The *X*-Statics
Preliminary Design Review
October 2015

M. Becher, A. Boissonnas, S. Bradshaw, M. Hernandez, N. Lee, A. McCulloch, B. McMahon, M. Morse, J. Rice, T. Shannon, B. Weber

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PDR Outline

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PDR Outline

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PDR Outline

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PDR Outline

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Mission Overview

S. Bradshaw and J. Rice

Mission Statement

The objective of our mission is to observe very low frequency (VLF) electromagnetic waves such as sferics to infer ionospheric dynamics.

Image courtesy of the Stanford VLF Group

Theory and Concepts

- Sferic (radio atmospheric signal) is a broadband electromagnetic impulse generated by natural lightning discharges
- Electromagnetic waves such as sferics reflect from the ionosphere
- Some energy escapes into magnetosphere
- This energy may play a role in the removal of energetic particles from the radiation belts
- Importance: These particles can degrade and destroy satellites especially in periods of strong solar activity
- This reflection process has not been observed in situ

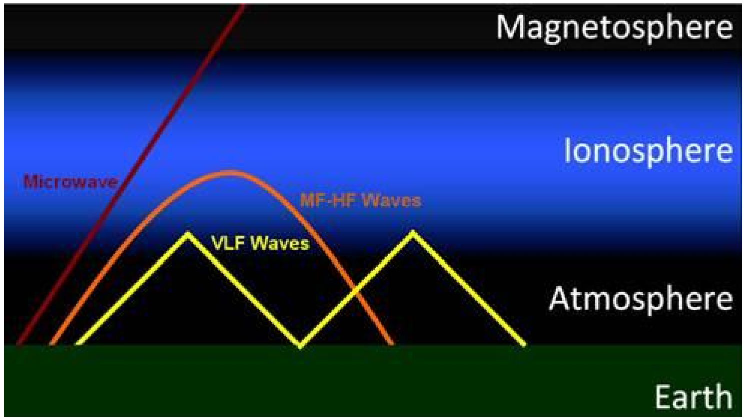


Image courtesy of the Stanford VLF Group

Mission Requirements

- Receive and store from electric and magnetic field signals
  - Picotesla for minimum magnetic field strength
  - Millivolt/meter for minimum electric field strength
- Store and record all data to onboard microSD card
  - Minimum ADC sampling rate of 100 kHz
  - Use of 5 analog to digital channels
  - Estimated total data will be around 500MB which will be stored onboard the microcontroller’s 2GB microSD card

Expected Results

- Receive 3-30 kHz signals from lightning
- These signals should disappear in the ionosphere
- Signals in ionosphere may indicate energy escape

Minimum Success Criteria

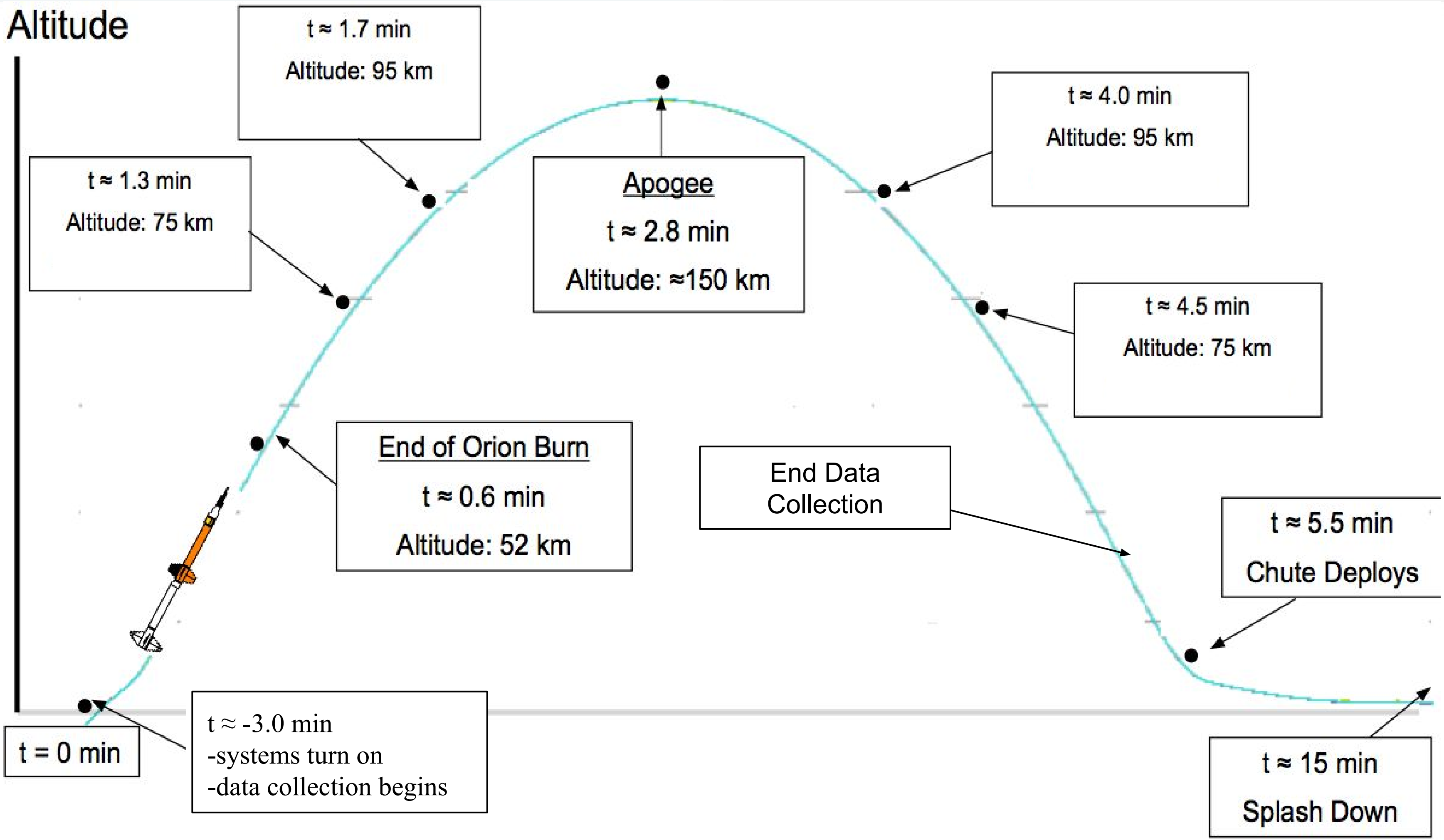
Minimum Success Criteria:

- Require preamplifiers to amplify signal
  - Measure sferic amplitude
  - Measure 60 Hz interference

Comprehensive Success Criteria:

- Record and store data in the netduino microSD card from antennae through preamplifiers

Concept of Operations



System Overview

A. McCulloch, J. Rice, T. Shannon

Science Design Overview

- Magnetic loop antennas (3) to receive magnetic field signals from the atmosphere
- Electric plate antennas (4) to receive electric field signals from the atmosphere
- Analyze electric field and magnetic field data
  - Observe electromagnetic waves
    - Infer ionospheric dynamics
    - Should appear below ionosphere. Above the ionosphere could indicate escape to magnetosphere
  - Compare to ground data

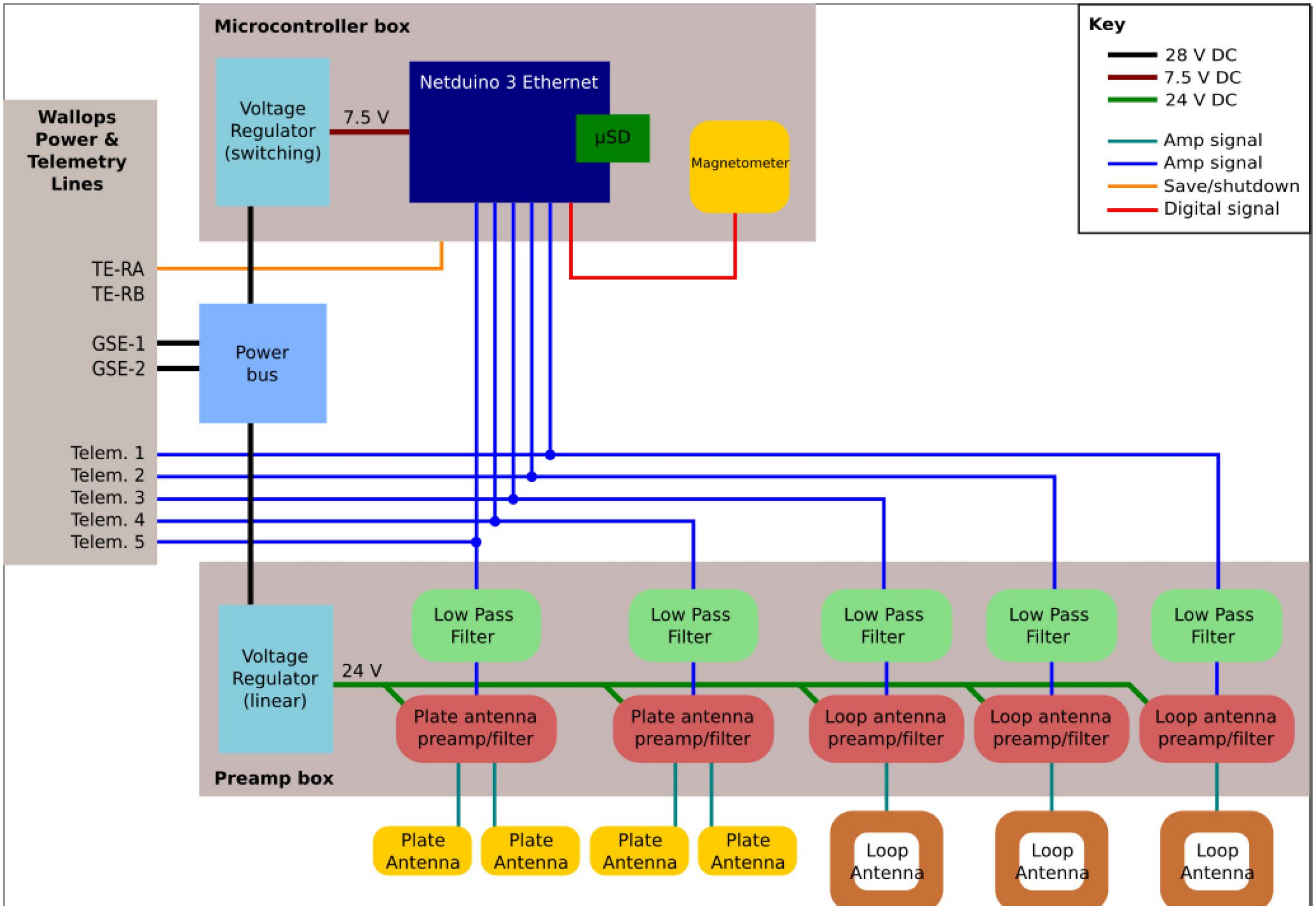
Engineering Design Overview

- All antenna will be connected to preamps
- Preamplifiers will be located far from loop antennas to reduce interference in a heat safe electronics box
- We will have the bottom mounting plate and a top plate to mount all instruments
- Electronics (including the microcontroller, magnetometer, and voltage regulator) will be located near power source in a heat safe electronics box

Top Level Requirements

The antennae will acquire EM field signals from the atmosphere that will be fed through preamps and converted into a digital signal for storage on a microSD card	Demonstration	This data acquisition and conversion will be performed with ground testing for verification
The antennae will not interfere with other experiments	Analysis	This system will be modeled in SolidWorks
The full system shall fit in on a single Rocksat-X deck	Inspection	A visual inspection will verify this requirement
The system shall survive the vibration characteristics prescribed by the Rocksat-X program	Test	This system will be subjected to these vibration loads in June during testing week.

Functional Block Diagram



Description of Partnerships

- We currently have no partnerships
- Collaborators:
  - Professor Morris Cohen (Georgia Tech)
  - Offered data from ground-based receivers

User's Guide Compliance

- Our payload will meet the 15±0.5 lbf weight requirement
- Our payload will fit in the 5.13x12 in area requirement
- Our payload's center of gravity will lie within the 1 x 1 x 1 inch envelope of the payload geometric center
- Our payload will be built to withstand 25 G on ascent
- Our payload will meet the activation requirements outlined in section 5.3.2.1
- Our payload will use the GSE line activation at T-3 minutes
- Our payload will use one timer event (5 seconds before power loss)

User’s Guide Compliance

- Our payload will not utilize high voltage
- Our payload will not have any deployables or booms
- Our payload will require 5 (2 E-field, 3 B-field) A/D lines
- Our payload does not possess any hazardous procedures
- Our payload will have the bolt heads on the bottom of the deck flush with mount
- Our payload is not utilizing any asynchronous/parallel lines
- Our payload will not transmit any RF signals
- All people on our team are US citizens

Special Requests

- Extra volume
  - Use the no-go-zone close to the longerons for electric field plates
- Faster sampling
  - The fastest possible sampling rate Wallops can offer us

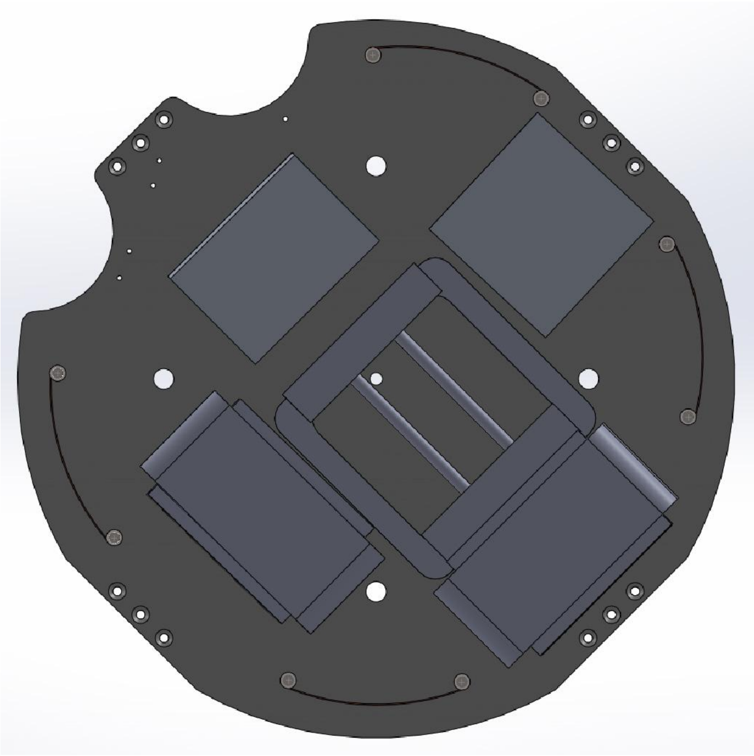
Subsystem Design

M. Becher, S. Bradshaw, N. Lee,
A. McCulloch, J. Rice, T. Shannon

Subsystem Design

- Subsystems of experiment
  - Structural
  - Power
  - Analog Electronics
  - Command and Handling
  - Software

Subsystem Design: Structure



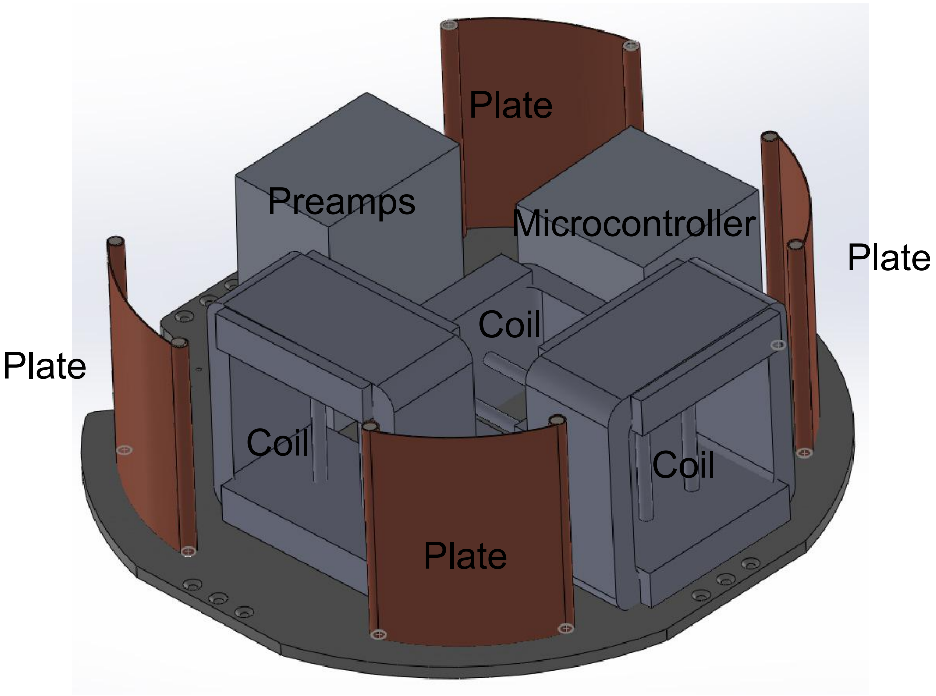
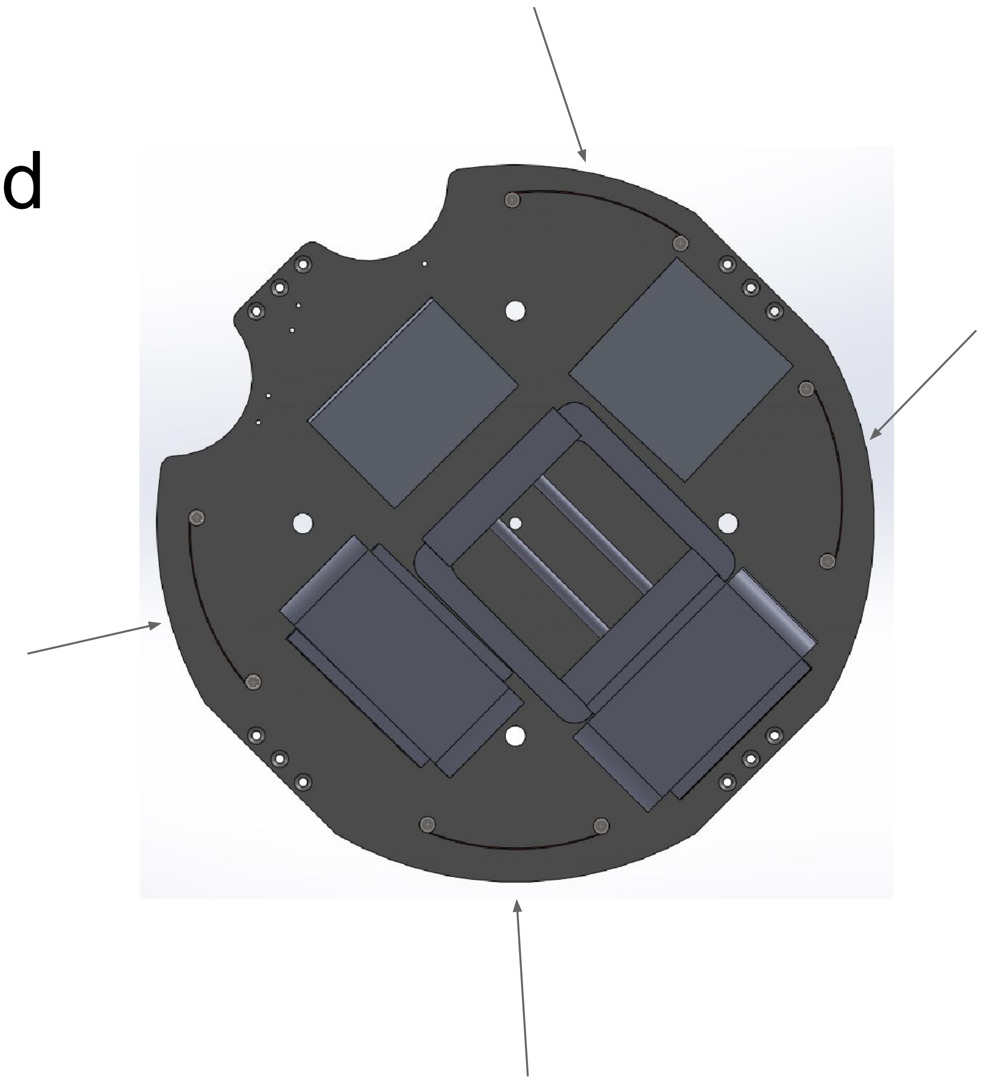


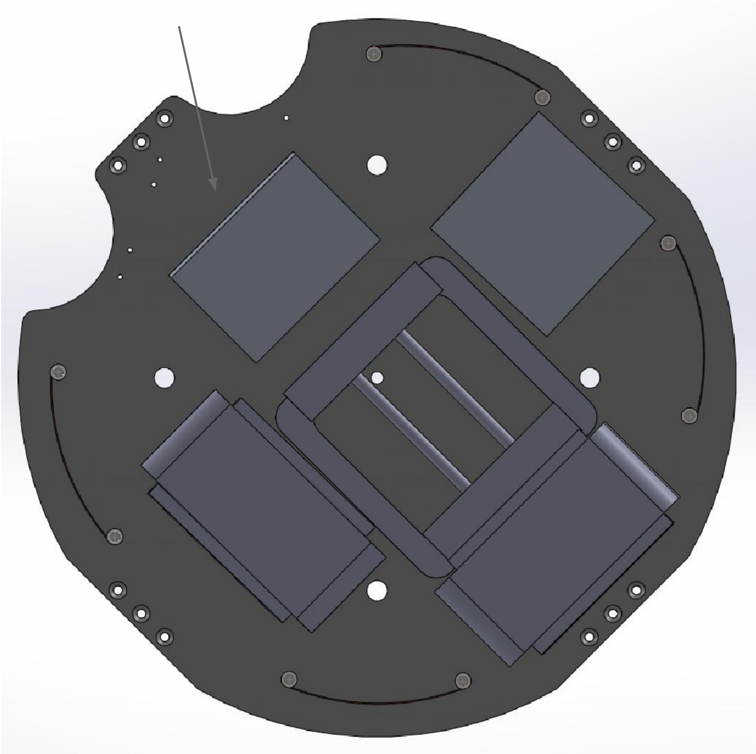
Plate antenna

Dimensions: Rods are 6.35mm in diameter and 83.06mm apart



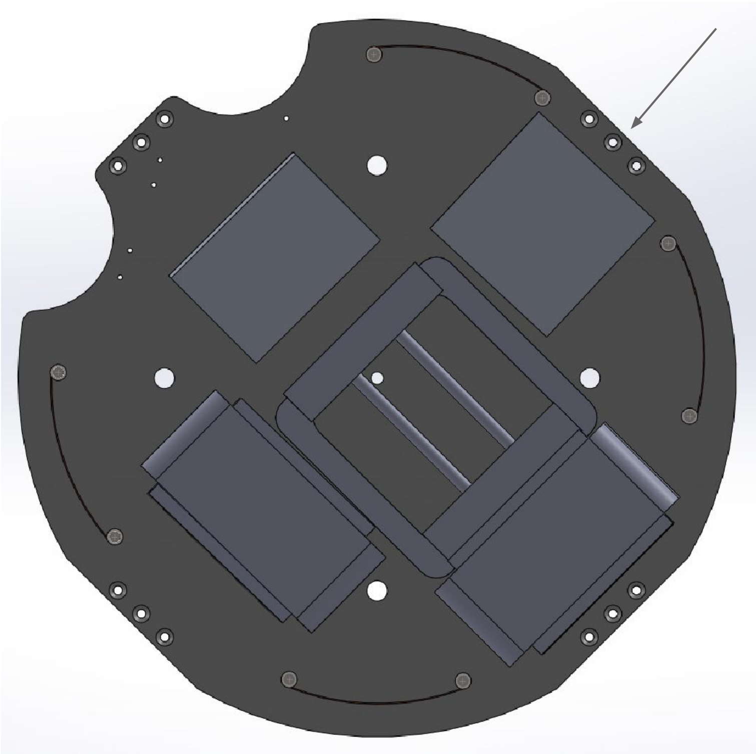
Microcontroller Box

Dimensions: 2.2in x 3.3in x 4.5in



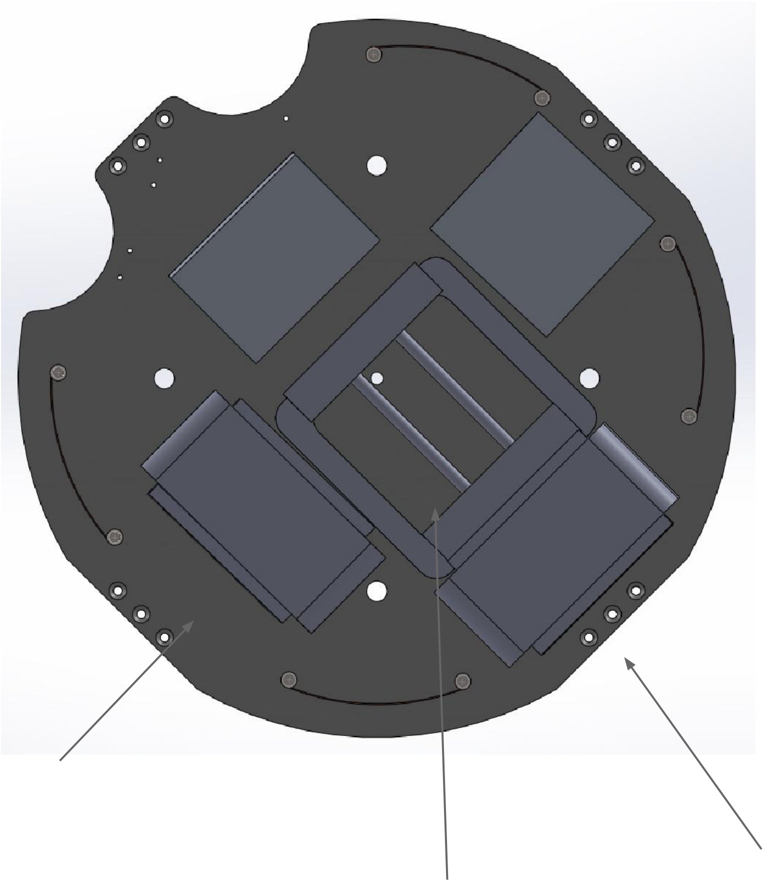
Preamplifier Box

Dimensions: 3in x 3in x 3in



Loop antennas

Dimensions: 4.5in x 2in on the outside, 3.5in x 2in on the inside, 4.5in tall



Subsystem Design: Structure

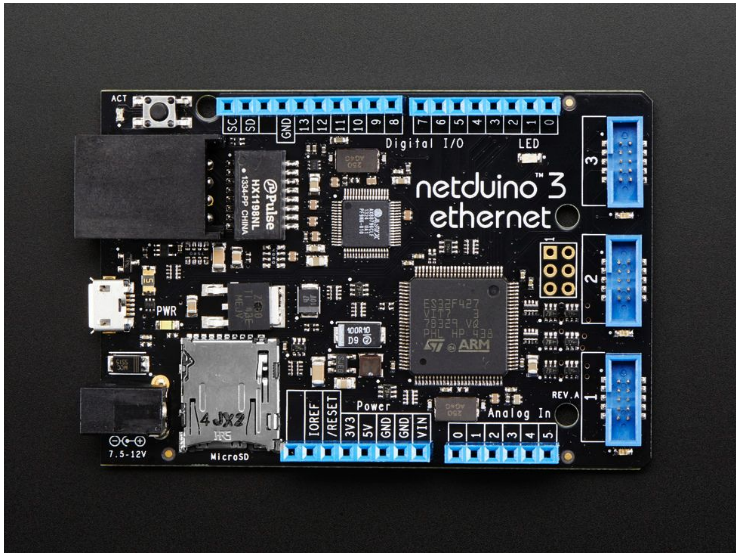
- Weight requirements will be upheld as our payload will be 15 lbs
- Current Issues
  - Supports in loops
  - Type of gasket to use
  - Sizes are not finalized

Subsystem Design: Power

- Power and Data
  - We plan on using two GSE lines and a single TE line provided by Wallops to power our electronics
  - Power electronics 180 seconds prior to launch
- Voltage Regulators
  - Microcontroller
    - We plan on using a switching regulator to power our microcontroller with a power input of 7.5V
  - Preamps and Low Pass Filters
    - We plan on using a linear voltage regulator to power our preamps and low pass filter with a power input of 24V

Subsystem Design: Power

- Electronics Hardware
    - Netduino 3 Ethernet
        - STMicro 32-Bit Microcontroller
        - ARM Cortex M4 microprocessor with clock speeds of 168 MHz
        - Onboard ADC with six analog pins and fourteen digital pins.
        - Onboard MicroSD slot
        - Power Input of 7.5 - 12 VDC
        - Dimensions: 3.2” x 2.1” x 0.5”
        - Weight: 27.0 g



Loop Antennae

- 3 loop antennae
- Detect magnetic field in pT (picotesla)
- Output in μV (microvolts) to be amplified
- VLF frequency between 3kHz and 30kHz
- Logistics
  - Magnet wire AWG between 32 and 40
    - .2 to .08 mm in diameter
  - Turns ~ 55000
  - Amount of Wire: ~ 22 km
  - Resistance ~ 25000 ohms
  - Cross Sectional Area ~ .01 m^2
  - Wire Layout ~ 450 wide (.06 m), ~125 tall (.0175 m)
  - Weight ~ 1 kg per antenna

Loop Antennae

- Current Issues
  - Logistics dependent on type of magnet wire
  - Winding the antenna
  - Materials for magnet wire support skeleton
  - Variance in areas of loops

Plate Antennae

- 4 copper plates oriented along outer edge of canister
  - 2 plates across from each other connected to be a dipole antenna
- Surface Area ~ 21.15in^2
- Thickness: thin metal plate with a material that can withstand reentry as a backing
- Weight ~ .856 lbs per plate (if plates are .125 inches thick of solid copper)
- E-field moves past plates inducing charge on them
  - Expecting to receive 10^{-4} V/m
  - Wires will run from each of the plates to the preamplifiers

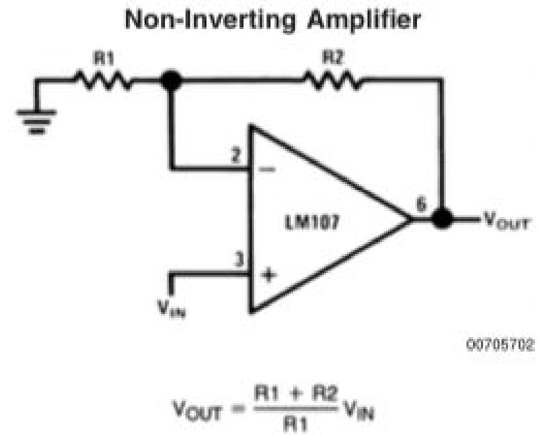
Plate Antennae

Issues

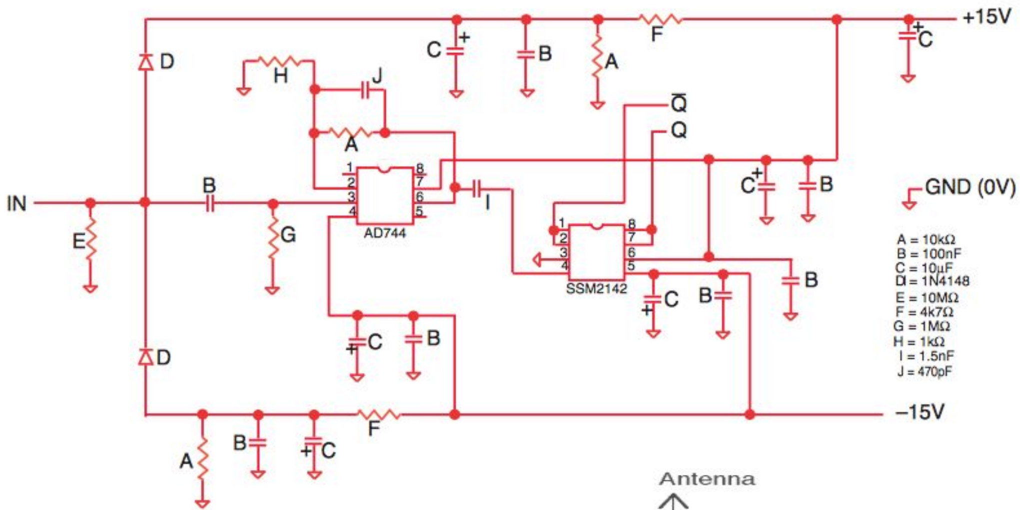
- Material for antenna backing (circuit board laminate?)
- Weight of plates
- Being inside or outside our cannister

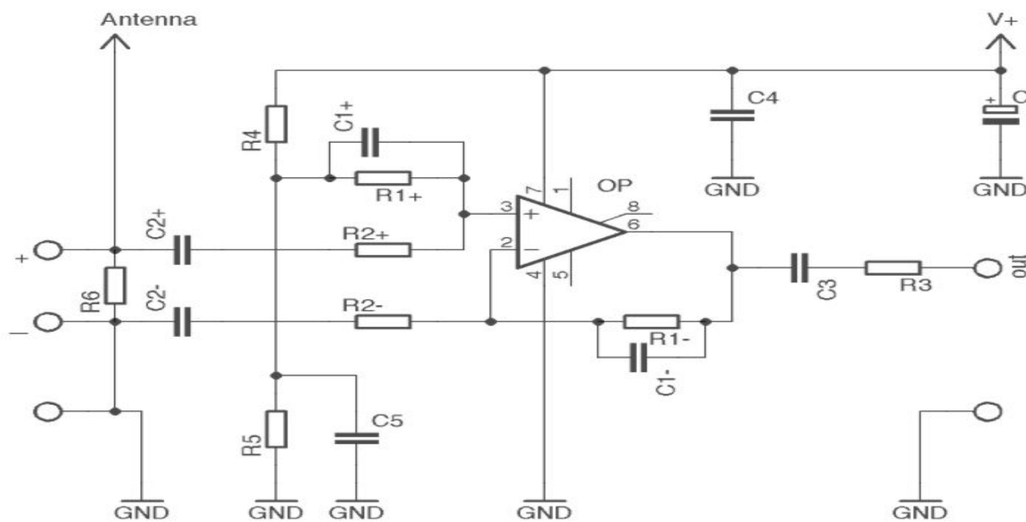
Amplification

- Non-inverting amplifiers
  - Loop and plate antennae
  - Prototype (breadboards)
    - Working with +12V & -12V
    - Signal generator
    - Use of different resistors
  - Eventually use PCB (about 3”x3”)
    - Weight: .03-.05 lbs with components
  - Looking into other circuit options
  - Understand what components are needed (troubleshooting)



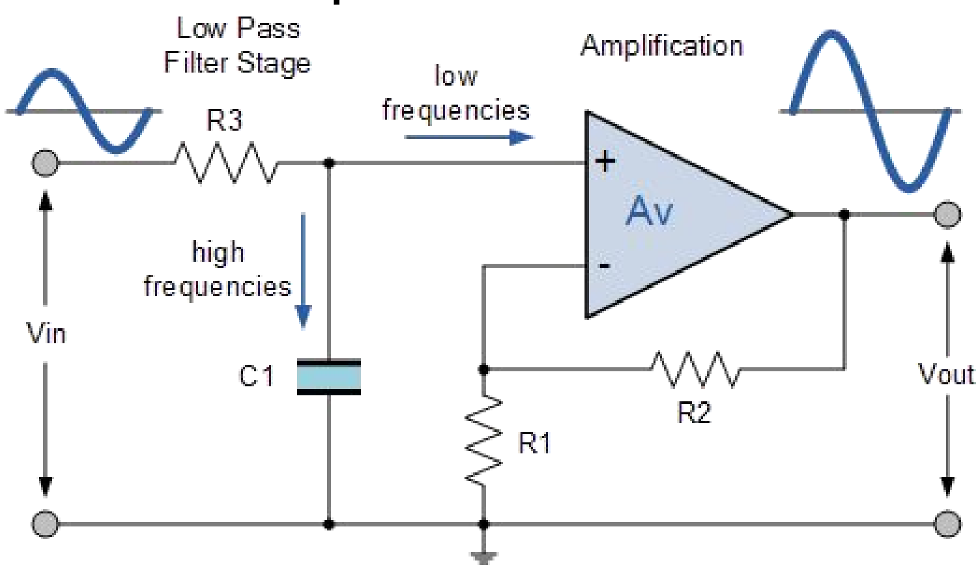
Amplification





Filters

- Active low pass filter
  - Allows for amplification (as opposed to passive)
  - Used to filter out high frequency noise
    - Don’t expect to hear much, if any low frequency noise
  - Dependent on amplifier circuit



Analog Electronic Subsystem

- Current:
  - Loop Antennae
    - Prototyping coils using magnet wire
    - Equivalent circuits
  - Plate Antennae
    - Have not prototyped yet
    - Examining best way to amplify signal
      - Equivalent circuits
  - Amplifiers
    - Prototyping non-inverting amplifiers
      - Understanding how different components affect performance
      - Use of voltage divider to simulate smaller inputs
      - Circuit simulations

Analog Electronic Subsystem

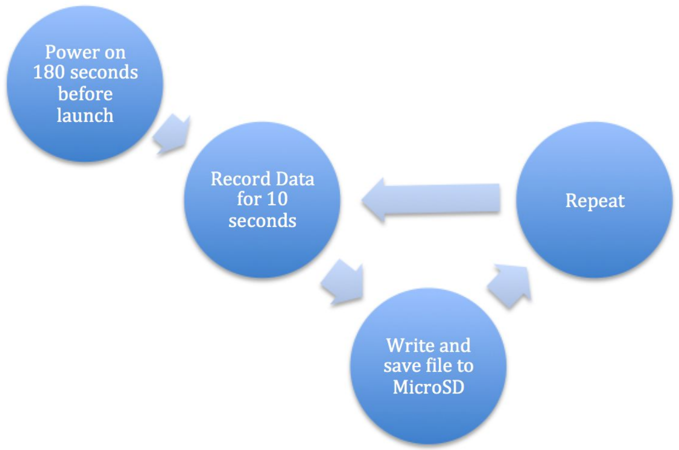
- Near future:
  - Loop Antennae
    - Build more prototypes
      - Different magnet wire
  - Plate Antennae
    - Equivalent circuits
  - Amplifiers
    - Examine different circuit options
      - Troubleshoot best options and components
      - Work with low pass filters
  - Overall
    - Prototype entire system
      - Using equivalent circuits
      - Circuit simulations

Subsystem Design: Command and Handling

- Data Storage
  - We will be writing all our data from our antennas and magnetometer to the microcontroller's onboard microSD card.
- Backup Storage
  - We plan to use Wallop's provided analog channels as a backup data option. We are doing this out of precaution just in case anything goes wrong with our data acquisition.

Subsystem Design: Software

- Data Safeguard
  - Devised plan to ensure data will be committed to microSD memory before electronics shutdown time.



- Total Data Volume
  - We plan to record around 500MB of data that will be stored on our 2GB onboard microSD card.
  - Each file will be approximately 1-2 MB each.

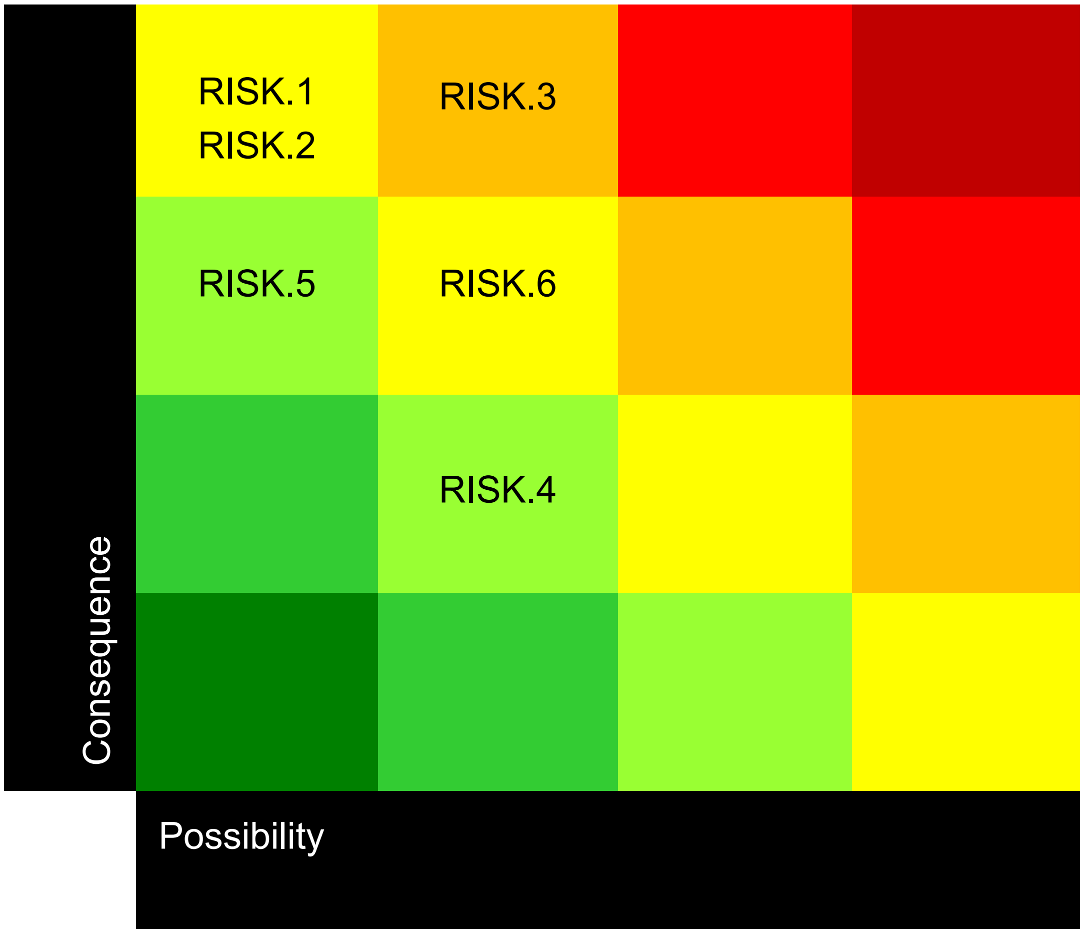
Subsystem Design: Software

- Current Issues
  - Sampling Rate
    - The Netduino 3 Ethernet is preloaded with .NET Micro Framework, which compiles managed code. (This drastically slows down the true potential of the microprocessor)
    - After testing, we found that it had an ADC read sampling rate of about 15 kHz with the managed code (The microprocessor is rated up to 2.4MHz)
    - We are now finding alternative ways to overwrite or get around the .NET Micro Framework (i.e. Native Code Interop and Native Code Compilers) to get to our desired sampling rate of 100kHz

Risk Matrices

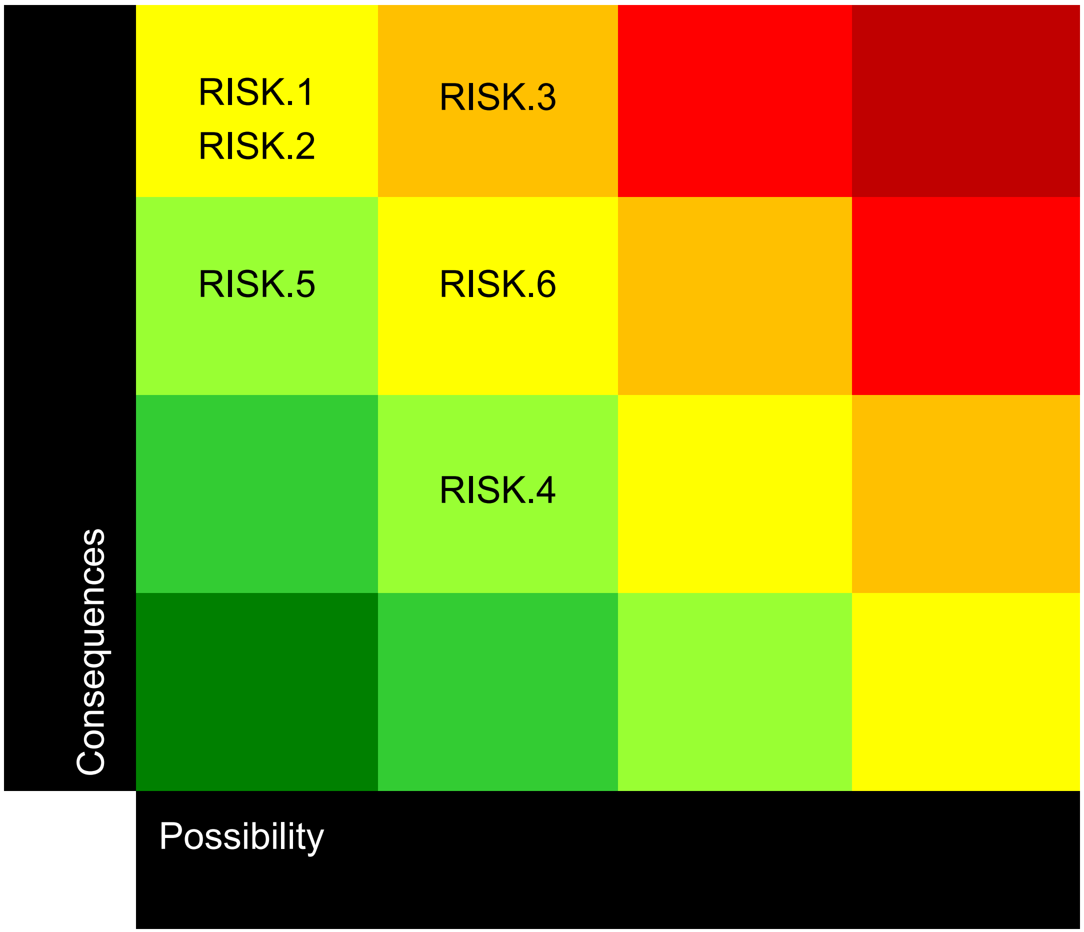
J. Rice

Risk Walk-Down



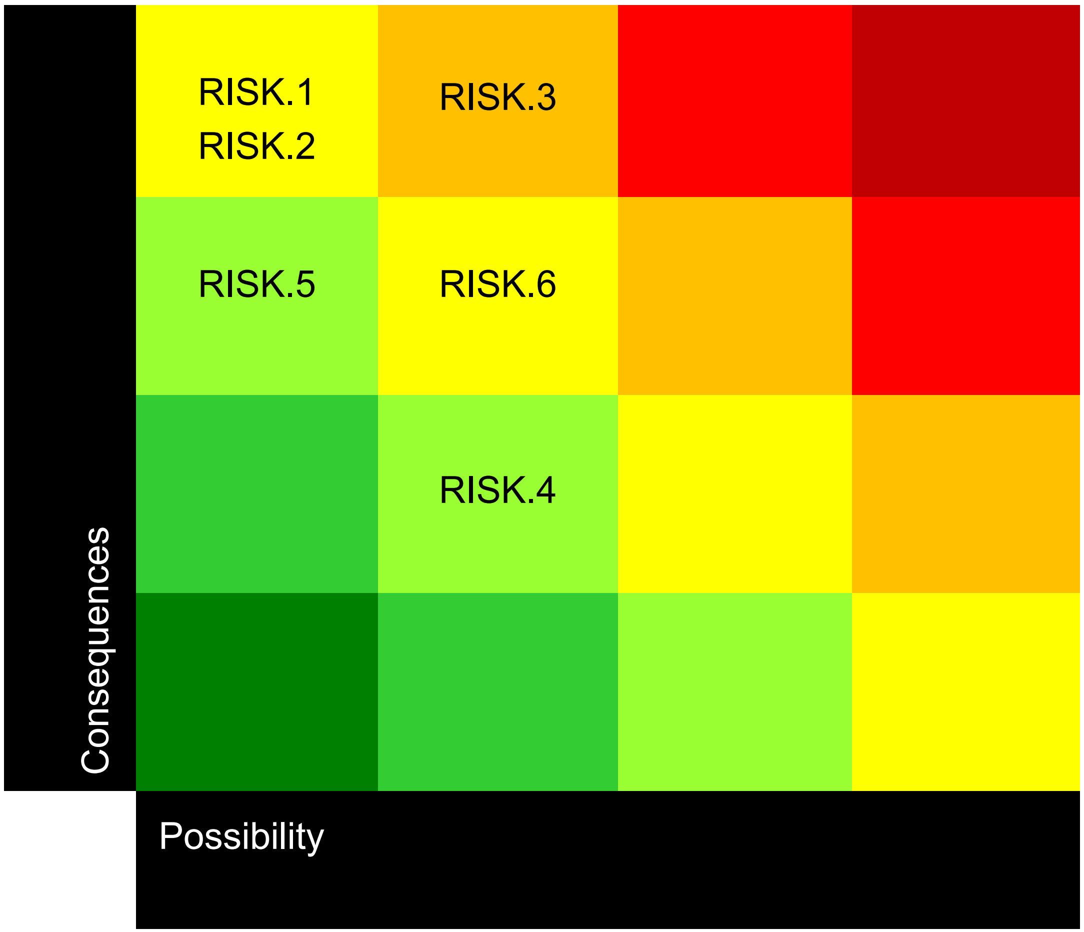
- RISK.1: Microcontroller fails in flight
  a. Mission objectives will not be met
- RISK.2: Primary containment for microcontroller box is compromised
  a. Data will not be accessible and mission requirements will not be met
- RISK.3: Structure fails during flight
  a. Mission objectives will not be met

Risk Walk-Down



- RISK.4: Antennae failure
  a. Mission requirements will not be met
- RISK.5: Primary containment for preamps box
  a. Parts will not be reusable

Risk Walk-Down

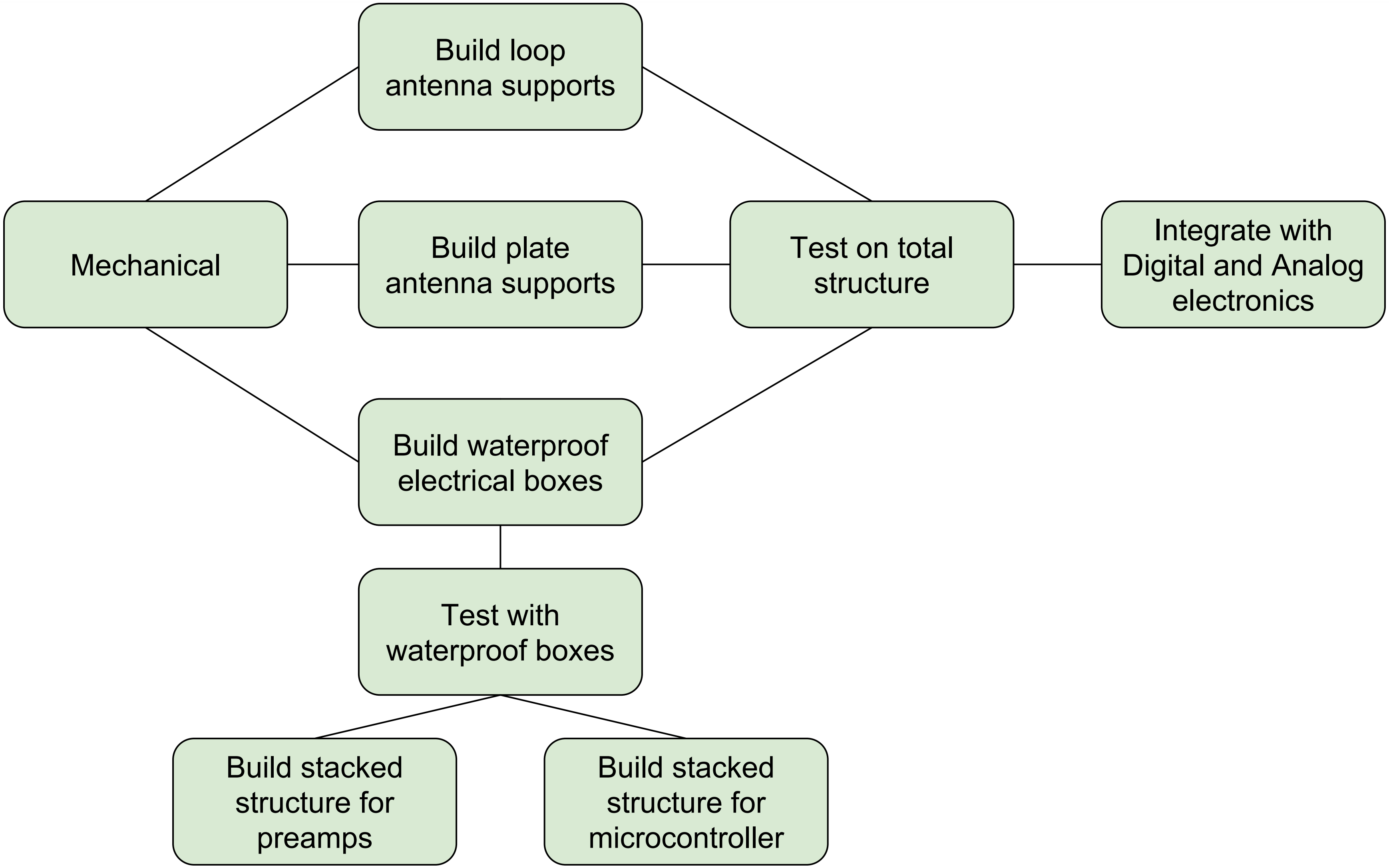


- RISK.6: Electronic parts needed are not found or are not suitable for our purposes
  a. Testing and programming may be delayed

Test and Prototyping Plan

N. Lee, A. McCulloch, T. Shannon

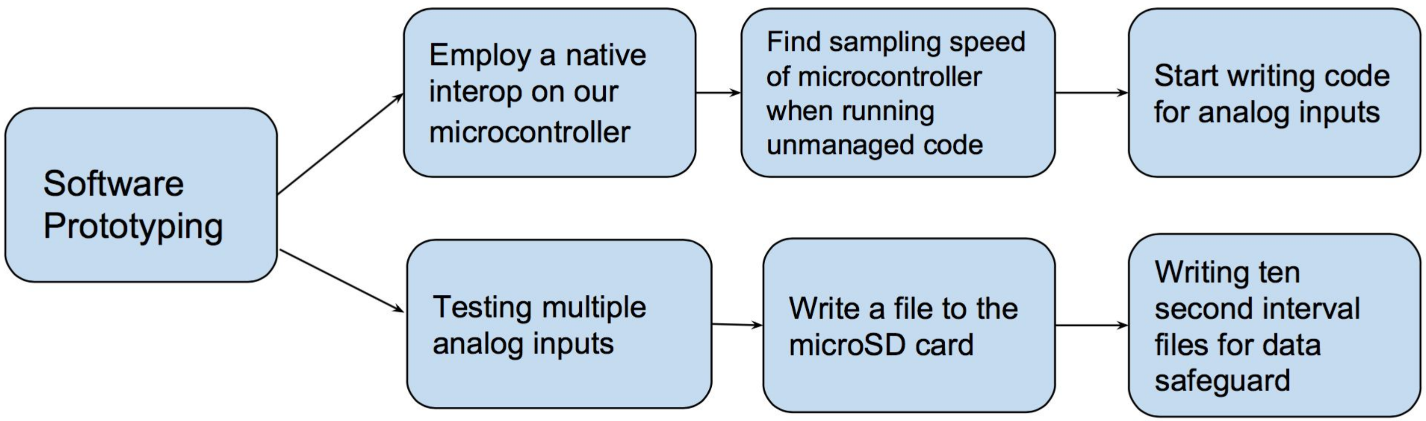
Structural Prototyping



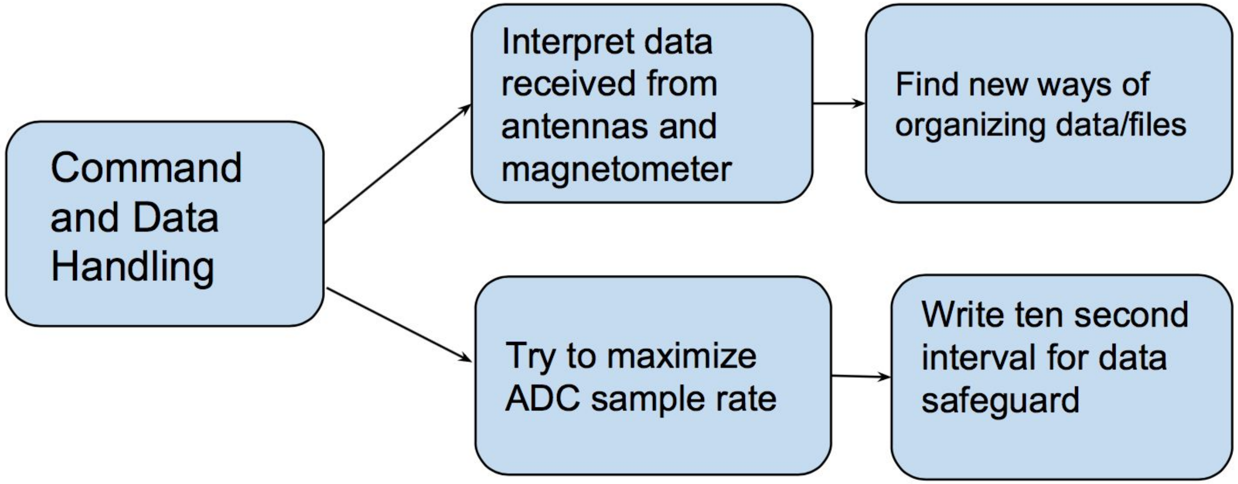
Power Prototyping

- Voltage Regulators
  - Test both switching and linear voltage regulators
  - Try powering entire system
- Preamps
  - Test linear voltage regulator
  - Output signals to Netduino from an antenna prototype
  - See if we get significant data
  - This will help give us a better idea of how the system is going to work, as well as give us enough time to fix any problems that may occur while testing.

Software Prototyping



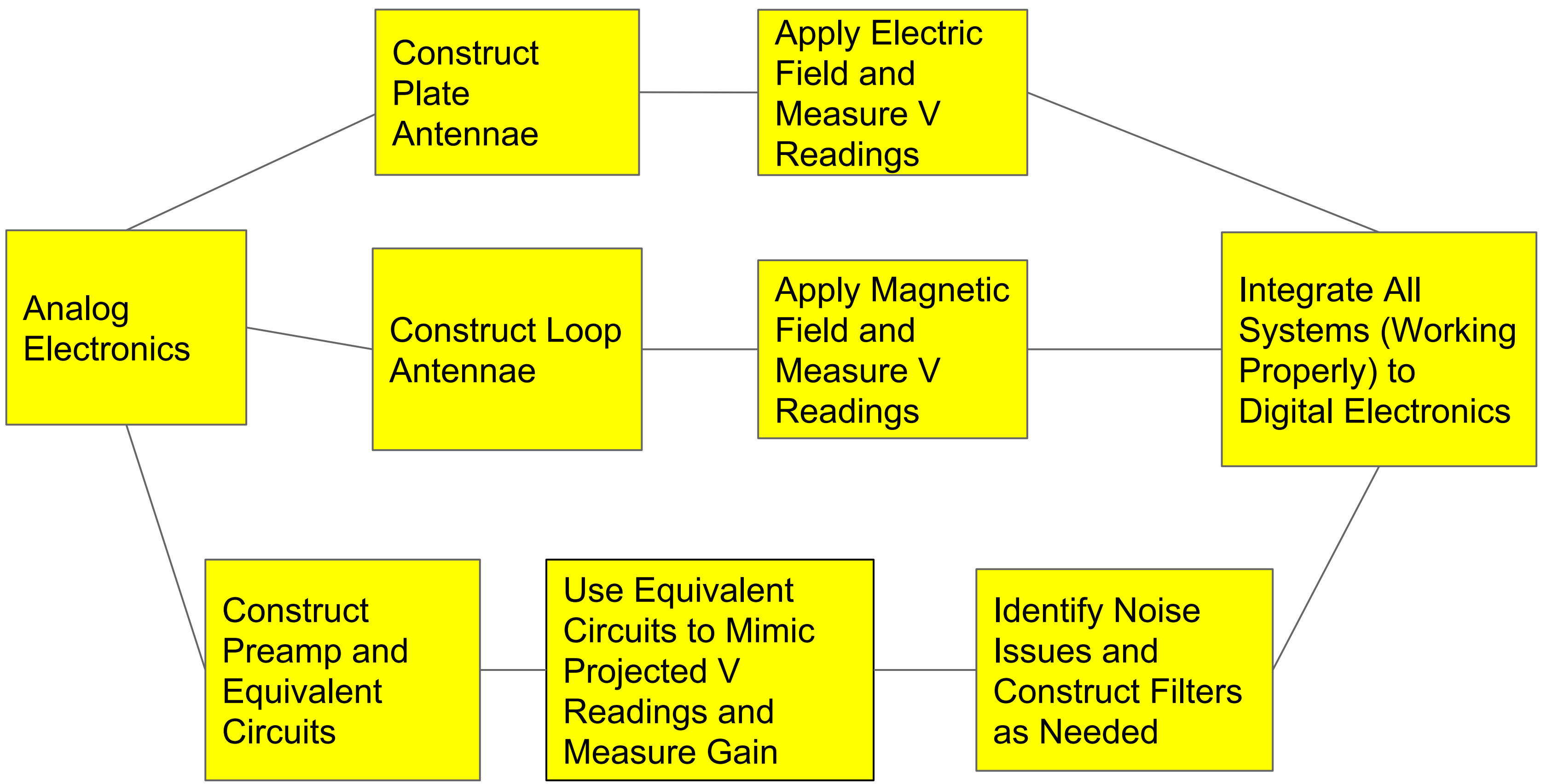
Command and Data Handling Prototyping



Analog Electronics Prototyping

- Loop Antennae
  - Construct prototype
  - Apply magnetic field and measure induced voltage
- Plate Antennae
  - Construct prototype
  - Apply electric field and measure potential difference
- Build and test preamp circuits using equivalent circuits
  - Will test for gain and functionality
  - Equivalent circuits to simulate projected readings
  - Gathering potential noise data
- Add filters into circuits to minimize noise
  - Troubleshoot with filter circuits

Analog Electronics Prototyping



Project Management Plan

J. Rice

Schedule

Milestone	Date
Finalize structural design	November
Critical Design Review	November 30th-December 4th
Down-Select	January
Purchasing equipment	January-February

Budget

Item	Estimated Cost	Total Cost
RockSat-X Can and Registration	$14000	$14000
Travel and lodging	$3300/person	$16500
Construction	$4000	$4000
Total		$34500

Funding

Funding Source	Estimated Amount
WSGC Grant	$12000
Natural sciences Division	$7000
Carthage Student Government	$9000
Another funding source	$6500
Total	$34500

Team Organization Chart

- Advisor: Dr. Brant Carlson
  - Team Lead: Jordan Rice
    - Conceptual Lead: Stephanie Bradshaw
    - Analog Lead: Nate Lee
      - Stephanie Bradshaw
      - Max Becher
    - Digital Lead: Thomas Shannon
      - Ben Weber
      - Michael Hernandez
      - Marshall Morse
    - Mechanical Lead: Adam McCulloch
      - Breonna McMahon
      - Arianne Boissonnas

Availability Matrix (newest)

The *X*-Statics/Carthage College:					
PDR RS-X Team Availability Matrix					
PLEASE USE MOUNTAIN TIME ZONE TIMES (MST)					
Nov 2-6	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
7:00 AM					
8:00 AM					
9:00 AM					
10:00 AM					
11:00 AM					
12:00 PM					
1:00 PM					
2:00 PM					
3:00 PM		1			
4:00 PM		2		4	
5:00 PM		3		5	

Contact Matrix (newest)

RSC 2016 Contact List for Carthage College

Team Member	Email Address	Phone Number
Jordan Rice (team lead)	jrice@carthage.edu	8163051518
Nate Lee (analog lead)	nlee1@carthage.edu	8473631899
Ben Weber (digital lead)	bweber1@carthage.edu	9206763124
Adam McCulloch (mech. Lead)	amcculloch1@carthage.edu	9207237376
Max Becher (analog)	mbecher@carthage.edu	7157816152
Stephanie Bradshaw (analog)	sbradshaw@carthage.edu	9208962185
Tom Shannon (digital)	tshannon@carthage.edu	2624961711
Michael Hernandez (digital)	mhernandez3@carthage.edu	5745180103
Ariane Boissonnas (mech.)	aboissonnas@carthage.edu	6085146229
Breonna McMahon (mech.)	bmcmahon1@carthage.edu	3195411454
Brant Carlson (advisor)	bcarlson1@carthage.edu	7202204869

Status of Deposit

- Starting grant proposal for Wisconsin Space Grant Consortium
- Begin scholarship application for Carthage Student Government

Worries

- ADC sample and write rate not fast enough
  - Currently working on a prototype
  - Backup plans:
    - xCORE
    - Sample channels in short bursts
    - Work with reduced sample rate
- Preamplifier gain not high enough
  - Working on a prototype
  - Backup plans:
    - Add additional gain stage
    - Add filter to remove noise

Worries

- Loop antenna winding impractical
  - Working on a prototype
  - Back up plans:
    - Fewer turns
    - Thicker wire
    - Round coils

Conclusion

- Reasons we deserve to fly:
  - Meaningful science goals as these observations have never been made before
  - We have a large and very active team and are learning many new things
- Steps to get to CDR
  - Overcome current worries