WV SPACE

Critical Design Review

WVU MU FSU BRCTC WVU-TECH BVCTC SU WVWC WVSU NASA IV&V

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CDR Presentation Contents

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Mission Overview

Steven Hard

Mission Statement

To embark on a collaborative effort with academic institutions across the state of West Virginia for development and expansion of knowledge and practical experience in designing, building, launching, and operating space payloads

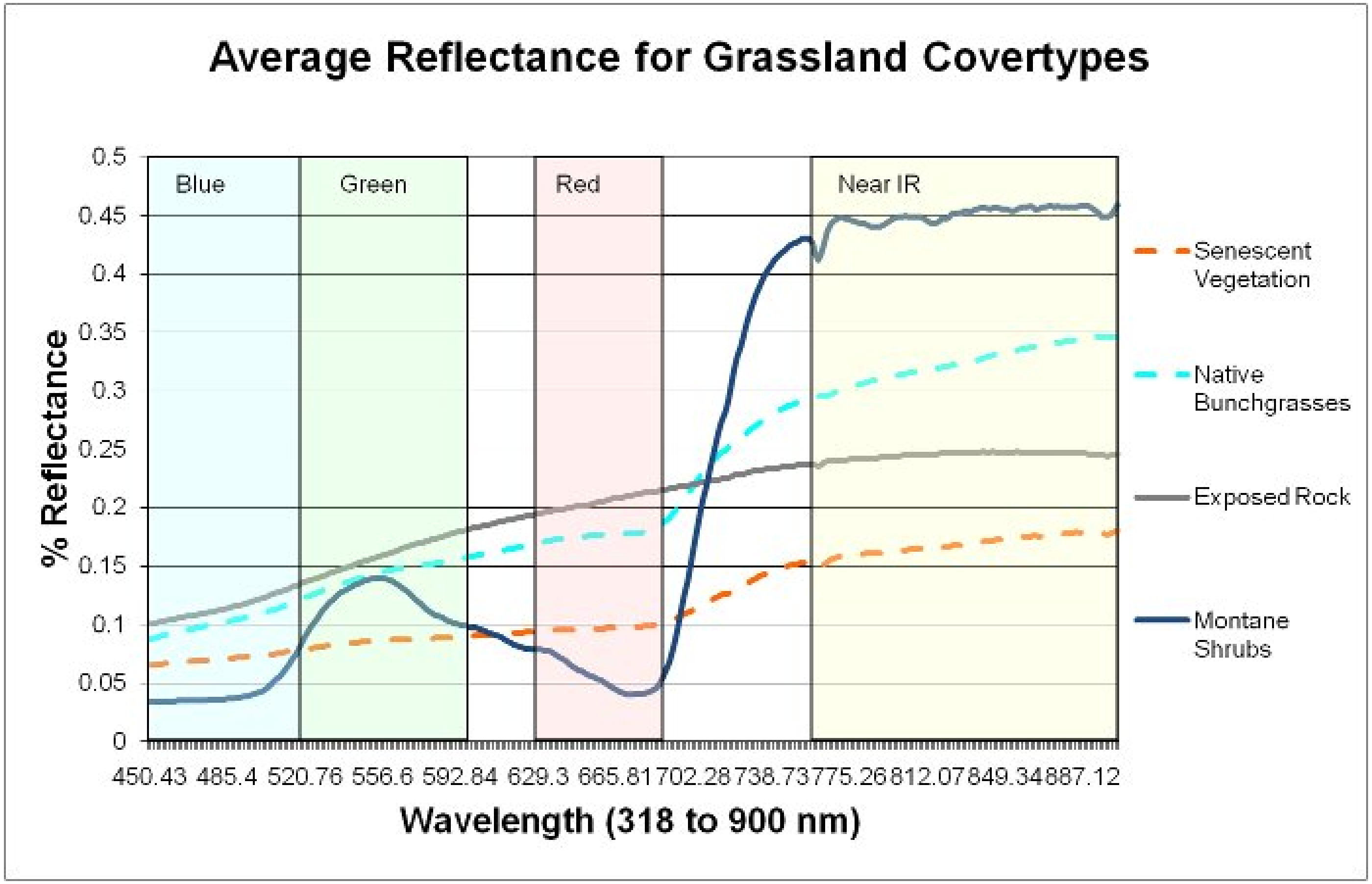
WV RSC'16 Mission Overview

- Goal: Develop and test several science and engineering experiments for space operations
- Objectives:
  - Capture NIR Earth images from space
  - Measure plasma density in upper atmosphere
  - Measure atmospheric pressure and magnetic field of Earth
  - Gather redundant flight dynamics data
  - Determine attitude in space relative to sun
  - Stress test ABS plastic in space
- Port Access: Optics port (1) and Multipurpose port (2)
- Benefits SmallSat community
  - Develop COTS orientation estimation techniques
  - Develop low-cost Langmuir probe package for plasma studies
  - Prove feasibility of 3D printed structural elements

Expected Results: WVU-CAM

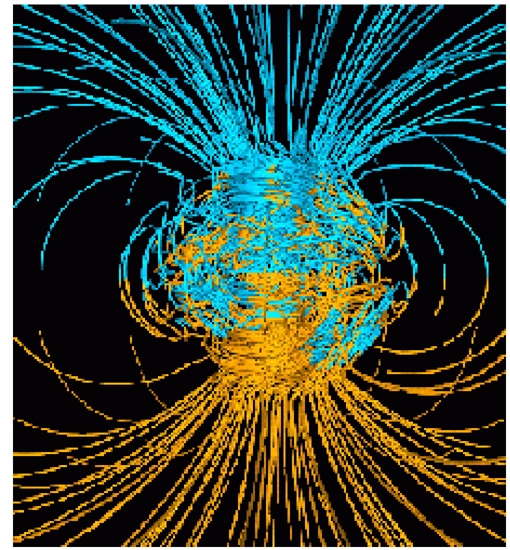
- Sequence of 60 second video clips throughout entire flight and payload recovery
- Extraction of “good” images from video data during flight
  - Good: visibly distinguishable land mass or NIR source
- Expect to create a Normalized Difference Vegetation Index (NDVI) of reflected NIR light intensities (from 0.7 to 1.1 µm) for each good image
  - Index of plant “greenness” or photosynthetic activity
- Visual telemetry showing evidence of any faults experienced during flight

Expected Results: NIR-NDVI



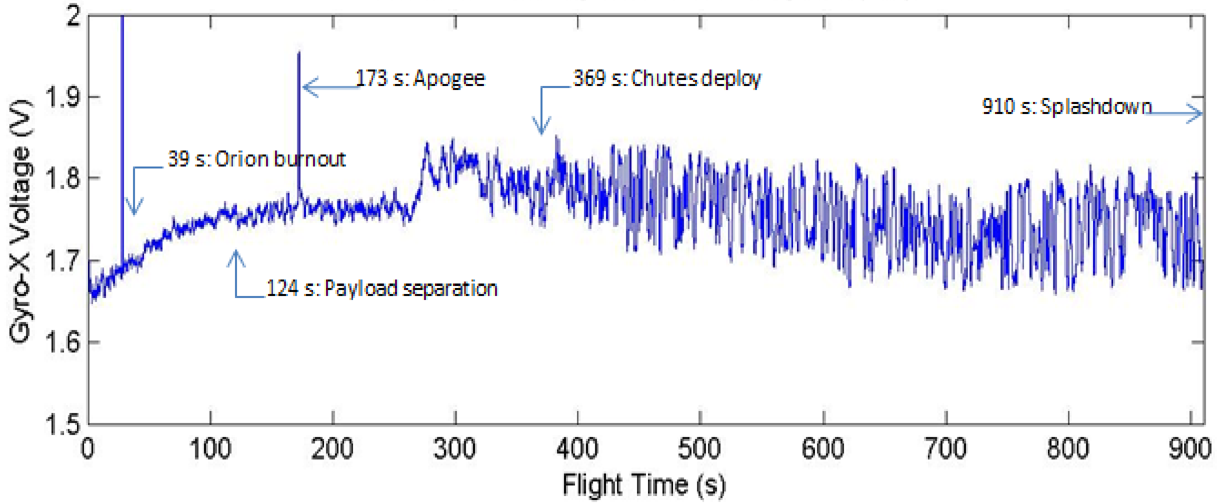
Expected Results: SPACE (8x)

- Background
  - Known variations of approximately (~0.2G) in the magnitude of Earth's surface magnetic field
- Purpose
  - Are there similar variations with altitude?
  - Based on NOAA's maps, have there been changes since last mapping?
    - What is the time scale for variations in earth's surface B-field?
    - Understanding complicated nature of Earth's B-field
    - Important for understanding the Earth's dynamo and how its B-field changes over time



Expected Results: SPACE (8x)

- Comparison of COTS IMU performance with high resolution IMU

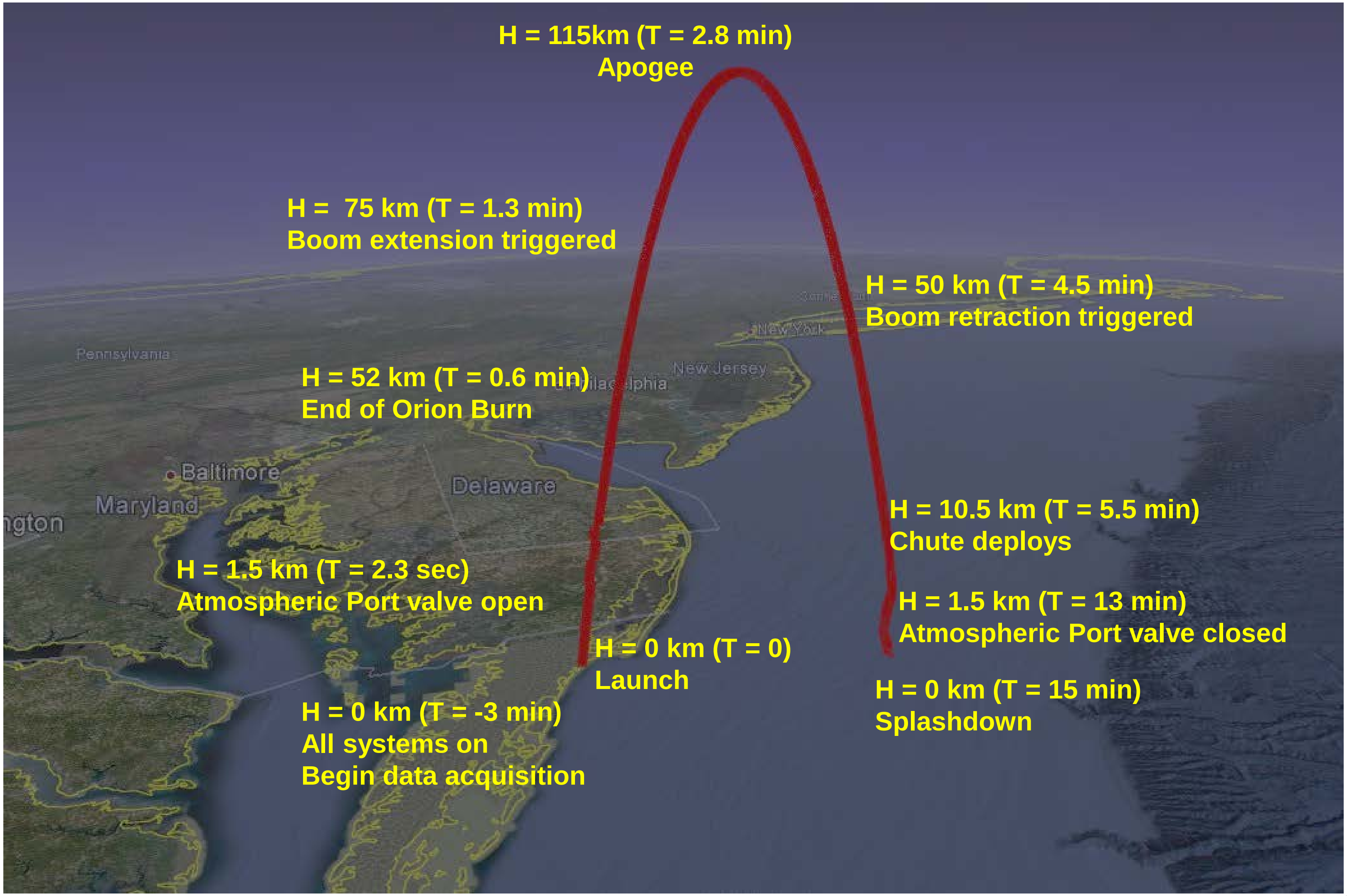


- Increased radiation levels with altitude
  - This radiation will be measured in terms of keV (kilo electron volts)
  - Expect that the radiation will be between .09-2.5 KeV in the E layer and 1-20 KeV in the D layer
- Detection of cosmic rays near apogee

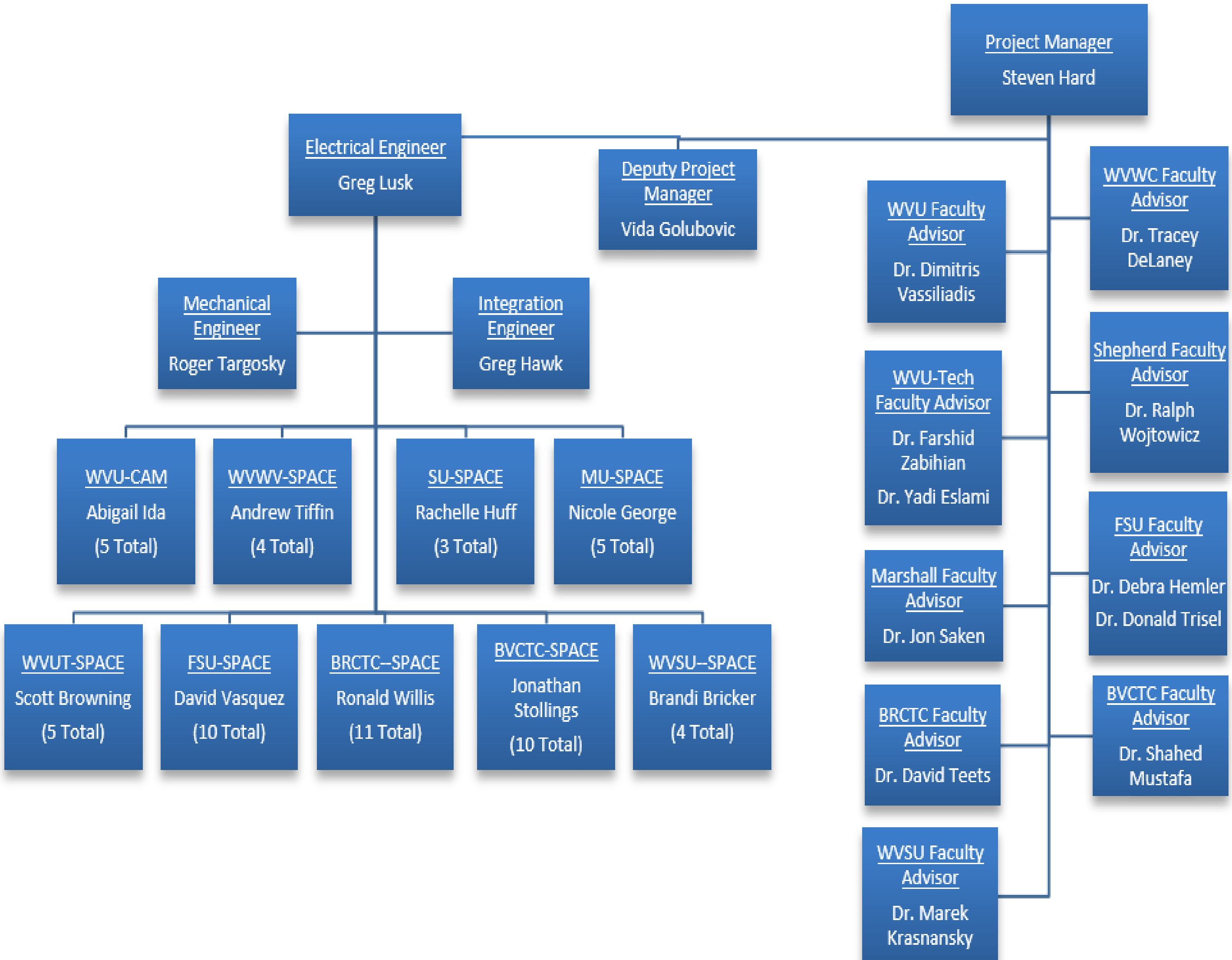
Success Criteria

- Minimum Success Criteria:
  - Sing NIR vegetation image
  - Visual indication data through entire flight
  - LP data near apogee
  - Measurable variations in solar panel currents
  - IMU and B-field data between 0km and apogee
- Comprehensive Success Criteria:
  - Data from all experiments collected throughout entire flight
  - IMU and B-field data is in accordance (< ~10% variance) with the other subteam data and the NOAA model
  - Determine plasma density in upper atmosphere
  - Estimate sun vector to within 3°
  - Determine stress variations in ABS plastic during flight

Concept of Operations



Organizational Chart



Design Modifications

Changes Since PDR

- WVU-CAM
  - Added RGB pi camera to perform NDVI analysis
- WVU-LP
  - Heritage experiment added with minor design modifications
  - Maximizes shared use of Multipurpose port
  - 3 data pins + PWR/GND
- MU-SPACE
  - Added 3"x3" solar panel to mechanical model
- FSU-SPACE
  - Shared use of the Multipurpose port rather than the Atmospheric port
  - No hermetically sealed box is needed, nor any airtight tubing
  - 2 data pins + PWR/GND
- BRCTC-SPACE
  - Shared use of the Multipurpose port rather than the Atmospheric port
  - No hermetically sealed box is needed, nor any airtight tubing
  - 2 data pins + PWR/GND

Changes Since PDR (Cont)

- SU-SPACE Since the PDR the following has changed:
  - Removed Honeywell Magnetometer
    - With compasses on 3 different IMU's for comparison, it wasn't necessary
  - Added the ADIS 16407
    - Wanted to be able to experiment with 10 DOF ADIS
  - Now using 2 Pro Micros to manage data
    - Needed this to manage the 3 IMU's with temp sensor and openlog
- WVSU-SPACE
  - Geiger counter, accelerometer, magnetometer are only sensors to be used
    - Ozone sensor and light sensor removed as atmosphere ports no longer free.
- PDS
  - Using 2x LiPo packs 7.4V 5000 mAh
    - Provides maximum energy density (will not charge at Wallops)
- SIS
  - Addition of a fourth Makrolon plate
    - Provide extra protection layer
    - Additional mounting surface for backup battery

Descopes/Off-ramps

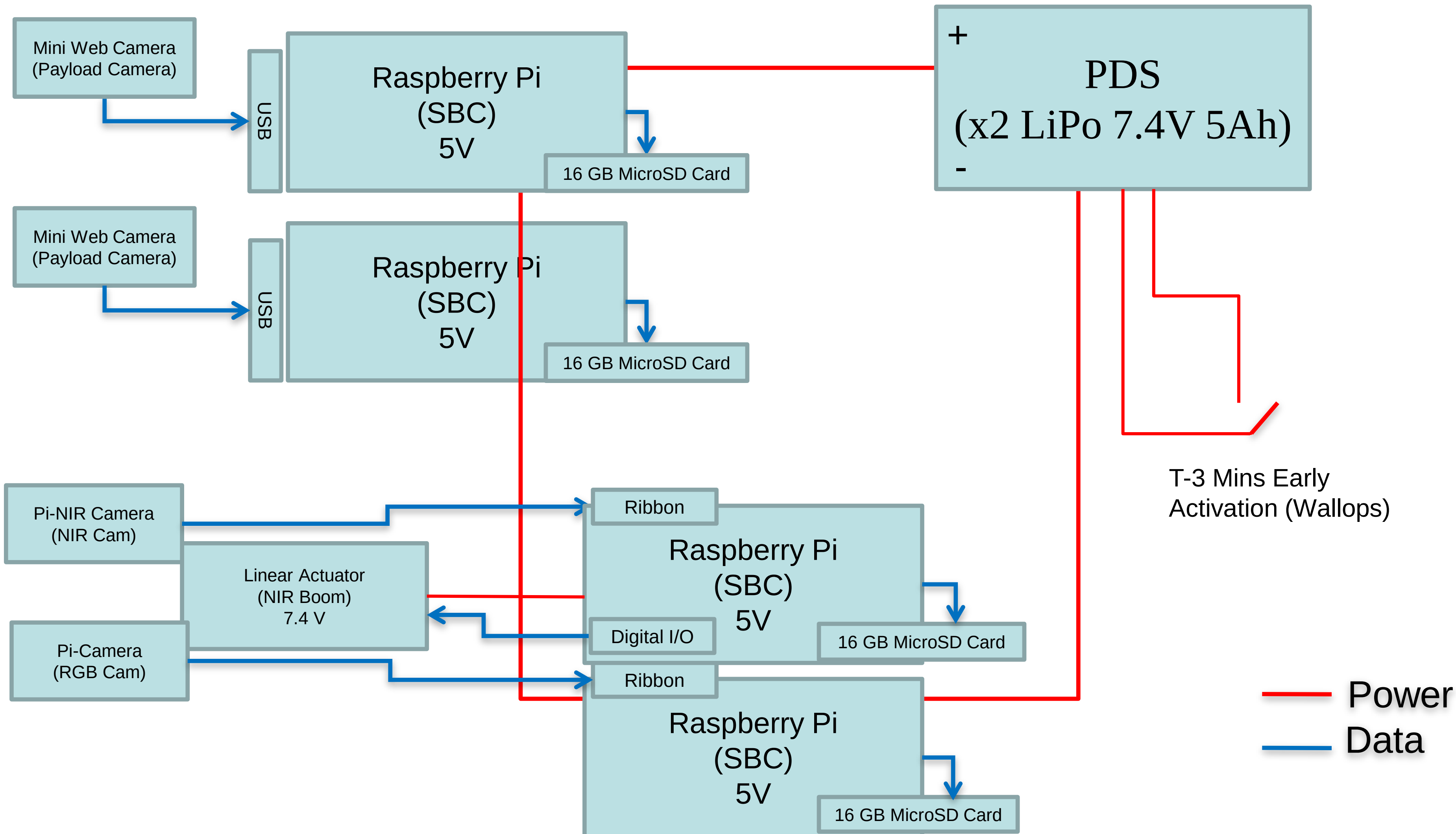
- WVU-CAM
  - Off-ramp if necessary
    - Audio Data collection from built in microphones on payload cameras
    - Include a rigid mount for NIR lens instead of including the linear actuator
  - Impact
    - No audio data to accompany video indication data
    - Cause image degradations with the NIR imaging experiment
- FSU-SPACE
  - Off-ramp if necessary
    - Barometric/Temperature sensor with BRCTC
  - No impact on objectives
- BVCTC-SPACE
  - Off-ramp if necessary
    - Use Arduino pro-mini microcontroller instead of Parallax Propeller ASC+
- WVUTech-SPACE
  - Descope
    - No longer including tensile apparatus for ABS strain experiment
    - Working with BVCTC to place strain gauge on their ABS container
  - Impact
    - No longer get yield stress data on ABS plastic in space
  - Off-ramp if necessary
    - Strain gauge experiment all together to focus on flight dynamics

Descopes/Off-ramps (Cont)

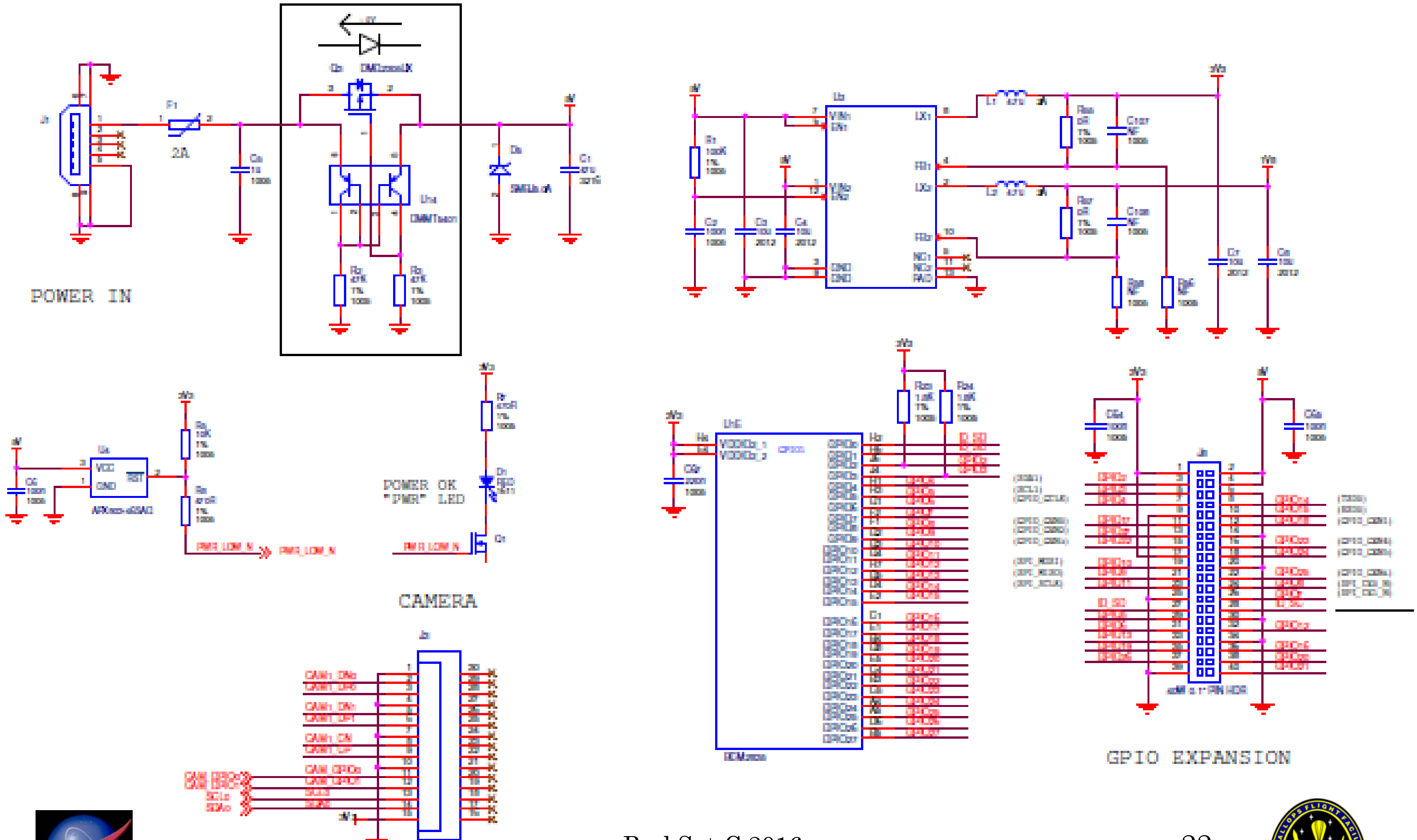
- BVCTC-SPACE
  - Off-ramp if necessary
    - Redundant sensors
  - Impact
    - No cost vs. performance comparison on COTS IMUs and magnetometers
- WVWC-SPACE
  - Off-ramp if necessary
    - Only use one inertial measurement unit
    - Only use gyroscope information from the inertial measurement unit
    - Only measure and respond to one degree of rotational freedom
  - No impact on objectives
- WVState-SPACE
  - Off-ramp if necessary
    - Use Micro-Geiger kit instead of building from scratch using LND 713 tube
  - No impact on objectives
- SU-SPACE
  - Off-ramp if necessary
    - To use NCP1402 voltage regulator in place of designing our own
    - To use iSensor board with ADIS instead of working proper connections into custom PCB design
  - No impact on objectives

WVU-Cam
Design Description

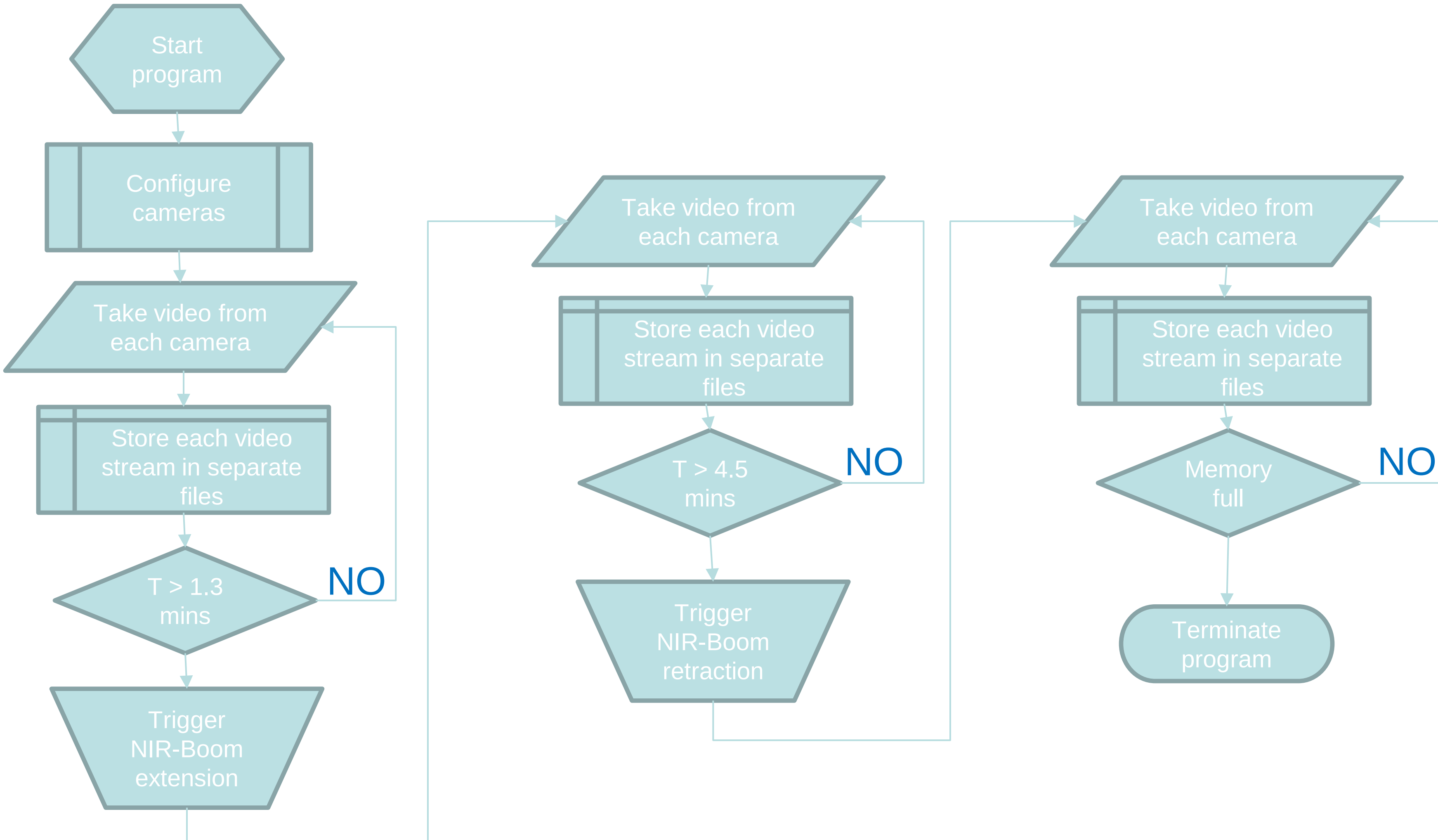
WVU-CAM: Block Diagram



WVU-CAM: Electrical Schematic (SBC)



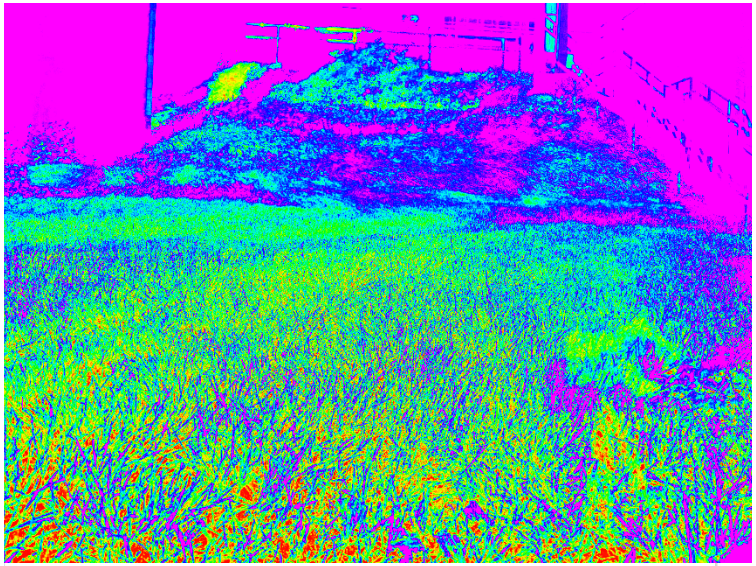
WVU-CAM: Software Design Elements

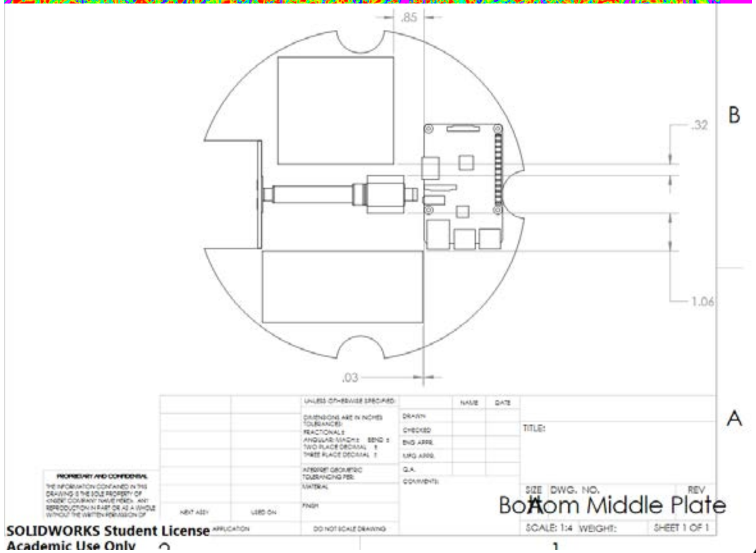


WVU-CAM Prototyping/Analysis

Analysis Results

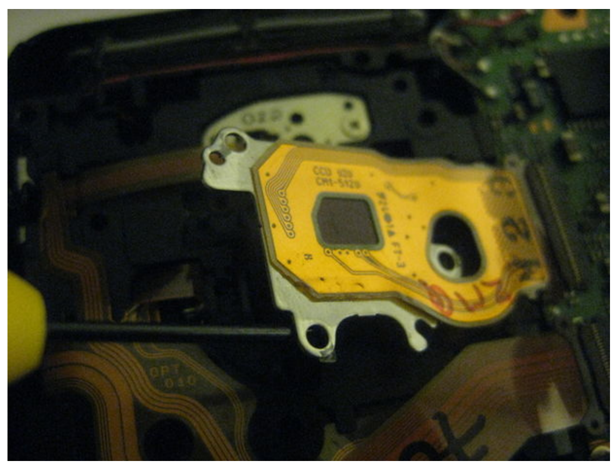
- Used imaging software (gimp) to process images from a RGB and NIR camera
  - Overlay images as necessary to produce the NDVI result
- L12 30mm boom extension analyzed using CAD modeling
  - Optimal positioning of linear actuator determined





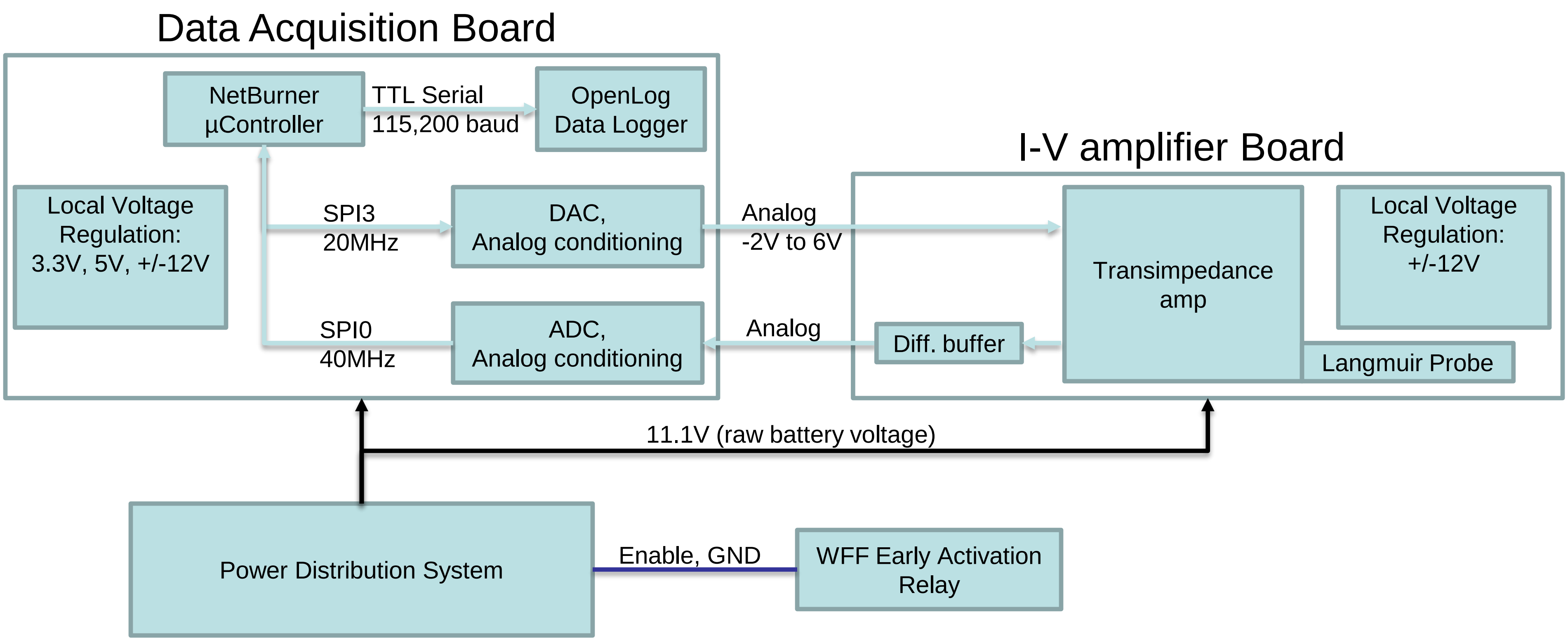
Prototyping Results

- Developed NIR camera by removing IR filter from standard digital camera and added RGB filter
  - Positioned both RGB/NIR cameras to capture identical frames
  - Results show frames were not perfectly aligned

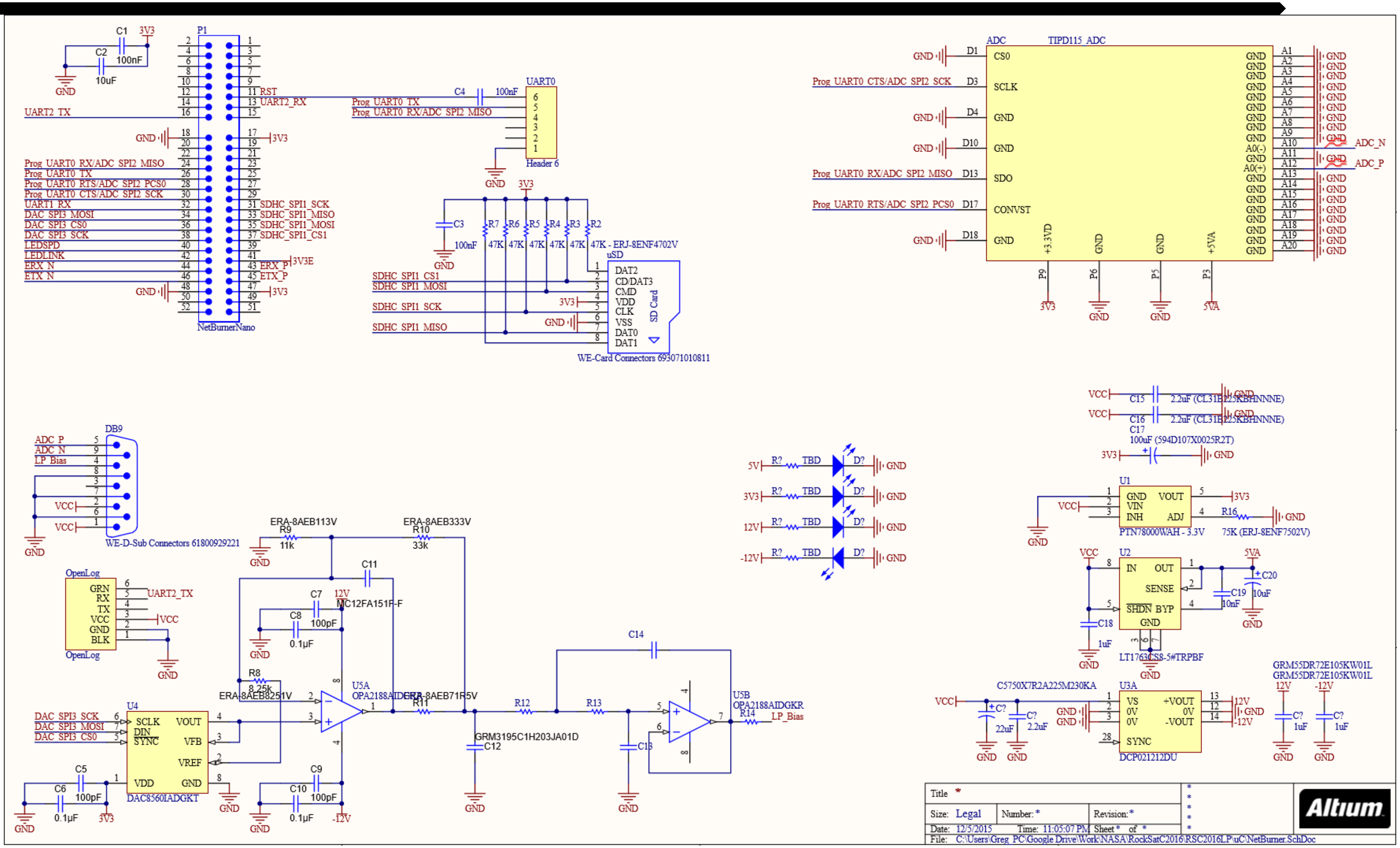


WVU-LP
Design Description

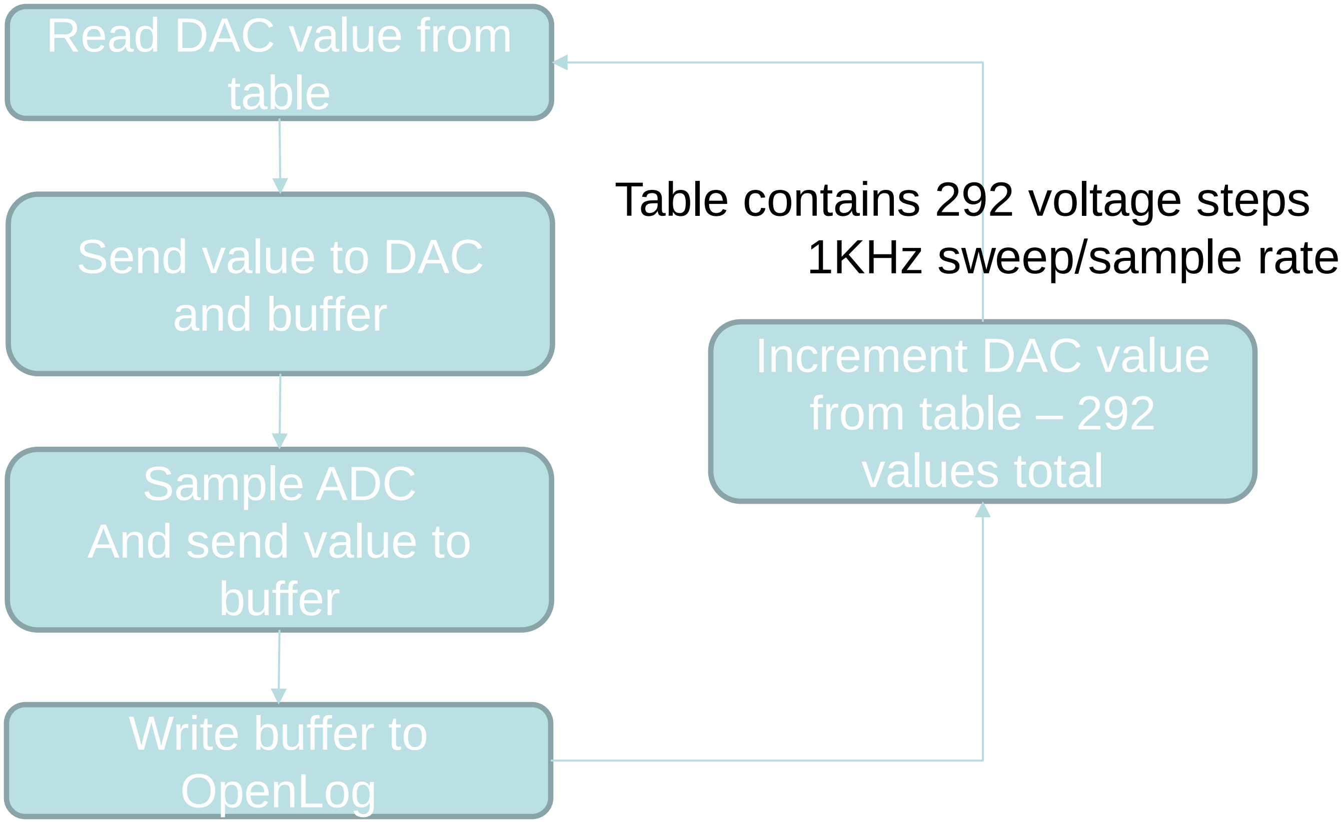
Electrical Block Diagram



I-V Amplifier Schematic



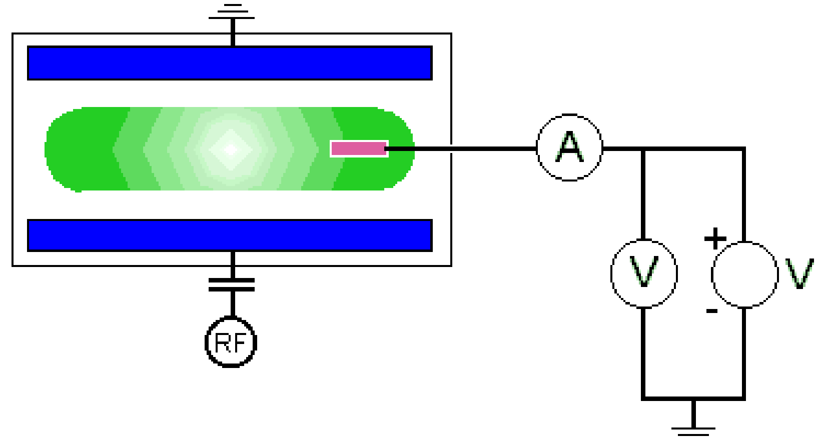
Software Block Diagram

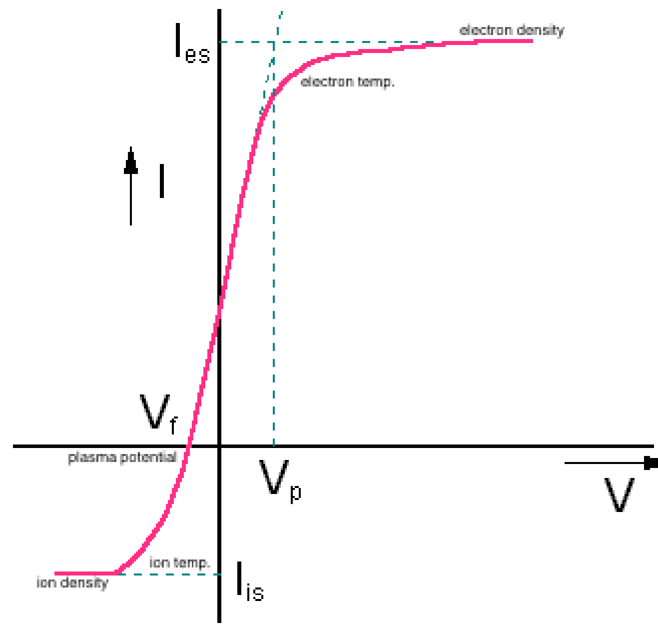


WVU-LP Prototyping/Analysis

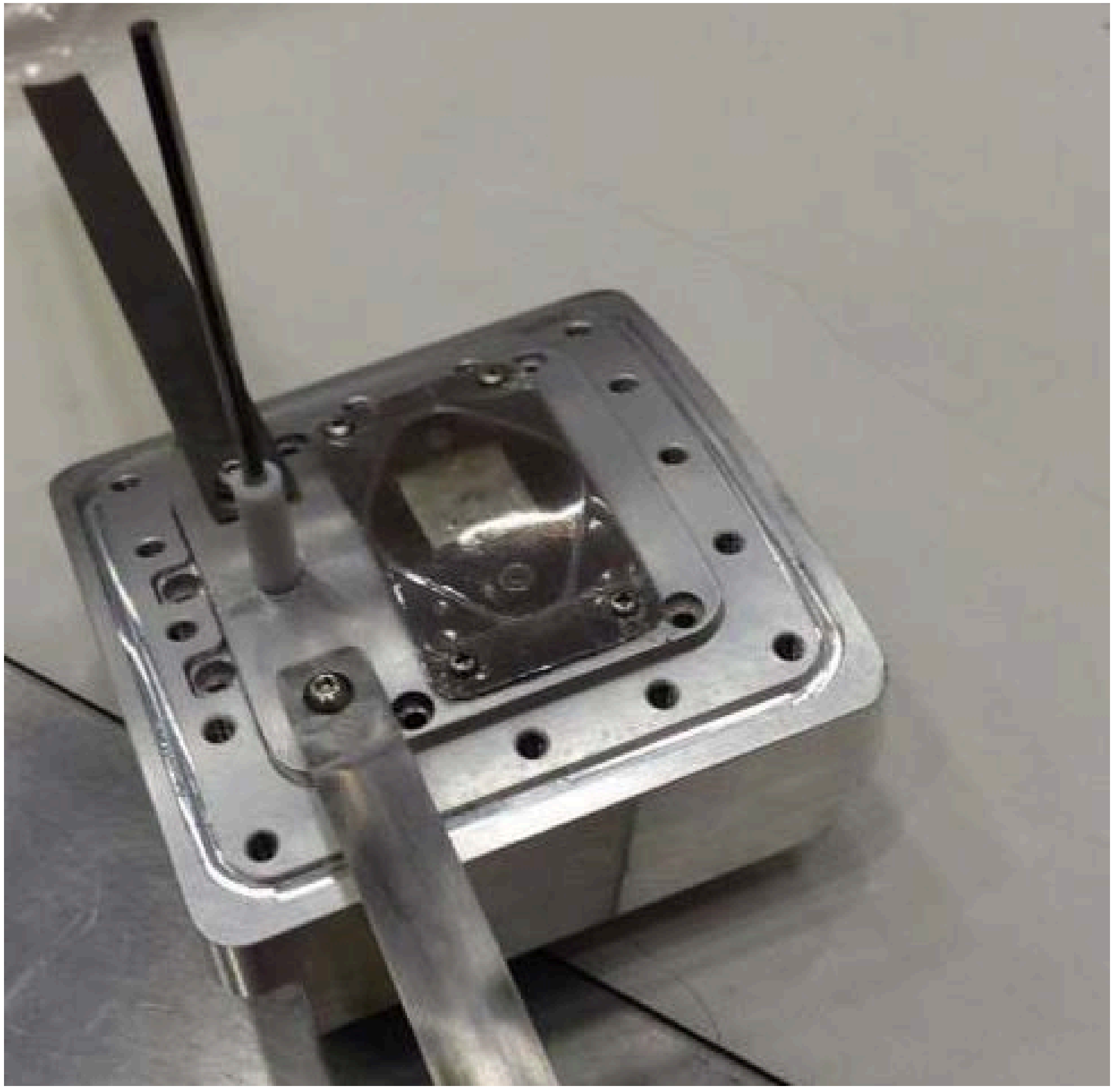
WVU-LP Analysis Results

- Used to determine electron/ion temperature, electron/ion density, and plasma potential of a plasma
- Works by inserting an electrode (LP) into a plasma, establishing electric potential between the electrode and surrounding vessel
- Measured currents and potentials allow the determination of physical properties of plasma
- Expected current range on probe
  - 10nA to 10mA
- LP: 4” stainless steel rod (3” uninsulated length), 1/8” diameter



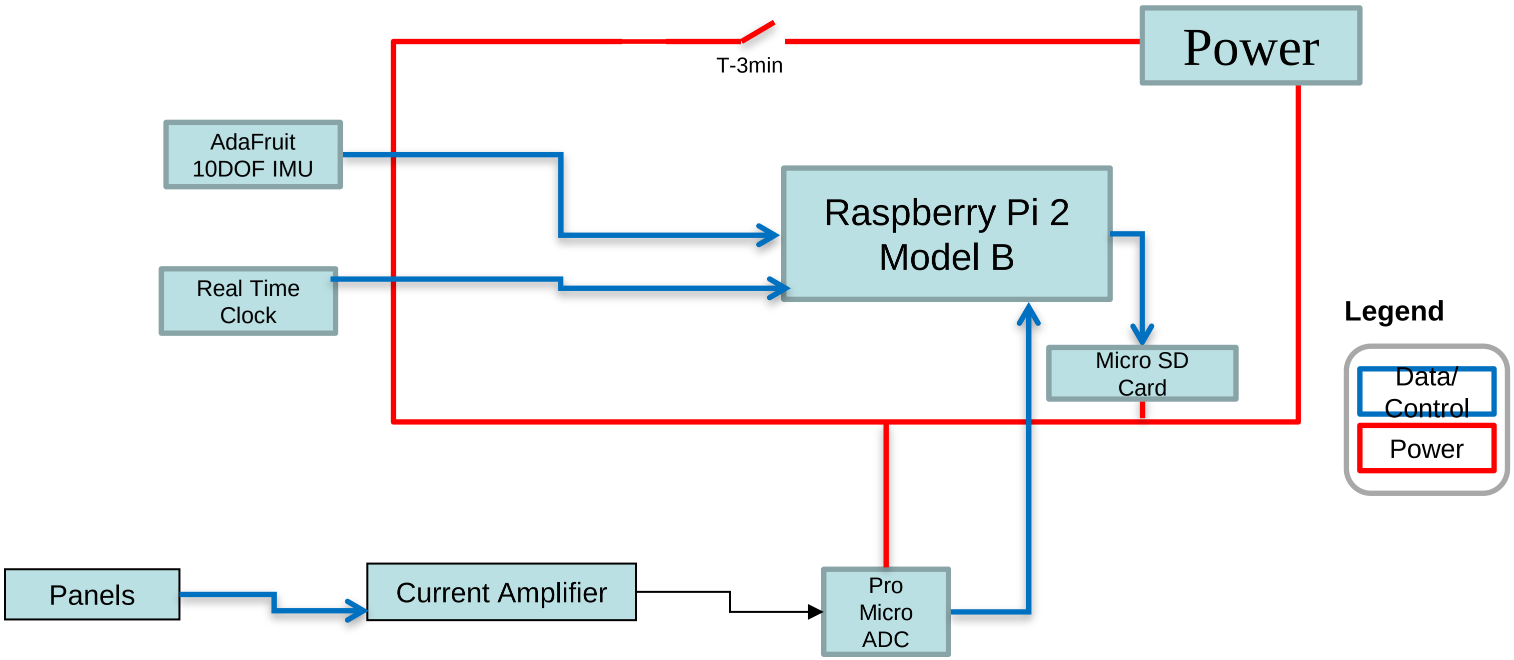


Prototyping Results



MU-SPACE
Design Description

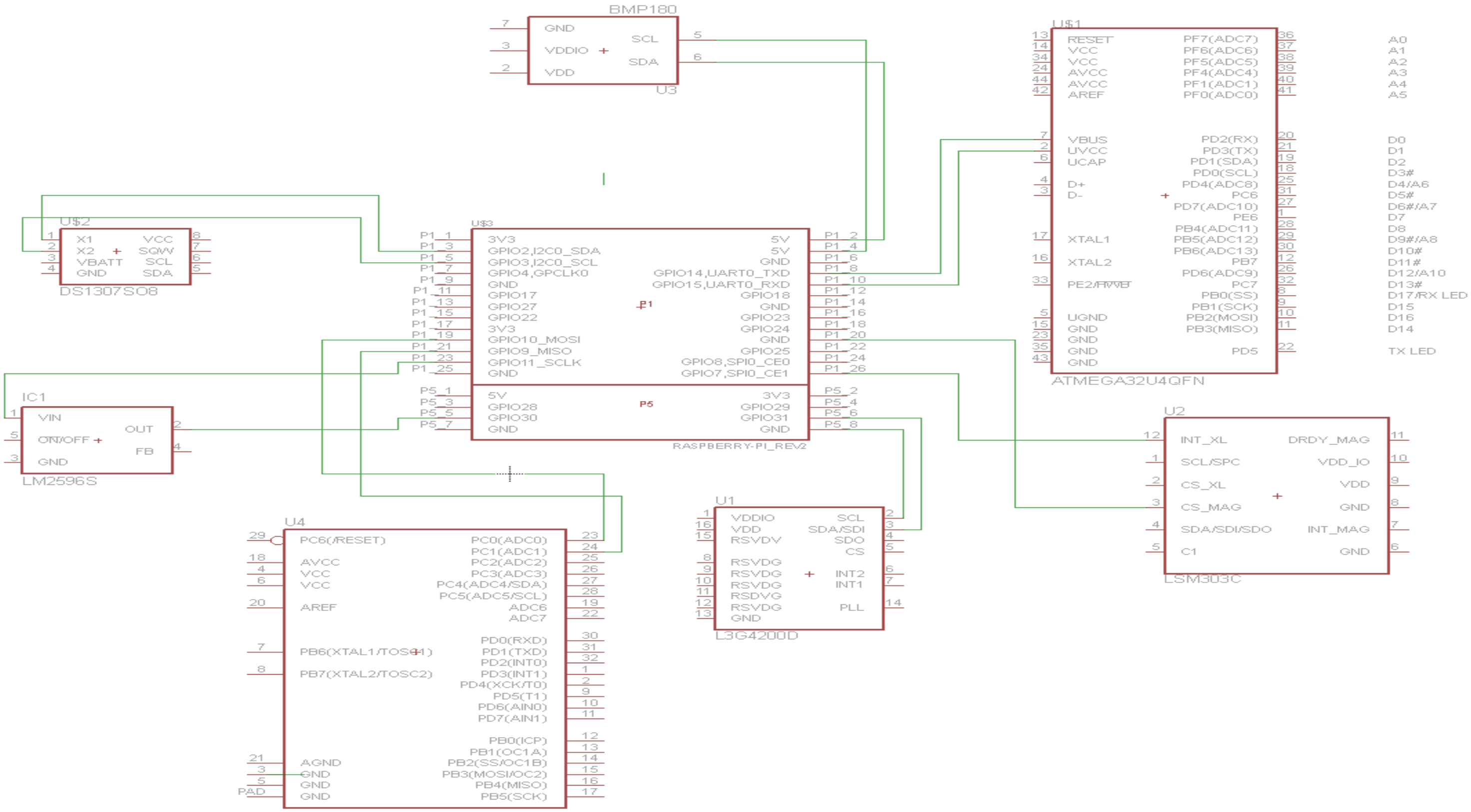
Electrical Design Elements



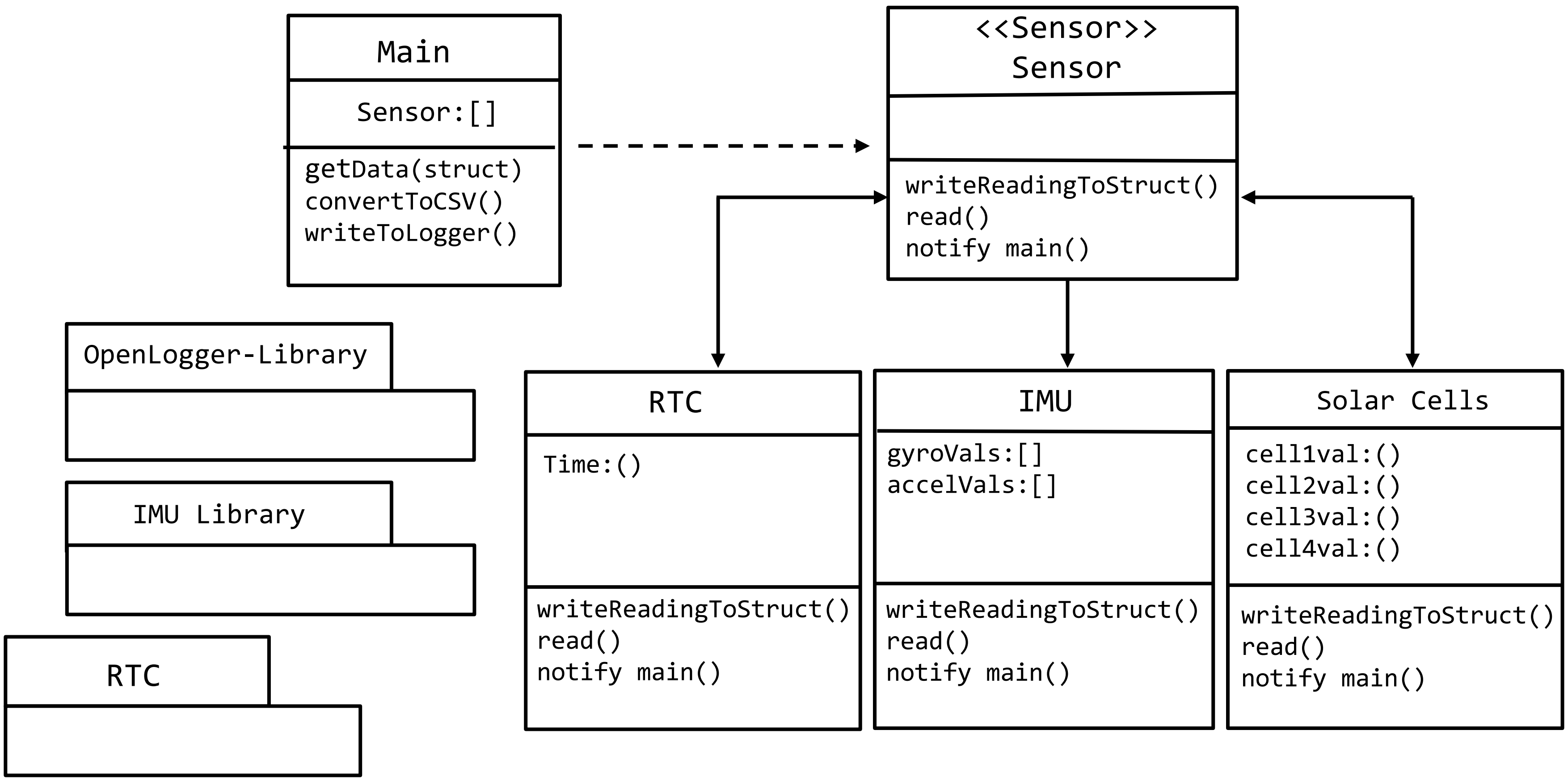
- We plan to use a two board stack.
- There have not been any major alterations since our PDR.

Rough Electrical Design

- This is subject to some alteration in the future



Software – Payload



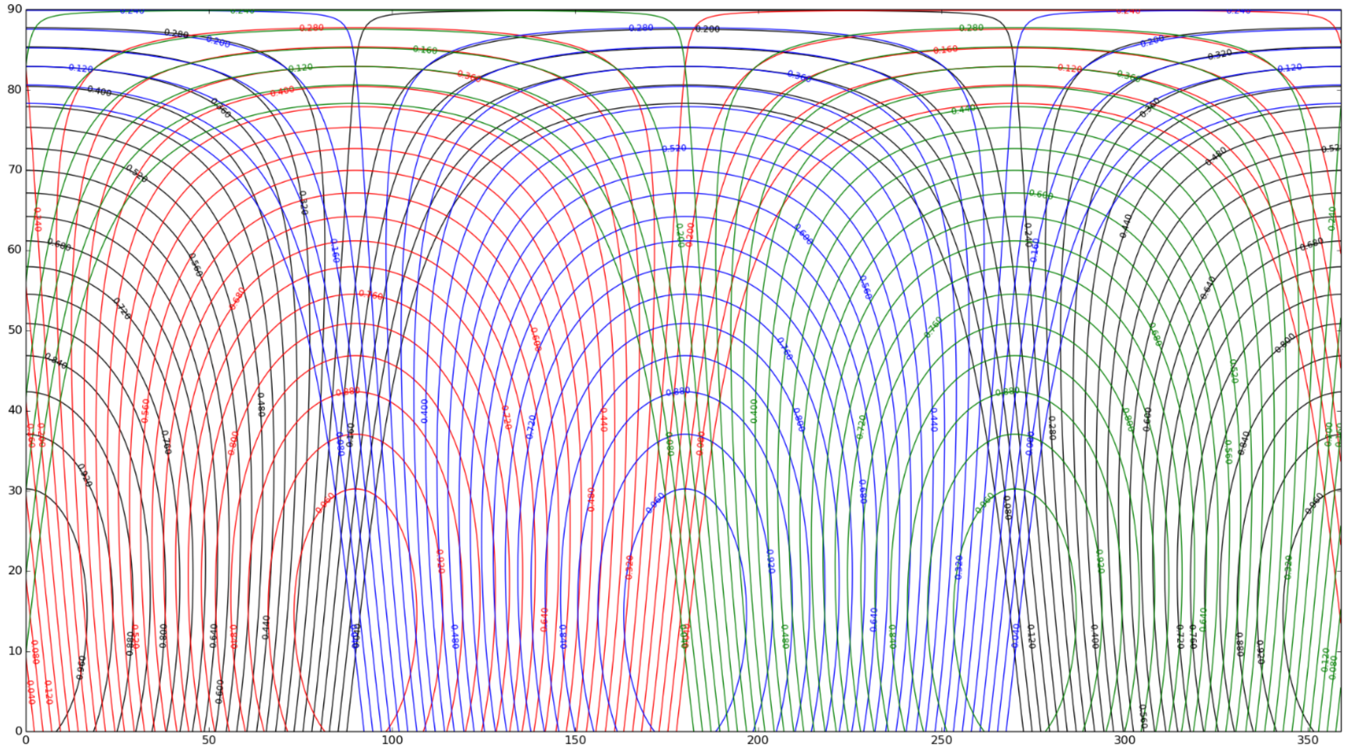
MU-SPACE Prototyping/Analysis

Analysis Results

- Developed a program to test and compare the angular discrimination along solar panels amongst different elevations
- Solar cells are pointed at the cardinal points
- 14 degrees is the angle of elevation of the solar cells
- This information is integral to our design
- Formula for current across the solar cell
- $I = I_o \sin(\theta - EL)\cos(AZ_{cell} - AZ_{Sun})$

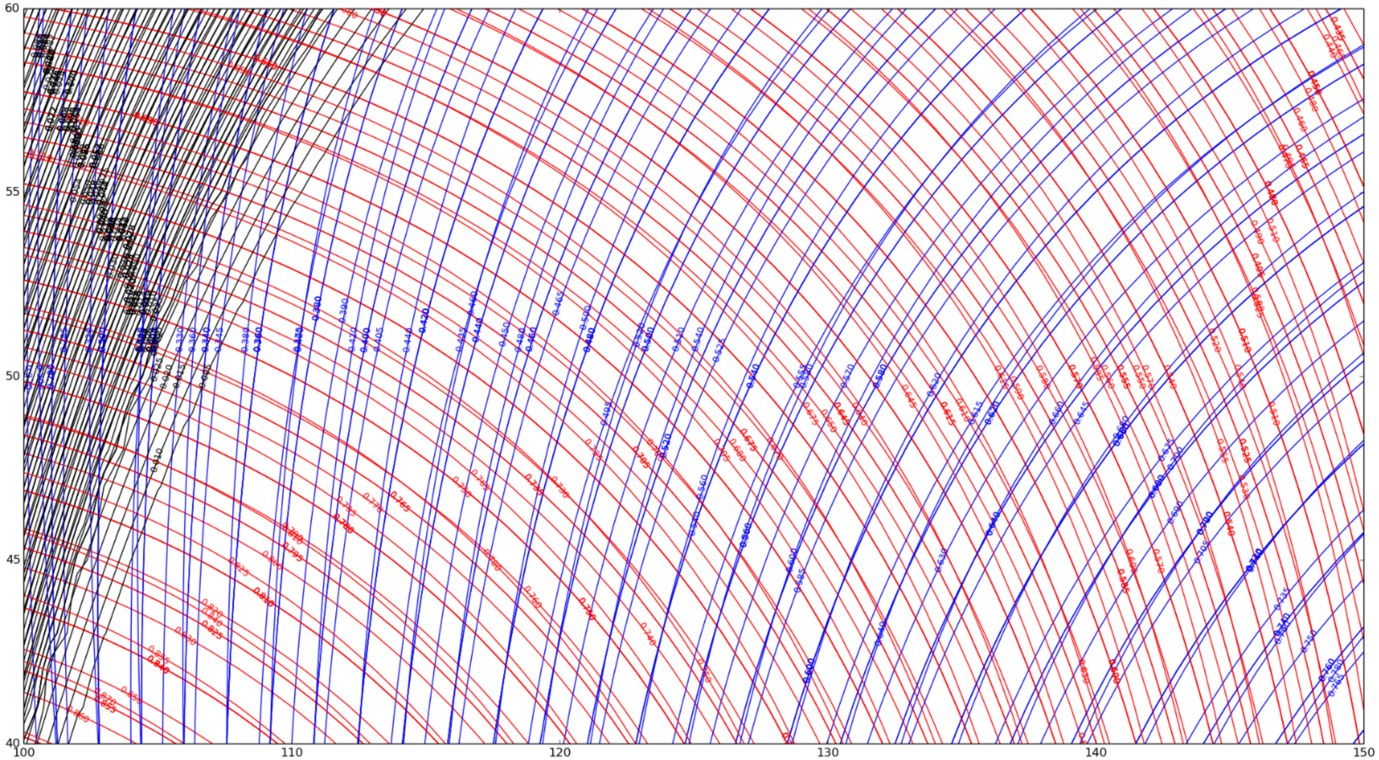
Results of the testing

This is a graph of the current across a solar panel that is angled up at 14 degrees. This basically is the graph of the discrimination across all azimuths and elevations.



More Results from Testing

This is a much more limited range of values of current read across a limited range of azimuths and elevations that can be controlled and altered.

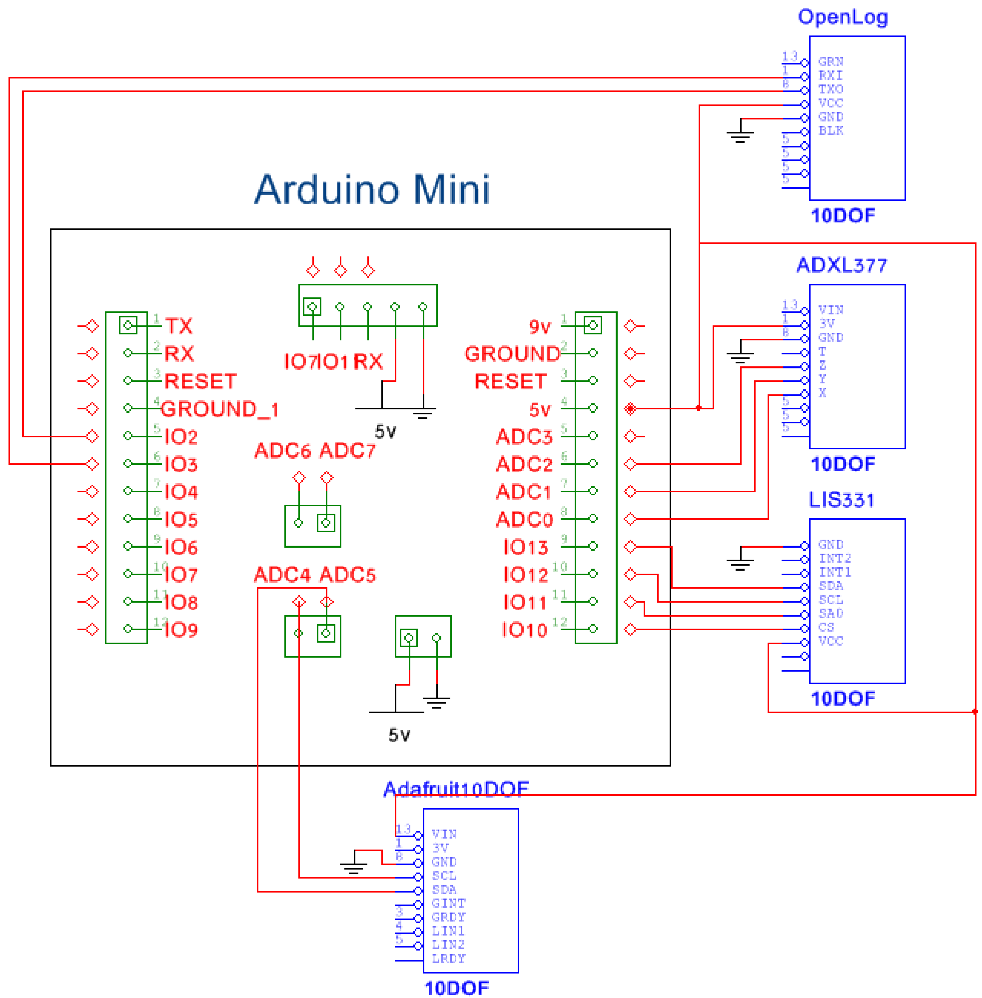


Prototyping Results

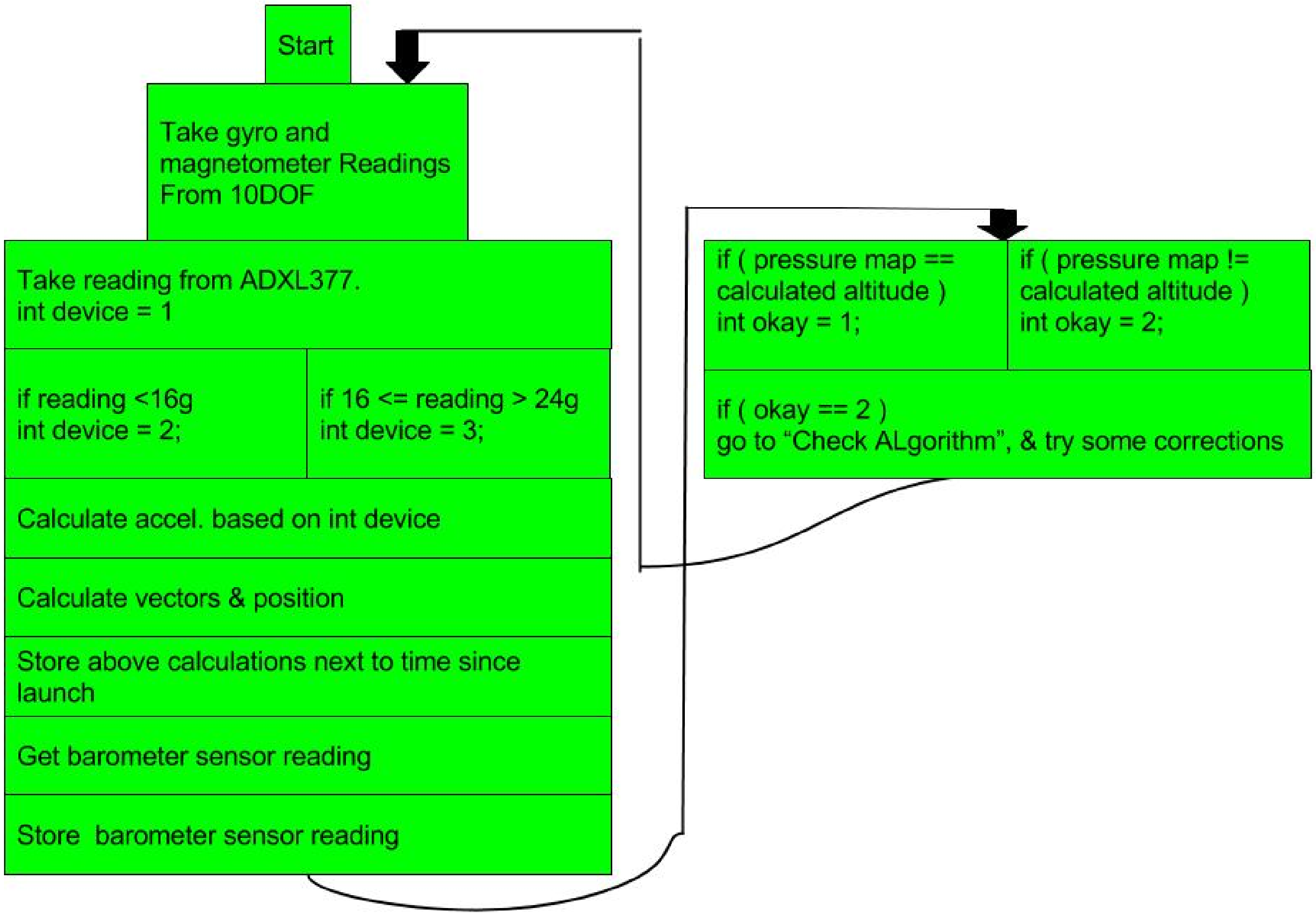
Large portion of the circuitry are based on the prior year's Rocksat mission, and we are waiting on parts to prototype the solar cells.

FSU-SPACE
Design Description

Electrical Design Elements



Software Design Elements



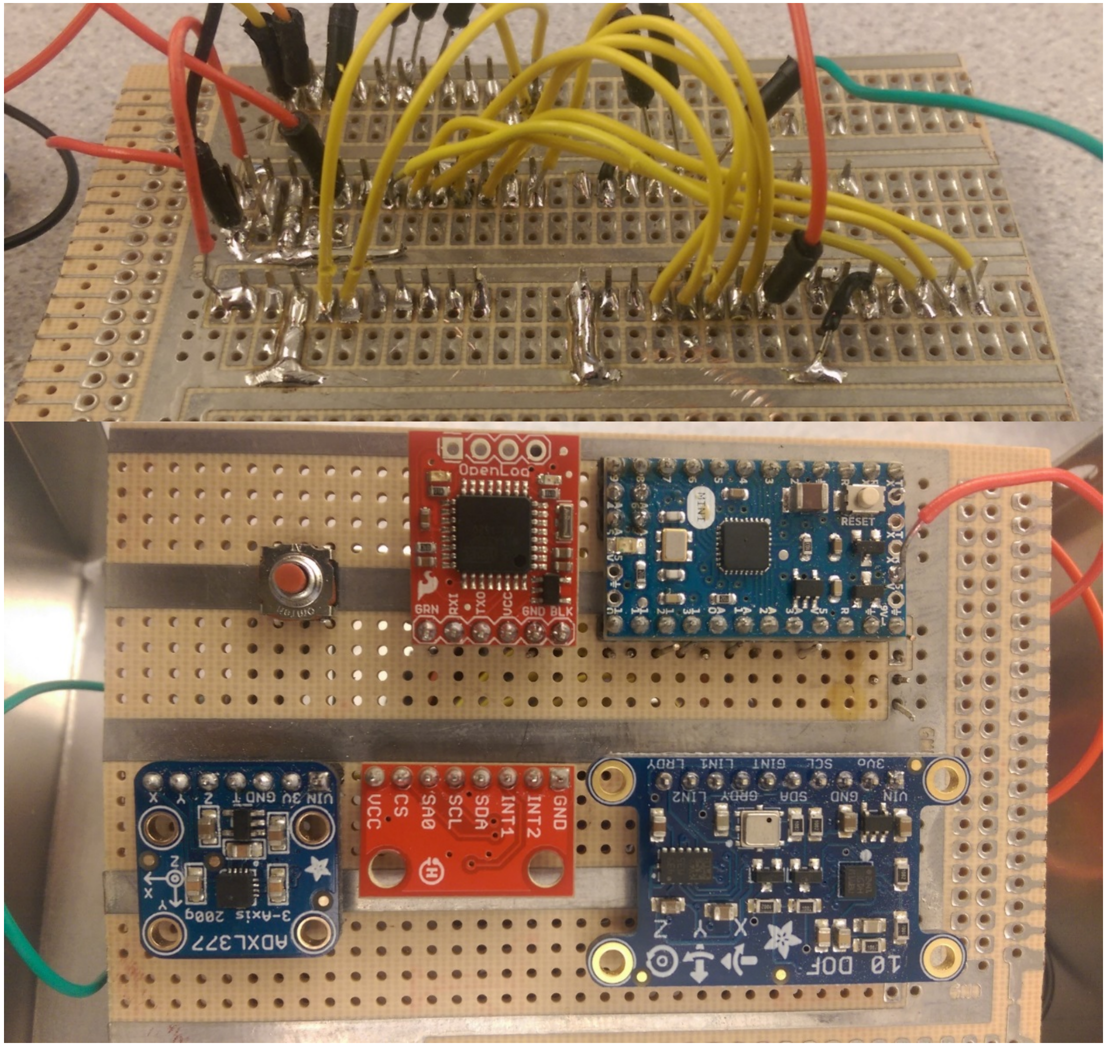
FSU-SPACE Prototyping/Analysis

Analysis Results

- Table used to determine appropriate barometric pressure sensor

MSISE-90 Model of Earth's Upper Atmosphere												
Altitude (km)	Low Solar Activity				Mean Solar Activity				Extremely High Solar Activity			
	Temp. (K)	Density (kg/m³)	Pressure (Pa)	Mol. Wt. (kg/kmol)	Temp. (K)	Density (kg/m³)	Pressure (Pa)	Mol. Wt. (kg/kmol)	Temp. (K)	Density (kg/m³)	Pressure (Pa)	Mol. Wt. (kg/kmol)
0	300.2511	1.17E+00	1.01E+05	28.9502	300.2511	1.17E+00	1.01E+05	28.9502	300.2511	1.16E+00	9.98E+04	28.9502
20	206.2085	9.48E-02	5.62E+03	28.9502	206.2085	9.49E-02	5.62E+03	28.9502	206.2085	9.41E-02	5.57E+03	28.9502
40	257.6979	4.07E-03	3.01E+02	28.9502	257.6979	4.07E-03	3.02E+02	28.9502	257.6979	4.04E-03	2.99E+02	28.9502
60	244.1212	3.31E-04	2.32E+01	28.9502	244.1212	3.31E-04	2.32E+01	28.9502	244.1212	3.28E-04	2.30E+01	28.9502
80	203.1065	1.69E-05	9.81E-01	29.1353	196.3636	1.68E-05	9.45E-01	29.0175	172.2146	1.68E-05	8.42E-01	28.5290
100	168.7219	5.77E-07	2.89E-02	28.0036	184.0160	5.08E-07	2.81E-02	27.7137	297.3338	2.78E-07	2.63E-02	26.1997
120	**356.8669**	**1.70E-08**	**1.92E-03**	**26.3948**	**374.9715**	**1.80E-08**	**2.17E-03**	**25.8745**	**430.8385**	**2.34E-08**	**3.55E-03**	**23.6456**
140	545.8594	2.96E-09	5.37E-04	25.0665	635.5703	3.26E-09	7.03E-04	24.5349	875.9174	4.93E-09	1.61E-03	22.3209
160	630.0652	9.65E-10	2.13E-04	23.7884	787.5532	1.18E-09	3.31E-04	23.4225	1,143.5426	2.23E-09	9.90E-04	21.4577

Prototyping Results

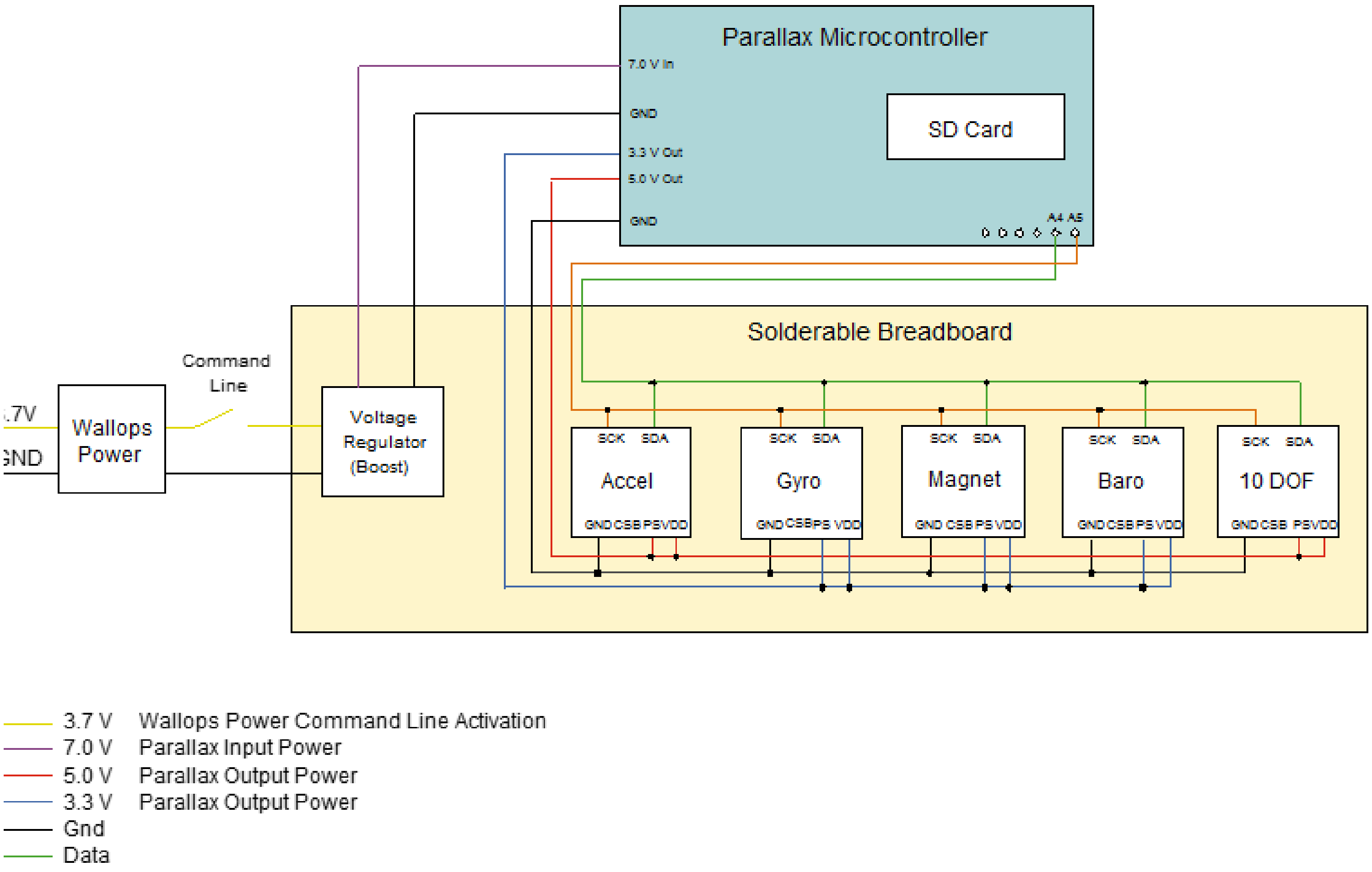


- Components prototyped to initiate software testing

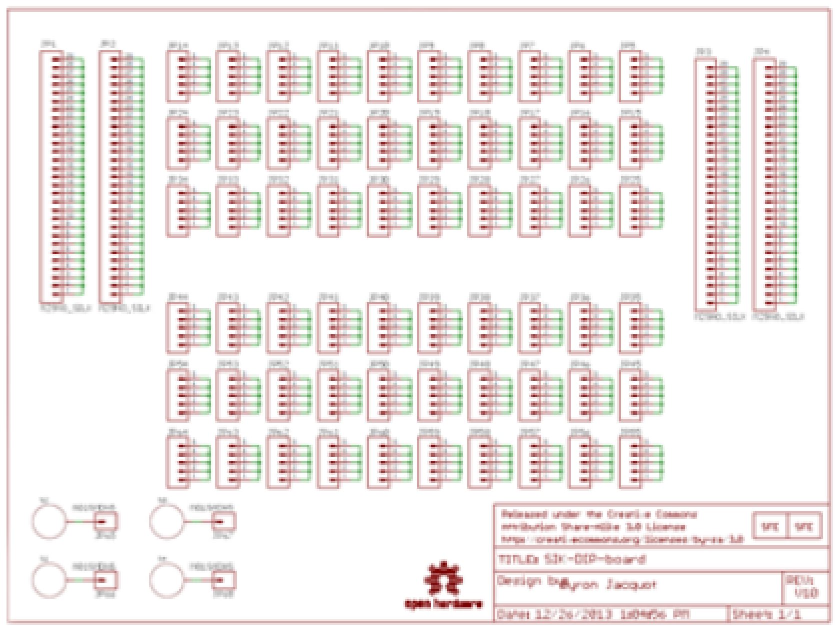
BRCTC-SPACE Design Description

Block Diagram

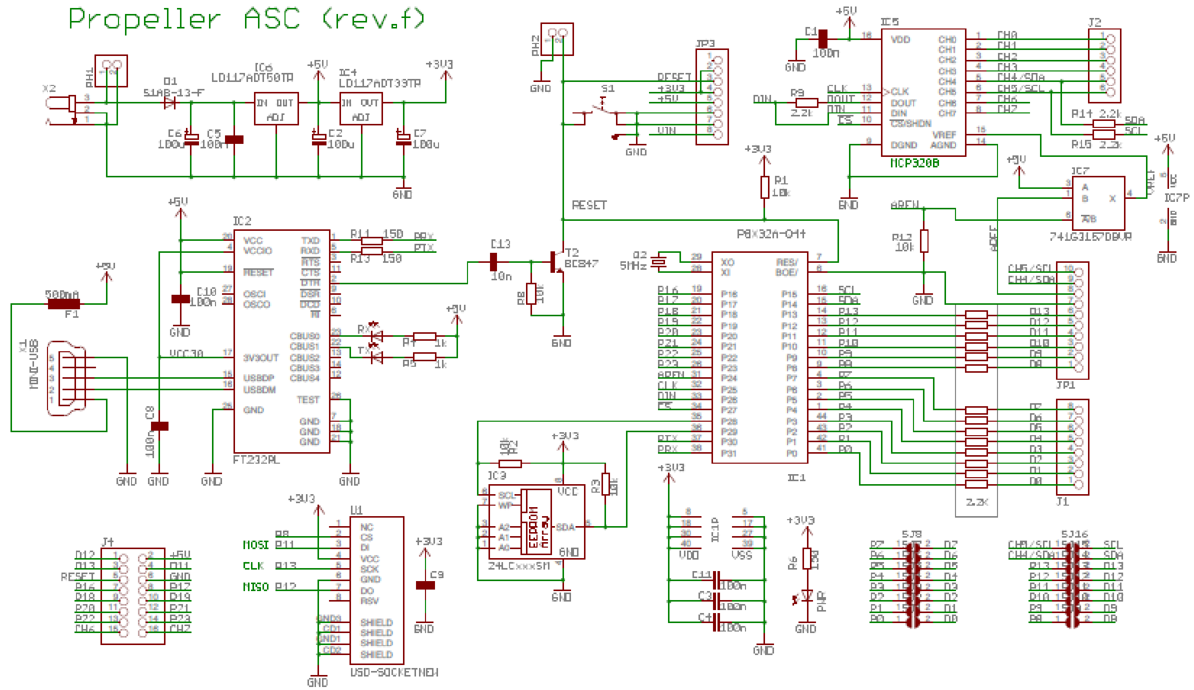
File: BRTC Payload Blk Diag Rev E



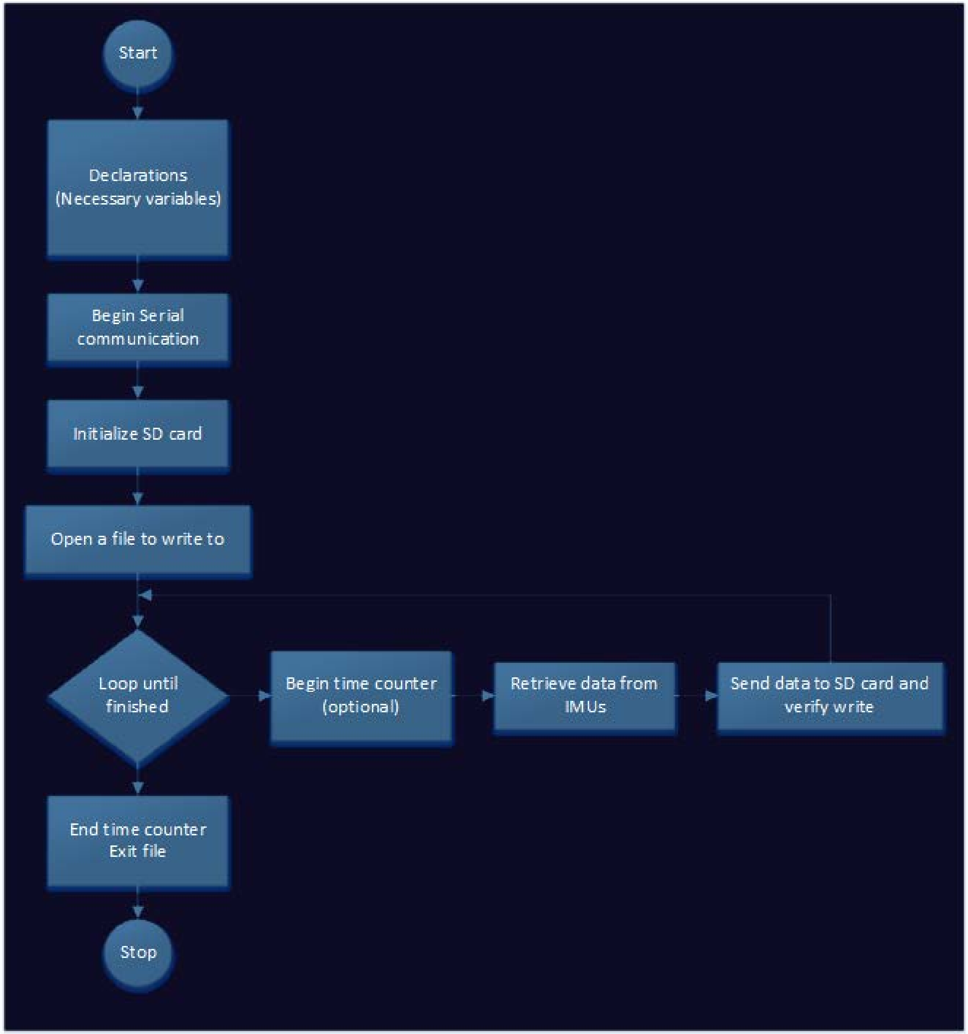
Solder-able Breadboard Schematic



Parallax Propeller ASC+ Schematic



Software flow diagram



Pseudo Code

```
Start
Declarations
          Variables
          Library inclusions
          Class files
Void Setup()
          InitializeSD()
          classFile = SD.open(name, FILE_WRITE) // The child class receives a file name and write status
Void Loop()
          startSensors
          --BeginTimer()-- //It is possible that we will use a timer using the built-in Arduino libraries.
                              //further testing will be required before we put this into effect.
          GetAccelerometerData() //Each of the following methods gets the IMU data
          GetGyroData() //After retrieving the data, it is written to the file opened earlier
          GetBarometerData()
          GetMagnetometerData()
          --ExitLoop()-- // Optional loop control function to end the loop and finalize all SD card writes
                              // Would only occur after project time limit, with error control time added

Finalize() // Finilze SD card write
Stop

Example method: This example shows what each of the IMU methods will look like
GetAccelerometerData()
          Declarations
                    Num AccelerometerVariable // This variable is only used within this method
          AccelerometerVariable = GetSensorEvent() //Assign data to the variable

          classFile.println(AccelerometerVariable) //Write data to the file declared earlier
          classFile.Flush() //Finalize writes to prevent corruption of data if something goes wrong
          return
```

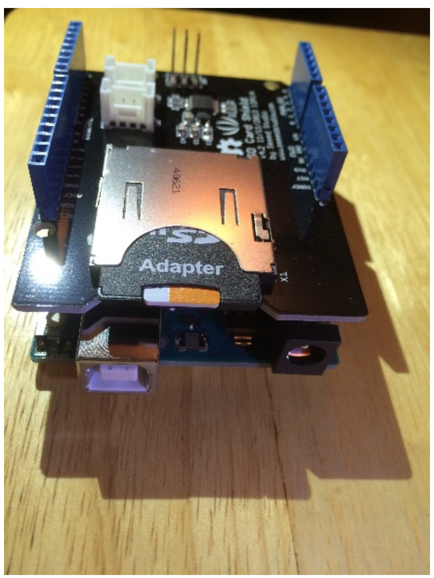
BRCTC-SPACE Prototyping/Analysis

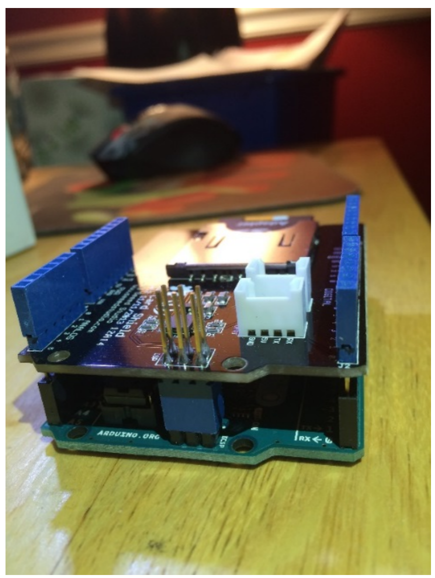
Analysis Results

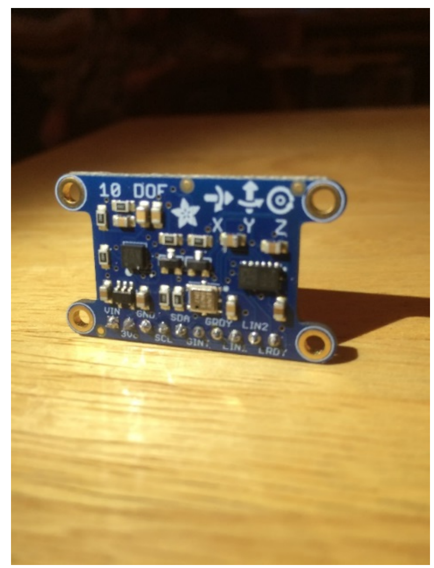
- Succeeding the PDR, coding has been routinely tested for comprehension.
- The Adafruit IMU testing consisted of:
  1. Operation and retrieval of data from all 10 DOF components
  2. Moving the IMU to test for fluctuations in measurements
  3. Writing data to the SD card (also a test of the storage unit)
  4. Measuring current to verify all parts received power when prompted
- Independent units yet to be received will allow assembly and testing of the fully constructed board
  - Testing on new units will precede completed testing

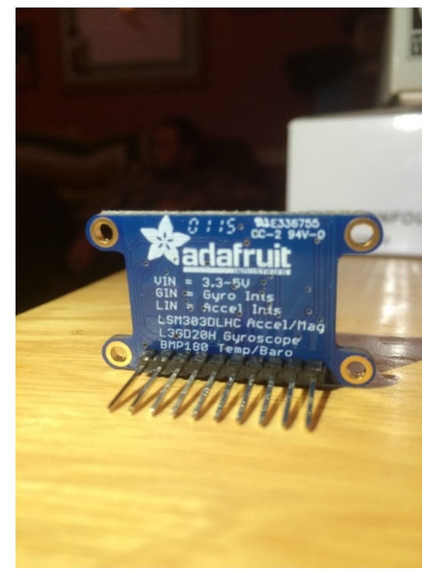
Prototyping Results

- The Adafruit 10 DOF was connected to the Arduino Uno to test for viability.
- Sensors were wired to breadboards for basic testing (no software was used, all manual control).
- The Arduino with SD Shield was connected to the breadboard to test read/write
- Prototypes were used to increase the level of understanding of basic circuitry and software programming.



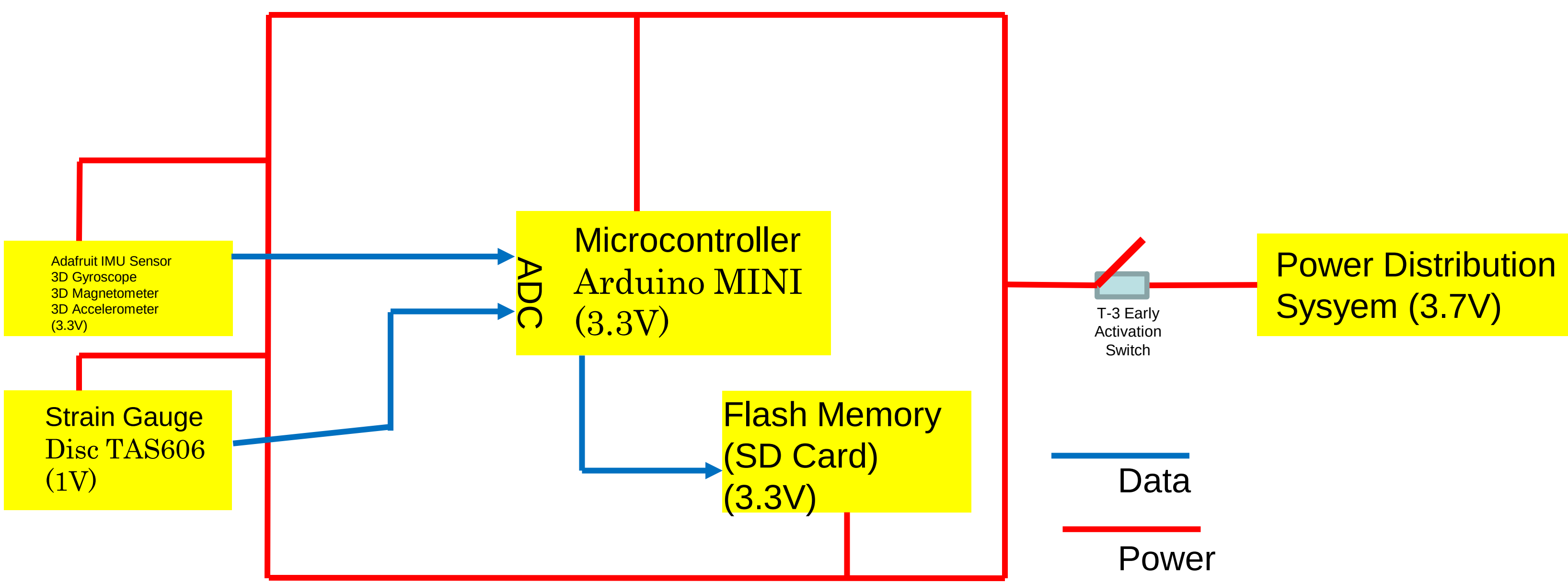




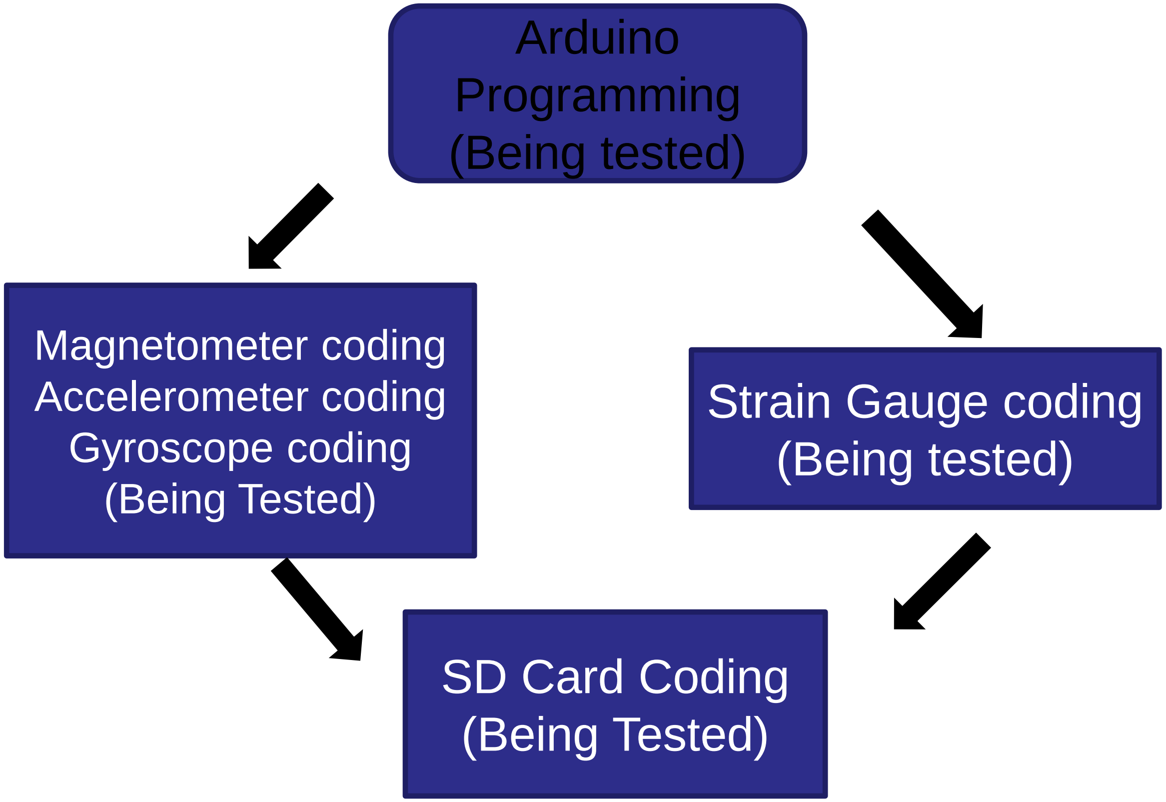


WVUTech-SPACE Design Description

Electrical Schematic Design



Software Flow Diagram

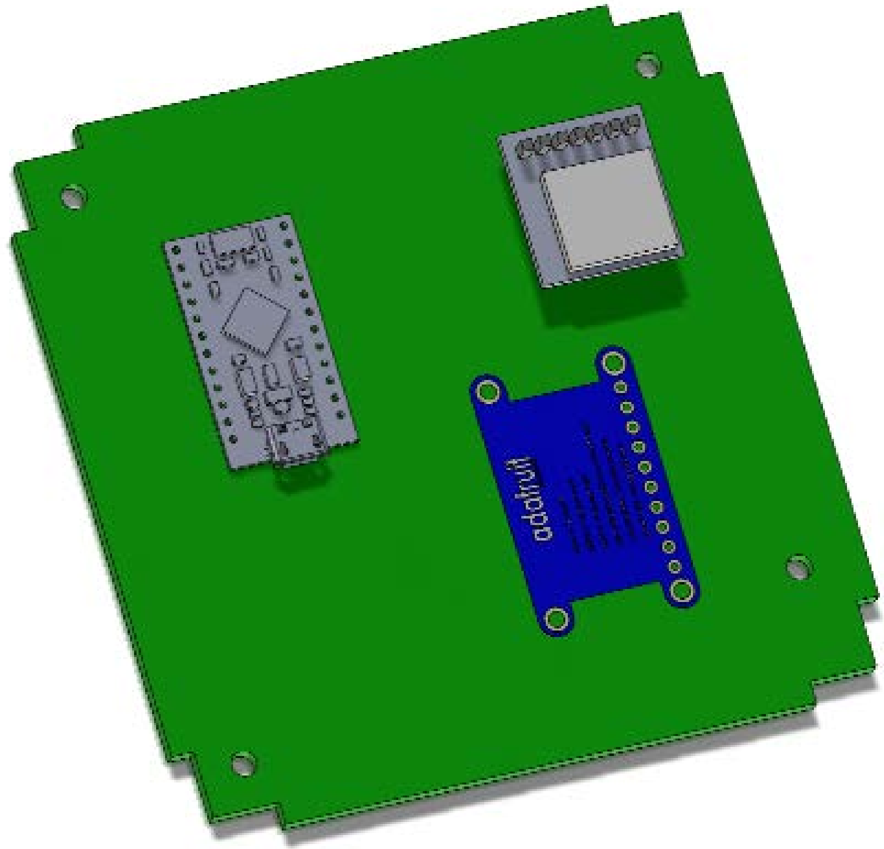


1) The Arduino program inputs the code into the SunFounder Uno kit
2) This signal is sent to the IMU for it to take readings
3) The readings are output to the SD Card and stored until received post launch
4) The purpose is to determine whether our readings of acceleration, angular velocity and magnetic field strength were accurately taken

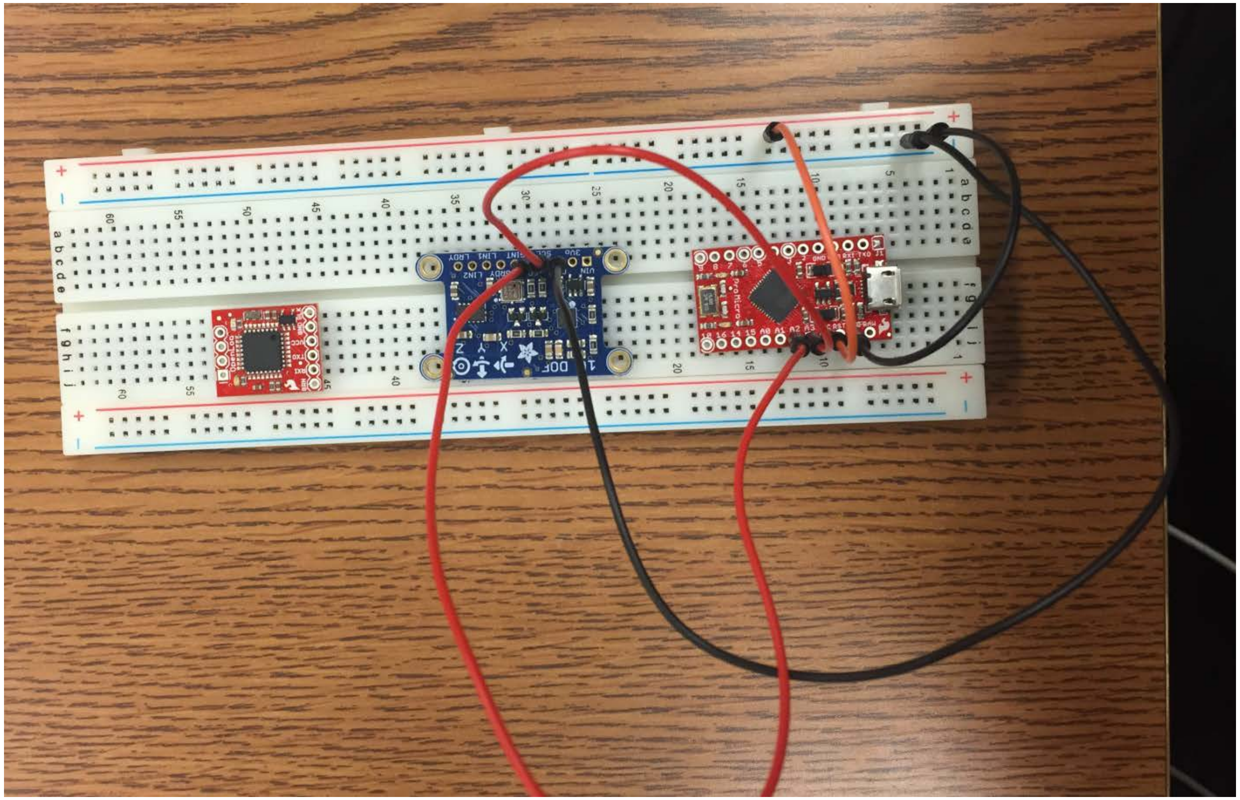
WVUTech-SPACE Prototyping/Analysis

Analysis Results

- Payload configuration on PCB
  - Includes microcontroller, IMU, and openlog device
- Integrating mechanical designs from each into overall canister model



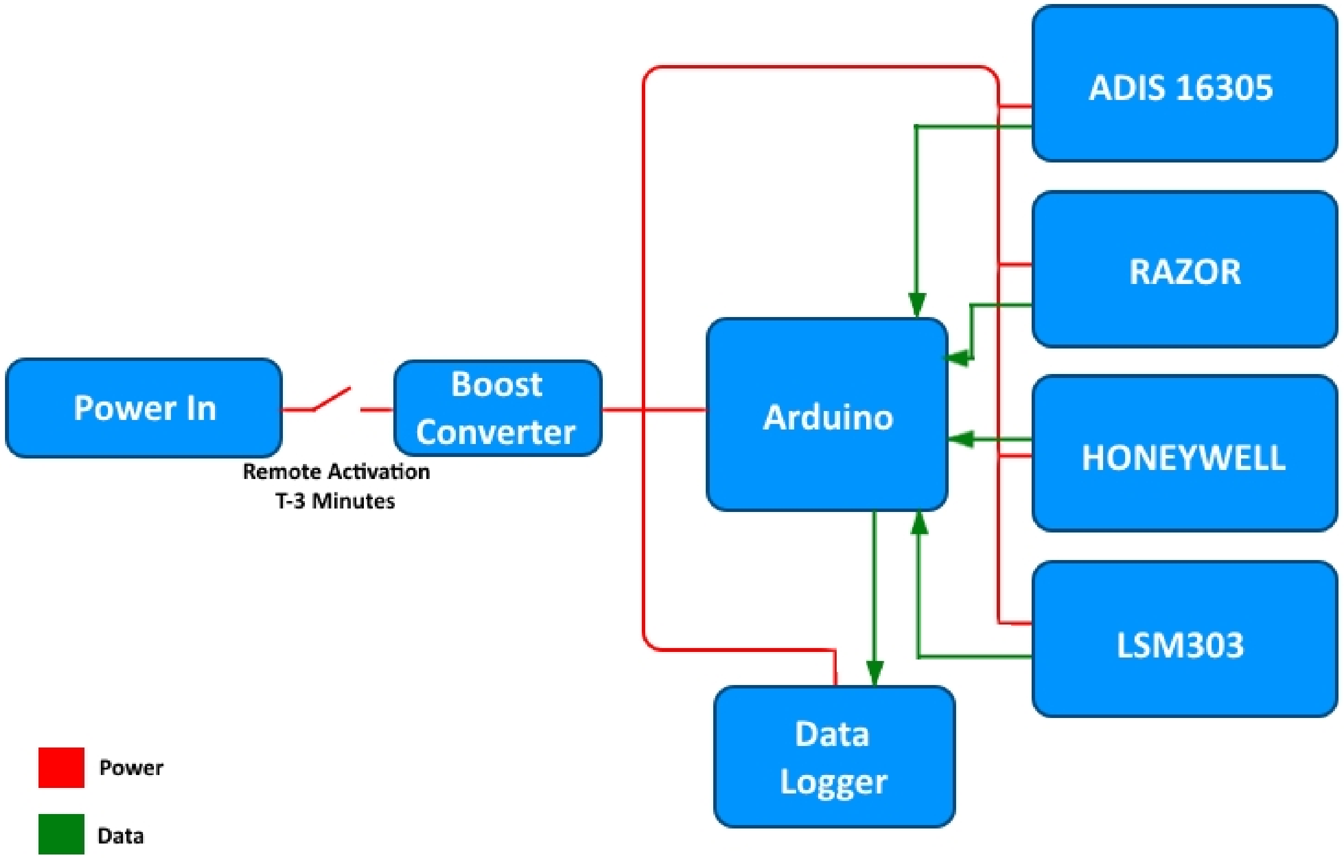
Prototyping Results



- Prototype setup of microcontroller to IMU
  - Excluding Micro USB that writes the program from the computer to microcontroller

BVCTC-SPACE Design Description

Electrical Design Elements



BVCTC-SPACE Prototyping/Analysis

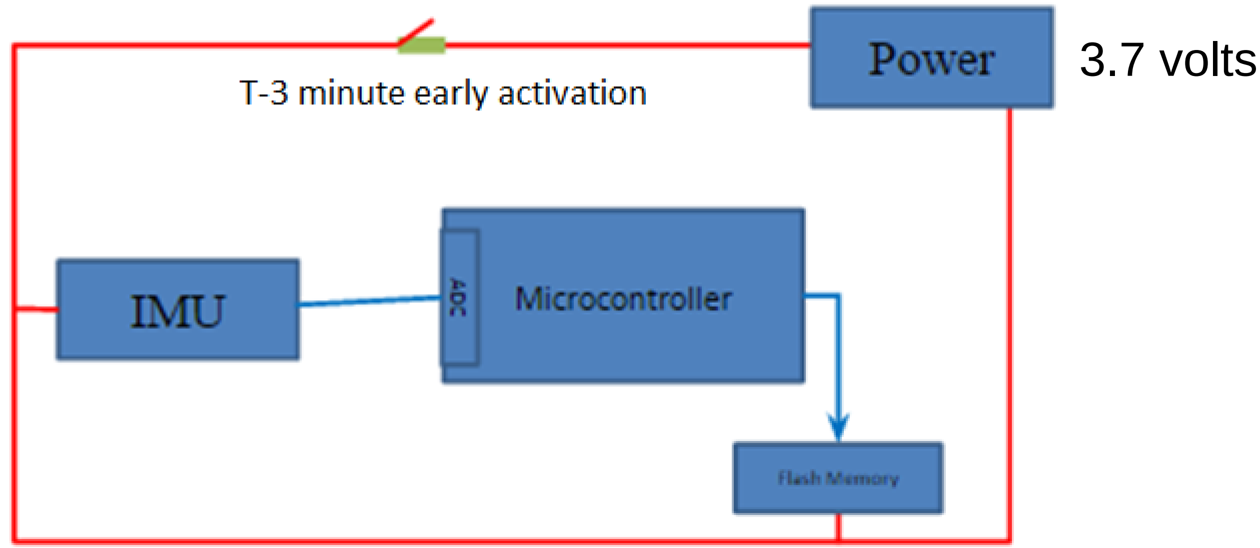
Analysis Results

- 3D Printed housing & overall assembly being modelled and tested in SolidWorks
  - Testing may result in changes to overall thickness
  - No results to show as detailed mechanical model is still in development

WVWC-SPACE
Design Description

Electrical Design Elements

Final Block Diagram



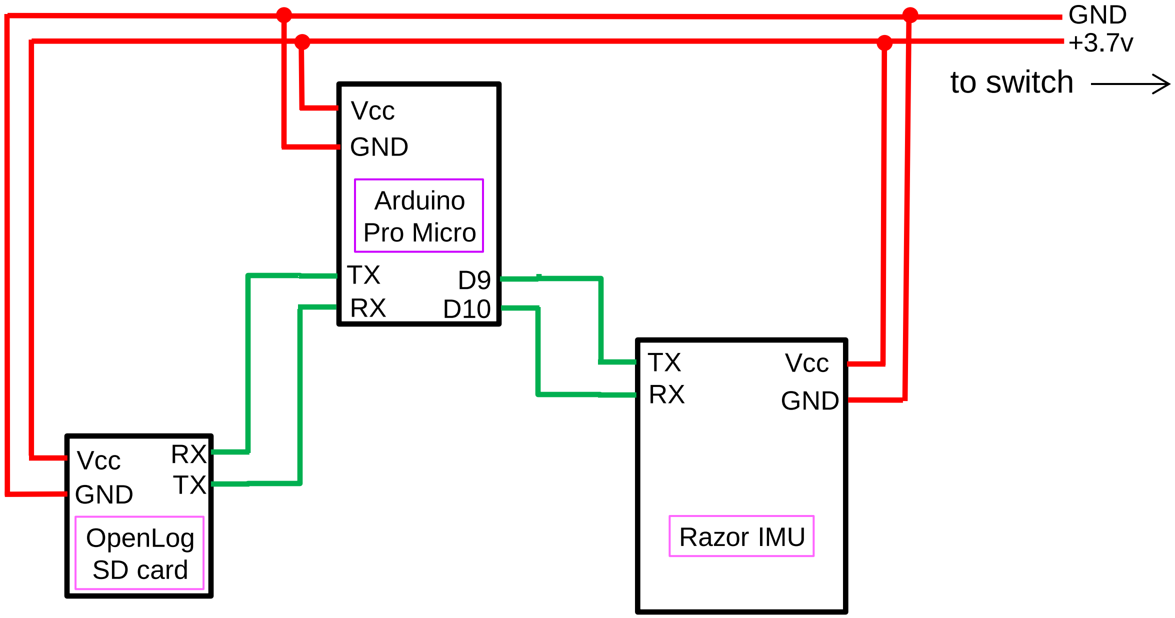
Design: perforated circuit board (4 in x 4 in)
Mounted to perforated circuit board:

- Razor inertial measurement unit
- Arduino Pro Micro microprocessor
- OpenLog flash memory
- Power connectors

No changes since PDR

Electrical Design Elements

Simple Electrical Schematic

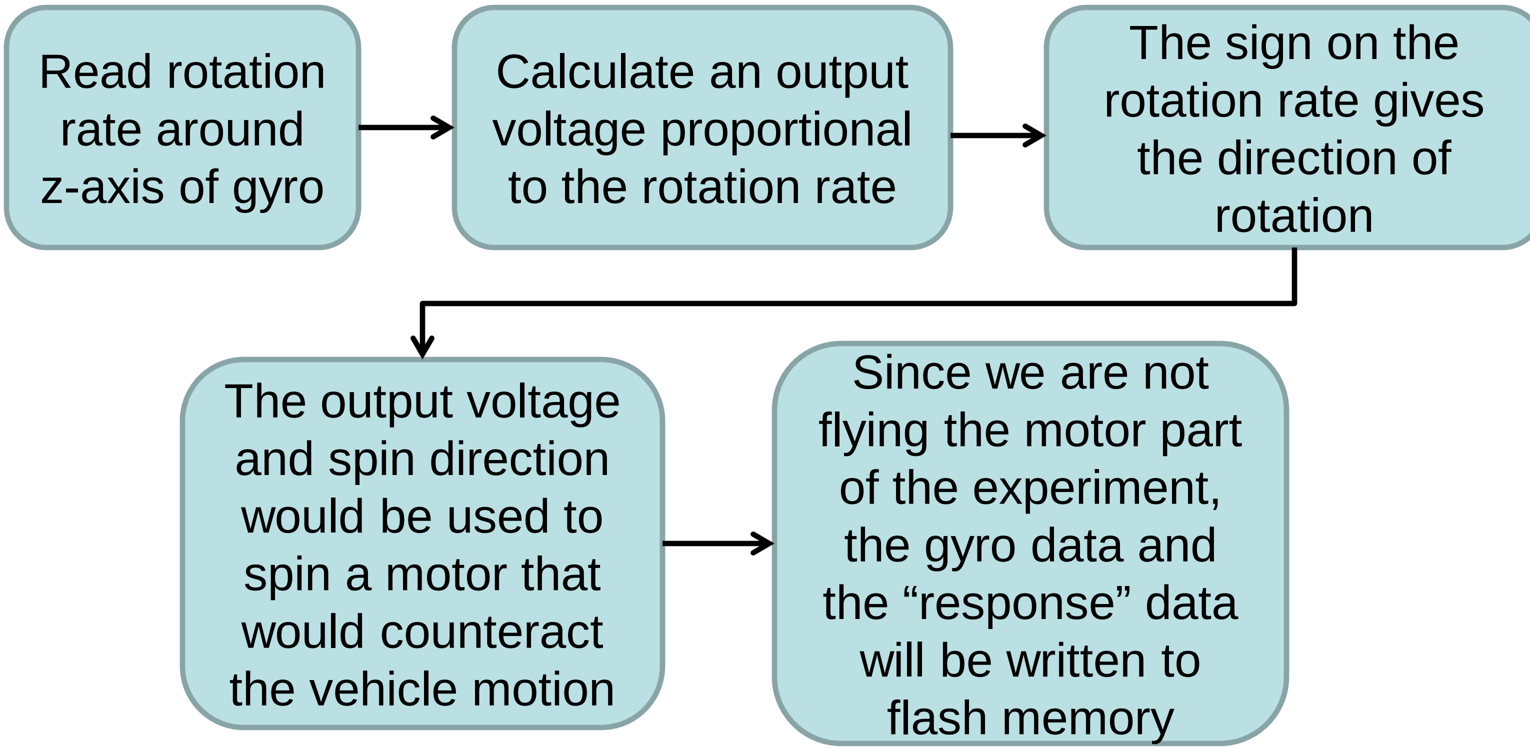


The Arduino Pro Micro has only one dedicated hardware serial interface

One of the devices will use the hardware serial and the other device will use software serial through assigned digital pins

Software Design Elements

Software Flow Diagram



Software Design Elements

- The following pieces of code are part of the software to be loaded onto the IMU
- The IMU then sends gyroscope output to microprocessor via a serial interface
- Portions of code needed to read and send gyro data from IMU:

```
#define GYRO_ADDRESS  ((int) 0x68) // 0x68 = 0xD0 / 2

Wire.beginTransmission(GYRO_ADDRESS);
WIRE_SEND(0x1D);  // Sends address to read from
Wire.endTransmission();

Wire.beginTransmission(GYRO_ADDRESS);
Wire.requestFrom(GYRO_ADDRESS, 6);  // Request 6 bytes

Serial.print(gyro[0]); Serial.print(",");
Serial.print(gyro[1]); Serial.print(",");
Serial.print(gyro[2]); Serial.println();
```

Software Design Elements

- The following pieces of code are part of the software to be loaded onto the microprocessor
- Portions of code needed to define software serial pins:

```
#include <SoftwareSerial.h>
const byte rxPin = 2;
const byte txPin = 3;
// set up a new serial object
SoftwareSerial mySerial (rxPin, txPin);
```

- Portions of code needed to send output to simulated motor:

```
// read the value from the sensor:
  sensorValue = 40.0*analogRead(sensorPin);
  clockwise(sensorValue);  //rotate clockwise
  delay(10);  //wait for 10 milliseconds
  //counterclockwise(sensorValue);  //rotate counterclockwise
  //delay(10);  //wait for 10 milliseconds

//The function to drive motor rotate clockwise
void clockwise(int Speed)
{
  analogWrite(motorIn1,Speed);  //set the speed of motor
  analogWrite(motorIn2,0);  //stop the motorIn2 pin of motor
}
//The function to drive motor rotate counterclockwise
void counterclockwise(int Speed)
{
  analogWrite(motorIn1,0);  //stop the motorIn1 pin of motor
  analogWrite(motorIn2,Speed);  //set the speed of motor
```

WVWC-SPACE Prototyping/Analysis

Analysis Results

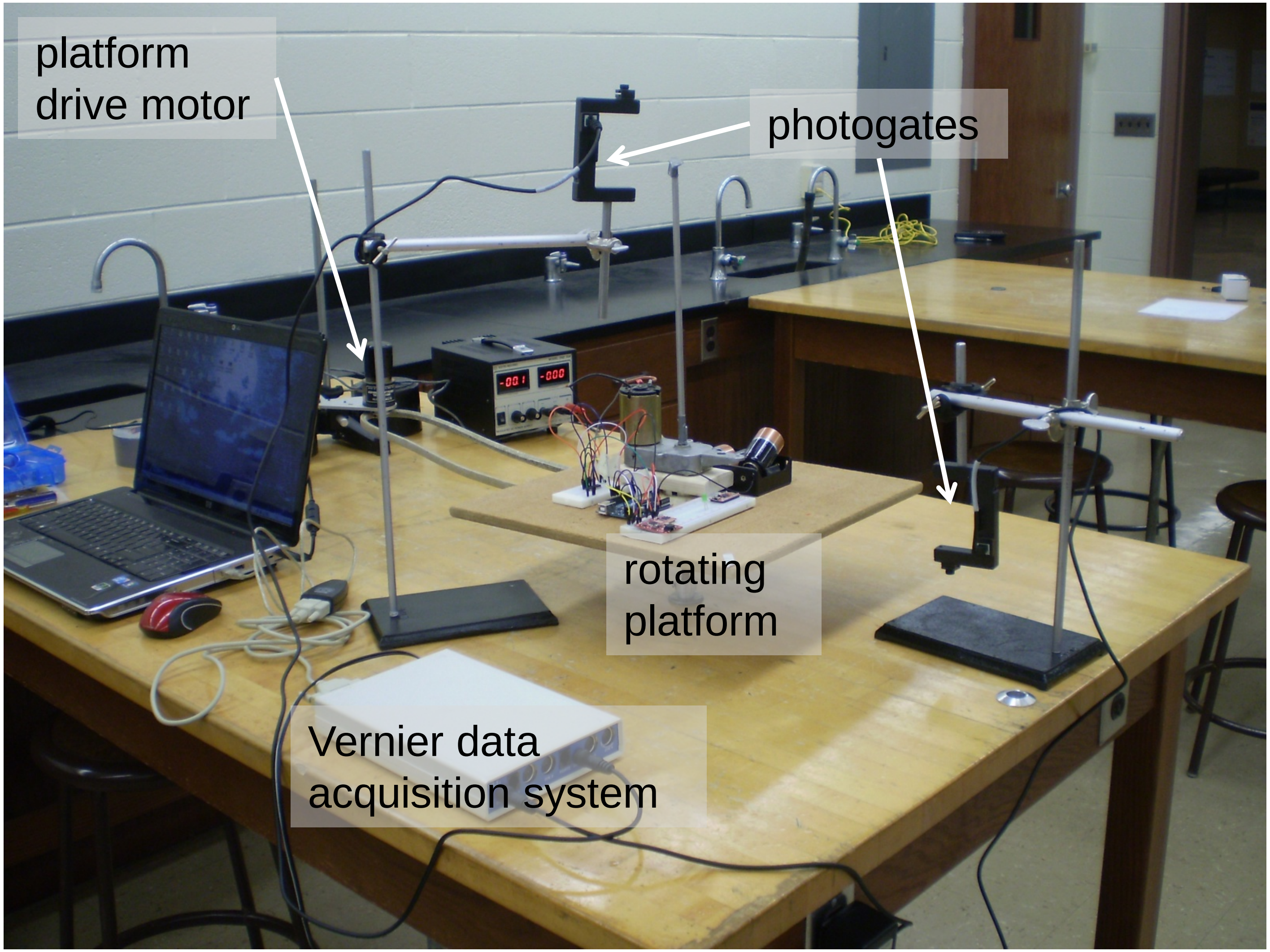
- IMU tested
  - Can read serial output from all sensors
  - Can set sensitivity range of sensors
  - Calibration not as straight-forward as we had hoped
- OpenLog and SD card tested OK
- Developed software to run a DC motor
  - Used an H-bridge IC chip to spin both clockwise and counterclockwise
  - Can control speed, but motor erratic at slow speed (5 Hz)
  - Found a new, geared motor with high torque and smooth operation at slow speed (<1 Hz)
- Using an Arduino Uno during testing, Pro Micro still needs to be tested

Prototyping Results

- Electrical system set up on bread boards
- Will use a rotating platform for testing
- Will use Vernier photogates for calibration of IMU gyros
- Will use Vernier photogates to test response of software and motor to spinning of platform

Prototyping – Rotating Platform

Rotating platform for testing IMU sensor and ability of the payload to drive a motor in response to rotation of platform

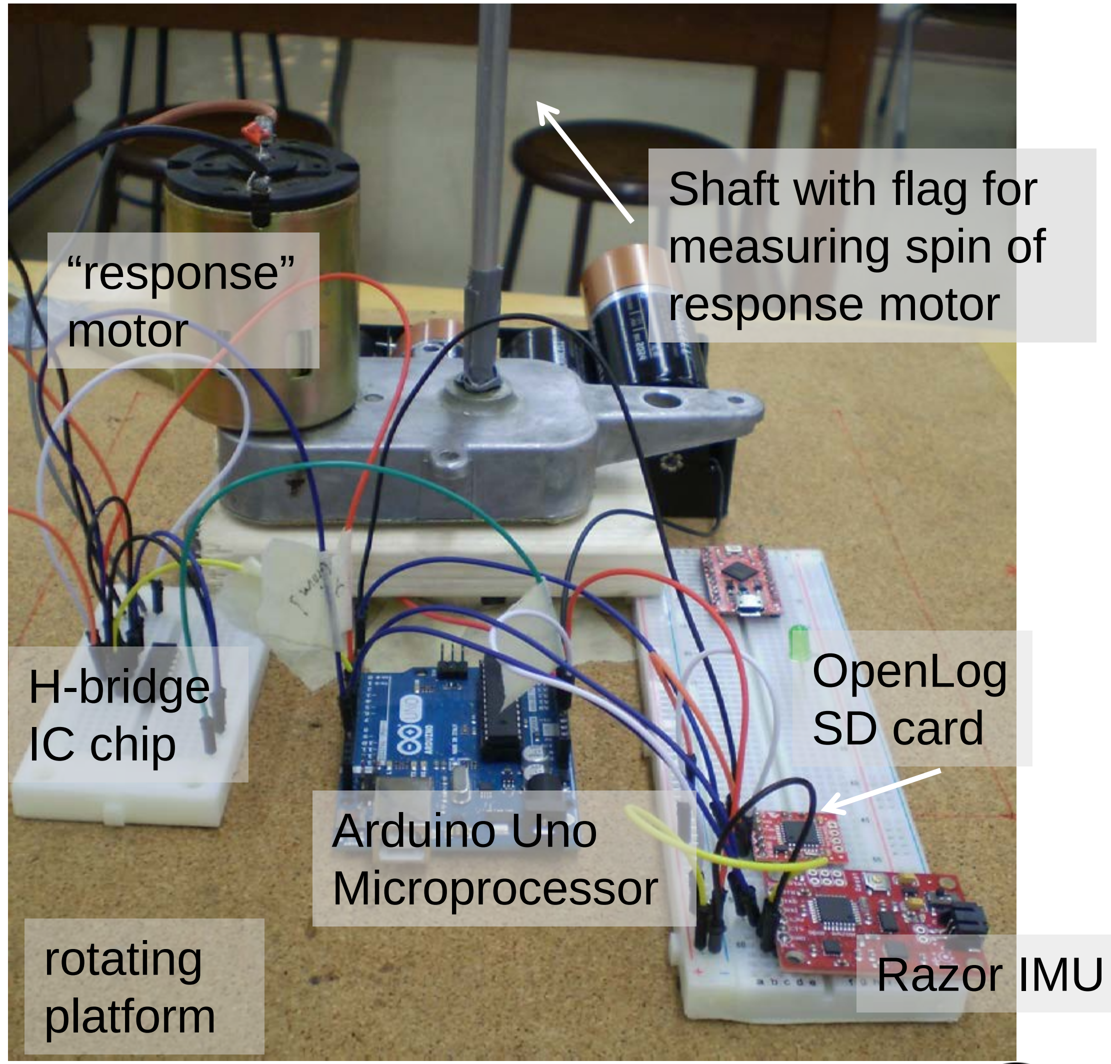


Prototyping -- Rotating Platform

Close-up of payload on rotating platform

H-bridge IC chip, “response” motor, and Arduino Uno will not fly on rocket

Razor IMU, OpenLog, and Arduino Pro Micro will fly on rocket

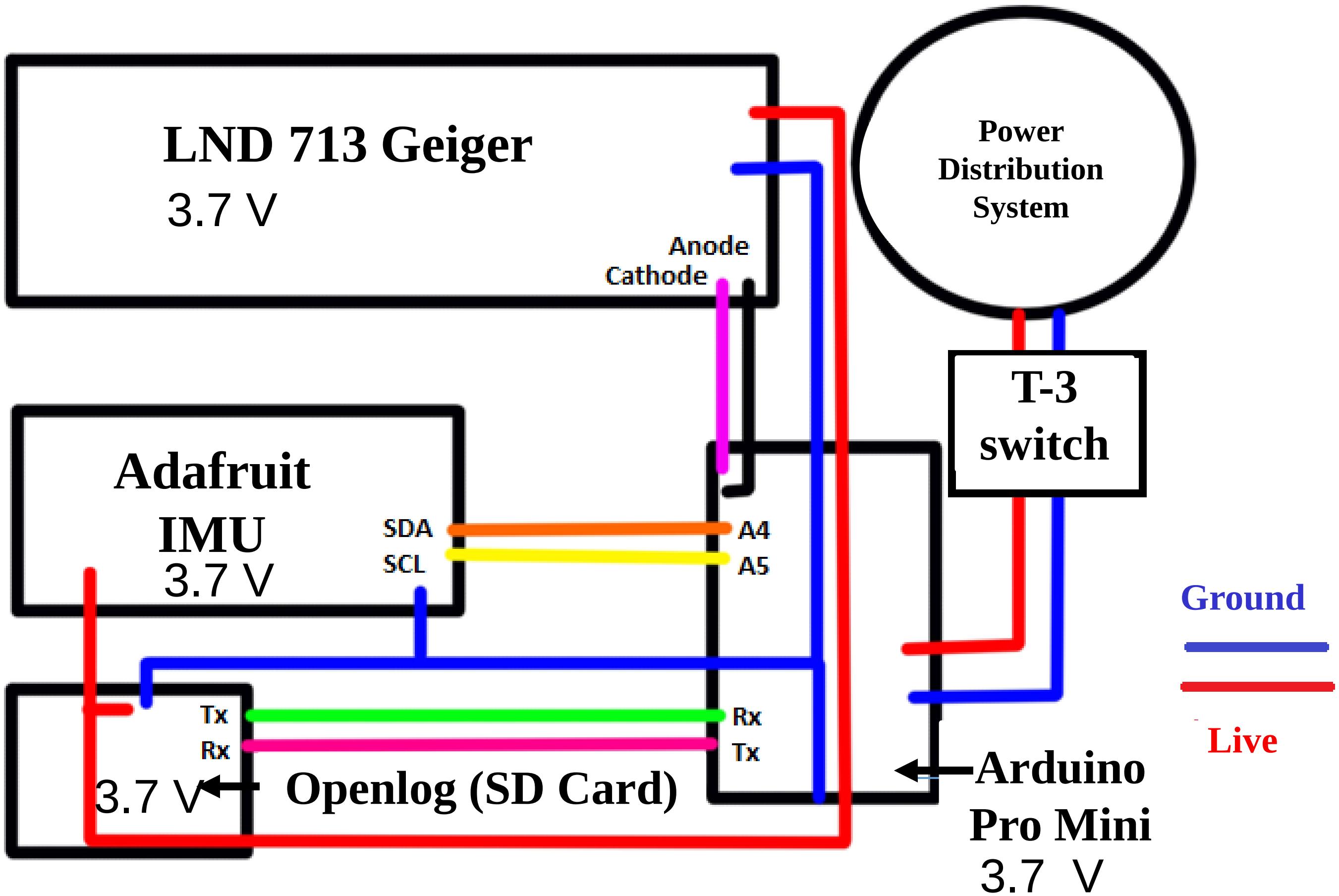


WVSU-SPACE
Design Description

Electrical Design Elements

- One 3x2x1 inch PCB board for all components.
  - Will activate with command line at T-3 minutes
- Ozone meter and light sensor removed.
  - Measuring ozone concentration and light is no longer a mission objective
  - Geiger counter and magnetometer, accelerometer sensor are finalized sensors to be used in payload design

System Level Block Diagram



Electrical Scheme

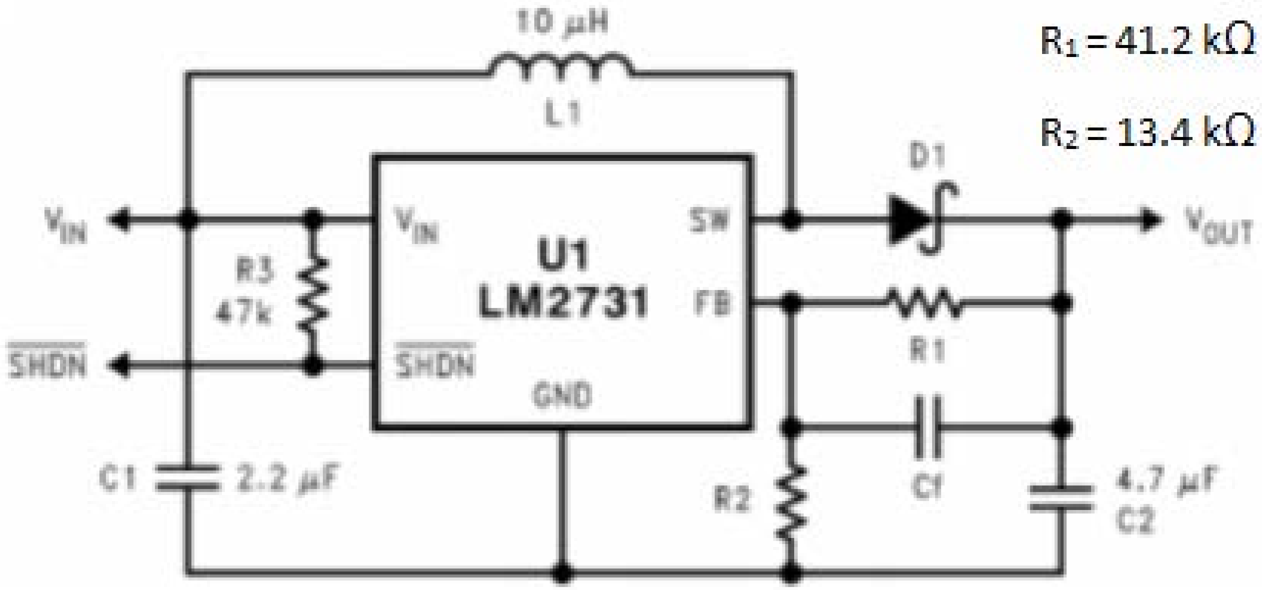
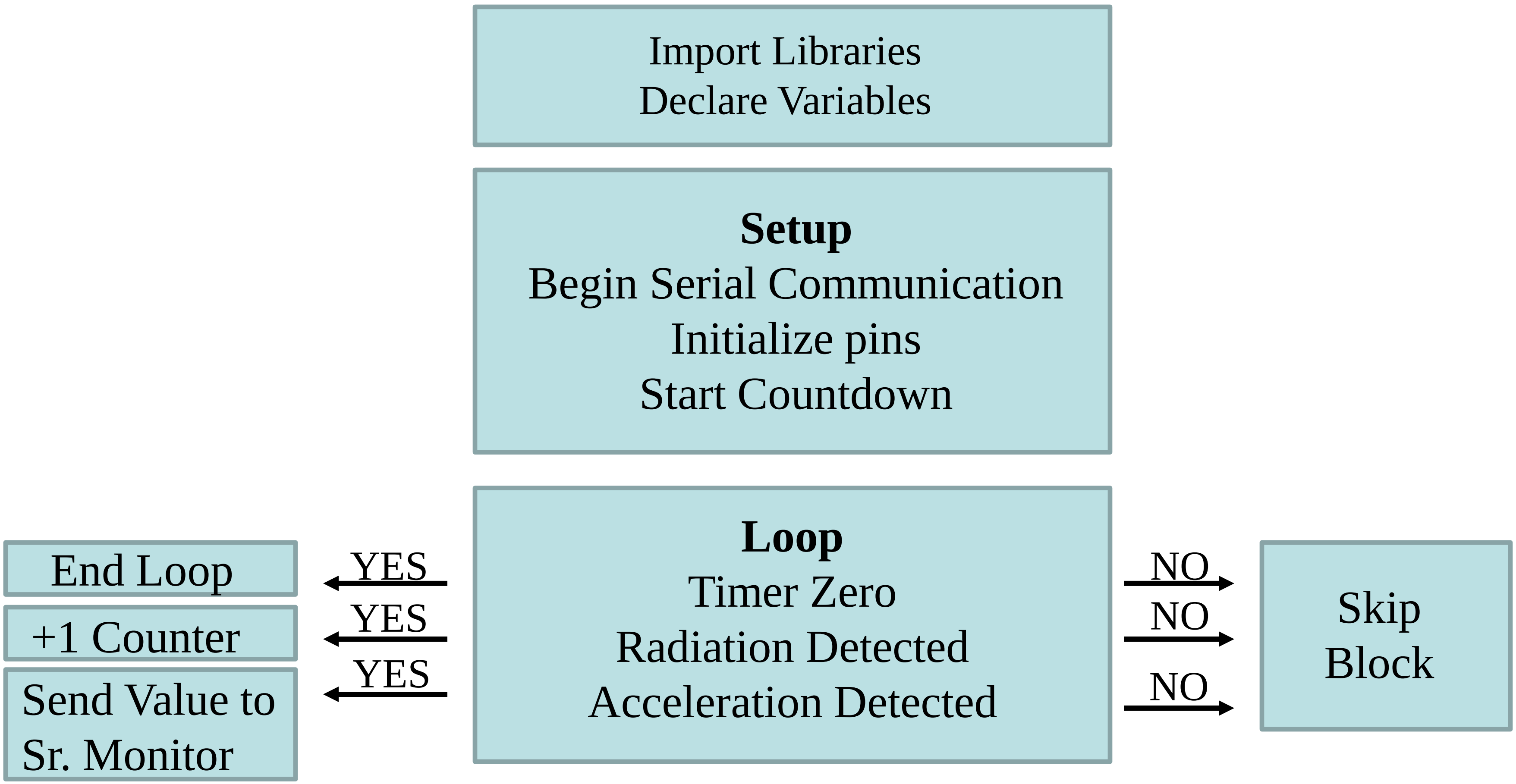


Figure 1: LM2731 Basic Application Circuit

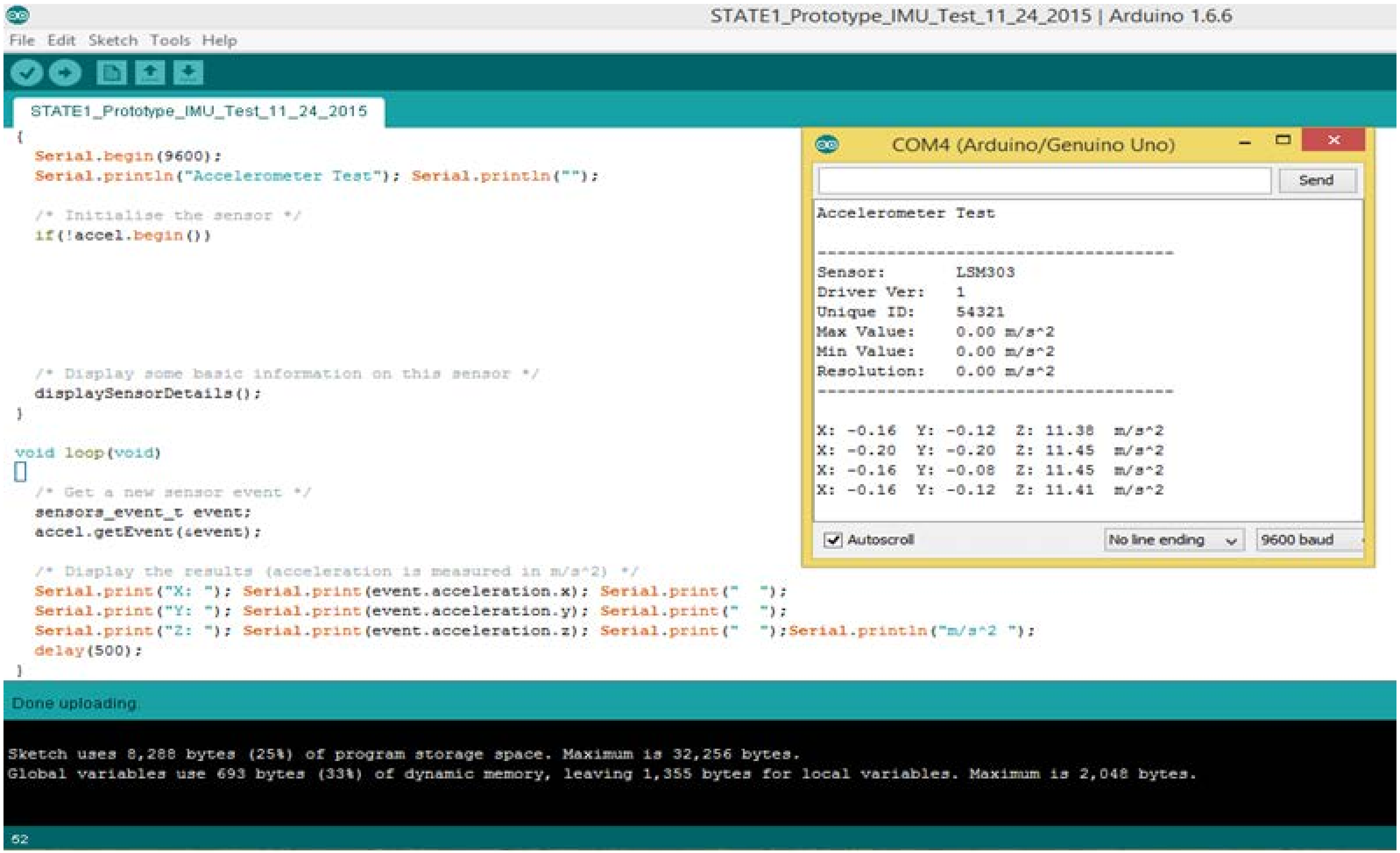
Code Stack


Import Libraries
Declare Variables
Setup
Begin Serial Communication
Initialize pins
Start Countdown
Loop
Timer Zero
Radiation Detected
Acceleration Detected
YES
YES
YES
End Loop
+1 Counter
Send Value to Sr. Monitor
NO
NO
NO
Skip Block

Software Design Elements

- Geiger counter code to be written over the winter break and start of spring semester
- Magnetometer and accelerometer code based on Adafruit LSM303 accelsense and magsense library examples
- Openlog reads data from Tx and Rx pins without additional programming

Code


STATE1_Prototype_IMU_Test_11_24_2015 | Arduino 1.6.6
File Edit Sketch Tools Help
STATE1_Prototype_IMU_Test_11_24_2015
{
Serial.begin(9600);
Serial.println("Accelerometer Test"); Serial.println("");
/* Initialise the sensor */
if(!accel.begin())
/* Display some basic information on this sensor */
displaySensorDetails();
}
void loop(void)
{
/* Get a new sensor event */
sensors_event_t event;
accel.getEvent(&event);
/* Display the results (acceleration is measured in m/s^2) */
Serial.print("X: "); Serial.print(event.acceleration.x); Serial.print(" ");
Serial.print("Y: "); Serial.print(event.acceleration.y); Serial.print(" ");
Serial.print("Z: "); Serial.print(event.acceleration.z); Serial.print(" ");Serial.println("m/s^2 ");
delay(500);
}
COM4 (Arduino/Genuino Uno)
Send
Accelerometer Test

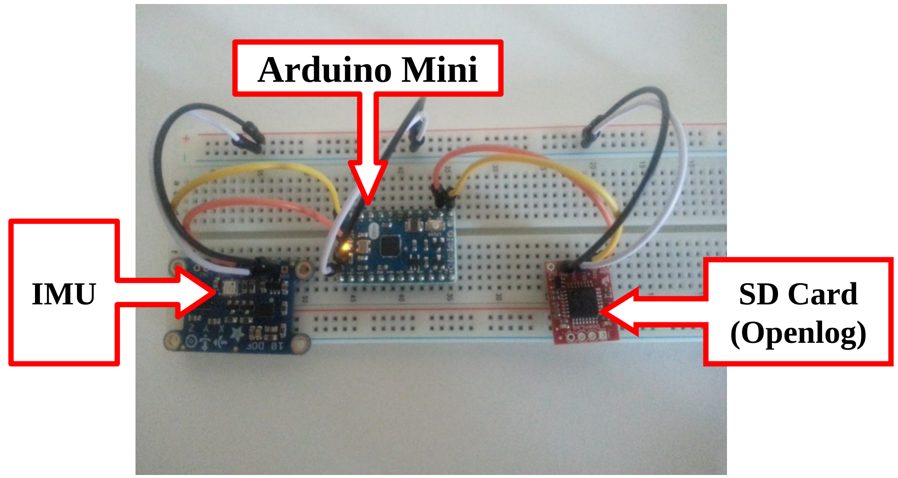
Sensor: LSM303
Driver Ver: 1
Unique ID: 54321
Max Value: 0.00 m/s^2
Min Value: 0.00 m/s^2
Resolution: 0.00 m/s^2

X: -0.16 Y: -0.12 Z: 11.38 m/s^2
X: -0.20 Y: -0.20 Z: 11.45 m/s^2
X: -0.16 Y: -0.08 Z: 11.45 m/s^2
X: -0.16 Y: -0.12 Z: 11.41 m/s^2
Autoscroll
No line ending
9600 baud
Done uploading.
Sketch uses 8,288 bytes (25%) of program storage space. Maximum is 32,256 bytes.
Global variables use 693 bytes (33%) of dynamic memory, leaving 1,355 bytes for local variables. Maximum is 2,048 bytes.
52

WVSU-SPACE Prototyping/Analysis

Prototyping Results

- Breadboard prototype of IMU and micro SD card (Openlog) tested
- CAD files for final design ready
- PCB fabrication and soldering pending GM tube arrival
- Final prototype will allow for performance testing and affirm final dimensions

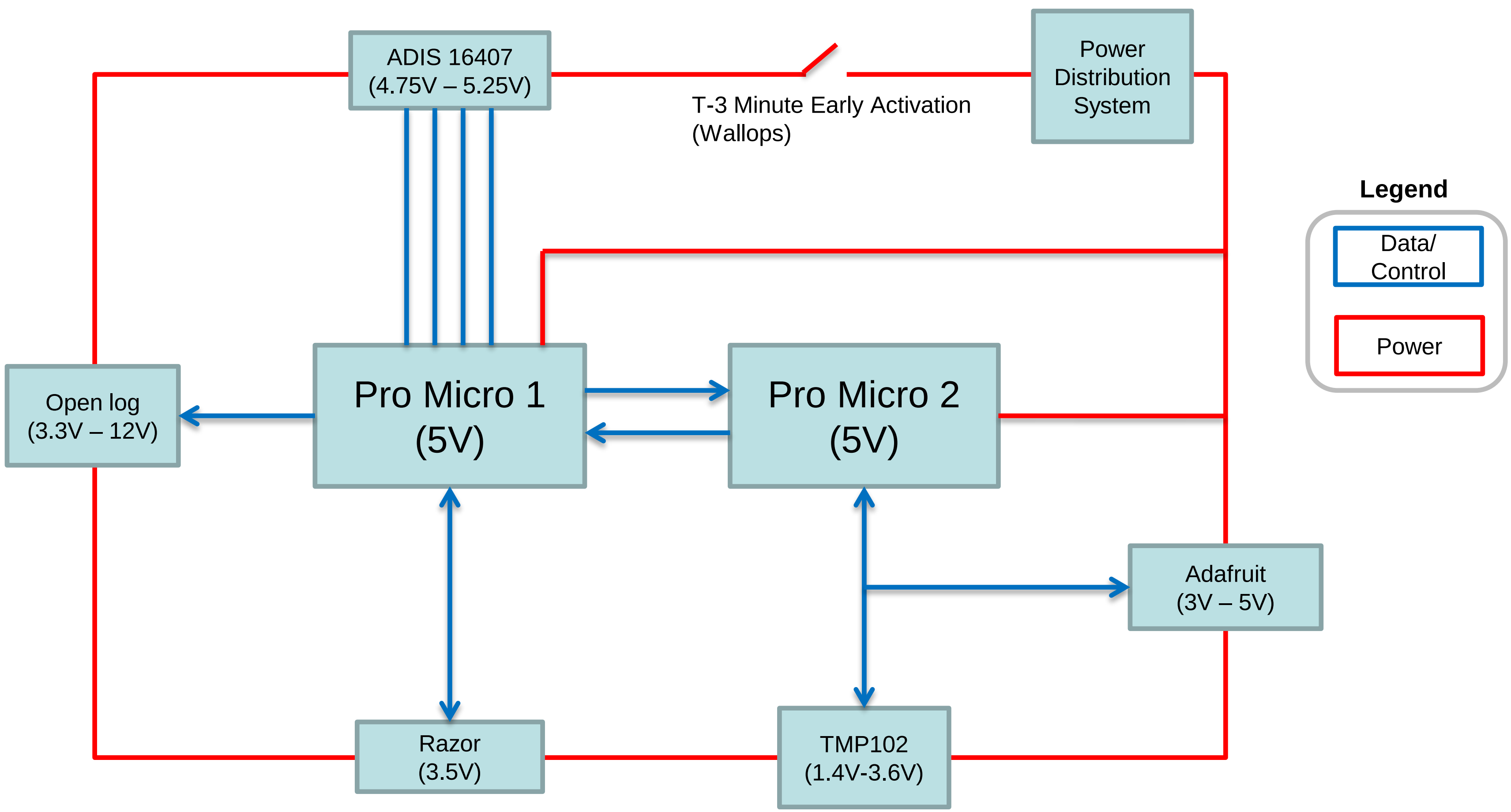


SU-SPACE
Design Description

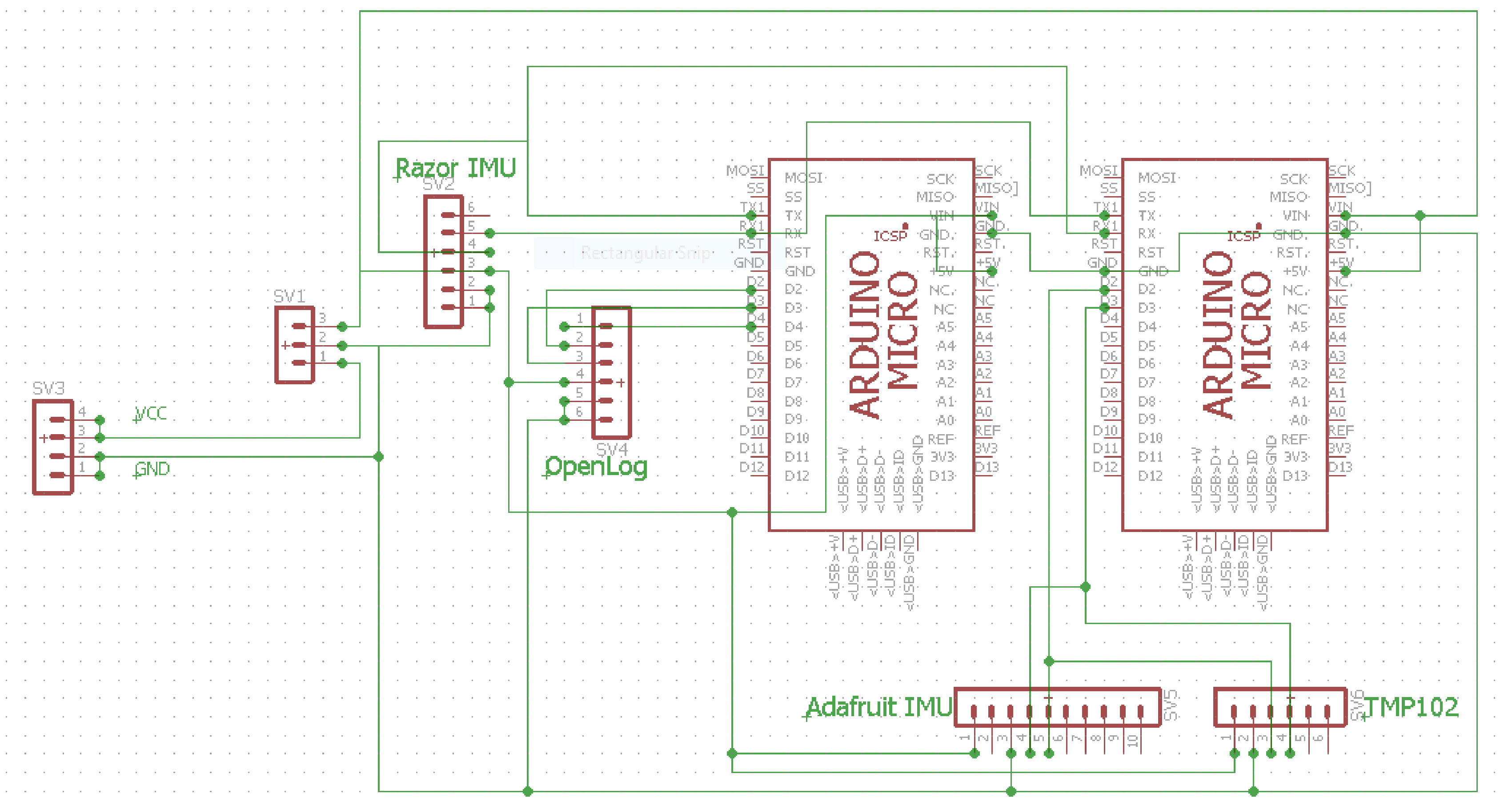
Electrical Design Elements

- One PCB with 3 IMU’s, temperature sensor, openlog, and 2 Pro Micros
  - Pro Micros for managing flow of data/control
  - 3 IMU’s each have 3 DOF gyro, accelerometer, and compass
    - ADIS and Adafruit also have temp sensor
  - Separate temp sensor for comparison to temp sensors on ADIS and Adafruit IMU’s
  - Openlog will store all gathered data through flight
- Since PDR, ADIS IMU was added and Honeywell Magnetometer removed
  - Final list of devices on our board is complete
  - Next, testing/prototyping to see each part works so our final PCB design can be completed

Block Diagram

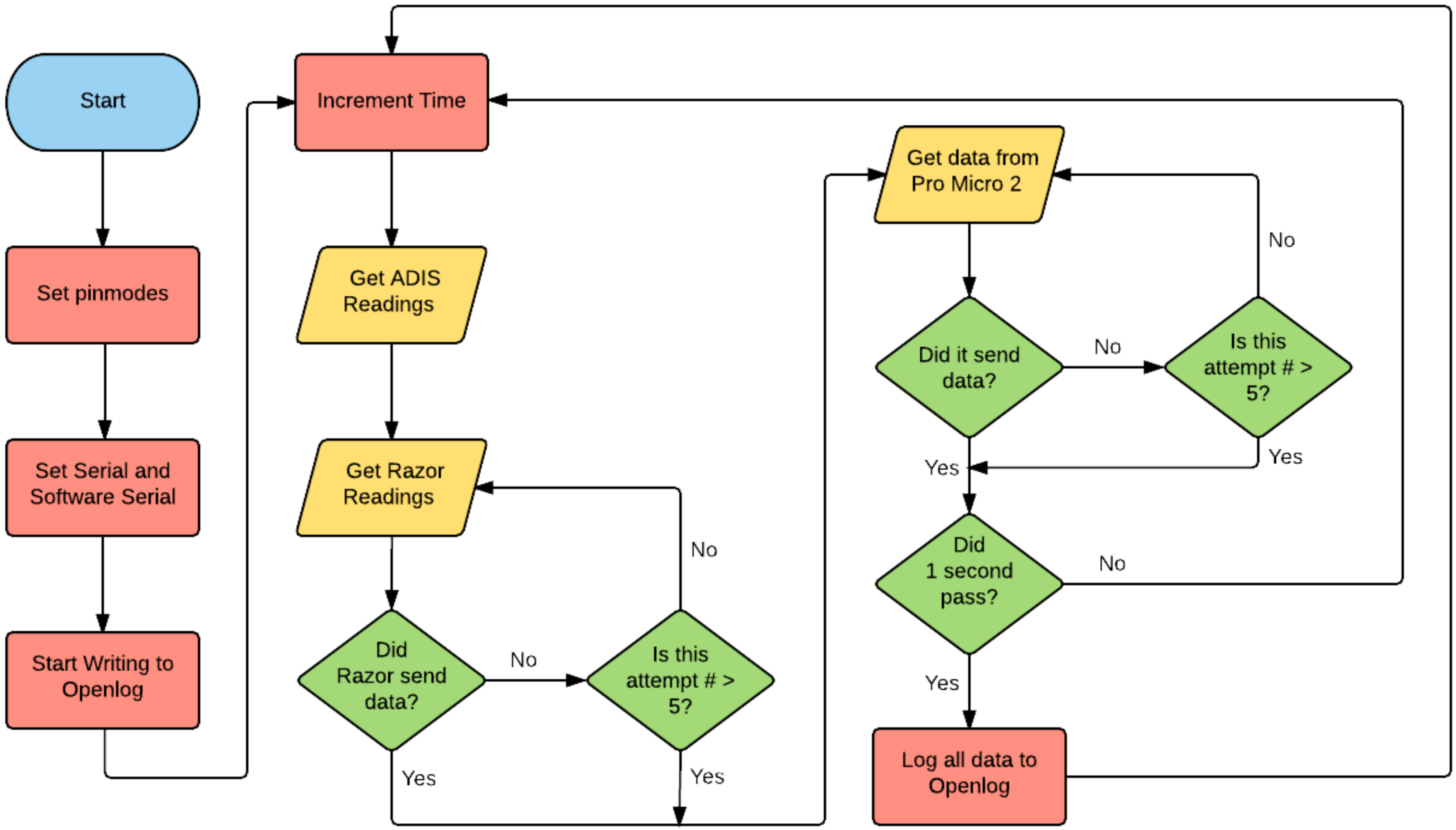


Partial PCB Schematic

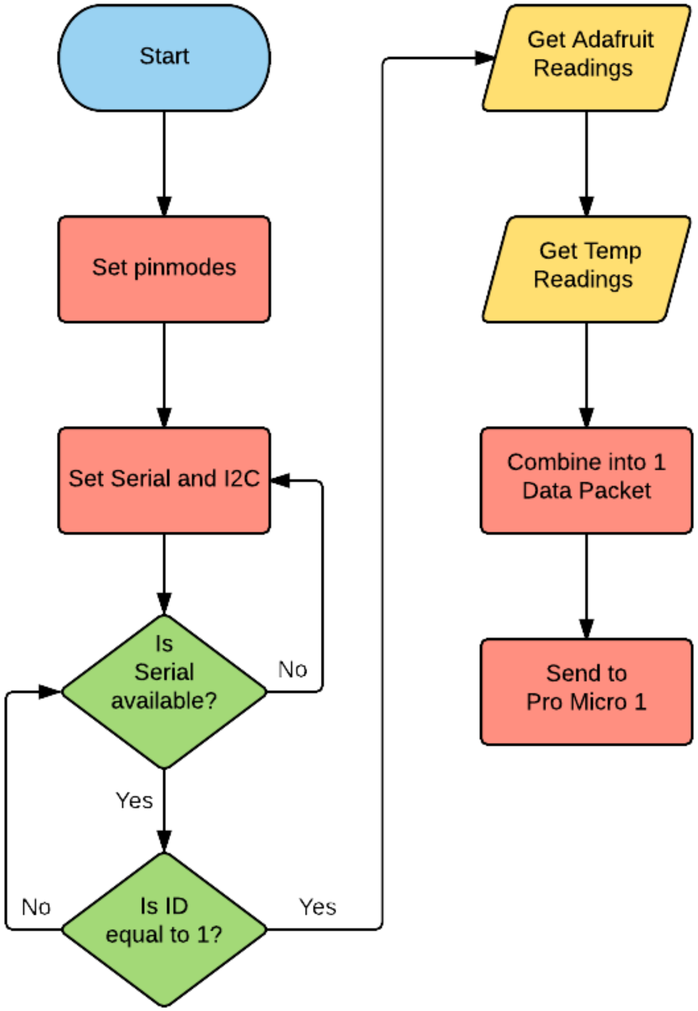


- Notice ADIS IMU is missing because proper pin connections are unclear

Software Flow Diagram: Pro Micro 1



Software Flowchart: Pro Micro 2

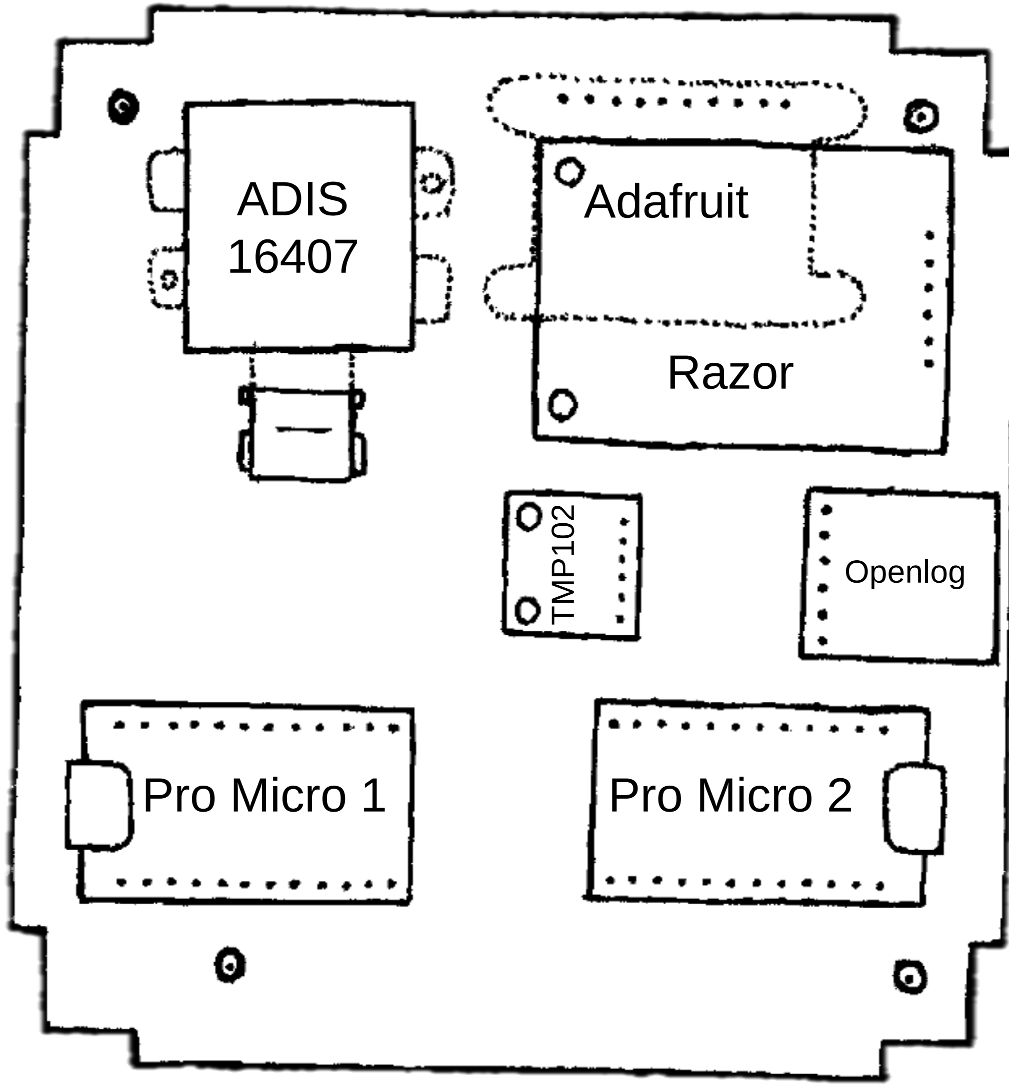


- Second flow chart enters loop of first at "Get data from Pro Micro 2" block
- First chart asks if data was sent by Razor/Pro Micro 2, then "is attempt # > 5?" to limit tries to resend data if previous efforts fail
  - It's "> 5" because loop times out after 5 attempts, each lasting 100ms

SU-SPACE Prototyping/Analysis

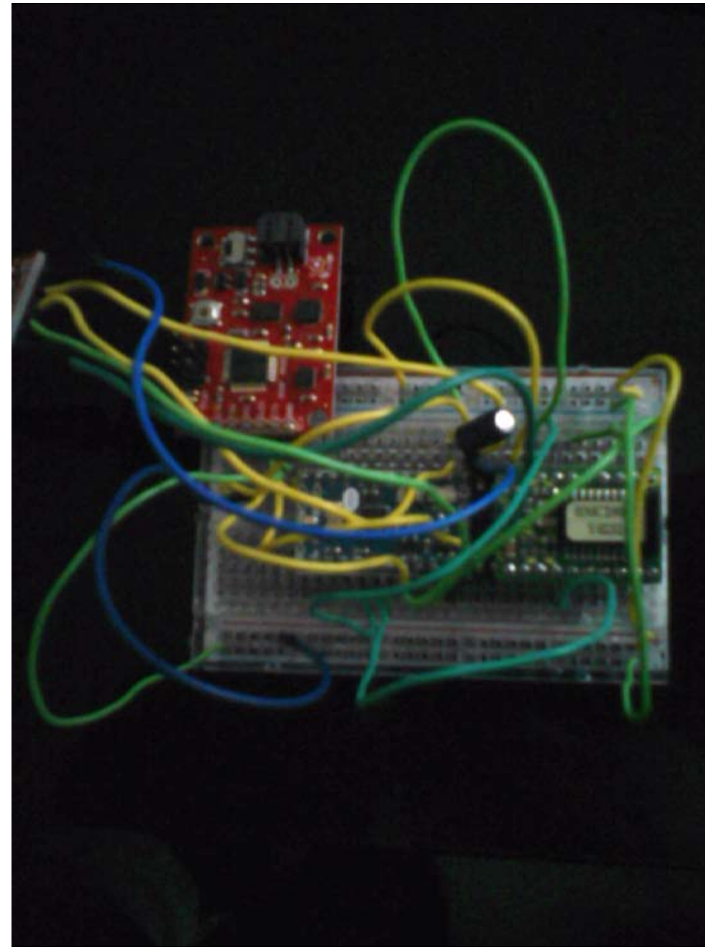
Analysis Results

- Dotted line indicates part is on other side of board
- ADIS is actually attached to bottom side (as denoted by dotted lines)
  - A hole allows the body to come up through PCB
  - Another slot allows ribbon to come through and connect to pin headers
- Design is subject to change once traces are placed



Prototyping Results

- Adafruit IMU, Razor IMU, and Openlog have been analyzed/tested
  - Reviewed firmware for Razor and Openlog
  - Studied libraries for Adafruit
  - Powered up each IMU to read data off of them, making sure they worked
- All currently present devices appear to work
  - Once last parts come in, full integration can begin
  - Will put final circuit design in a breadboard prototype
  - Makes sure everything is wired and programmed correctly before moving onto final PCB design



Manufacturing Plan

Mechanical Elements

- WVU-CAM
  - To be procured:
    - Payload cameras
    - ABS plastic material
    - Structural materials
- WVU-LP
  - To be manufactured:
    - Multi-purpose port lid modifications
    - Multi-purpose port housing for testing
    - Langmuir Probe
  - BOM is in progress
- MU-SPACE
  - 3D print the solar cell panel mount
  - Acquire Raspberry Pi 2 Model B

Mechanical Elements

- FSU-SPACE
  - The prototype needs to be placed a mock up multipurpose port
  - Pressure sensor needs to be procured
- BRCTC-SPACE
  - Needs to be procured:
    - Parallax Propeller ASC+
    - SparkFun Triple Axis Magnetometer Breakout – MAG3110
    - SparkFun Pressure Sensor Breakout – MS5803-14BA
    - Tri-Axis Gyro Breakout – L3G4200D
    - SparkFun Single Axis Accelerometer Breakout – ADXL193
    - SparkFun Solder-able Breadboard (PRT-12070)
- WVUTech-SPACE
  - Strain gauge needs to be procured
- BVCTC-SPACE
  - 3D printed backing plate needs to be manufactured

Mechanical Elements

- WVWC-SPACE
  - Relays need to be acquired to run "response" motor for ground experiment
- WVSU-SPACE
  - Components will be soldered onto PCB
- SU-SPACE
  - ADIS, 2nd Pro Micro, and TMP102 still need to be acquired for testing
- SIS
  - To be manufactured:
    - Makrolon plates
    - 3D printed camera and actuator mounts
  - To be procured:
    - Stand-offs and fasteners
    - ABS plastic
    - Makrolon material

Electrical Elements

- WVU-CAM
  - No electronics manufacturing required
  - COTS SBS for main PCB
  - To be procured:
    - Raspberry Pi A+
  - Procure remaining components: 1/18/16
- WVU-LP
  - Two PCBs required – two revisions of each planned
    - Data acquisition board installed in canister
      - NetBurner NANO54415 μController
      - 16-bit DAC – sweep bias voltage on LP
      - 18-bit ADC – measure V(I) sourced/sank by LP
      - Storage via OpenLog μSD data logger @ 115,200 baud
      - Local voltage regulation
    - I-V amplifier board installed in multi-purpose port housing
      - Connects directly to probe
      - Transimpedance amplifier
      - Differential output amplifier
      - Local voltage regulation

Electrical Elements

- MU-SPACE
  - Need to design and order the PCB and populate
  - Should be ~ 3 revisions to electronics design
- FSU-SPACE
  - PCB needs to be designed
  - We need to find and procure a Barometric pressure sensor that can sense down to around .07 hpa or less
  - Will use I2C communication protocol
- BRCTC-SPACE
  - Solder-able Breadboard connections to be soldered
    - All sensors will be soldered in place to reduce the likelihood of connection failure
  - The solder-able breadboard, Propeller ASC+ and sensors need to be acquired
- WVUTech-SPACE
  - IMU breakout board has to be soldered to pins that were provided so that it can be used on the breadboard as well as the circuit board

Electrical Elements

- BVCTC-SPACE
  - PCBs need to be manufactured
  - Sensors/data logger need to be wired to Arduino
  - Voltage regulation circuit needs to be assembled
  - Anticipate 3 versions of PCB designs
  - Need to procure specified power connector and remaining sensors [ADIS 16305, Honeywell]
- WVWC-SPACE
  - Need to assemble circuit on perforated circuit board
  - Perfboard needs to be cut to appropriate dimensions
  - Need appropriate power connectors
    - Hirose Electric Co Ltd DF11-4DP-2DS(52) [Digikey H2865-ND]
- WVSU-SPACE
  - Geiger counter has to be connected to Arduino pro mini on the PCB
  - Electronics may need 3 revisions
- SU-SPACE
  - PCB design needs completed, then ordered, and all components must be soldered to it
    - 1-2 revisions are anticipated for PCB design
- PDS
  - PCB needs redesigned to accommodate additional experiments
  - Batteries need procured

Software Elements

- WVU-CAM
  - Camera configuration
    - Configure frame rate and image quality
  - Video capture
    - Single command to capture continuous video file until power interrupted
    - Use current date/time to write new file names
  - Audio capture
    - Single command to capture continuous video file until power interrupted
    - Use current date/time to write new file names
  - Camera software testing: 1/18/16 – 3/10/16
- WVU-LP
  - DAQ software
    - Sweep, Sample, Record…loop
    - Timing needs to be worked out

Software Elements

- MU-SPACE
  - Need to write the code to read the values off of solar cells
  - Need to be able to time stamp the data from the RTC
  - Utilizing libraries built for the past Rocksat mission
- BRCTC-SPACE
  - Initializing SD card and then writing the data from the IMU to the SD card
  - Libraries for methods to automatically take data from IMU and pressure sensor
- WVUTech-SPACE
  - Existing code needs to be installed onto the IMU from the computer
  - The IMU has to be programmed to send its data to the SD card for storage
- BVCTC-SPACE
  - Code for activating and logging each sensor must be completed.
  - Block that records readings to memory depends upon blocks activating sensors

Software Elements

- WVWC-SPACE
  - Example code that runs the IMU is very long and needs to be shortened to include only the code to read the gyro
  - Code to set up the software serial pins needs to be tested
  - The code needed to run the "response" motor based on the gyro data from flight still needs to be written
- WVSU-SPACE
  - Geiger counter code to be written. Plan to use existing code
  - Magnetometer, accelerometer code developed, included. Tests being conducted
  - Micro SD code being completed
- SU-SPACE
  - Need to put code into Arduino, but can only test some parts without all components
  - Loops depend on whether processor blocks involved in loop are true or false; inner loops also depends on outer loop
  - Start by making sure outer loop works and then work our way in so it all works

Manufacturing Schedule

- Procure and distribute remaining components/materials
  - 1/18/16
- Machine Makrolon plates
  - 1/25/16
- Machine a mock-up multi-purpose port
  - 2/15/16
- 3D print mounts and housings
  - 2/22/2016
- Subsystem integration
  - 2/5/2016
- PCB fabrication
  - 3/4/16
- PCB soldering/assembly
  - 3/25/16
- System integration
  - 4/29/16

Testing Plan

Electrical Testing

- WVU-CAM
  - Verify NIR camera boom moves lens to optimal position when linear actuation is triggered
    - Mount linear actuator to Makrolon plate and check against design spec (Wallops)
  - Verify NIR camera boom retracts when power is disconnected
- WVU-LP
  - Change transimpedance gain for testing
    - ~100μA – 15mA range
    - Test electronics with Zener diode
      - Plot I-V curve
    - Test in WVU plasma chamber
      - ~100μA – 15mA range

Electrical Testing

- MU-SPACE
  - Construct solar cells on mount and test under full sun and in lab
  - Full prototype payload assembly completed by end of February
- BRCTC-SPACE
  - Each sensor to be connected to the Propeller ASC+ independently to measure actual draw
  - All sensors then connected and complete power consumption will then be measured
- WVUTech-SPACE
  - Each component must be tested at intervals of equal length
  - IMU will need each axis accelerometer tested
    - Can be shown with earth's gravitational acceleration
    - The IMU should read 1g on the axis pointing toward the ground.
  - Tests on each component will be tested regularly to ensure accurate readings
  - The SD card will be tested to make sure it can store the data properly

Electrical Testing

- WVSU-SPACE
  - Geiger counter to be tested with calibrated counter or radiation sources of known value
  - Accelerometer will be tested on the air track and circular pendulum
  - Magnetometer to be tested using Helmontz coils and compare readings of sensor with known magnetic field
- SU-SPACE
  - Need to make sure payload is properly powered
    - Use multi-meter to make sure it has acceptable voltage
  - Current sample rate is 1 sample/sec due to experience showing this generally works for this kind of payload
    - If errors, can change incrementally to find minimum rate needed for data to write to SD card accurately
  - Test power and openlog once software for devices is working and are giving appropriate data
  - Power tests will be repeated later on PCB design

Software Testing

- WVU-CAM
  - Camera configuration and video capture software elements must be development first
  - Analyze NDVI method with control elements using GIMP graphics editor
    - Gather image of wood plank and insulation material against grassy backdrop
    - Check NDVI against reference
- WVU-LP
  - Reuse DAQ software from RSC-14
- MU-SPACE
  - Solar cells, Adafruit IMU, RTC, and logger tests should begin in January
  - Begin bread boarding and additional software unit testing of Raspberry Pi, SD logger, solar cells and Adafruit IMU
  - Data post-processing system development
  - Move from prototype to final assembly
- BRCTC-SPACE
  - Read/Write Commands are required for sending and retrieval of data, providing a fluctuation in draw needed to test min, max and average power consumption
  - Activation Commands are required to measure any electrical activity

Software Testing

- WVUTech-SPACE
  - Coding has to be installed onto the IMU and executed in order to test it
  - Libraries of code are downloadable for the different sensors
- BVCTC-SPACE
  - Code for respective sensors must be developed before sensors can be tested
  - Code for logging readings must be developed before testing OpenLog
- WVSU-SPACE
  - Record count rate with sensor and compare results to calibrated Geiger counter
  - Testing magnetometer and accelerometer will involve measuring output readings and comparison with known magnetic field
  - All sensors will be tested independently on breadboard setup
  - Data saved to microSD card will also be verified with all payload sensors working together
- SU-SPACE
  - Need to test software for each part yet to be received to make sure they work
  - Need to test program for whole payload to make sure viable data is being logged to SD card

Testing Schedule

- Initial component prototyping and testing
  - 12/7/15 to 1/15/16
- Software development and testing
  - 12/21/15 to 3/28/16
- Subsystem prototyping and testing
  - 1/18/16 to 2/29/16
- Data processing
  - 1/25/16 to 3/21/16
- PCB design
  - 2/22/16 to 3/18/16
- Full system testing
  - 5/2/16 to 5/13/16

System Level Design

Steven Hard

Detailed Mass Budget

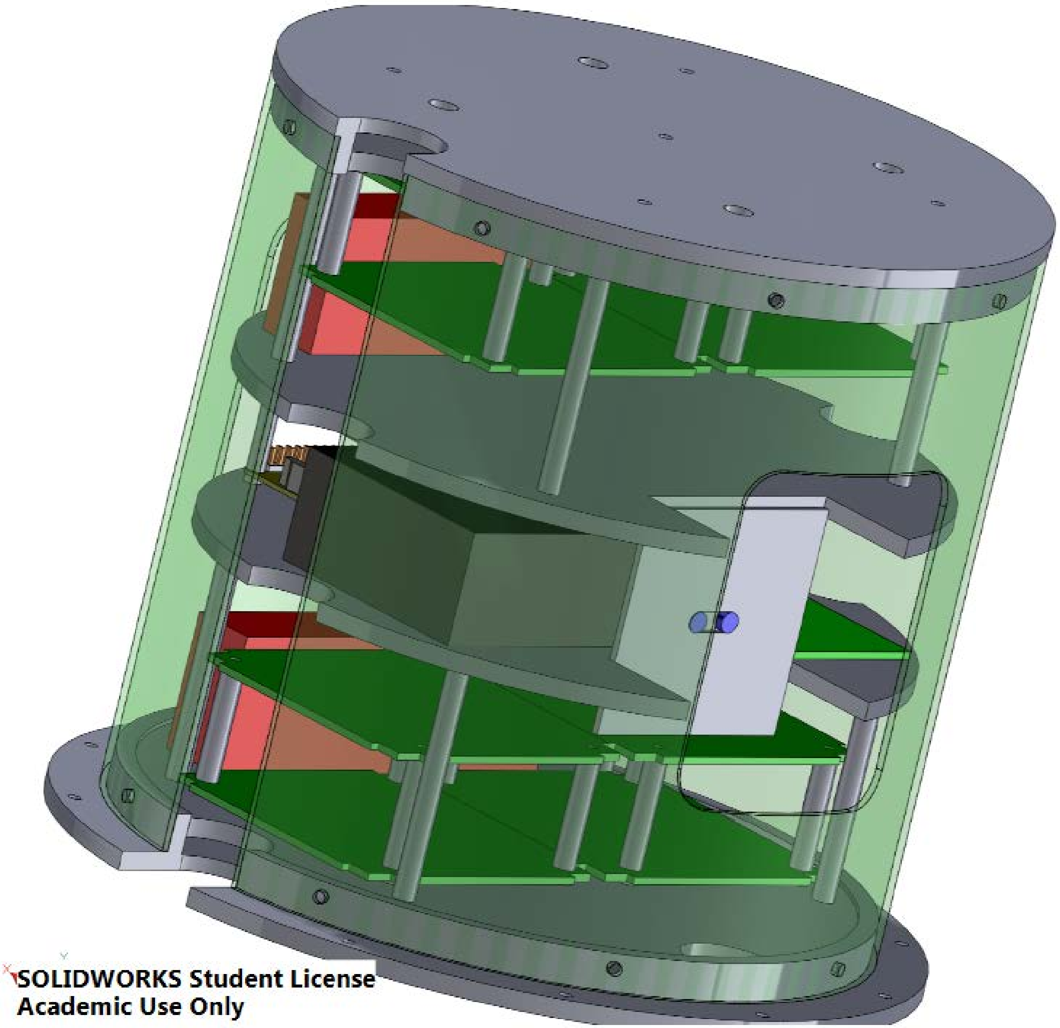
WV-SPACE		
RSC 2016 Mass Budget		
Subsystem	Component	Total Mass (lbf)
WVWC-SPACE	PCB	0.1
	Sensors/DAQ	0.04
WVUTech-SPACE	PCB	0.1
	Sensors/DAQ	0.05
Marshall-SPACE	PCB	0.1
	Sensors/DAQ	0.12
Shepherd-SPACE	PCB	0.1
	Sensors/DAQ	0.3
WVSU-SPACE	PCB	0.05
	Sensors/DAQ	0.05
FSU-SPACE	PCB	0.1
	Sensors/DAQ	0.1
BRCTC-SPACE	PCB/Housing	0.1
	Sensors/DAQ	0.08
BVCTC-SPACE	PCB	0.4
	Sensors/DAQ	0.12

WV-SPACE		
RSC 2016 Mass Budget		
Subsystem	Component	Total Mass (lbf)
WVU-CAM	Sensors	1.4
	Single Board Computer	0.3
	Actuator	0.1
WVU-LP	PCB	0.2
	Probe	0.1
	Sensors/DAQ	0.2
PDS	Batteries	1.3
	PCB	0.1
	Components	0.3
SIS	Makrolon Plates	2.7
	Standoffs/Fasteners	1
	Mounting Brackets	1
	Ballast	3.65
Canister	Full Can	6.65
Target Weight (lbf)		20
Total		20
Over(+)/Under(-)		0

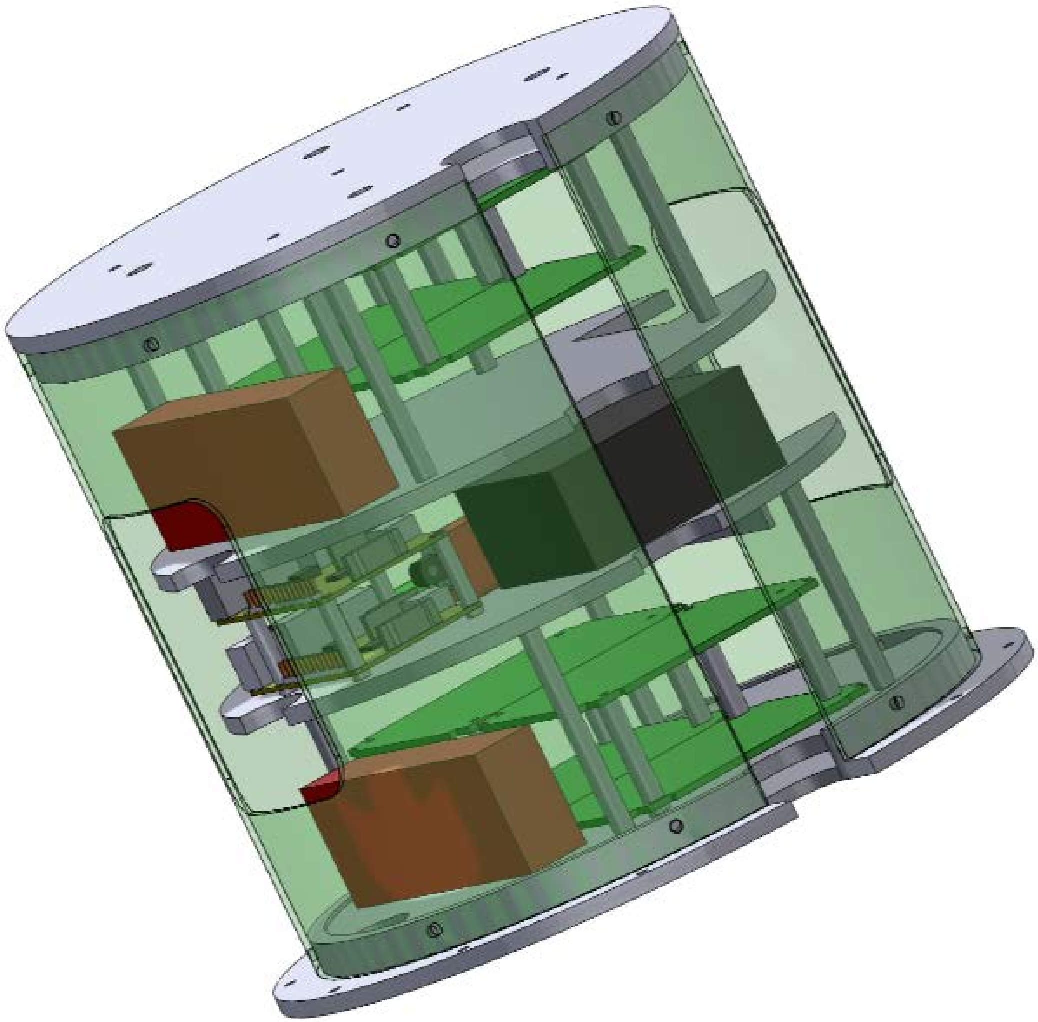
Power Budget

WV Rocketeers - RSC2015 Power Budget					
12/8/2014					
Subsystem	**Voltage (V)**	**Max Current (A)**	**Time On (min)**	**Watts**	**Ah**
WVWC-SPACE	3.7	0.03	30	0.10	0.01
WVU-TECH SPACE	3.7	0.13	30	0.47	0.06
Marshall-SPACE	3.7	0.65	30	2.41	0.33
Shepherd-SPACE	3.7	0.19	30	0.69	0.09
WVSU-SPACE	3.7	0.10	30	0.35	0.05
FSU SPACE	3.7	0.10	30	0.37	0.05
BRCTC-SPACE	3.7	0.11	30	0.39	0.05
BVCTC-SPACE	3.7	0.14	30	0.52	0.07
WVU-CAM	7.4	0.60	3	4.44	0.03
	5.0	2.00	30	10.00	1.00
WVU-LP	7.4	0.80	30	5.92	0.40
	Total	3.04		16.07	2.15
	Total Power Capacity				10.00
	Over (+)/Under (-)				7.86
			# of Flights Margin		4.7

Mechanical Model: Isometric Front



Mechanical Model: Isometric Back



Risks

Steven Hard

Risks:

Mission objectives are not met IF:

R1: WVU-CAM.RSK.1 – Linear actuator boom causes damage to the NIR camera lens

R2: WVU-CAM.RSK.2 – USB connections on the Raspberry Pi CPU vibrate excessively during launch causing temporary or permanent loss of device from Linux OS

R3: WVU-CAM.RSK.3 – Optical port and the linear actuator are not properly aligned causing the optimal view angle of the NIR/Rpi cameras to be decreased or lost

R4: WVWC-Space.RSK.1-- Mission objectives are not met IF microcontroller fails in-flight

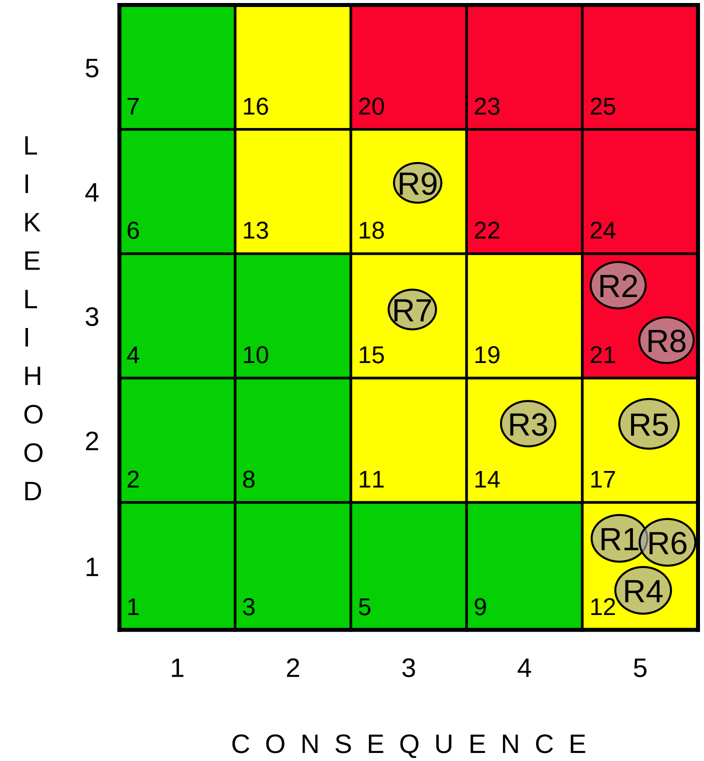
R5: SU-SPACE.RSK.1 - Mission objectives are not met IF any part becomes disconnected, especially power

R6: MU-Space.RSK.4- Insufficient discrimination of solar cell currents

R7: WVUTech-SPACE.RSK.1 - Mission objectives are not met IF the tensile apparatus breaks during flight.

R8: FSU-SPACE.RSK.2/BRCTC-SPACE.RSK.1 - Most mission objectives ARE met IF circuit's hermetic seal does not hold

R9: WVSU-SPACE.RSK. 1- Mission fails IF Geiger counter is not calibrated and properly mounted



Risk Matrix: Walk-down

Mitigation Plan

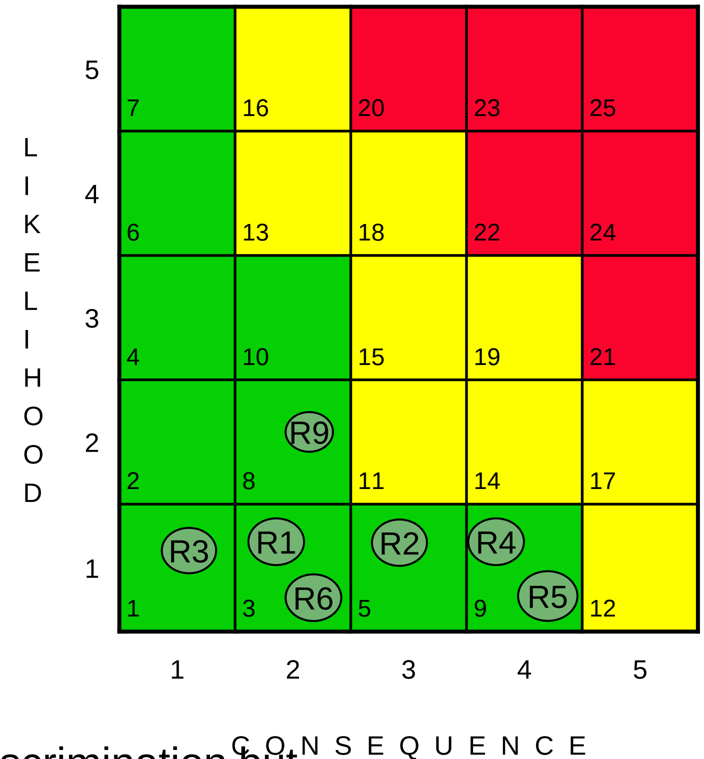
R1: Physically constrain the maximum stroke of linear actuator by mounting and inspecting dimensions of travel after mounting

R2: Stake USB connections into USB port of CPU using either solder or silicon RTV and verify software operations during vibrations testing

R3: Create an accurate CAD model of payload assembly and build in room for adjustment if necessary…double check final dimensions of lower section payload assembly

R4: To prevent microcontroller from failing during flight, many test flights will be performed

R5: Shield the components, check components before flight, include LEDs and switches for testing purposes, and perform vibe tests on the payload before the launch



R6: Analysis has shown there will likely be sufficient angular discrimination but further testing under a full Sun will prove this

R7: Design apparatus descoped

R8: Circuit box no longer required for use of multipurpose port – eliminated risk

R9: Geiger counter upgraded, accuracy increased, calibration still necessary

New Risks:

Mission objectives are not met IF:

R10: WVU-CAM.RSK.4 – Solar panel mounts fail causing blockage of optics port or damage to NIR/RGB cameras
- Overdesign mounts and perform extensive vibration testing

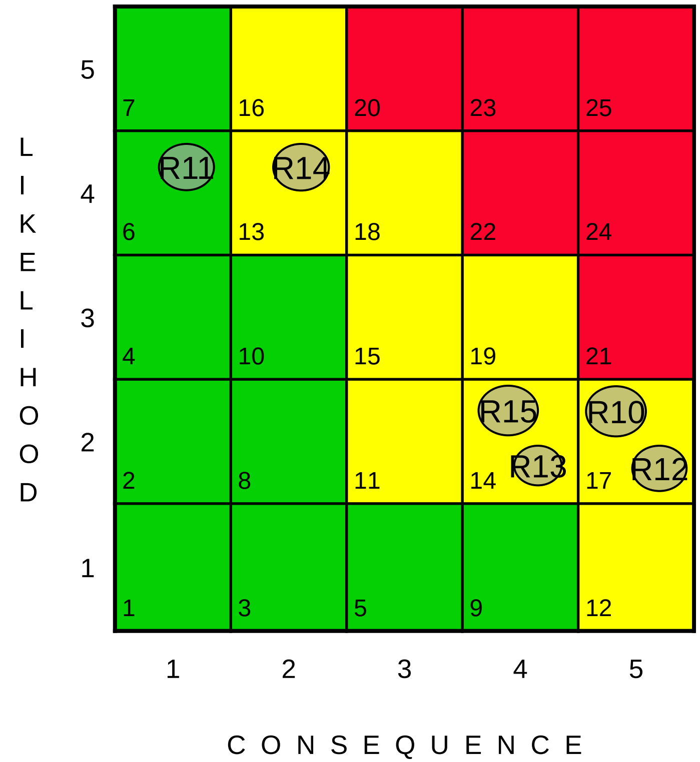
R11: WVU-CAM.RSK.5 – Vegetation can not be distinguished
- Perform NDCI analysis instead

R12: WVU-LP.RSK.1 – Langmuir Probe could disconnect from PCB due to vibration
- LP mechanically supported in two locations - the multi-purpose port cover and PCB

R13: WVU-LP.RSK.2 – Langmuir Probe could break off from stresses during launch
- Probe constructed from stainless steel

R14: MU-Space.RSK.5 – Sun does not illuminate solar cells during flight
- Risk must be accepted

R15: BVCTC-SPACE.RSK4: Printed plate may have excessive weight or could break if not designed properly
- Perform FEA on plate housing to minimize weight while providing sufficient structural integrity
- Use custom PCB if necessary



User Guide Compliance

Steven Hard

User Guide Compliance

- Mass – 13 lb
- CG within 1”x1”x1” envelope
  - SolidWorks verification to be performed once material properties are specified
  - Ballasts will be placed strategically to ensure CG compliance
- Batteries: LiPo 7.4V 5000mAh x2
- RESTATE: T-3min activation type

Design Overview: Shared Can Logistics

- Partners (NASA IV&V Sponsored):
  - West Virginia University Team: WVU-CAM
  - West Virginia Wesleyan College: WVWC-SPACE
  - Shepherd University: SU-SPACE
  - Marshall University: MU-SPACE
  - West Virginia University Institute of Technology: WVUTech-SPACE
  - Fairmont State University: FSU-SPACE
  - Bridge Valley Community Technical College: BVCTC-SPACE
  - Blue Bridge Community Technical College: BRCTC-SPACE
  - West Virginia State University: WVSU-SPACE

Design Overview: Shared Can Logistics

- Plan for collaboration
  - Weekly/Monthly Telecon sessions
  - Share designs using Google drive
  - Will fit check before June
- Mounting to both bottom and top bulkheads of canister.
- Structural interfacing:
  - Aluminum standoffs
- **Not** using a mid-mounting plate
- Ports:
  - Optical (WVU & MU)
  - Atmospheric (FSU & BRCTC)

Project Management Plan

Steven Hard

Schedule

- Major Milestones
  - CDR (12/8/2015)
  - Prototype high risk items (12/20/2015)
  - Flight award announcement (1/16/2016)
  - Procure remaining components (1/18/2016)
  - Design PCBs (Week of 2/1/2016)
  - SIT (Week of 2/15/2016)
  - ISTR (Week of 3/28/2016)
  - Receive canister (Week of 4/11/2016)
  - FMSR (Week of 5/2/2016)
  - Deliver preliminary check-in document (Week before 6/6/2016)
  - LRR (Week of 6/6/2016)
  - Travel to Wallops (6/16/2016)
  - Launch (6/23/16)*
  - * Tentative, no guarantee – small chance launch could get cancelled due to weather or other unforeseen delays

Budget

Margin:	0.25	Budget:	$17,000.00	Last Update:	11/11/2015 19:28
WV RSC'16 Payload					
Item	**Supplier**	**Estimated, Specific Cost**	**Number Required**	**Toal Cost**	**Notes**
Devices	Various	$980.00	9	$8,820.00	9 experiments kept under $1k each
PCBs	Advanced Circuits	$270.00	9	$2,430.00	9 subsystems require custom PCBs, expect 2 revisions each
Electronic Components	Digi-Key	$150.00	9	$1,350.00	1 set of components per 9 PCBs
Structural Supplies	McMaster-Carr	$300.00	1	$300.00	Only need 1 set of mechanical parts
Lab Supplies	Various	$70.00	9	$630.00	Allowance for lab supplies for each team
Total (no margin):					$13,530.00
Total (w/ margin):					$16,912.50

Project Summary

- No critical severity issues currently identified
- Areas of concern
  - NIR/RGB camera mount
  - Solar panel mount
  - PCB design

Team Contact Matrix

Institution	Team Member	Email Address	Phone Number	US Person? (Y/N)
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Conclusion

- Plan of action:
  - Procure remaining components
  - Finish prototyping of subsystem configurations
  - Finalize PCB designs
- Before break:
  - Place components order
  - Norm on PCB software and initial prototyping