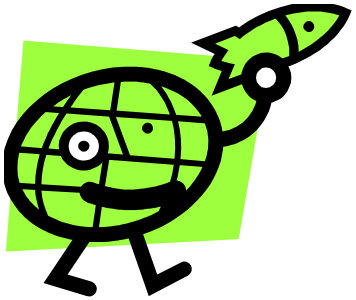
WV Rocketeers

Conceptual Design Review



WVU WVU-TECH FSC SU
MU WVWC JFFL NASA IV&V

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10/17/2014

Purpose of CoDR

- Confirm that:
  - Science objectives are understood and well-defined
  - Preliminary mission requirements are defined and traceable to science objectives
  - Understand concept of operations
  - Technology dependencies and alternative strategies for achieving science objectives

CoDR Presentation Contents

- Section 1: Mission Overview
  - Mission Overview
  - Theory and Concepts
  - Mission Requirements (brief, upper level)
  - Concept of Operations
  - Expected Results
- Section 2: Conceptual Design Overview
  - Design Overview
  - Functional Block Diagrams
  - Payload Layout
  - RockSat-C 2015 User's Guide Compliance
  - Shared Can Logistics (if applicable)

CoDR Presentation Contents

- Section 3: Management
  - **Team Organization**
  - Schedule
  - Budget
  - Mentors (Faculty, industry)
- Section 4: Conclusions

Mission Overview

- To design and test a science payload in space
- System shall provide knowledge and hands-on experience to students
- System shall be able to save data during flight for post analysis
- B-field/IMU correlation and space images
- Benefits SmallSat community – COTS orientation estimation
- Elementary school systems – promote STEM

WVU-CAMs Experiment

"The goal of the WVU-CAMs experiment is to capture video footage of earth and outer space as well as to provide video telemetry of the payload canister (actuators/LEDs/etc) throughout entire flight"

- Mission requirements from this statement:
  - Capture IR video of earth and space during flight
  - Capture video telemetry of payload experiments
- Expect to extract vegetation health on land masses from earth images
- Expect to study near-infrared light sources from space
- The sensor developed will reduce future payload weight and footprint size

WVU-CAMs Overview: Theory and Concepts

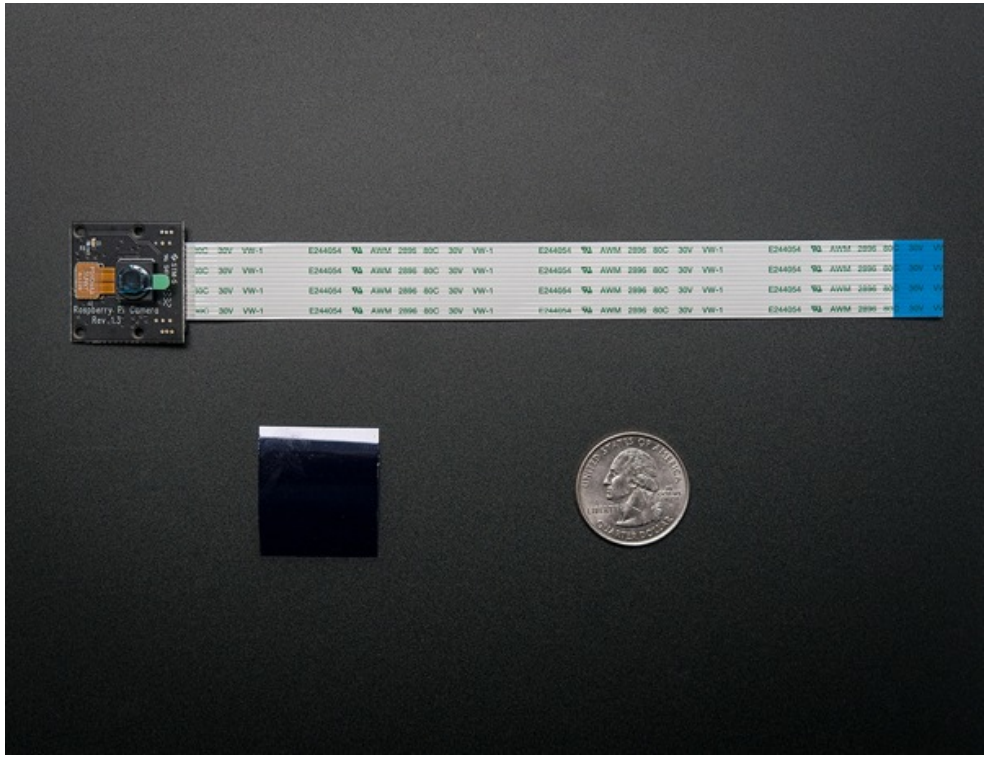
- Study how earth's surface reflects/absorbs Sun's near-infrared (NIR) radiation
  - Observe health of vegetation and soil composition
- Collect images of cooler red stars and red giants for spatial analysis
  - Try to identify certain stars based on orientation
- NIR wavelength: 800 – 2500 nm
- Camera hardware/software flown on RSC'14
  - Results prove imaging apparatus feasible
  - Replacing standard cam lens w/ NIR cam lens

WVU–CAMs Overview: Mission Requirements

- Objectives: Capture images of earth at 60 fps in-flight, capture images of payload operations at 60 fps in-flight, store data for post-processing and analysis
- System Requirements (from the objectives):
  - Camera must be able to view earth's surface and configurable to take video at 60 fps
  - Additional camera must be positioned to view necessary telemetry information and provided adequate lighting
  - Need structure to support the instrument(s) in-flight
  - Need a data collection system to store the measurements (in-flight)
- Minimum Success
  - One image of earth's surface to distinguish landmass and potential vegetation health assessment
  - Visual telemetry collected after launch and at apogee

WVU-CAM Layout

Payload Camera



NIR Camera

JFLL-BOOM Experiment

"The goal of the JFLL-BOOM experiment is to set new heights for JFLL by providing a telescoping camera boom to enhance the WVU-CAM experiment while satisfying the JFLL challenge in outer space (this will be 1st time a JFFL build has flown in space)"

- Mission requirements from this statement:
  - Provide telescoping boom for WVU-CAM
  - Use one motorized part and incorporate simple machine
- Expect to enhance the WVU-CAM experiment by broadening field of view
- Expect to inspire the youth to reach for the stars

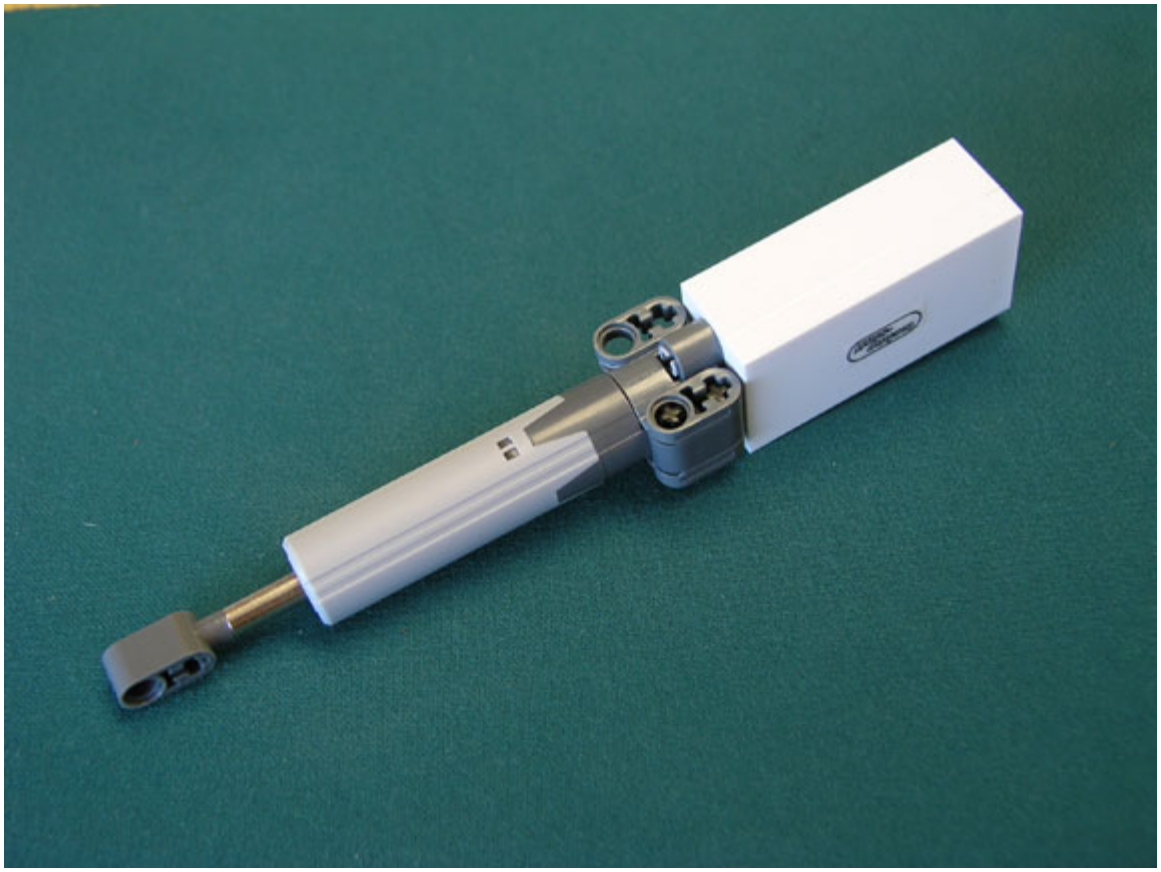
JFLL-BOOM Overview: Theory and Concepts

- A screw can be thought of as a spiraled incline plan
  - Worm gear is a type of screw mechanism
- Worm gear and track system will be used to translate camera
- Electric motor used to drive worm gear
- Results from RSC'14 show potential for image enhancement
  - Optical port clearly visible, glares evident

JFLL-BOOM Overview: Mission Requirements

- Objectives: Minimize distance between optical port and camera lens after 2nd stage burnout
- System Requirements (from the objectives):
  - Minimize distance between WVU-CAM NIR lens and optical port using linear translation
  - Implement a simple machine and motorized part
  - Must not allow NIR lens to be driven into optical port
  - Must provide adequate structural support during reentry
  - Fit within allotted space (TBD)
- Minimum Success
  - Provide stable support system for WVU-CAM NIR lens

JFLL-BOOM Layout



Linear Actuator Boom

WVWC-SPACE Experiment

"The goal of the WVWC-SPACE experiment is to detect cosmic rays at high altitude and radiation at ground level in addition to collecting flight dynamics (FD) and B-field data in-flight"

- Mission requirements from this statement:
  - Detect cosmic rays at high altitude
  - Detect radiation at low altitude
  - Collect flight dynamics data in-flight
  - Measure Earth's magnetic field in-flight
- Expect radiation levels to drop with altitude until cosmic rays are detected
- Expect to observe a spin-rate of ~5Hz
- Expect to saturate vertical accelerometers at launch

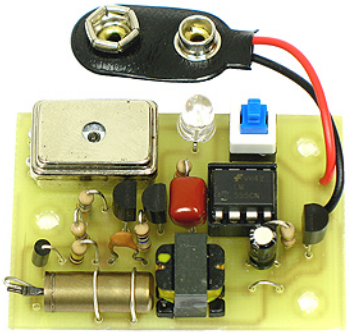
WVWC-SPACE Overview: Theory and Concepts

- Study how radiation levels drop with altitude
- Study cosmic rays above the Karman line
- Correlate payload orientation with Earth's magnetic field readings and World Magnetic Model (WMM)
  - Spin rate presents a challenge
- WVWC-SPACE flown on RSC'14
  - Did not include Geiger counter
  - Redesigning PCB to fit CubeSat payload specs

WVWC-SPACE Overview: Mission Requirements

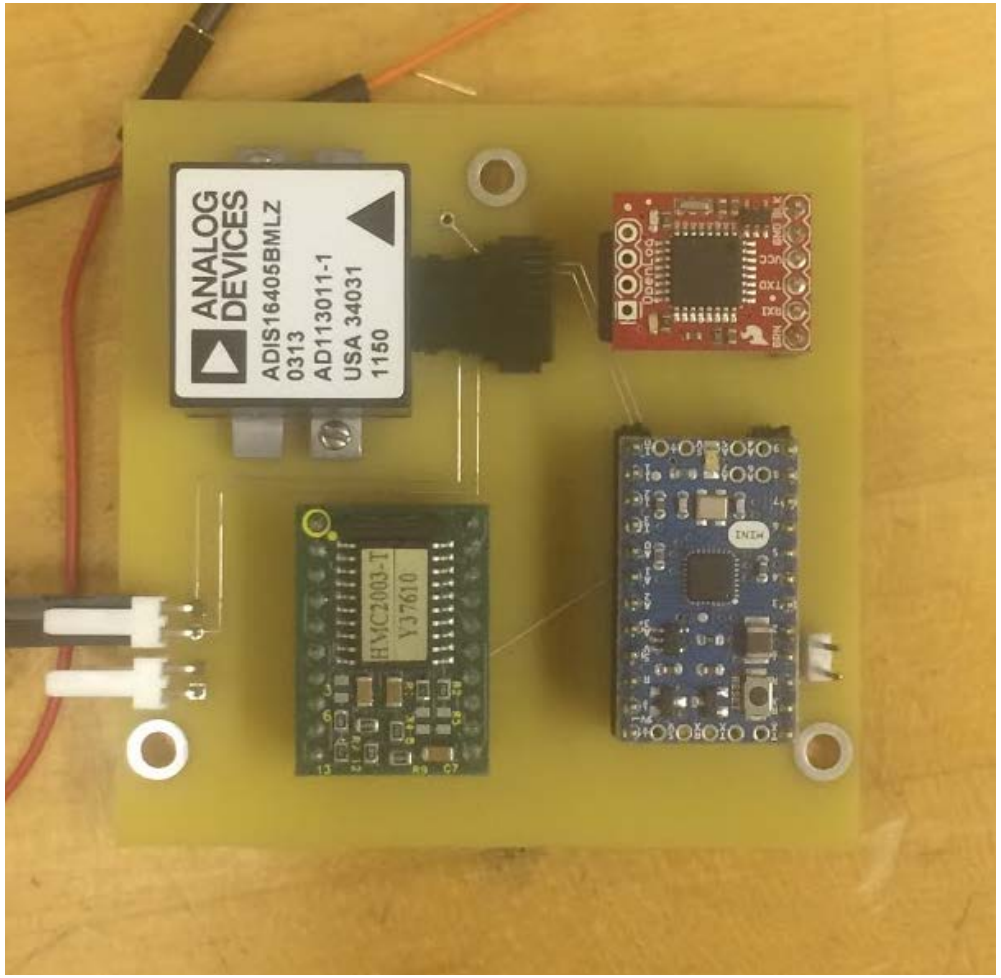
- Objectives: Observe a decrease in radiation levels with altitude and detect cosmic rays in space environment using Geiger counter, collect FD and B-field measurements, store data for post-processing and analysis
- System Requirements (from the objectives):
  - Detect radiation levels and cosmic rays in-flight
  - Collect FD data and B-field data
  - Store measurements (in-flight) for post-processing and data correlation with WMM
- Minimum Success
  - Radiation level detected and cosmic ray detected
  - FD and B-field data collected

WVWC-SPACE Layout



Geiger Counter

Gas Sensor



Flight Dynamics Board

Shepherd-SPACE Experiment

"The goal of the Shepherd-SPACE experiment is to collect FD data and B-field data in-flight using multiple inertial measurement units (IMUs) for redundancy"

- Mission requirements from this statement:
  - Collect FD data in-flight
  - Collect B-field data in-flight
  - Provide redundancy in FD data measurements
- Expect to observe a spin-rate of ~5Hz
- Expect to saturate vertical accelerometers at launch
- COTS IMU will be compared to high-end IMU for flightworthiness assessment

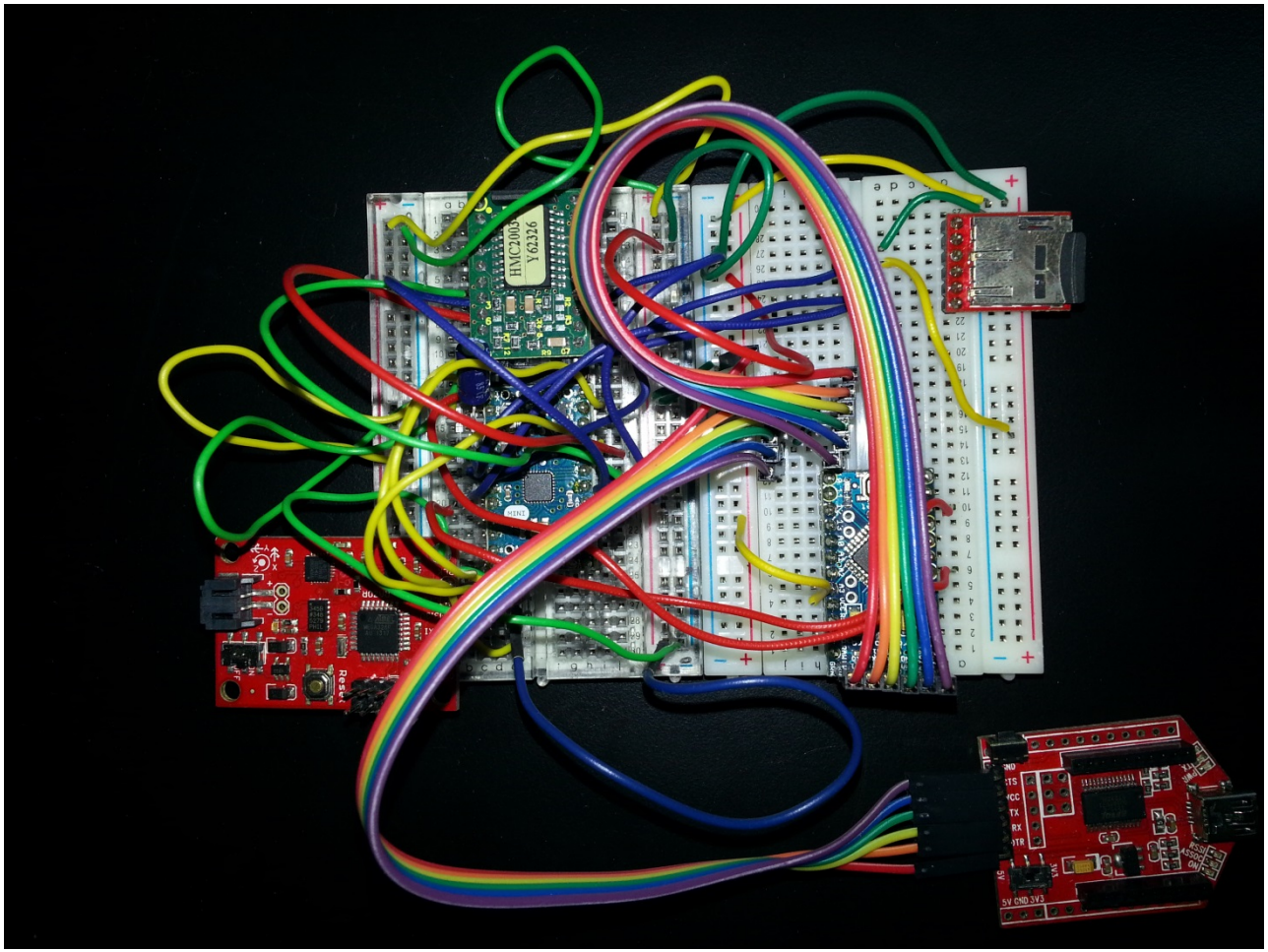
Shepherd-SPACE Overview: Theory and Concepts

- Compare B-field with WMM
- Study how Earth's magnetic field can be used as a mechanism for attitude determination
- Study differences in data resolution with high g force application
  - Determine if COTS IMU is feasible for space applications
- Microcontroller, magnetometer, and microSD data logger flown by WVU team on RSC'14
  - Results prove devices operate successfully in space environment

Shepherd-SPACE Overview: Mission Requirements

- Objectives: Collect FD and B-field in-flight, store data for post-processing and analysis, prove COTS IMU device
- System Requirements (from the objectives):
  - Collect FD data and B-field data
  - Store measurements (in-flight) for post-processing and data correlation with WMM
  - Determine reliability of COTS IMU
- Minimum Success
  - Redundant FD and B-field data collected

Shepherd-SPACE Layout



Flight Dynamics Prototype

Marshall-SPACE Experiment

"The goal of the WVU-CAMs experiment is to measure radiation levels and select atmospheric gas concentrations, count ionized particles, and collect FD data and B-field data in-flight using multiple inertial measurement units (IMUs) for redundancy"

- Mission requirements from this statement:
  - Measure radiation levels and count ionized particles
  - Measure concentration of select atmospheric gases
  - Collect FD and B-field data in-flight
  - Provide redundancy in FD data measurements
- Expect to observe a spin-rate of ~5Hz
- Expect to saturate vertical accelerometers at launch
- COTS IMU flightworthiness assessment
- Observe variations in radiation levels, ionized particle count, and gas concentrations

Marshall-SPACE Overview: Theory and Concepts

- Study how radiation levels drop with altitude
- Study ionized particles in ionosphere
- Study concentrations of select atmospheric gases in ionosphere (TBD)
- Microcontroller, magnetometer, and microSD data logger flown by WVU team on RSC'14
  - Results prove devices operate successfully in space environment

Marshall-SPACE Overview: Mission Requirements

- Objectives: Observe decrease in radiation levels with altitude and count ionized particles in ionosphere using Geiger counter, collect FD and B-field measurements, store data for post-processing and analysis, prove COTS IMU device
- System Requirements (from the objectives):
  - Measure radiation levels and detect ionized particles
  - Measure atmospheric gas concentration
  - Collect redundant FD and B-field measurements
  - Need a data collection system to store the measurements (in-flight)
- Minimum Success
  - Detect radiation and ionized particles
  - Redundant FD and B-field data collected

Marshall Layout

- In the process of procuring experimental devices
- Flight Dynamics very similar to Shepherd-Space prototype
- Addition Geiger counter experiment will be flown as secondary experiment

WVUTECH-SPACE Experiment

"The goal of the WVUTECH-SPACE experiment is to test payload components in space environment to assess attitude determination using upgraded microcontroller for future CubeSat mission"

- Mission requirements from this statement:
  - Integrate upgraded microcontroller into design
  - Collect FD and B-field data in-flight
  - Fit within CubeSat payload specs
- Expect to observe a spin-rate of ~5Hz
- Expect to saturate vertical accelerometers at launch
- Upgraded microcontroller provides additional flexibility for interfacing future hardware devices

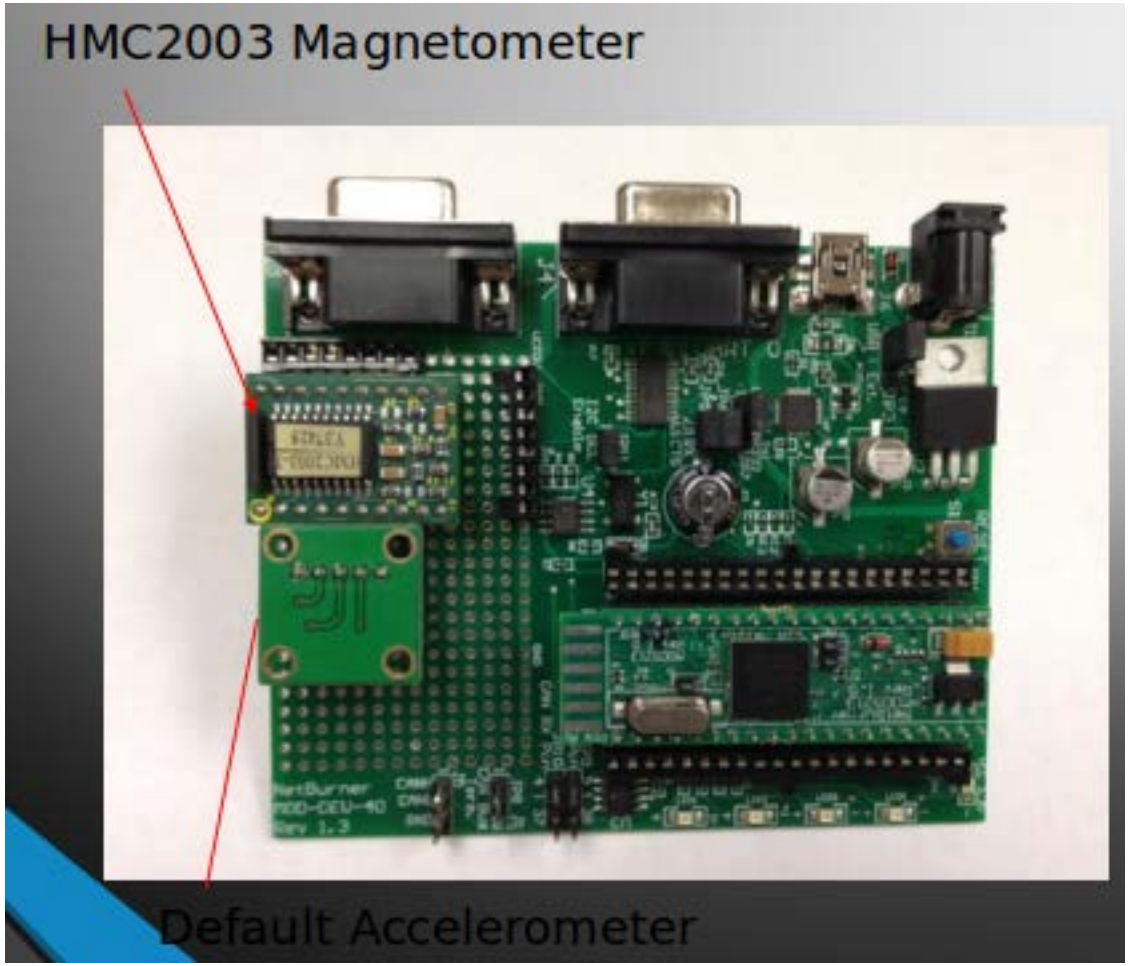
WVUTECH-SPACE Overview: Theory and Concepts

- Compare B-field with WMM
- Study how Earth's magnetic field can be used as a mechanism for attitude determination
- Microcontroller, magnetometer, and microSD data logger flown by WVU team on RSC'14
  - Results prove devices operate successfully in space environment

WVUTECH-SPACE Overview: Mission Requirements

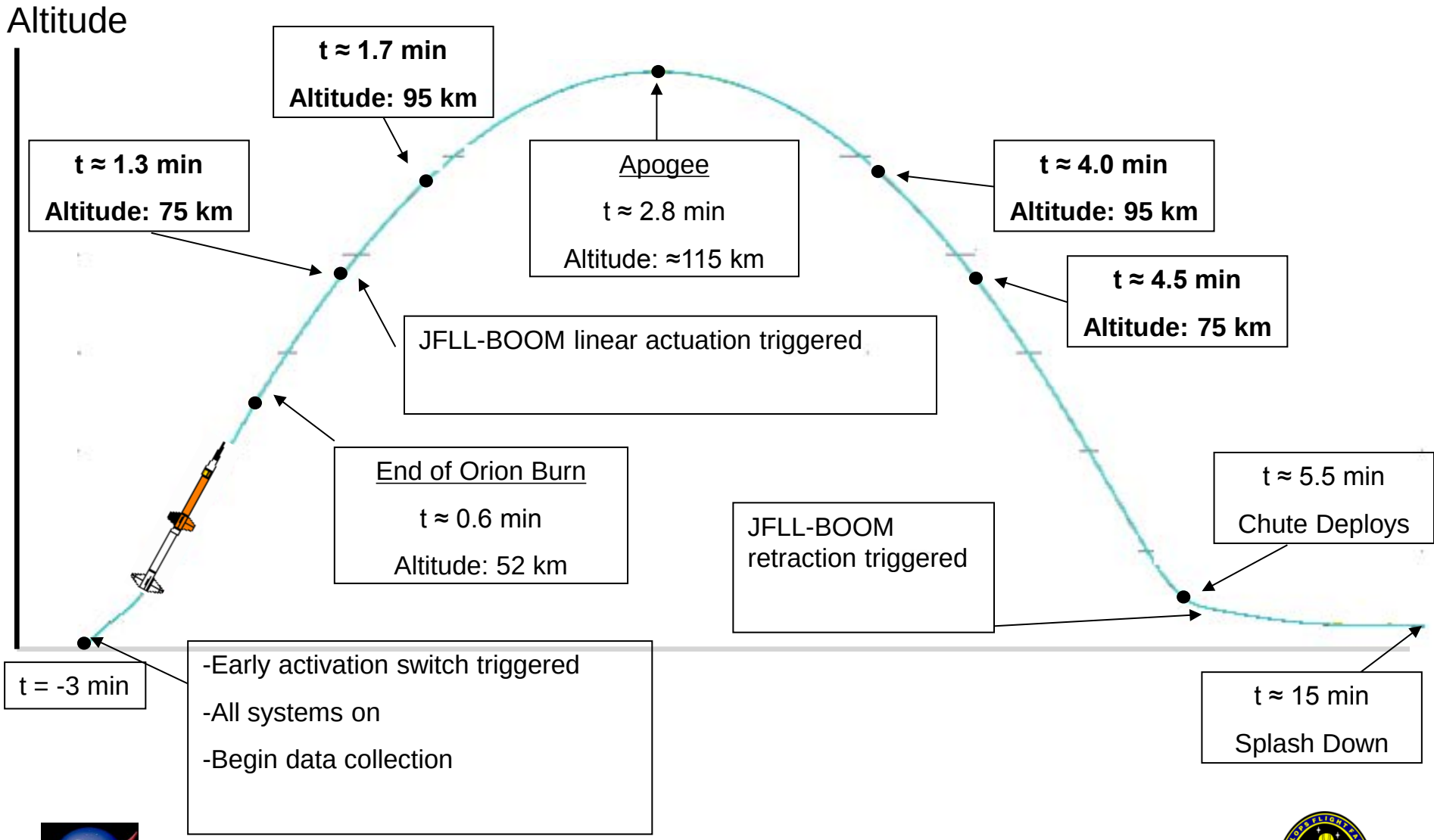
- Objectives: Collect FD and B-field in-flight using upgraded microcontroller, store data for post-processing and analysis
- System Requirements (from the objectives):
  - Integrate upgraded microcontroller
  - Collect FD data and B-field data
  - Store measurements (in-flight) for post-processing and data correlation with WMM
- Minimum Success
  - FD and B-field data collected

WVUTECH-SPACE Layout



Flight Dynamics Prototype

Mission ConOps



Mission Overview: Expected Results Summary

- Correlate FD data with B-field using WMM
- Reference frame correlation of redundant FD and B-field data
- COTS IMU usability assessment
- Decreased radiation levels with increased altitude
- Ionized particle (cosmic ray) count
- Atmospheric gas concentration
- Vegetation health along eastern coast
- Visual telemetry to provide fault detection

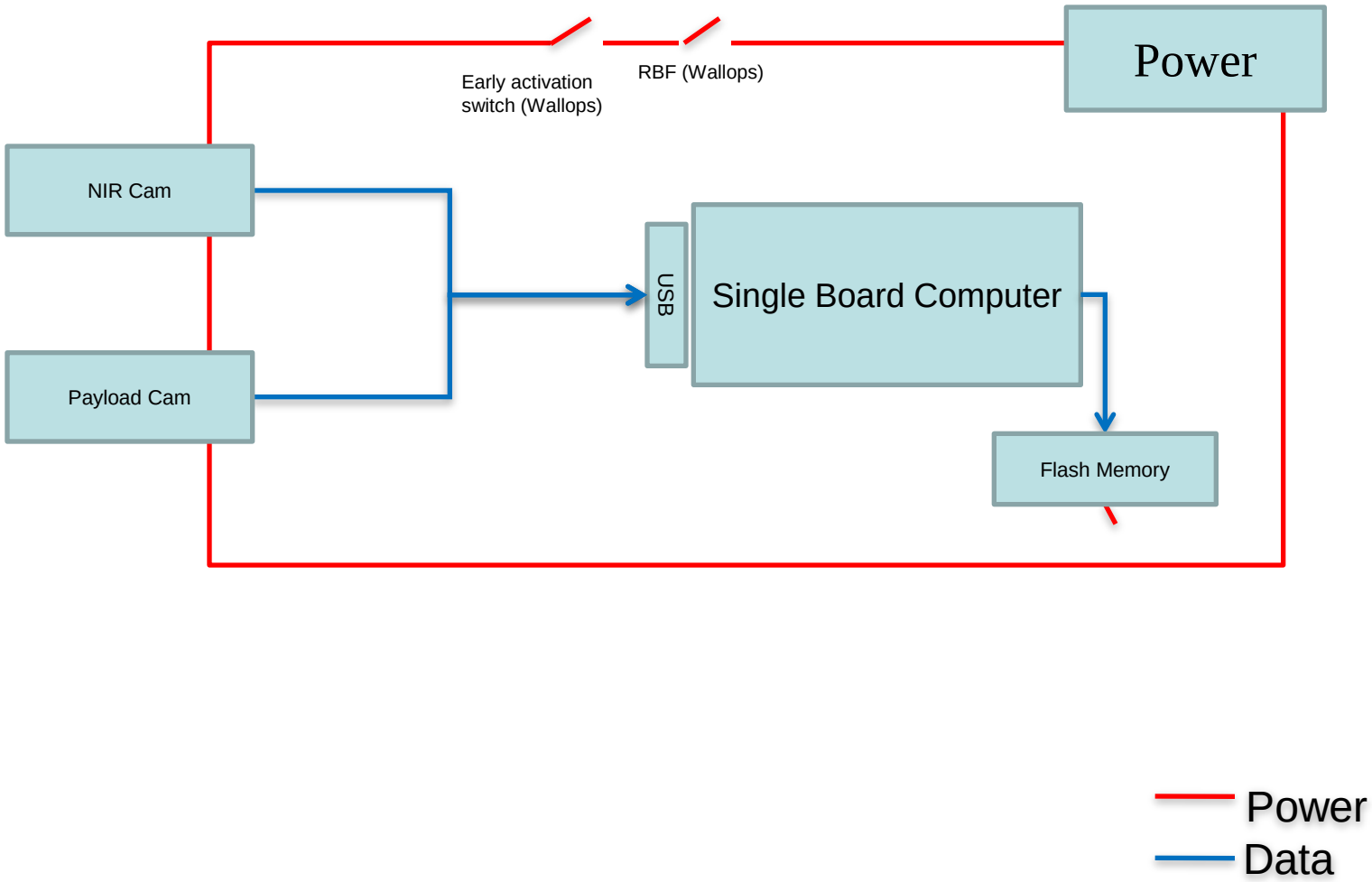
Design Overview

- Major Components
  - Structure:
    - Square stack
    - NIR camera boom
    - Payload camera mount
  - Major technology dependencies:
    - Sensors:
      - IMU
      - Magnetometer
      - Geiger counter
      - Gas sensor
      - NIR optical sensor
      - Payload optical sensor

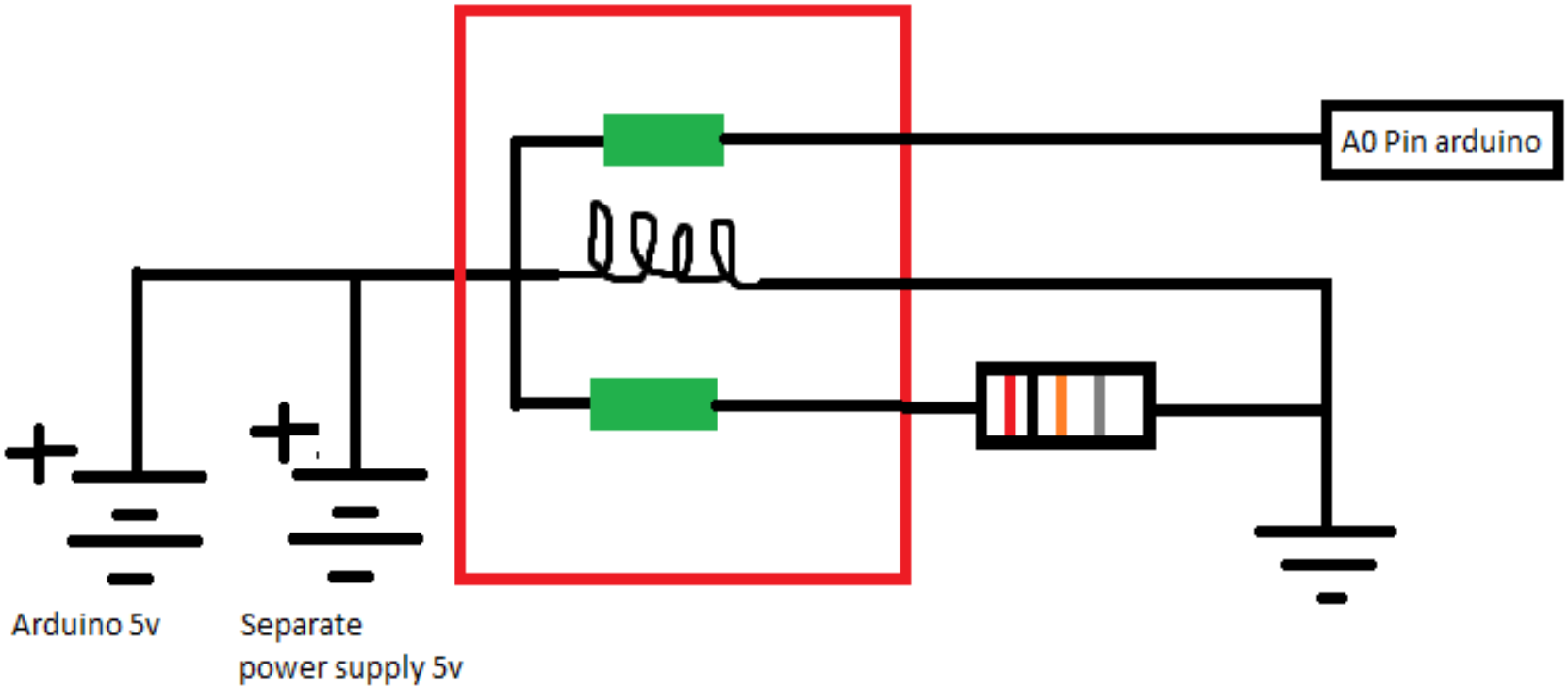
Design Overview Continued

- Major Components (cont' d)
  - Electrical: Provide 12 V power for each experiment
    - Store data (memory), sampling sensors
  - Programming:
    - Arduino (C++ variant)
    - Netburner (C++)
  - Heritage:
    - Various devices have been flown by members of team on RSC'14

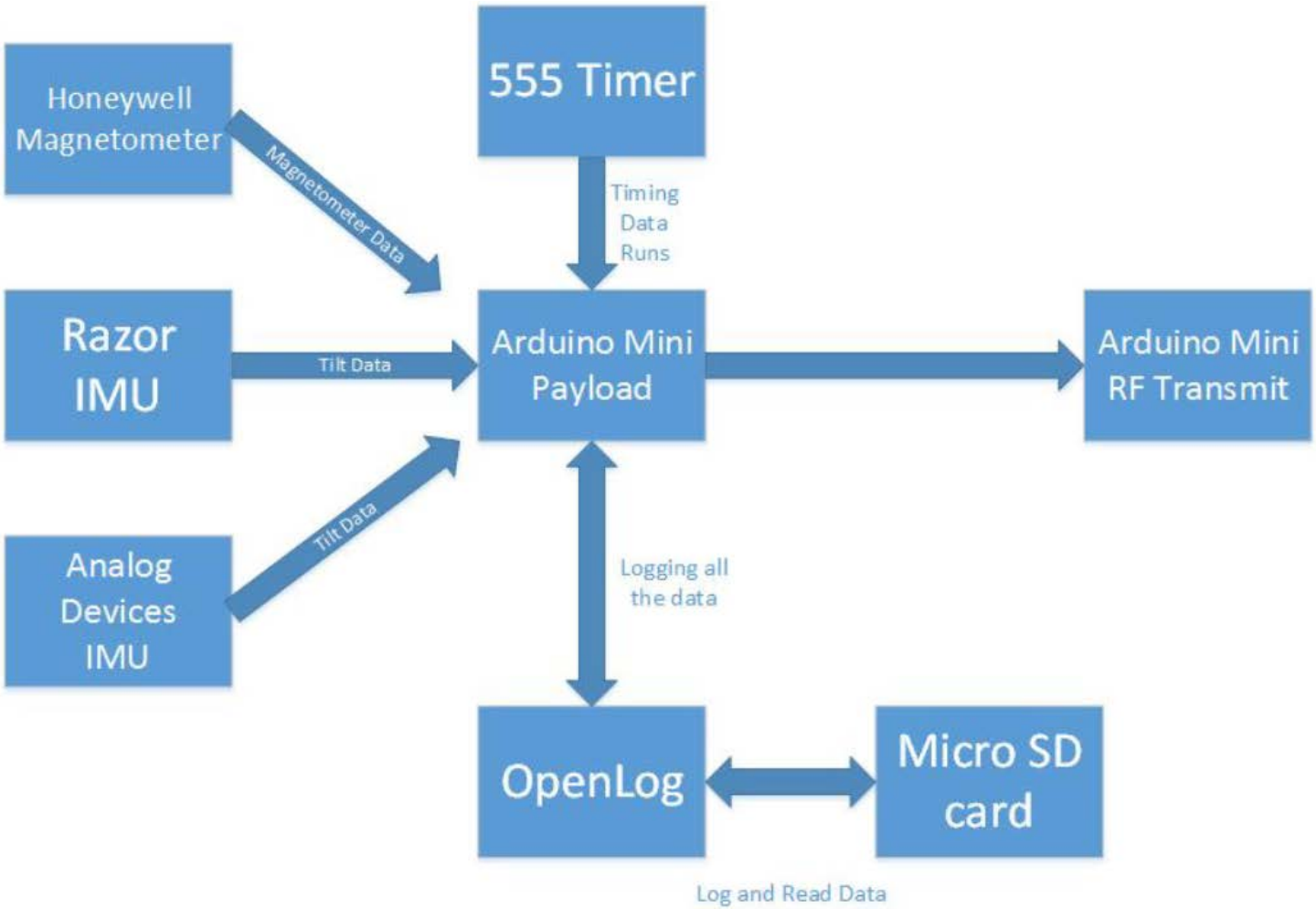
WVU-CAM Electrical Diagram



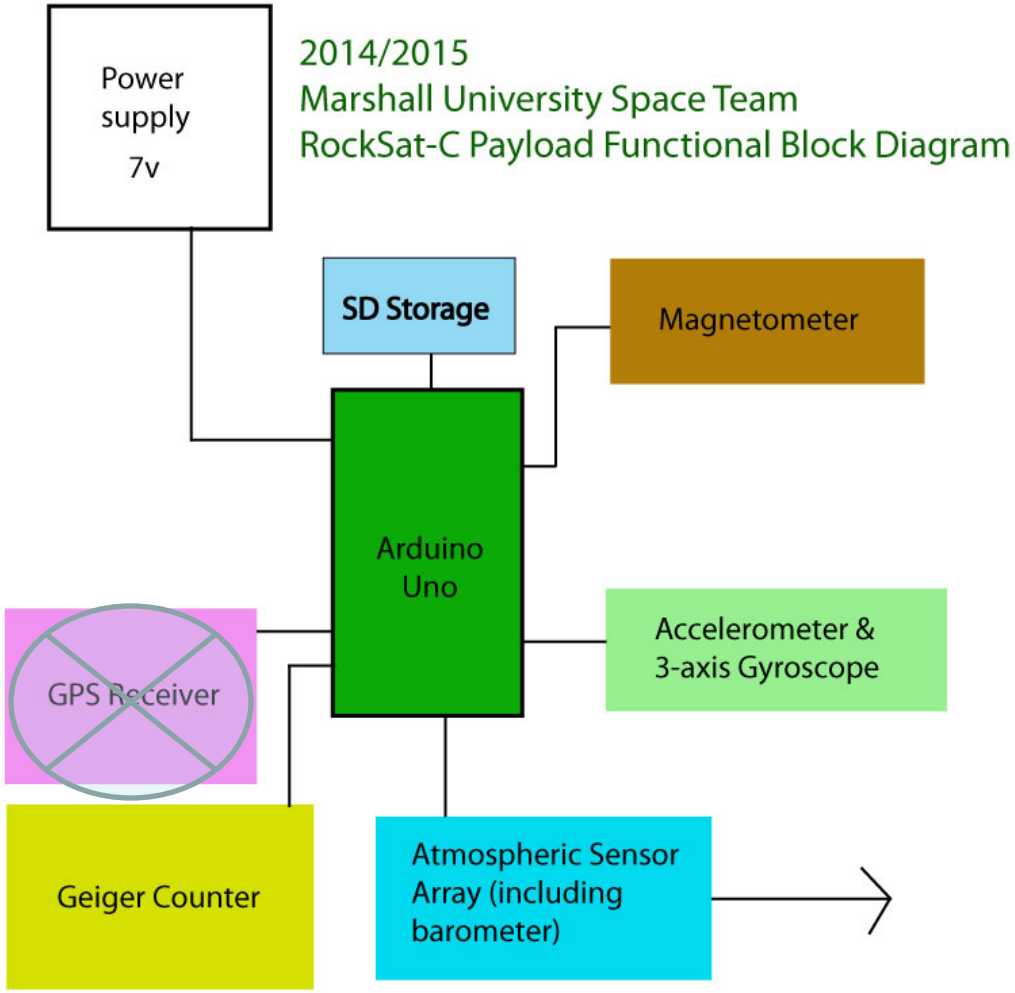
WVWC-SPACE Electrical Diagram



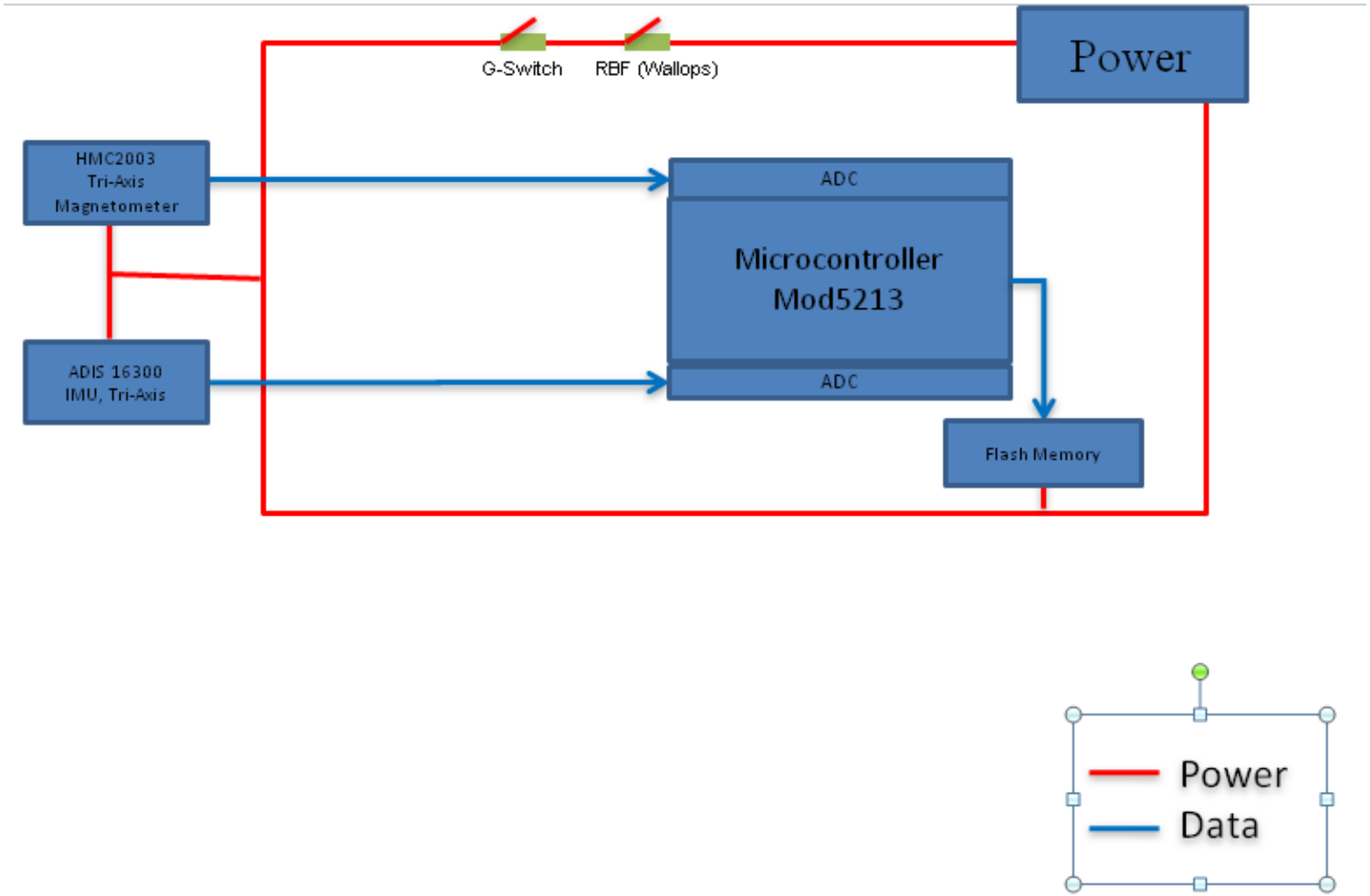
Shepherd-SPACE Electrical Diagram



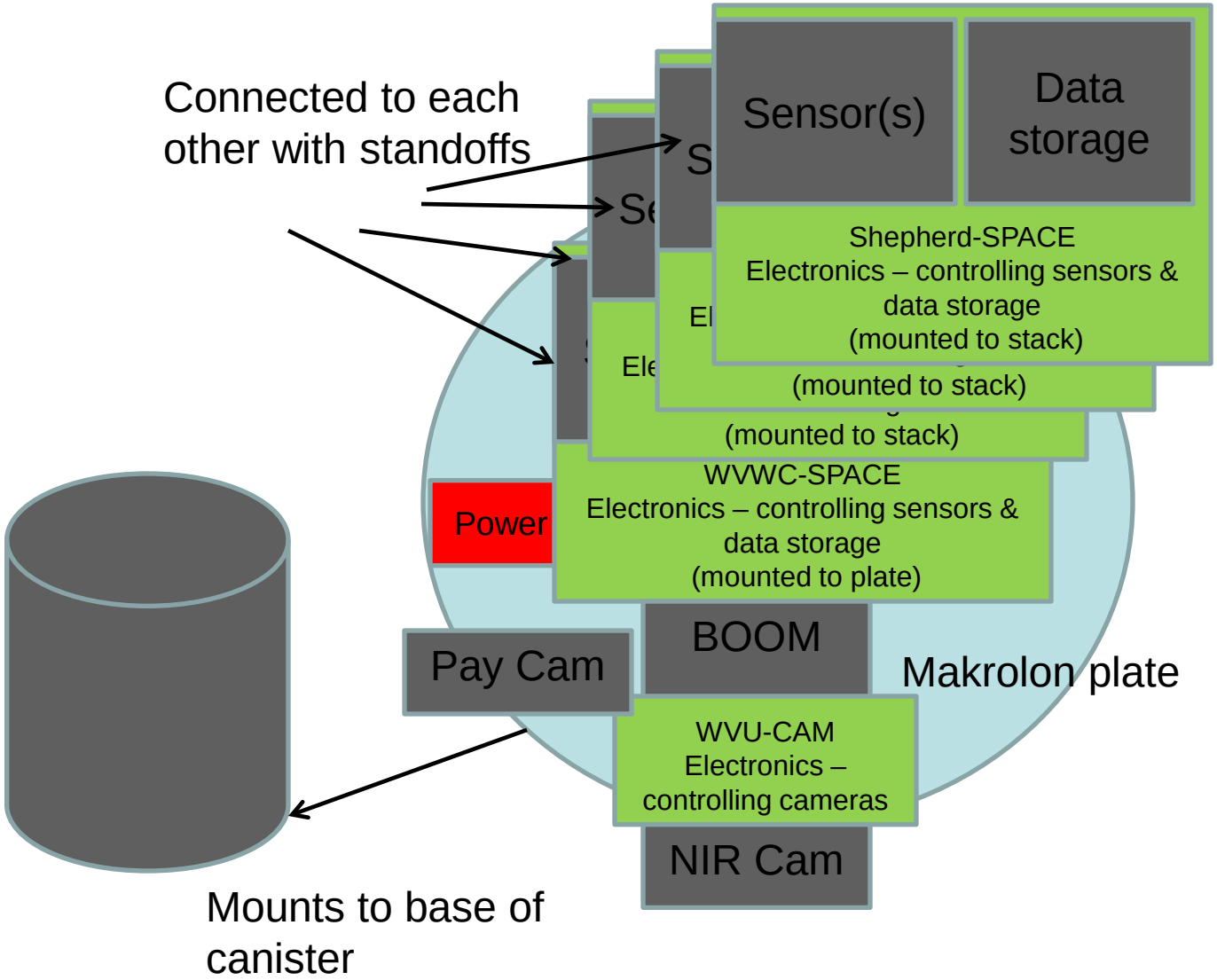
Marshall-SPACE Electrical Diagram



WVUTECH-SPACE Electrical Diagram



FBD – mechanical/system (rough diagram)



Design Overview: Payload Canister Layout

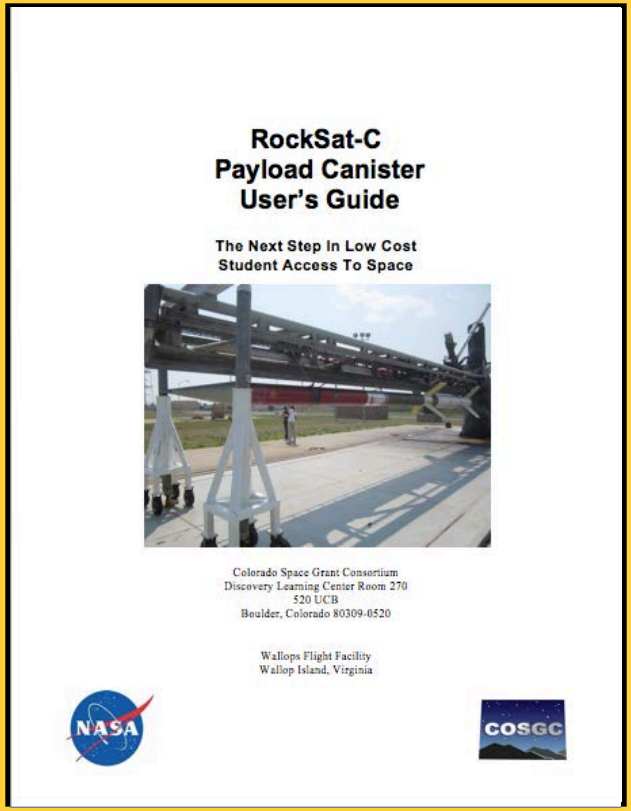
- Single plate
  - 4”x4” square PCB stack for SPACE experiments
    - 4 Total PCBs
  - Horizontal boom mount for BOOM experiment
  - NIR cam mounted on BOOM experiment
  - Payload camera mount facing inward

Design Overview: Payload Canister Layout

- All Flight Dynamics experiments will be in 4 layer stack
  - Each layer designed similar to the WVWC-SPACE FD board (~4”x4”)
  - Will resemble a CubeSat stack with all payload boards
    - Separated by 1.5” standoffs
- All other experiments will be fixed to bottom Makrolon plate in unoccupied areas

Design Overview: RockSat-C 2013 User's Guide Compliance

- User's Guide Requirements
  - Predicted mass: ~8 lb
  - Predicted volume: Whole can
  - Activation type: Early activation
    - T-3mins
    - One activation only
  - Special requests: Ports
    - Optical and atmospheric port


RockSat-C
Payload Canister
User's Guide

The Next Step In Low Cost
Student Access To Space

Colorado Space Grant Consortium
Discovery Learning Center Room 270
520 UCB
Boulder, Colorado 80309-0520

Wallops Flight Facility
Wallop Island, Virginia

Design Overview: Shared Can Logistics

- Partners:
  - West Virginia University Team: WVU-CAM
  - NASA IV&V/Junior FIRST Lego League: JFLL-BOOM
  - West Virginia Wesleyan College: WVWC-SPACE
  - Shepherd University: Shepherd-SPACE
  - Marshall University: Marshall-SPACE
  - West Virginia University Institute of Technology: WVUTECH-SPACE
  - Fairmont State University: Canister Integration

Design Overview: Shared Can Logistics

- Plan for collaboration
  - Weekly/Monthly Telecon session
  - Share designs using Google drive
  - Will fit check before June
- Mounting to bottom plate
- No mid mounting plate
- Ports:
  - Optical port
  - Atmospheric port

Team Organization

Team Member	Email Address	Phone Number	US Person? (Y/N)
Steven Hard (NASA IV&V - Team Lead)	Steven.L.Hard@nasa.gov	304-367-8287	Y
Dimitris Vassiliadis (WVU - Advisor)	Dimitris.Vassiliadis@mail.wvu.edu	304-293-4920	Y
Josh Waggoner (WVU)	jdwaggoner@mix.wvu.edu		Y
Greg Lusk (Fairmont State)	grglusk@gmail.com		Y
Farshid Zabihian (WVU-Tech- Advisor)	Farshid.Zabihian@mail.wvu.edu	304-442-3280	Y
Thy Dinh (WVU-Tech - Student Lead)	tdinh@mix.wvu.edu		Y
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Jon Saken (Marshall U - Advisor)	saken@marshall.edu		Y
Seth Baker (Marshall U - Student Lead)	baker53@marshall.edu		Y
Jeremy Chapman (Marshall U)			Y
Nick Zarilla (Marshall U)			Y
Cody Porter (Marshall U)			Y
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Ralph Wojtowicz (Shepherd U - Advisor)	rwojtowi@shepherd.edu	304-876-5783	Y
Rachelle Huff (Shepherd U - Student Lead)	rhuff02@rams.shepherd.edu		Y
Andy Shtanko (Shepherd U)	iqvasya@gmail.com		Y

Management

- Preliminary schedule for the semester
  - Weekly/monthly telecons in preparation for PDR
  - Rotate by team/experiment
- Monetary budget – covered
- Team mentors (industry, faculty)
  - NASA IV&V Facility

Don't let the schedule sneak up on you!

Conclusion

- Overall Mission: To design and test a science payload in space
  - System shall provide knowledge and hands-on experience to students for future space endeavors
- Issues, concerns, any questions
- Plan for where you will take your design from here?
  - Atmospheric gas research & concepts
  - Electrical FBDs
  - Mechanical FBDs
  - Programming tutorials and demonstrations