CRev
Preliminary Design Review

Northwest Nazarene University
Drew Johnson, Lukas Rieke, Alex Hanson, Devon Ellis, Connor Back, Dakota Martin, Caleb Wolfe, Jordan Poundstone, Matthew Spires, Brenton Peck, Cassie Wade, Lucas Schamber

11/8/13
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  . Concept of Operations
  . Expected Results
  . Minimum Success Criteria
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1.0 Mission Overview
Mission Overview: Mission Statement

The Northwest Nazarene University (NNU) RockSAT-X 2014 payload will release several 3D printed airfoil shapes into space to test for flight stability in low atmospheric conditions. In addition to simple airfoils, NNU desires to mount flexible sensors onto some of the airfoil structures and retrieve the data through RFID communication. This data will be stored internally and downlinked for redundancy.

This data retained from the airfoils including accelerations, temperature, and video footage of flight paths will benefit the Printable Spacecraft program run through NASA Jet Propulsion Laboratory (JPL) program directed by Dr. Kendra Short. This data will help determine ideal structures and sensor capabilities for a data reconnaissance of an extraterrestrial body.
Mission Overview: Mission Objectives

- Deploy several airfoil structures into upper atmosphere
- Retrieve sensor data including temperature, pressure, and acceleration from the sensors
- Obtain video data of airfoils orientating in low atmospheric conditions
- Downlink images of airfoils orienting in low atmospheric condition
Mission Overview: Theory and Concepts

• Flexible Electronics in Space
  . NNU RockSAT-C 2012 and RockSAT-X 2013
    . Tested electrical and material properties of various flexible electronic components in space
    . Function flexible electronics
  . Printable Spacecraft: Dr. Kendra Short – JPL
    . Wide variety of flexible sensors functional
    . Small printable spacecraft with conformably mounted flexible electronics

NNU ConOps

Altitude

- **t ≈ 1.3 min**
  - Altitude: 95 km
  - *Aim airfoils*

- **t ≈ 1.4 min**
  - Altitude: 100 km
  - *Deploy Airfoils*

- **t ≈ 0.6 min**
  - Altitude: 60 km
  - *Begin storing sensor data, cameras on*

- **t = -3 min**
  - All systems on
  - Begin data collection
  - Calibrate Sensors

- **t ≈ 1.2 min**
  - Altitude: 75 km
  - *Skirt Deployment*

- **t ≈ 2.8 min**
  - Altitude: ≈115 km
  - *Apogee*

- **t ≈ 4.0 min**
  - Altitude: 95 km
  - *Begin shutdown procedure*

- **t ≈ 4.5 min**
  - Altitude: 75 km
  - *All systems off*

- **t ≈ 5.5 min**
  - Chute Deploys

- **t ≈ 0.6 min**
  - Altitude: 52 km
  - End of Orion Burn

- **t ≈ 15 min**
  - Splash Down
Deployment Procedure

- Time to deploy: 5 sec/airfoil
  - Total: 30-45 seconds
- Time to record data: > 3 min
- Orientation for optimal deployment: perpendicular to magnetic field
  - Reduces risk of airfoils colliding with rocket
Mission Overview: Expected Results

- Airfoils will stabilize and orient in atmosphere
- Temperature data will remain roughly similar as airfoils reside outside canister
- Range data will reflect order of deployed airfoil
Mission Overview: Success Criteria

- **Minimum Success Criteria:**
  - Deploy some airfoils into the upper atmosphere
  - Retrieve video data of orientation
  - Downlink one low resolution image of airfoil deployment

- **Comprehensive Success Criteria:**
  - Video footage of airfoil orientation
  - Data from sensors on internal memory and downlinked telemetry file
  - Uninhibited deployment of airfoils
  - Downlink several low resolution images
2.0 System Overview
System Overview: Science Design Overview

- Onboard sensors
  - Optical sensor for skirt deployment detection
  - Motor encoder for deployment status
  - GoPro Hero 3 camera for video capture
  - Low resolution camera for still capture and downlink
- Airfoil sensors
  - Temperature sensors
  - Distance (range) determined from IEEE protocol within RF system
  - Signal TOF
System Overview: Engineering Design Overview

- The main focus of this experiment is to determine the viability of the 3D printed airfoils. In order to test and deploy these airfoils, a housing system, Confetti Revolver (CRev), will house the airfoils in a safe environment until the appropriate deployment time.
- An optical sensor will be used to determine when the skirt has been deployed and the airfoils are unobstructed.
- The airfoils will be recorded visually through a GoPro camera and a smaller camera designed to downlink stills of airfoil deployment.
- Airfoils will contain temperature sensors and RF systems to communicate with the payload.
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revolver will deploy airfoils at a rate of no greater than 1 airfoil/5 seconds</td>
<td><strong>Demonstration</strong></td>
<td>Revolver will be tested and motor speed tuned to determine optimal rate</td>
</tr>
<tr>
<td>Linear actuator will aim camera in less than three seconds, extending &lt;1in/sec</td>
<td><strong>Demonstration</strong></td>
<td>Power for actuator will be tested to determine max speed for positioning camera</td>
</tr>
<tr>
<td>The full system shall fit on a single RockSAT-X deck</td>
<td><strong>Inspection</strong></td>
<td>Visual inspection will verify this requirement</td>
</tr>
<tr>
<td>The system shall survive the vibration characteristics prescribed by the RockSAT-X program.</td>
<td><strong>Test</strong></td>
<td>The system will be subjected to these vibration loads in June during testing week.</td>
</tr>
</tbody>
</table>
System Overview: Functional Block Diagram
System Overview: Description of Partnerships

- **Printable Spacecraft, Jet Propulsion Laboratory**
  - Create small scale example of mission
  - Collaboration in, but not restricted to:
    - Airfoil design
    - Deployment method
    - Data retrieval
  - Funding sponsor

- **American Semiconductor, Inc.**
  - Collaboration in sensor design
System Overview: User’s Guide Compliance

- Rough Order of Magnitude (ROM) weight estimate: 15 lb.
- Estimate on payload dimensions (will it fit in the payload space?) 9” diameter, 5” tall
- Deployables/booms? YES
- How many ADC lines?
- Asynchronous/Parallel use? YES
  - Do you understand the format? YES
- Power lines and timer events use? YES
- CG requirement
  - Do you understand the requirement? YES
- Are you utilizing high voltage? NO
- Hazardous Procedures? NO
- RF? YES
- Bolt heads on bottom of deck flush mount? YES
- US Persons for whole team? YES
- ITAR? NO
System Overview: Special Requests

• The NNU RockSAT-X team requires no special requests from Wallops
3.0 Subsystem Design
Subsystem Design: CRev

- Confetti Revolver Deployment Housing
  - Launches 3D printed Airfoil “Confetti” into space
  - 3.6 lb.
  - Guide track for precise launch location
  - Estimated launch time of five seconds per airfoil
  - Estimated total launch time of 35 seconds
Subsystem Design: AF

• 3D Printed Airfoil “Confetti”
  – Aerodynamic design for controlled fall
  – Attached electronic sensors
  – Temperature sensors
  – Current design ideas:
    I. Improved maple seed
       i. < 1 gram
    II. Birdy
       i. 22 g (.05 lb.)
Subsystem Design: GP

- **GoPro Hero 3 Case:**
  - 0.60 lb.
  - 3.3V Internal Li-ion battery
  - Linear actuator
  - SD card, HDMI out, serial bus
  - Current GPH3 isn’t fully functional
Subsystem Design: RF Communication

- **Xbee Series 1:**
  - Power - 3-3.3v lines with <50mA
  - Weight - 3 grams
  - Size – 1.09” x .299” footprint
  - 3 Chips, 1 Xbee shield/adapter
  - Easy to use
  - Currently not owned and more expensive
Subsystem Design: RP

- **Raspberry Pi:**
  - Size – 2.6” x 5.0” x 7.0”
  - 5V
  - 0.9 lb.
  - Controls all onboard systems
    - GoPro System
    - Optical Sensor
    - RF Communication
    - Low Resolution Camera
Subsystem Design: Power

- Power Board
  - Voltage Regulators
  - Using three lines
  - Internal Power for RF and GP
  - ~1A for GSE 1
  - ~50mA for TE-1
  - ~50mA for TE-2

![Diagram of power distribution](image)
Subsystem Design: Data Handling

- **Data to store – Internal SD**
  - States of subsystems
    - GP on/off
    - Motor on/off
    - Optical sensor
  - Sensors temperature and range data
- **Data to downlink**
  - States of subsystems
    - GP on/off
    - Motor on/off
  - Sensors temperature and range data
  - Low resolution image of airfoil deployment
4.0 Risk Matrices
Risk Matrix: NNU Payload

RF.RSK.1: Interference from metal of rocket or other payloads could inhibit communication
CRev.RSK.1: Rotational forces of launch cause revolver to revolve and potentially deploy
CRev.RSK.2: Airfoils jam up during deployment and restrict deployment and increase strain on power system
5.0 Test/Prototyping Plan
## Test/Prototyping Plan

<table>
<thead>
<tr>
<th>Test</th>
<th>System</th>
<th>Test Outcome</th>
<th>Accomplish by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Airfoil Drop Test</td>
<td>AF</td>
<td>Test initial structures</td>
<td>11/15/2013</td>
</tr>
<tr>
<td>GoPro Controller Test</td>
<td>GP</td>
<td>Initializing and recording through serial bus</td>
<td>11/15/2013</td>
</tr>
<tr>
<td>RF Communication Test</td>
<td>RF</td>
<td>Establish communication between antenna and receiver</td>
<td>11/22/2013</td>
</tr>
<tr>
<td>RF Data retrieval test</td>
<td>RF/RP</td>
<td>Read data from a static RF enabled sensor</td>
<td>11/22/2013</td>
</tr>
<tr>
<td>RF Multi-Comm test</td>
<td>RF/RP</td>
<td>Read data from multiple static RF enabled sensors</td>
<td>11/22/2013</td>
</tr>
<tr>
<td>Airfoil RF Comm Test</td>
<td>RF/AF</td>
<td>Read data from a falling RF enabled sensor</td>
<td>11/29/2013</td>
</tr>
<tr>
<td>Airfoil RF Multi-Comm Test</td>
<td>RF/AF/RP</td>
<td>Read data from multiple falling RF enabled sensors</td>
<td>11/29/2013</td>
</tr>
<tr>
<td>Power/Timer Event Distribution Test</td>
<td>PWR</td>
<td>Reducing GSE/TE power to appropriate measures</td>
<td>11/29/2013</td>
</tr>
<tr>
<td>Camera Actuation Test</td>
<td>GP/RP</td>
<td>Directional control of Camera</td>
<td>12/10/2013</td>
</tr>
<tr>
<td>Revolver Motor Test</td>
<td>RV/RP</td>
<td>Control of the revolver motor through Raspberry Pi</td>
<td>12/10/2013</td>
</tr>
<tr>
<td>Integrated Camera Test</td>
<td>GP/RP</td>
<td>Point and shoot the camera</td>
<td>1/20/2014</td>
</tr>
<tr>
<td>Integrated Revolver Test</td>
<td>RV/AF/RP/RF</td>
<td>Read data from several falling RF enabled airfoils</td>
<td>1/20/2014</td>
</tr>
<tr>
<td>Day in the life test - Payload R1</td>
<td>R1</td>
<td>Full simulation of two separate tests</td>
<td>3/10/2014</td>
</tr>
<tr>
<td>Cold Environment Test</td>
<td>RV/RP/RF/GP</td>
<td>Full simulation in cryogenic temperatures</td>
<td>3/10/2014</td>
</tr>
<tr>
<td>Full Revolver Test</td>
<td>AF/RV/RP</td>
<td>Deploying structures under controlled Revolver</td>
<td>3/10/2014</td>
</tr>
<tr>
<td>Day in the life test - Payload R2</td>
<td>R2</td>
<td>Full simulation of two separate tests</td>
<td>4/23/2014</td>
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</tbody>
</table>
6.0 Project Management Plan (PMP)
PMP: Team Organization Chart

Advisors:
Dr. Dan Lawrence
Dr. Stephen Parke

Team Leader:
Drew Johnson

Mechanical Lead:
Lukas Rieke

Software Lead:
Devon Ellis

Electrical Lead:
Alex Hanson

Connor Back
Caleb Wolfe
Jordan Poundstone
Cassie Wade

Dakota Martin
Brenton Peck
Lucas Schamber
## PMP: Team Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/27/2013</td>
<td>RockSAT-X weekly member meeting</td>
</tr>
<tr>
<td>11/1/2013</td>
<td>Airfoil Testing</td>
</tr>
<tr>
<td>11/8/2013</td>
<td>Preliminary Design Review (PDR) Due</td>
</tr>
<tr>
<td>11/14/2013</td>
<td>Advisor Trip to JPL</td>
</tr>
<tr>
<td>11/15/2013</td>
<td>Airfoil Drop Test</td>
</tr>
<tr>
<td>11/15/2013</td>
<td>GoPro Controller Test</td>
</tr>
<tr>
<td>11/20/2013</td>
<td>Partnership with JPL Solidified</td>
</tr>
<tr>
<td>11/22/2013</td>
<td>RF Communication Test</td>
</tr>
<tr>
<td>11/22/2013</td>
<td>RF Data retrieval test</td>
</tr>
<tr>
<td>11/22/2013</td>
<td>RF Multi-Comm test</td>
</tr>
<tr>
<td>11/29/2013</td>
<td>Airfoil RF Comm Test</td>
</tr>
<tr>
<td>11/29/2013</td>
<td>Airfoil RF Multi-Comm Test</td>
</tr>
<tr>
<td>11/29/2013</td>
<td>Power/Timer Event Distribution Test</td>
</tr>
<tr>
<td>12/2/2013</td>
<td>Critical Design Review (CDR) Due</td>
</tr>
<tr>
<td>12/10/2013</td>
<td>Camera Actuation Test</td>
</tr>
<tr>
<td>12/10/2013</td>
<td>Revolver Motor Test</td>
</tr>
<tr>
<td>1/20/2014</td>
<td>Integrated Camera Test</td>
</tr>
<tr>
<td>1/20/2014</td>
<td>Integrated Revolver Test</td>
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<tr>
<td>1/27/2014</td>
<td>CDR Action Items Due</td>
</tr>
<tr>
<td>2/17/2014</td>
<td>Subsystem Testing Review (STR) Due</td>
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<tr>
<td>3/10/2014</td>
<td>First Full Payload Fabrication Complete</td>
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<tr>
<td>3/10/2014</td>
<td>Day in the life test - Payload R1</td>
</tr>
<tr>
<td>3/10/2014</td>
<td>Cold Environment Test</td>
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<tr>
<td>3/10/2014</td>
<td>Full Revolver Test</td>
</tr>
<tr>
<td>3/17/2014</td>
<td>Integrated Subsystem Testing Review (ISTR) Due</td>
</tr>
<tr>
<td>4/14/2014</td>
<td>Full Mission Simulation Review (FMSR) Due</td>
</tr>
<tr>
<td>4/23/2014</td>
<td>Day in the life test - Payload R2</td>
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<tr>
<td>5/5/2014</td>
<td>Weekly teleconferences begin</td>
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<tr>
<td>5/12/2014</td>
<td>Second FMSR Due</td>
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<tr>
<td>6/17/2014</td>
<td>GSE Checkouts at Refuge Inn</td>
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<tr>
<td>6/18/2014</td>
<td>Integration and Testing at WFF</td>
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<tr>
<td>7/21/2014</td>
<td>Launch Readiness Review (LRR) Due</td>
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<tr>
<td>8/5/2014</td>
<td>GSE Checkouts at Refuge Inn</td>
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<tr>
<td>8/6/2014</td>
<td>Final Integration and Testing at WFF</td>
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<tr>
<td>8/12/2014</td>
<td>Launch</td>
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<tr>
<td>9/19/2014</td>
<td>Final Reports Due</td>
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# PMP: Team Budget

<table>
<thead>
<tr>
<th>NNU RockSAT-X 2014 Team Budget</th>
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<tbody>
<tr>
<td><strong>Total Cost:</strong></td>
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<tr>
<td>$39,223.46</td>
</tr>
</tbody>
</table>

### Hardware:
- **Controller**: $50
- **Camera(s)**: $400
- **Electronics**: $75

### Travel:
- **Flight BOI-DCA**: $600.00

### Materials:
- **Aluminum**: $300
- **Machine tools**: $100

### Other:
- **PCB material**: $100

### RockSAT Fees
- **Deposit**: $ 2,000.00
- **Sharing Payload Cost**: $14,000.00
- **Dedicated Payload Cost**: $24,000.00

<table>
<thead>
<tr>
<th><strong>Deposit</strong></th>
<th><strong>$ 2,000.00</strong></th>
<th><strong>Large SUV</strong></th>
<th><strong>$ 832.23</strong></th>
<th><strong>$ 832.23</strong></th>
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<tr>
<td><strong>Sharing Payload Cost</strong></td>
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<td><strong>$ 29,223.46</strong></td>
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<td><strong>Dedicated Payload Cost</strong></td>
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<td><strong>$ 39,223.46</strong></td>
<td><strong>$ 39,223.46</strong></td>
<td><strong>$ 39,223.46</strong></td>
</tr>
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</table>

**Single Trip Total**: $ 6,099.23

**Two Trip Total**: $12,198.46

**Deposit status:** Invoice sent to department secretary
Northwest Nazarene University

Fall 2014 RS-X Team Availability Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td>7:00 AM</td>
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<td>3:00 PM</td>
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<tr>
<td>4:00 PM</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
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</tr>
</tbody>
</table>

ALL TIMES ARE IN MOUNTAIN TIME
## PMP: Latest Contact Matrix

### Fall 2014 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>OK to Add to Mailing List?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team Leader</td>
<td>Andrew Johnson</td>
<td>253-970-7899</td>
<td>253-970-7900</td>
<td>Yes</td>
<td><a href="mailto:drewjohnson@nnu.edu">drewjohnson@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrical Lead</td>
<td>Alex Hanson</td>
<td>509-690-8021</td>
<td>509-690-8022</td>
<td>Yes</td>
<td><a href="mailto:ahanson@nnu.edu">ahanson@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Mech Team</td>
<td>Connor Back</td>
<td>503-991-2315</td>
<td>503-991-2316</td>
<td>Yes</td>
<td><a href="mailto:cback@nnu.edu">cback@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Mechanical Lead</td>
<td>Lukas Rieke</td>
<td>509-845-9833</td>
<td>509-845-9834</td>
<td>Yes</td>
<td><a href="mailto:lrieke@nnu.edu">lrieke@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrical Team</td>
<td>Matthew Spires</td>
<td>208-553-3540</td>
<td>208-553-3541</td>
<td>Yes</td>
<td><a href="mailto:mspires@nnu.edu">mspires@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Mech/Electrical Team</td>
<td>Jordan Poundstone</td>
<td>208-477-7636</td>
<td>208-477-7637</td>
<td>Yes</td>
<td><a href="mailto:jpoundstone@nnu.edu">jpoundstone@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Mech Team</td>
<td>Caleb Wolf</td>
<td>253-820-7527</td>
<td>253-820-7528</td>
<td>Yes</td>
<td><a href="mailto:cwolf@nnu.edu">cwolf@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Lead Programmer</td>
<td>Devon Ellis</td>
<td>208-859-5446</td>
<td>208-859-5447</td>
<td>Yes</td>
<td><a href="mailto:Dellis@nnu.edu">Dellis@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrical Team</td>
<td>Brenton Peck</td>
<td>208-994-8729</td>
<td>208-994-8729</td>
<td>Yes</td>
<td><a href="mailto:Bpeck@nnu.edu">Bpeck@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrical Team</td>
<td>Lucas Schamber</td>
<td>208-392-2685</td>
<td>208-392-2686</td>
<td>Yes</td>
<td><a href="mailto:lschamber@nnu.edu">lschamber@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Electrical Team</td>
<td>Dakota Martin</td>
<td>208-761-5851</td>
<td>208-761-5852</td>
<td>No</td>
<td><a href="mailto:austinmartin@nnu.edu">austinmartin@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
<tr>
<td>Mechanical Team</td>
<td>Cassie Wade</td>
<td>208-8301462</td>
<td>208-8301463</td>
<td>Yes</td>
<td><a href="mailto:cassandrawade@nnu.edu">cassandrawade@nnu.edu</a></td>
<td>U.S.</td>
<td>Yes</td>
</tr>
</tbody>
</table>
PMP: Worries

- JPL collaboration insufficient to proceed
- Airfoil deployment could become jammed and restrict further deployment
- Procurement of flexible sensors will prove difficult to impossible in the time frame allotted
The NNU RS-X payload involves current NASA research and will serve as a small scale demonstration for the Printable Spacecraft program. By determining optimal airfoil design for upper atmosphere stabilization and RF communication through a low cost RockSAT launch, the CRev payload could save NASA valuable time and money and expedite the Printable Spacecraft program.

Next steps:
- Determine NASA RF protocol
- Obtain microcontrollers and begin small tests
- Finalize initial payload design and prep for fabrication