema 11 non-captive Linear Stepper Motor
  - Male/ Female 5 pin 2mm pitch headers
  - Spring
- **Power:**
  - 12 V and 0.70A for Nema 11
- **Interfaces:**
  - With boom and electronics box
- **Overall design is final**
  - Spring strength not determined
Subsystem Design: Detailed Weight Budget

- Shared payload spaces must weigh 15 ± 0.5 lb

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Total Weight (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>7.9</td>
</tr>
<tr>
<td>Nema 8 (x2)</td>
<td>.3</td>
</tr>
<tr>
<td>Door w/ Spring</td>
<td>.3</td>
</tr>
<tr>
<td>Nema 11</td>
<td>.3</td>
</tr>
<tr>
<td>Ejection System</td>
<td>.4</td>
</tr>
<tr>
<td>Deck Plate</td>
<td>3.4</td>
</tr>
<tr>
<td>Hero 5</td>
<td>.3</td>
</tr>
<tr>
<td>Session</td>
<td>.2</td>
</tr>
<tr>
<td>Electronics</td>
<td>.9</td>
</tr>
<tr>
<td>Sensors</td>
<td>.01</td>
</tr>
<tr>
<td>Nucleo</td>
<td>.2</td>
</tr>
<tr>
<td>Fasteners</td>
<td>.3</td>
</tr>
<tr>
<td>Wiring/Connectors</td>
<td>.2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>14.71</strong></td>
</tr>
</tbody>
</table>

*Within weight range*
## Subsystem Design: Detailed Budget / Parts List

<table>
<thead>
<tr>
<th>Part</th>
<th>Purpose</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nema 11</td>
<td>Linear stepper motor for ejection mechanism</td>
<td>$36</td>
</tr>
<tr>
<td>Nema 8 (x2)</td>
<td>Stepper motors for door release</td>
<td>$30</td>
</tr>
<tr>
<td>Torsional Spring</td>
<td>Door release spring</td>
<td>$7</td>
</tr>
<tr>
<td>Compression spring</td>
<td>Spring for ejection mechanism</td>
<td>$5</td>
</tr>
<tr>
<td>Aluminum 6061 T6</td>
<td>Structure material</td>
<td>$126</td>
</tr>
<tr>
<td>Fasteners</td>
<td>Bolts for securing various structural components</td>
<td>$50</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$ 254</strong></td>
</tr>
</tbody>
</table>
Risk Matrix: Structures

STR.RSK.1: Boom cannot be deployed IF stepper motor for door fails in-flight
STR.RSK.2: Boom characterization data cannot be collected IF release door mechanism fails in flight
STR.RSK.3: Electronics may be damaged post landing IF structure is not sealed properly
STR.RSK.4: Mechanisms may fail IF structure cannot withstand temperature extremes
STR.RSK.5: Boom cannot fit into structure IF the recommended lead up of 11 inches is required
Risk Mitigation Graph

- High TRL, stepper motors are "off the shelf"
- Deployment Mechanism and Release Mechanism Tests 2/20/17
- Vibration Test 2/27/17
- Temperature Test 3/6/17
- Pressure Test 3/13/17
- Water Dunk Test 3/20/17
- Wallops Vibe Test
3.3 Avionics System Design
Power Conversion

- One of 3 DC-DC converter circuits
  - 3.3V for MCU, cameras, and sensors
  - 5V for level stepper
  - 12V for motors
Command and Data Handling: Interrupts

Microcontroller

Comparator Circuit
Command and Data Handling: Motors

Driver Chip

Motor

Diode Diode Diode Diode

5V

12V

Motor1

In1 In2 In3 In4

Stepper Motor

Diode Diode Diode Diode

GND

L298

IN1 IN2 IN3 IN4 ENA ENB SENSEA SENSEB NC NC VSS Vs OUT1 OUT2 OUT3 OUT4 GND GND GND GND
Command and Data Handling: Sensors

![Diagram of sensors and microcontroller connections]

**Sensors**

**Microcontroller**
Command and Data Handling: Cameras

GoPros

Low-Res Cameras

Microcontroller
## Avionics Design: Parts List – Main Hardware

<table>
<thead>
<tr>
<th>Part</th>
<th>Purpose</th>
<th>Cost</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x NUCLEO-L073RZ</td>
<td>Main MCU controller</td>
<td>$12</td>
<td>&lt;250 g</td>
</tr>
<tr>
<td>1 x DS1307 Real Time Clock Breakout board</td>
<td>Onboard clock for reference in data</td>
<td>$15.00</td>
<td>&lt; 9 g</td>
</tr>
<tr>
<td>2 x PCB</td>
<td>Board Mount for various hardware</td>
<td>$66.00 (Total)</td>
<td>&lt;60 g</td>
</tr>
<tr>
<td>1 x Adafruit Feather M0 Adalogger</td>
<td>Data reader</td>
<td>$22.00</td>
<td>&lt; 6 g</td>
</tr>
<tr>
<td>3 x L298N</td>
<td>Small board controlling Input voltage to motors</td>
<td>$20.97 (Total)</td>
<td>&lt; 90g (Total)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$135.97</strong></td>
<td><strong>415g</strong></td>
</tr>
</tbody>
</table>
# Avionics Design: Parts List – Support Hardware

<table>
<thead>
<tr>
<th>Part</th>
<th>Purpose</th>
<th>Cost</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC Buck Converters</td>
<td>Converts the payload voltage to a lower voltage for various hardware.</td>
<td>$30</td>
<td>30 g</td>
</tr>
<tr>
<td>Op Amps</td>
<td>Act as ‘triggers’ for the timer events.</td>
<td>$10</td>
<td>10 g</td>
</tr>
<tr>
<td>RS232 Level Shifter</td>
<td>Translator between RS232 and Nucleo.</td>
<td>$6</td>
<td>10 g</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>$46</strong></td>
<td><strong>50 g</strong></td>
</tr>
</tbody>
</table>

**Avionics Total** | **$171.97** | **465 g (1.03 lbs)**
## Subsystem Design: Detailed Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Current (A)</th>
<th>Time On (min)</th>
<th>Amp-Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoPros(2)</td>
<td>3.8</td>
<td>0.70</td>
<td>3</td>
<td>0.035</td>
</tr>
<tr>
<td>Nucleo MCU</td>
<td>3.3</td>
<td>.8</td>
<td>20</td>
<td>0.26</td>
</tr>
<tr>
<td>External Sensors*</td>
<td>--</td>
<td>.005</td>
<td>20</td>
<td>0.002</td>
</tr>
<tr>
<td>Internal Sensors*</td>
<td>--</td>
<td>.004</td>
<td>20</td>
<td>0.001</td>
</tr>
<tr>
<td>Motors</td>
<td>12</td>
<td>1.15</td>
<td>0.5</td>
<td>0.010</td>
</tr>
<tr>
<td>OV7670 Internal</td>
<td>3</td>
<td>.015</td>
<td>15</td>
<td>0.004</td>
</tr>
<tr>
<td>OV760 External</td>
<td>3</td>
<td>.015</td>
<td>0.5</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>L298’s</td>
<td>7-35</td>
<td>1.15</td>
<td>0.5</td>
<td>0.010</td>
</tr>
<tr>
<td><strong>Total (A*hr):</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>0.322</strong></td>
</tr>
<tr>
<td><strong>Over/Under</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>0.178</strong></td>
</tr>
</tbody>
</table>

* External consists of HoneyWell temperature sensor, SPK fun IMU.
* Internal consists of SPK fun Internal Press, Temp, Adafruit Accel.
Software Elements

- FIFO (First In, First Out) Buffer
  - Raw data storage
- Sensor Sampling
  - Dependent on FIFO
  - Request data from sensor and store in FIFO
- Sensor Data Processing
  - Dependent on Sampling
  - Pop data from FIFO and process, then store to SD card
- Image Sampler
  - Request camera image and store on SD
- Image Compression/Transmission
  - Dependent on sampler
  - Compress data and transmit
- Event Handler
  - Handle timing events and pin toggling events
## Software Development Schedule

<table>
<thead>
<tr>
<th>Priority</th>
<th>Block</th>
<th>Completed By</th>
<th>Margin (weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>FIFO Buffer</td>
<td>1/6/2017</td>
<td>.5</td>
</tr>
<tr>
<td>2</td>
<td>Image Sampler</td>
<td>1/20/2017</td>
<td>.5</td>
</tr>
<tr>
<td>3</td>
<td>Image Compression/Transmission</td>
<td>1/27/2017</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Event Handler</td>
<td>2/3/2017</td>
<td>.5</td>
</tr>
<tr>
<td>4</td>
<td>Sensor Sampling</td>
<td>2/10/2017</td>
<td>.5</td>
</tr>
<tr>
<td>4</td>
<td>Sensor Data Processing</td>
<td>2/10/2017</td>
<td>.5</td>
</tr>
</tbody>
</table>
Risk Matrix: (Avionics)

EPS.RSK.1: Mission objectives aren’t met IF microcontroller fails in-flight
EPS.RSK.2: Mission objectives aren’t met IF critical data is not downlinked and stored data is not recoverable
EPS.RSK.3: Mission objectives aren’t met IF the EPS system can’t survive launch conditions
EPS.RSK.4: Mission objectives aren’t met IF the comparator circuit fails
Risk Mitigation Graph

- **High:**
  - Microcontroller is off the shelf but does not have legacy in space application
  - Power conversion test, verifies microcontroller will be supplied correct voltage 12/7/16

- **Moderate:**
  - Image downlink test, verifies images will be sent down RS232 1/27/17
  - Comparator test, verifies timer events will be received as expected 1/27/17
  - Temperature test, verifies components will not fail in temperature extremes 3/8/17
  - Structures environmental tests, verifies electronics box will survive flight 3/2017

- **Low:**
  - Wallops Vibe Test
4.0 Prototyping / Analysis Results / Plans
4.1 Science Prototyping / Analysis
Science: What has been prototyped?

• Test footage of deployment
  – Including “mouse ears”
• Generic MATLAB code reviewed and drafted
  – Awaiting modification and filter refinement
• Results
  – Able to get ‘blob’ object tracking successfully
  – Filter tracks movement, steady background is essential
  – Footage will have to be slowed substantially
Slow Motion Boom Rollout - 720p @ 120FPS
Real Tracking Test Image
Torsional Test Image
Science: Future Prototyping Plans

• Reconstruct an exact defined/measured test stand

• Generate substantial test footage for video overlay

• Live tracking of “mouse ears” on boom
  — Trace position/path reliably and in a scaled coordinate system
  — Live flexing and torsion data in real time and slowed. High accuracy 720p 240fps

• Accelerometer reconstruction
  — Using 9DOF IMU and high position requisite can draw path in 3D of boom’s path of deployment.
Animated Accelerometer Reconstruction

Reconstruction of man walking along flat ground
Animated Accelerometer Reconstruction

Reconstruction of man walking up stairs
4.2 Mechanical Prototyping / Analysis
Structures - Prototyping Boom Deployment

- Slow-motion video of boom used to determine:
  - Ball-park holding conditions for boom
  - How to minimize boom movement during deployment

- This helped to:
  - Refine deployment mechanism
  - Determine the approximate door thickness and spring strength

- Further experimentation with the boom will yield more quantitative data
Future Prototyping Plan:

- 3D print camera structures and boom guides.
- Machine release and ejection mechanisms.

Mission Critical

- Prototyping is used to determine part sizes and spring constants.
- Make sure the release and ejection occurs with little to no problems.
4.3 Avionics Prototyping / Analysis
Prototyping Objective and Procedure:

- **Objective:**
  - Ensure buck converters can operate under a voltage range of 22-34V
  - Power Nucleo
  - Power GoPro

- **Procedure:**
  - Test powering Nucleo with buck converters with voltage input from 22-34V
  - Turn on GoPro with GPIO pin
  - Test range of input voltages for GoPro
Prototyping Results and Future Plans

• Results
  – DC/DC converter successfully regulates 24-32V to 5V
  – Nucleo is successfully powered
  – GoPro has a voltage range of 3.3-4V
    • Can be turned on remotely using a logical high

• Further Protoyping Plans
  – Test driver circuit
  – Test comparator circuit
Low-Resolution Image Format Analysis

- Baud rate (19,200 baud) is limiting factor in downlinking image
- Sample images with resolution of OV7670 camera (640 x 480)

![Color Image](image1.png)  
**Color** – 126 kB  
25 Total Images

![Black and White Image](image2.png)  
**Black and White** – 51 kB  
62 Total Images

![Grayscale Image](image3.png)  
**Grayscale** – 42 kB  
75 Total Images
Low-Resolution Image Format Analysis

• Results
  – Images will be downlinked in greyscale to increase number of images

• Further Analysis Plans
  – Determine if any additional compression is necessary
5.0 Manufacturing Plan
5.1 Mechanical Manufacturing Plan
Mechanical Elements:

Parts that will need to be manufactured:
- Boom deployment structure
- Boom release mechanism
- Boom ejection mechanism
- Camera housings
- Electronics housing

Parts that will be purchased:
- Glenair Electrical Connectors
- 6061 Aluminum
- Various Springs
- Quartz Lens
- Gaskets
# Mechanical Elements - Plan

<table>
<thead>
<tr>
<th>Component</th>
<th>Manufactured by Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom Mounting Plate</td>
<td>1/16/2017</td>
</tr>
<tr>
<td>Ejection Mounting Block</td>
<td>1/16/2017</td>
</tr>
<tr>
<td>Guides / Electronics Housings</td>
<td>1/23/2017</td>
</tr>
<tr>
<td>Deployment Door</td>
<td>1/23/2017</td>
</tr>
<tr>
<td>Test Fit</td>
<td>1/30/2017</td>
</tr>
<tr>
<td>Subsystem Testing</td>
<td>2/6/2017</td>
</tr>
<tr>
<td>Final Adjustments</td>
<td>2/10/2017</td>
</tr>
<tr>
<td>Final Assembly</td>
<td>2/14/2017</td>
</tr>
</tbody>
</table>
5.2 Electrical Manufacturing Plan
Electrical Elements: PCB Manufacturing

Manufacturing Plan

1) Finalize schematics
2) Design board layout
3) Print PCB
4) Populate PCB

Materials

• Buck converters
• Comparator circuits
• Motor driver circuits
• Sensor breakout boards
• Real time clock
• Resistors
• Capacitors
• Diodes
**Electrical Elements: Schedule**

<table>
<thead>
<tr>
<th>PCB Revision</th>
<th>Design Complete</th>
<th>Board Ordered*</th>
<th>Board Populated</th>
<th>Board Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1/9</td>
<td>1/11</td>
<td>1/15</td>
<td>1/20</td>
</tr>
<tr>
<td>FINAL</td>
<td>1/22</td>
<td>1/25</td>
<td>2/1</td>
<td>2/3</td>
</tr>
</tbody>
</table>

*Note: Schedule allows for a margin of 1 week*

*3-Day turnaround when ordering boards from Advanced Circuits*
6.0 Testing Plan
# Testing Plan: Science Design

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrate Tracking Markers</td>
<td>Add bright spherical markers on either side of the boom without disrupting packing or deployment</td>
<td>MATLAB requires objects to track for computer vision and bright ones provide more contrast</td>
</tr>
<tr>
<td>(1/23/17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camera Field of View Testing</td>
<td>Integrate the cameras with their final housing</td>
<td>Verify that the housing allows full view of the deployed boom</td>
</tr>
<tr>
<td>(1/30/17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Accelerometer Reconstruction</td>
<td>Check MATLAB code’s analysis of accelerometer data</td>
<td>Acquire data about the boom’s position and velocity over time</td>
</tr>
<tr>
<td>Code (2/27/17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tracking Code</td>
<td>Check MATLAB code’s analysis of boom marker positions</td>
<td>Allow for tracking of boom markers during deployment</td>
</tr>
<tr>
<td>(3/13/17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereoscopic Reconstruction</td>
<td>Check MATLAB code’s reconstruction of stereoscopic video</td>
<td>Model the entire deployment of the boom in 3D for ROCCOR to use commercially</td>
</tr>
<tr>
<td>Code (3/27/17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Science System DITL</td>
<td>Deploy boom and analyze the footage/data</td>
<td>Verify our analysis tools can extract all necessary information</td>
</tr>
<tr>
<td>(4/1/17)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Testing Plan: Mechanical Testing

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deployment Mechanism (1/30/17)</td>
<td>Using the linear actuator, allowing the pin to pull back enough so the fastening strap can release</td>
<td>Ensure that the boom will deploy correctly and we can proceed with the data collection</td>
</tr>
<tr>
<td>Release Mechanism (1/30/17)</td>
<td>Using the linear actuator to pull the pin all the way out and cause the spring to release</td>
<td>Ensure that the boom will disconnect from the payload and be discarded before re-entry</td>
</tr>
<tr>
<td>Vibration (2/1/17)</td>
<td>Using a vibration table both here at CU and again at Wallops</td>
<td>Ensure that the payload can handle the vibrations of launch and re-entry</td>
</tr>
<tr>
<td>Temperature (2/3/17)</td>
<td>Using Dry Ice for the cold test and an oven for the heat testing</td>
<td>Ensure that the payload can survive the range of temperatures experienced in space</td>
</tr>
<tr>
<td>Pressure (2/3/17)</td>
<td>Using the Space Grant Bell Jar</td>
<td>Ensure that the payload can survive a vacuum environment</td>
</tr>
<tr>
<td>Water Dunk (2/6/17)</td>
<td>Submerge the payload in a tub of water and check for leaks</td>
<td>Ensure that the payload is watertight so that our cameras and electronics are protected</td>
</tr>
</tbody>
</table>
## Testing Plan: Electrical Testing

<table>
<thead>
<tr>
<th>Test</th>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Conversion (12/7/16)</td>
<td>Setup and test DC buck power converters on perf board</td>
<td>Reduce high voltage from payload for hardware</td>
</tr>
<tr>
<td>Calibration (1/11/17)</td>
<td>Test all sensors against previously recorded or known data</td>
<td>Ensure data collected and stored is accurate</td>
</tr>
<tr>
<td>Motor Driver Circuits (1/18/17)</td>
<td>Use motor and motor driver circuit</td>
<td>Payload preparation for launch and deployment of boom</td>
</tr>
<tr>
<td>Data Collection (1/30/17)</td>
<td>Full 15 minute simulated tests</td>
<td>Emulate true flight conditions to greatest possible degree</td>
</tr>
<tr>
<td>PCB Hardware (1/30/17)</td>
<td>Full test cycle of hardware on PCB</td>
<td>Prepare for flight and integration</td>
</tr>
<tr>
<td>PCB Integration (2/4/17)</td>
<td>Software and hardware integration</td>
<td>Integrate full payload components with PCB Hardware</td>
</tr>
<tr>
<td>Test</td>
<td>Method</td>
<td>Purpose</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Grayscale Conversion (12/30/16)</td>
<td>Check readability of images after processing and efficiency of process</td>
<td>Conversion of OV7670 color images to grayscale for storage and streaming</td>
</tr>
<tr>
<td>Event Handler (2/2/17)</td>
<td>Check failure rate of interrupts and responsiveness of interrupt service routines</td>
<td>Detection of timer event signals to change and send signals out to cameras, hardware, etc</td>
</tr>
<tr>
<td>Image Sampler (1/19/17)</td>
<td>Check efficiency of process and sampling read / write speed</td>
<td>Grab images from SD card and send down when appropriate</td>
</tr>
<tr>
<td>FIFO Buffer (1/5/17)</td>
<td>Check corner cases and for memory leaks</td>
<td>Set up cache for data before processing</td>
</tr>
<tr>
<td>Image Handling (1/26/17)</td>
<td>Check decompressed data quality, and transmission speed and efficiency</td>
<td>Format data for more efficient transmission</td>
</tr>
<tr>
<td>Sensor Sampling (2/9/17)</td>
<td>Check communication and data storage is working properly</td>
<td>Sample data from sensors and store in FIFO</td>
</tr>
<tr>
<td>Sensor Data Processing (2/9/17)</td>
<td>Check data accuracy and that data is being stored and retrieved correctly</td>
<td>Process data during free processor cycles and then store</td>
</tr>
</tbody>
</table>
Testing Plan: System Level Testing

• **Systems Testing: 3/1/17 – 4/31/17**
  – Test all timer events individually
    • Ensures that each component responds individually to power and communication
  – Vibration Testing
    • Run test after vibration to ensure all components can handle launch conditions
  – Conduct full tests under varying voltages
    • Rocket may give a range, all systems must work accordingly
  – Deploy downward off of balcony
    • Ensures external forces act along boom path, closest to 0-g deployment

• **Day in the Life Testing: 4/3/2017**
  – Full 15 minute “hands off” test
  – All timer events triggered remotely
  – Data to be analyzed for comparison to flight data
Testing Equipment

- Built by CU for RockSat-X program to fully simulate rocket-payload interface
- Allows us to conduct multiple mission simulations before official mission sim at Wallops
- Will ensure payload can receive data and power from the rocket with no issues
7.0 User Guide Compliance
# User Guide Compliance: Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; plane of plate?</td>
<td>YES</td>
</tr>
<tr>
<td>Weight 30.0+/- 1.0 (15.0 +/- 0.5) lbs?</td>
<td>14.7 lbs</td>
</tr>
<tr>
<td>Max Height &lt; 10.75” (5.13”)</td>
<td>5.03”</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>YES</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
<td>YES</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>NO</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
<td>YES - 6 Parallel Lines</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
<td>YES - Necessary for image downlink</td>
</tr>
<tr>
<td>Using X GSE Line(s)</td>
<td>YES - 1 GSE Line</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
<td>2 Timer Event Lines - Control deployment and release of booms</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
<td>NO</td>
</tr>
<tr>
<td>Using &lt; 1 Ah</td>
<td>.32 A</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>YES</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>NO</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>YES - Rate of deployment &gt; 1 in/s</td>
</tr>
<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>
</tr>
</tbody>
</table>
## User Guide Compliance: Power Interface

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Power on Main System</td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Camera On (H) / Camera Off (L)</td>
</tr>
<tr>
<td>5</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Boom Deploy (H) / Boom Release (L)</td>
</tr>
<tr>
<td>11</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>
# User Guide Compliance: Telemetry Interface

## Telemetry Connector—Customer Side

<table>
<thead>
<tr>
<th>Pin</th>
<th>Function</th>
<th>Pin</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Accelerometer X-Axis Data</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Accelerometer Y-Axis Data</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Accelerometer Z-Axis Data</td>
<td>32</td>
<td>Low-Quality Image Stream</td>
</tr>
<tr>
<td>14</td>
<td>Gyro X Data</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Gyro Y Data</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Gyro Z Data</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8.0 Project Management Plan
## Project Management Plan: Schedule

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avionics Prototyping Complete</td>
<td>1/5/17</td>
</tr>
<tr>
<td>Structural Prototyping Complete</td>
<td>1/13/17</td>
</tr>
<tr>
<td>Science Prototyping Complete</td>
<td>1/15/17</td>
</tr>
<tr>
<td>Structural Manufacturing Complete</td>
<td>1/23/17</td>
</tr>
<tr>
<td>Deployment/Release Testing Complete</td>
<td>1/30/17</td>
</tr>
<tr>
<td>Final PCB Board Populated</td>
<td>2/1/17</td>
</tr>
<tr>
<td>Electronics Testing Complete</td>
<td>2/3/17</td>
</tr>
<tr>
<td>Software and Electronics Integration</td>
<td>2/4/17</td>
</tr>
<tr>
<td>Structural Testing Complete</td>
<td>2/6/17</td>
</tr>
<tr>
<td>Software Testing Complete</td>
<td>2/9/17</td>
</tr>
<tr>
<td>Subsystem Testing Review</td>
<td>2/17/17</td>
</tr>
</tbody>
</table>
## Project Management Plan: Schedule

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsystem Integration</td>
<td>February 2017</td>
</tr>
<tr>
<td>Begin Systems Testing</td>
<td>3/1/17</td>
</tr>
<tr>
<td>Integrated Subsystem Review</td>
<td>March 2017</td>
</tr>
<tr>
<td>Begin Full Mission Simulations</td>
<td>4/3/17</td>
</tr>
<tr>
<td>Full Mission Simulation Review</td>
<td>April/May 2017</td>
</tr>
<tr>
<td>Final Mission Simulation</td>
<td>June 2017</td>
</tr>
<tr>
<td>Integration Readiness Review</td>
<td>June 2017</td>
</tr>
<tr>
<td>Testing @ WFF</td>
<td>June 2017</td>
</tr>
<tr>
<td>Launch Readiness Review</td>
<td>July 2017</td>
</tr>
<tr>
<td>Final Integration @ WFF</td>
<td>August 2017</td>
</tr>
<tr>
<td>LAUNCH</td>
<td>August 2017</td>
</tr>
</tbody>
</table>
# Project Management Plan: Monetary Budget

## Costs and Expenses

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Cost – Half Payload</td>
<td></td>
</tr>
<tr>
<td>Half Payload</td>
<td>$14,000</td>
</tr>
<tr>
<td>Total</td>
<td>$14,000</td>
</tr>
<tr>
<td>CU Hardware</td>
<td></td>
</tr>
<tr>
<td>Science</td>
<td>$1250</td>
</tr>
<tr>
<td>Structures</td>
<td>$750</td>
</tr>
<tr>
<td>Avionics</td>
<td>$750</td>
</tr>
<tr>
<td>Summer Shop Access</td>
<td>$1000</td>
</tr>
<tr>
<td>Other</td>
<td>$350</td>
</tr>
<tr>
<td>Total</td>
<td>$4,100</td>
</tr>
<tr>
<td>Labor</td>
<td></td>
</tr>
<tr>
<td>Spring Stipends ($650 x 14 Students)</td>
<td>$9,100</td>
</tr>
<tr>
<td>Summer Labor (14 students @ $10, 15 hours, 10 weeks)</td>
<td>$21,000</td>
</tr>
<tr>
<td>Total</td>
<td>$30,100</td>
</tr>
<tr>
<td>Travel</td>
<td></td>
</tr>
<tr>
<td>Trip #1 – Integration @ Wallops – June – 6 Days</td>
<td>$6,300</td>
</tr>
<tr>
<td>Trip #2 – Flight @ Wallops – August – 7 Days</td>
<td>$7,500</td>
</tr>
<tr>
<td>Total</td>
<td>$13,800</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$62,000</td>
</tr>
</tbody>
</table>

## Sources of Funding

<table>
<thead>
<tr>
<th>Source</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Known Sources of Funding</strong></td>
<td></td>
</tr>
<tr>
<td>Colorado Space Grant Consortium</td>
<td>$10,000</td>
</tr>
<tr>
<td>Undergraduate Research Opportunity Fund</td>
<td>$3,000</td>
</tr>
<tr>
<td>Total</td>
<td>$13,000</td>
</tr>
<tr>
<td><strong>Unknown Sources of Funding</strong></td>
<td></td>
</tr>
<tr>
<td>Engineering Excellence Fund</td>
<td>$0 - $15,000</td>
</tr>
<tr>
<td>Industry/Sponsorship</td>
<td>$34,000 - $49,000</td>
</tr>
<tr>
<td>Total</td>
<td>$49,000</td>
</tr>
<tr>
<td>Grand Total</td>
<td>$62,000</td>
</tr>
</tbody>
</table>
Project Management Plan: Worries - Science

• Camera settings
  – Doing enough testing to correctly set camera settings (focus, exposure, etc.)

• Stereoscopic Reconstruction
  – Developing an analysis tool that will be able to extract and output the correct information

• Mounting
  – Developing an appropriate mounting system for accelerometer and tracking markers on boom
Project Management Plan: Worries - Structures

- **Structure**:  
  - Having enough space for cameras and boom lead-up  
  - Giving the cameras a good field of view  

- **Stepper Motors**:  
  - Prefer 2 steppers but limited by power constraints  
  - Boom release is mission critical and dependent on stepper motor functioning as expected  

- **Payload Integrity**:  
  - Will be testing to ensure the following:  
    - Payload is airtight  
    - Can withstand vibrational damage  
    - Can withstand thermal damage
Project Management Plan: Worries - Avionics

• Powering all cameras and sensors
  – May strain power budget
• Downlinking pictures
  – Have looked into grayscale, but may still require greater compression
  – Difficulty with compression / downlink
• Picture file size
  – Currently grayscale pictures are ~41kb
• Image Storage
Project Management Plan: Next Steps - Science

• Order hardware for testing
• Look into mounting markers on boom
• Collect test footage for overlay comparison
• Collect test data with accelerometer
• Complete draft of analysis software
Project Management Plan: Next Steps - Structures

- Order specific parts needed
- Start prototyping
- Start manufacture of components
- Start testing on mechanisms
Project Management Plan: Next Steps - Avionics

- Start setting up the NUCLEO
- Begin PCB layout
- Test motors
- Order final hardware
- Start writing software
The R.E.X.-B. experiment should fly because it is testing and collecting useful data for a product that has the potential to revolutionize deployable space structures while adhering to the requirements set forth by NASA’s Wallops Flight Facility and the RockSat-X program.
Thank you for attending REX-B’s CDR presentation!

Any questions?
9.0 Appendix
# Appendix: Timer Events Matrix

**University of Colorado Boulder**  
**Date: December 9, 2016**

<table>
<thead>
<tr>
<th>Event</th>
<th>Time On</th>
<th>Units</th>
<th>Dwell Time</th>
<th>Units</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSE 1</td>
<td>T-210</td>
<td>(T-X) (sec)</td>
<td>600</td>
<td>(sec)</td>
<td>Power on NUCLEO (controls 1 microcamera (internal), all sensors)</td>
</tr>
<tr>
<td>GSE 2</td>
<td></td>
<td>(T-X) sec</td>
<td></td>
<td>(sec)</td>
<td></td>
</tr>
<tr>
<td>TE-R</td>
<td></td>
<td>(T+X) (sec)</td>
<td></td>
<td>(sec)</td>
<td></td>
</tr>
</tbody>
</table>
| TE-1  | T+200   | (T+X) (sec) | 15        | (sec) | **ON:** Sends interrupt signal to begin video on 2 GoPros, stills on 1 microcamera (external)  
**OFF:** End recording                                                                 |
| TE-2  | T+205   | (T+X) (sec) | 265       | (sec) | **ON:** Activates stepper motors to open release door  
**OFF:** Activates stepper motor to eject boom                                       |
| TE-3  |         | (T+X) (sec) |            | (sec) |                                                                                  |
Appendix: Team Organization Chart

- **Nick Gentz**
  - Co-Project Manager

- **Virginia Nystrom**
  - Co-Project Manager

- **Ross Kloetzel**
  - Systems Engineer

- **Ryan McCormick**
  - Structures Lead
    - Anahid Blaisdell
    - Yohannese Gebremedhim
    - Nick Gentz
    - Rebekah Haysley

- **Nolan Ferguson**
  - Avionics Lead
    - Zachary Asmussen
    - Jacob Grunwald
    - Leina Hutchinson
    - Virginia Nystrom

- **Joseph Frank**
  - Science Lead
    - Adam Boylston
    - Ross Kloetzel
    - Jack Maydan
Appendix: Electrical Schematics