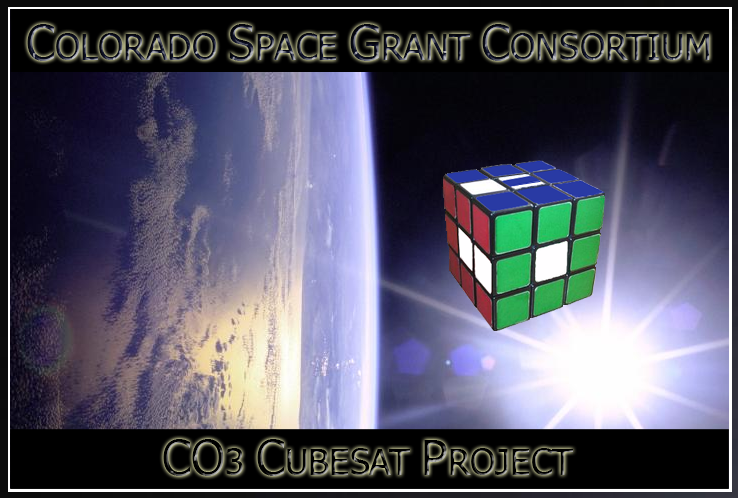


Hermes CubeSat:

Testing the Viability of High Speed Communications on a Picosatellite

Colorado Space Grant Consortium

Space Grant: The '90s and Early 2000s

3 Rocket Payloads

HOMER:
- Launched 08-12-96
- Sounding Rocket
- Students from six Colorado campuses

CSHARP:
- Launched 08-22-94
- Sounding Rocket
- Students from six Colorado campuses and Virginia

CSOAR:
- Launched 09-21-92
- Sounding Rocket
- Students from six Colorado campuses and Virginia

3 Shuttle Launches

DATA-CHASER:
- Launched 08-07-97, STS-85
- Space Shuttle, Hitchhiker Payload
- Technology Demonstrations

ESCAPE II:
- Launched 11-03-94, STS-66
- Space Shuttle, Complex Autonomous Payload
- Support from Industry

ESCAPE I:
- Launched 04-07-93, STS-56
- Space Shuttle, Get Away Special
- Students from UC Boulder

3 Satellite Missions

3 Corner Satellite (3CS): Launched on December 21, 2004
- Constellation of three nanosatellites
- Completed satellites delivered to Air Force Research Lab
- Stereographic Imaging of Cloud Formations
- Joint student project with New Mexico State & Arizona State University

Citizen Explorer Satellite (CX) – In COSGC Clean Room
- Science/Education Mission
- Real-world engineering and science challenges.
  - UV Measurements / Total Column Ozone
  - Engage K-12 students in mission.

Deployment and Intelligent Nanosatellite Operations (DINO) – In Clean Room
- Determine cloud heights from space
- Evaluate the performance of intelligent operations
- Assess deployment technologies for nanosatellites from industry
- Onboard evaluation of science and engineering data

Within the Last Two Years

3 Developing Satellite Missions

DANDE - Nanosatellite
- Upper atmosphere drag composition and wind measurements
- Helping to enhance and develop new atmospheric models
- Proving low cost space weather observing techniques
- >50kg satellite

Hermes - CubeSat
- High speed communications testing for CubeSats
- Progression toward generic bus
- Environmental characterization
- Staffing of the Missions Operation Center

Testbed for Responsive Experiments And Demonstrations in Space (TREADS)
- 'full-service' technology demonstration and science gathering platform
- Connects to ride share adapter
- >50kg satellite

3 RocketSat Payloads

RocketSat I:
- Launched 09-29-06
- Proof of concept
- Environmental Sensors

RocketSat II:
- Launched 04-28-07
- Proof of concept for workshop
- Video camera

RocketSat III:
- Launched 06-03-07
- Environmental Sensors

3 Upcoming Launches

HASP:
- Scheduled to launch in August '08
- High altitude observatory proof of concept

RocketSat IV:
- Scheduled to launch in June '08
- High altitude gas and density measurement with NOAA

RocketSat Workshop:
- Scheduled to launch in June '08
- RocketSat for everyone

Team Organization

- Completely student-led & student-run project
  - Mostly ***undergraduates***
  - Budgets, management and systems engineering by students
  - Subsystem design, fabrication and testing by students
- 13 students on project currently
  - 61 have been involved in the project

Hermes Mission Objectives

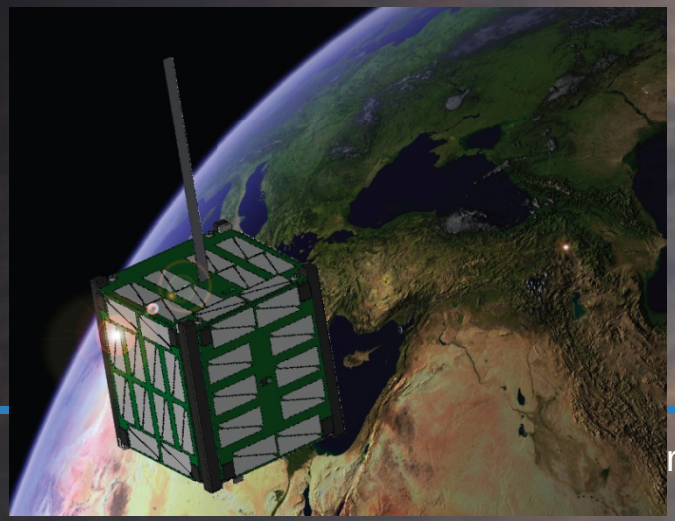
1. Create modular and extensible subsystems

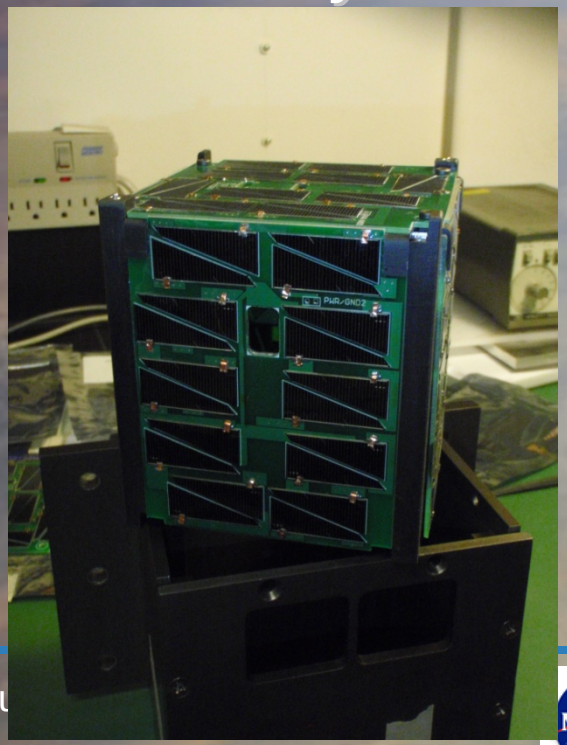
2. Utilize S-band frequency to communicate at data rates higher than those obtainable with Ultra-High Frequencies (UHF)

3. Characterize Hermes' orbital environment and satellite status to validate models and design

Hermes Cubesat Bus

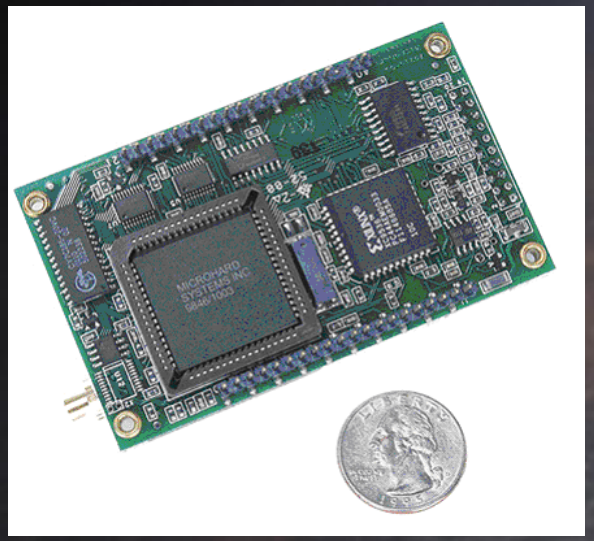
- Command and Data Handling
- Primary (UHF) Communications System
- High Speed (S-Band) Communications System
- Electrical Power System
- System Structure





Payload: High Speed Communications

- Testing Feasibility of High Data Throughput Communications on the COSGC Cubesat Bus
- Utilizes the Microhard MHX-2400 S-Band Modem
- Capable of Data Rates up to 50 kbaud

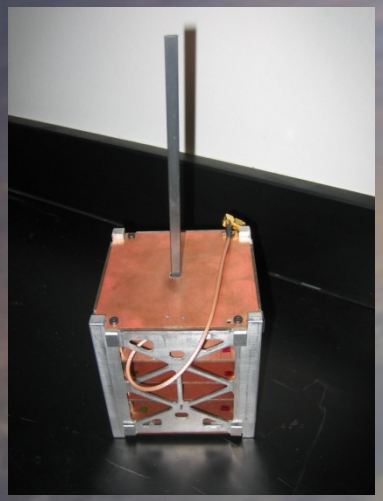


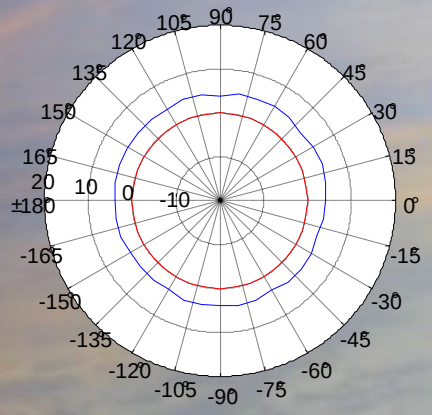
Primary Communications

- Half Duplex Communications in UHF Range
- Uses a Yaesu VX-3R COTS Radio
- In-House Designed TNC
  - Built around the ATMega 168 MCU
  - MX604 for D/A Conversion
  - Data rate of 1200 baud

Communications Antennas

- Tuned at FIRST RF Corporation in Boulder, CO
  - HSCOM Monopole Antenna
    - Tuned to 2.4 GHz range
  - PCOM Monopole Antenna
    - Tuned to 437.425 MHz

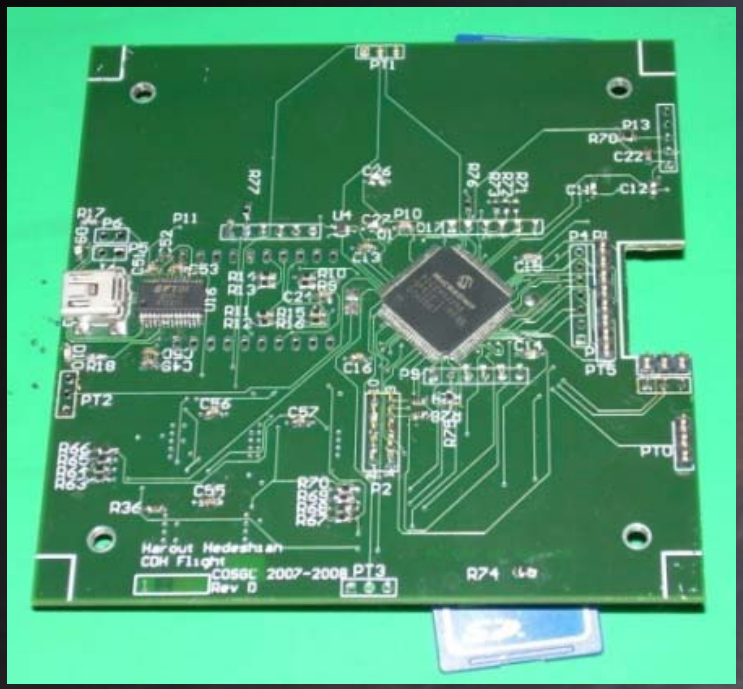




  - Both antennas constructed of spring steel with a Kynar cover

Command and Data Handling

- Based around Microchip PIC24H MPU
- Utilizes Pumpkin Salvo RTOS



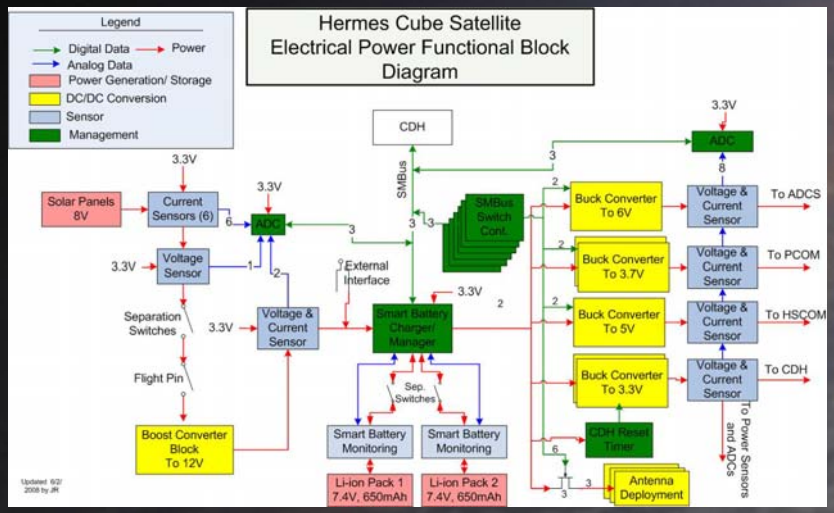
Salvo
The RTOS that runs in tiny places™
PUMPKIN
REAL-TIME SOFTWARE

Command and Data Handling

- Features
  - Triple Redundancy on Critical Components
    - Three SD cards for data integrity
    - Three RTCs for accurate timing
  - Ability to Reprogram All Satellite Software
    - Two stage bootloader
    - First stage checks second stage and main code section
    - Second stage checks first stage
    - Main code checks communications system

Power System

- Designed for High Efficiency and Extensibility
- Completely Autonomous Base Operation
  - Does not depend on CDH for charging/power
- Completely Student Designed, Built, and Tested

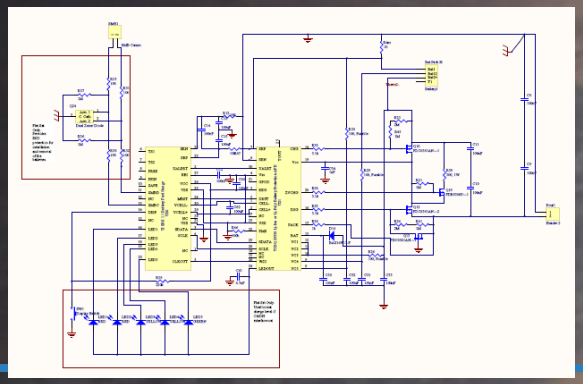


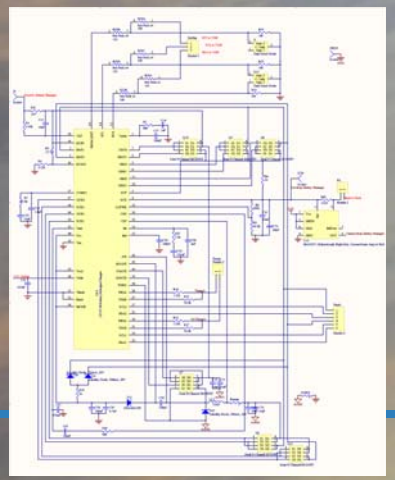
Power System

- Interface
  - I²C Communication with CDH
  - Full Array of Sensors for All System Voltages and Currents

Power System

- Battery Charging
  - Li-Ion / Li-Poly Battery Support
    - Automatic Cell Balancing
    - Ability to Charge/Discharge Both Batteries at Once
    - Fully Autonomous Protection Circuitry
    - Automatic Time-to-Empty Calculation at Current or Hypothetical Load



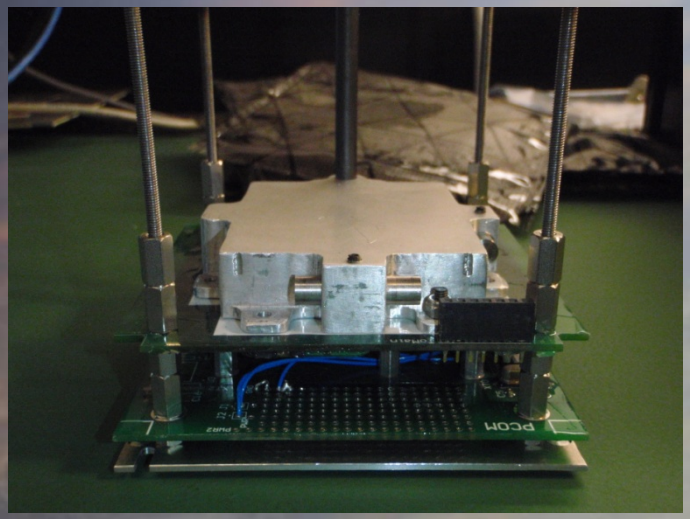


Power System

- Power Regulation and Distribution
  - 3.3 V, 5 V, and 7.4 V Outputs to Subsystems
  - Less than 5% Ripple on All Outputs
  - All Regulation Performed with Switching Converters
  - Can Enable or Disable All Outputs Other than 3.3 V for CDH
  - Redundancy on Critical Converters

ADCS

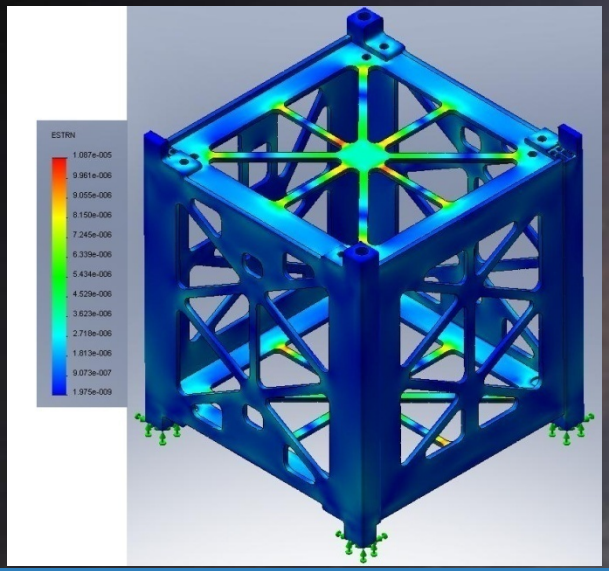
- Passive Magnetic Control
  - AlNiCo Cast-5 magnet aligned with antenna axis
  - 0.005 Amp/m²
  - 1 in. x 3/16 in.
  - High strength, low mass

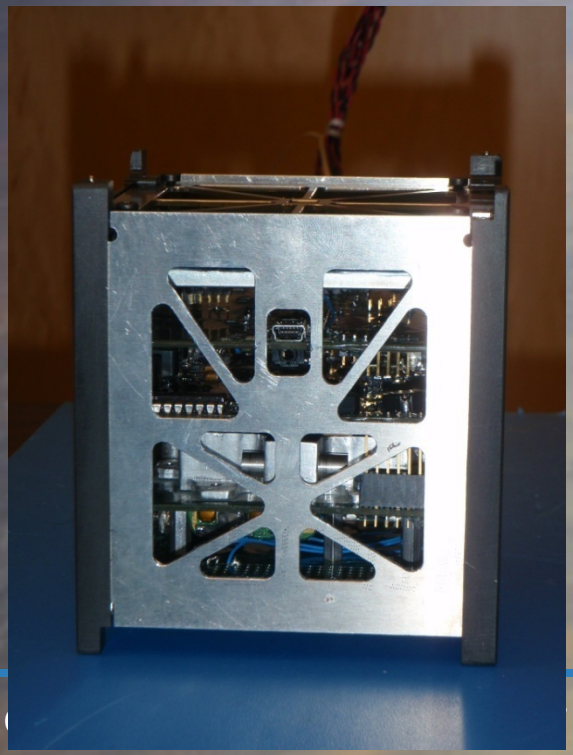


- Damping
  - Ferrous material for magnetic hysteresis
    - Ni80/Fe15.5/Mo4.5 used on previous missions

System Structure

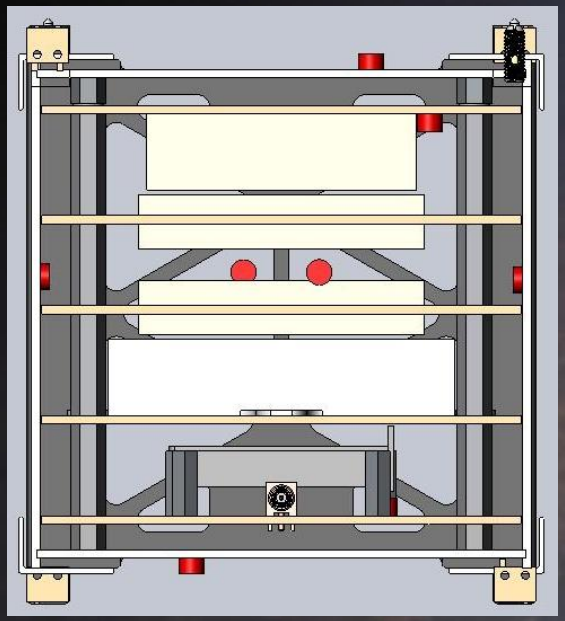
- Aluminum 6061 Exoskeleton Designed and Manufactured In-House
- 6 Solar Panels Restrained on Exterior with Solar Panel Clips

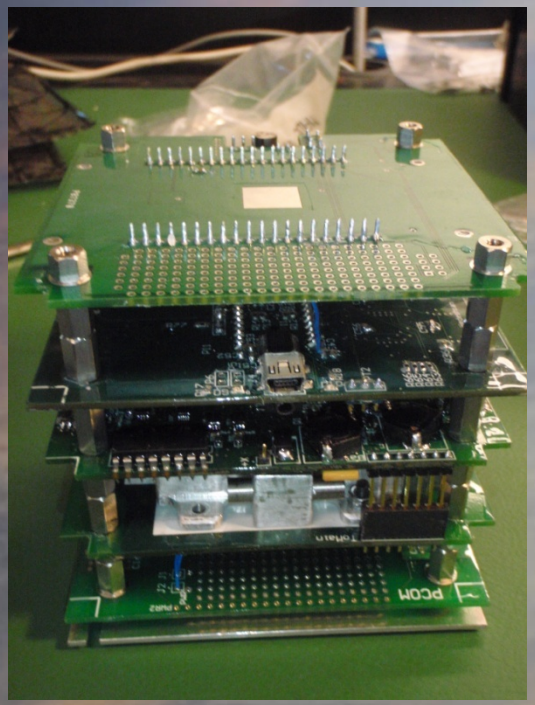




System Structure

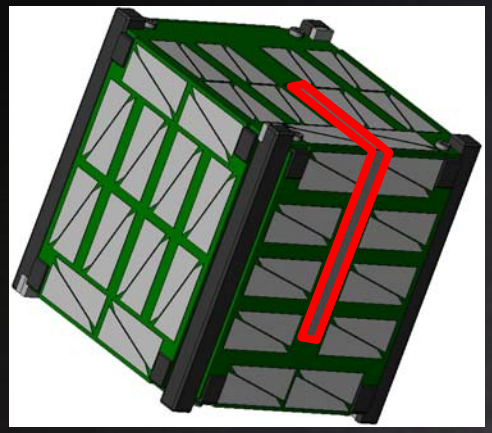
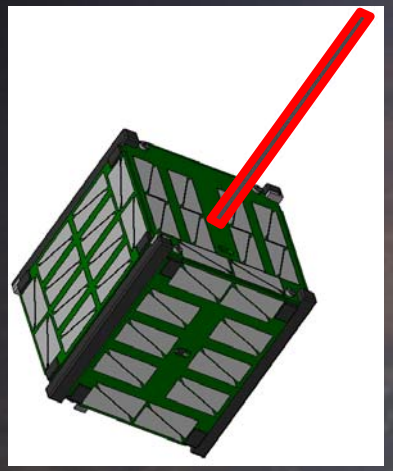
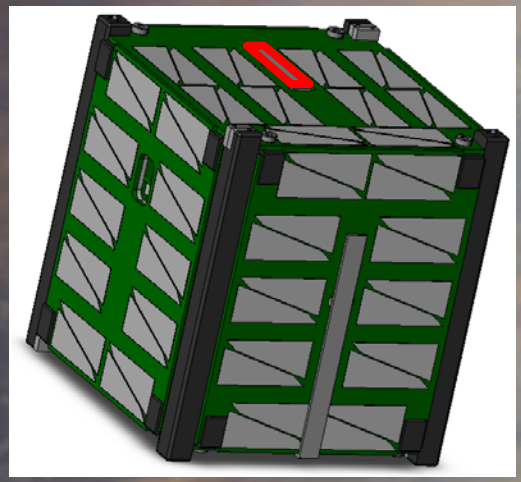
- 5 PCB Internal Stack Configuration
- Aluminum 6061 Battery Box





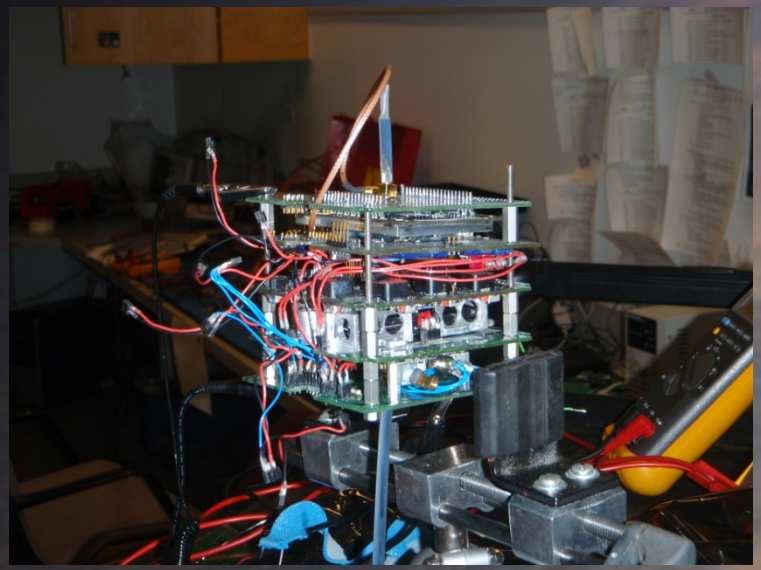
System Structure

- Deployment Systems
  - 40AWG Nichrome Burn Wire
  - Dacron Restraints Looped Through Aluminum Structure


Integration

- Wiring Harness and Stacking Headers
  - Fully Functional Systems Interface
- Class 10,000 Clean Room



Testing

- Long Range Communication Testing
- Deployment Testing in Vacuum Chamber
- Environmental Testing
  - Vibration Testing at Lockheed Martin Company
  - Thermal Vacuum Testing at SpaceDev (Sierra Nevada Corporation)
- Day in the Life

Lessons Learned

- Stack Integration
  - Limit Wire Connections
  - Emphasize Stacking Headers
- HSCOM/Structure Interference Issues
- Clearly Defined Requirements Early in Development
- Configuration Management
- Team Turnover