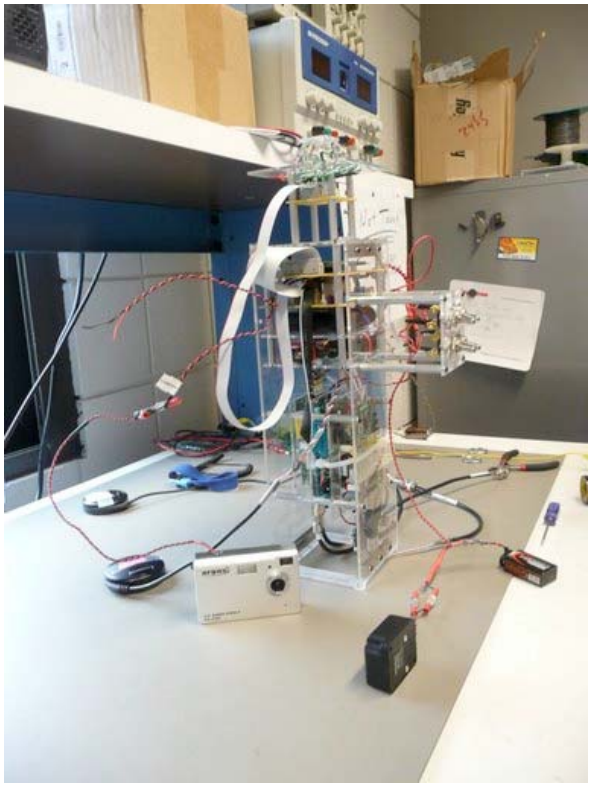
High Altitude Balloon Bus for CubeSat Testing

Kiko Dontchev

CubeSat Developers Workshop
Cal Poly San Luis Obispo
4/24/09

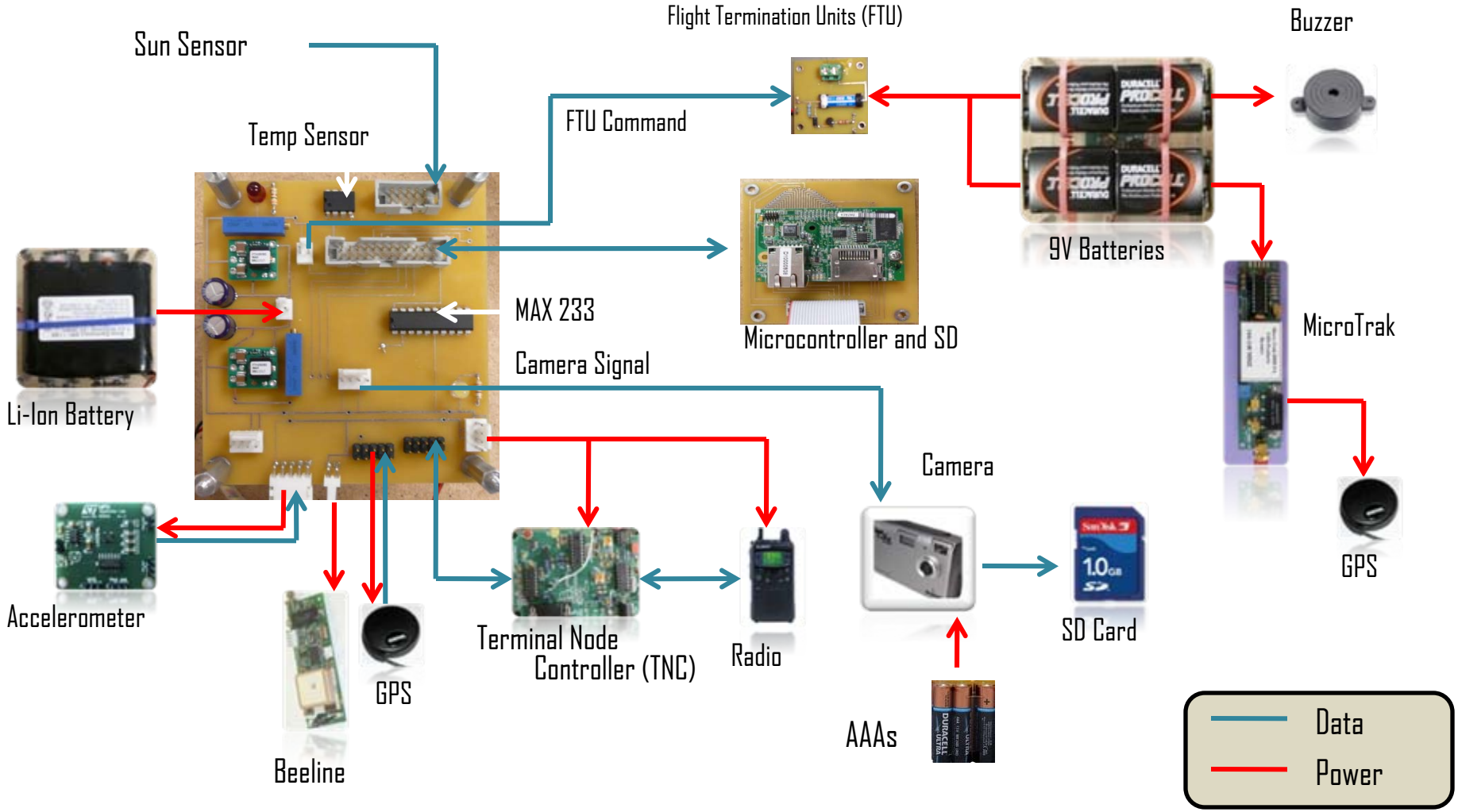
Development Overview

- High Altitude Balloon Bus
  - Integrates 1-3U CubeSats for testing
  - Reliable tracking platform
  - Provide launch/flight experiences for students
  - Improve Ground Station operations
- Student Thermal Vacuum
- 2x2x2 Meter Helmholtz Cage



1U Configuration

Balloon Bus Overview



Bus Tracking/Communication

- 3 communication systems for redundancy

Garmin 18 GPS

Byonics MicroTrak

9V

TX Only: 144.39 MHz (APRS Network)

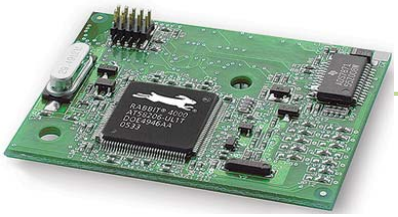
3 Orthogonal Half Wave Dipole Antennas

BeeLine 2M GPS

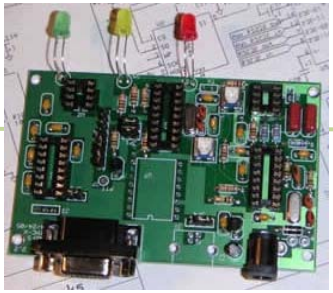
TX Only: 144.39 MHz (APRS Network)

TX/RX: Simplex 147.50 MHz

Garmin 18 GPS

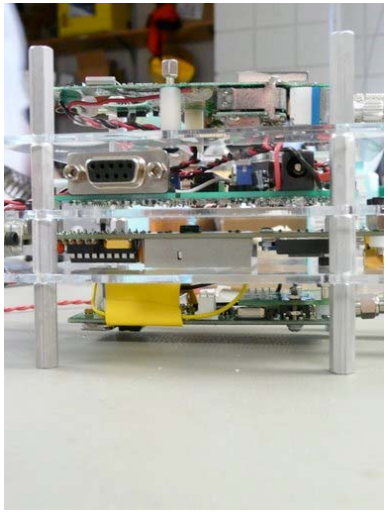


Rabbit Microcontroller



Terminal Node Controller

Alinco VHF Radio

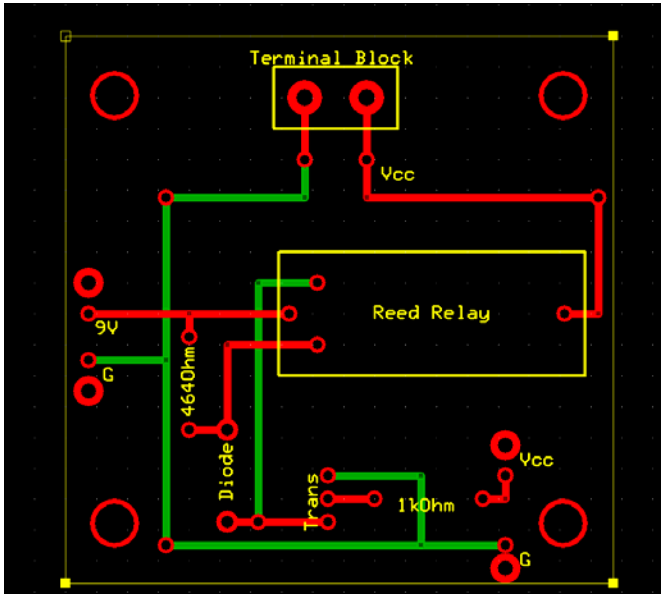


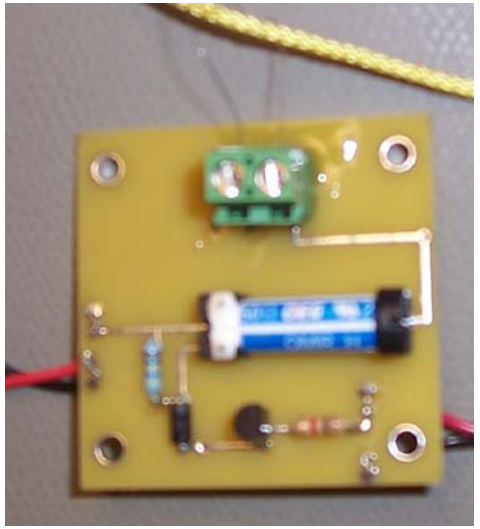
Cell Phone Tracking

- Separate package provides redundancy
- Open GPS Tracker built with COTS components
  - GPS communicates to cell phone through Microcontroller
  - Location/Altitude data is stored onboard
  - Retrieve most recent packet through text message command
    - Operator reads on email or text
- Advantage: No need for direct communication between systems
- Disadvantage: Unable to track without phone coverage

Flight Termination Unit

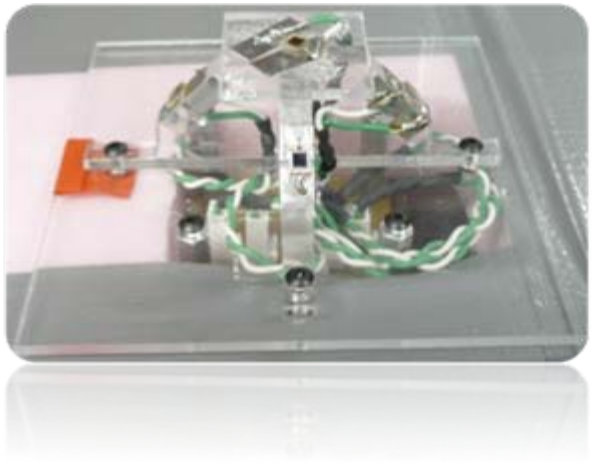
- Federal Aviation Administration
  - Notify prior to flight
  - Provide details about launch and system
  - Terminate flight upon request
- Flight Termination Unit
  - Microcontroller receives uplink, triggers current draw from 9V battery, heats nichrome wire wrapped around line, releases balloon
  - Coded timestamp activation
    - Avoids prolonged flight from neutral buoyancy





Attitude Determination

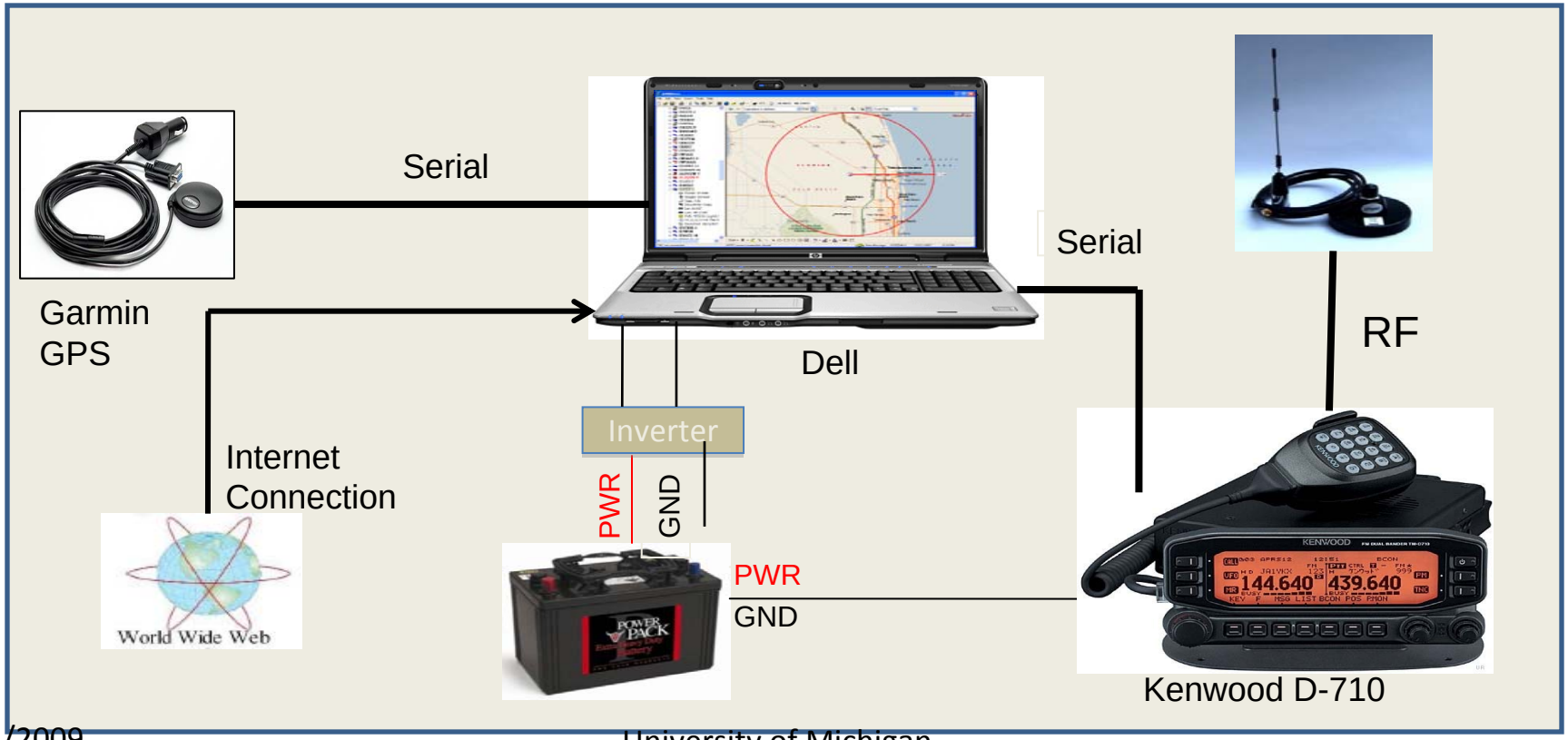
- 3-Axis Accelerometer - ST LIS331A
  - Determines payload orientation with respect to gravity vector
- Sun Sensor
  - Measures position of the Sun relative to the balloon
  - (5) photodiodes measure angle of Sun



Mobile GS Design

- Developed Tracking Capabilities with 2 Software Packages
  - APRS Point + MapPoint
  - Balloon Track+ MapPoint +AGPS

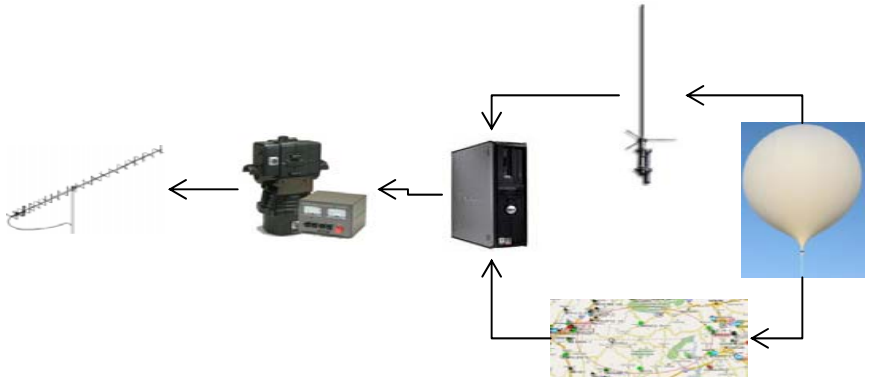
- Real time mapping capabilities
- Flight prediction display
- Displays user GPS position on map



Permanent GS Tracking

APRS Rotator Controller

- Retrieve GPS data through iGates or omnidirectional antenna
- Parse APRS Packet Data
- Calculate Azimuth and Elevation from Ground Antenna Reference
- Changes rotator automatically to point at balloon location



iGates

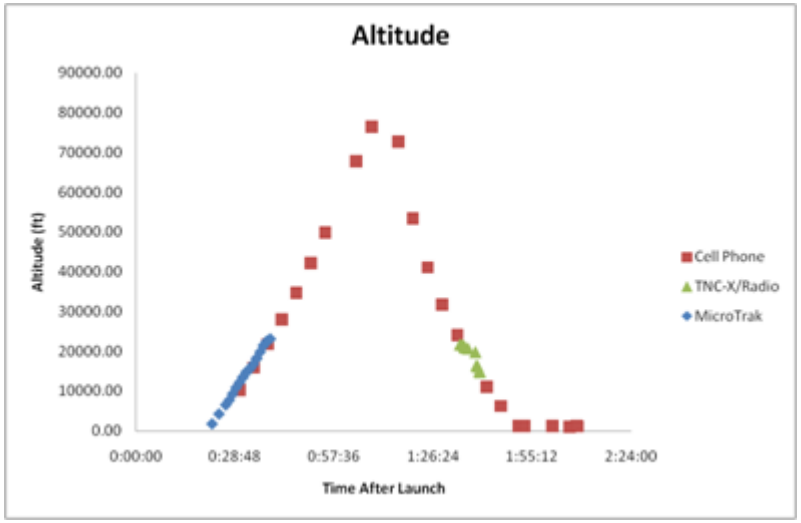
First Flight Results

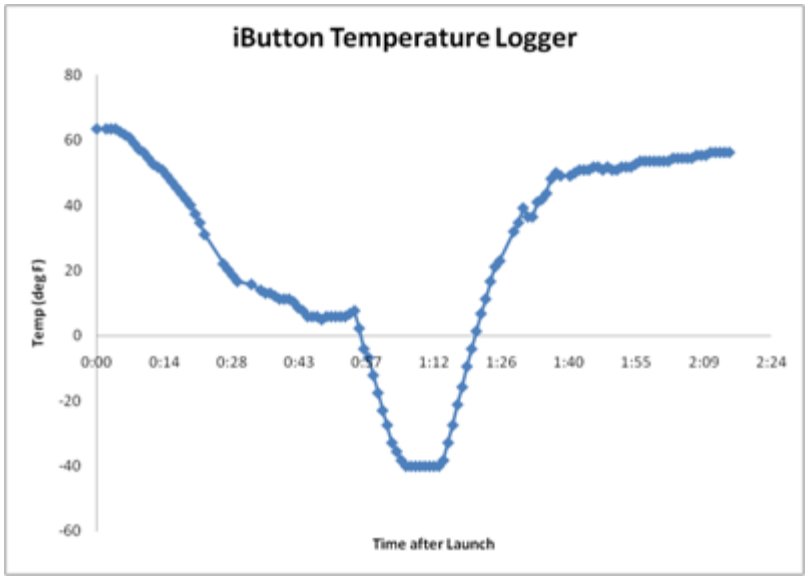
- Launch Spring Arbor, MI
- Max altitude ~76,000 ft.

- Landed in a tree
- Minimum success criteria met: recovered payload
- Analyzing Data

Hardware Performance

- Received beacons from MicroTrack 300 but lost altitude data above 27k feet
- Beeline never achieved lock
  - Faulty patch antenna
- TNC-X and Alinco provided few ascent/descent packets but none above 27k feet
- Cell Phone Tracker had lock throughout flight
  - Only able to retrieve data under 5k feet
- Attitude data failed to store onboard
- Minimum temp of -40F at max altitude



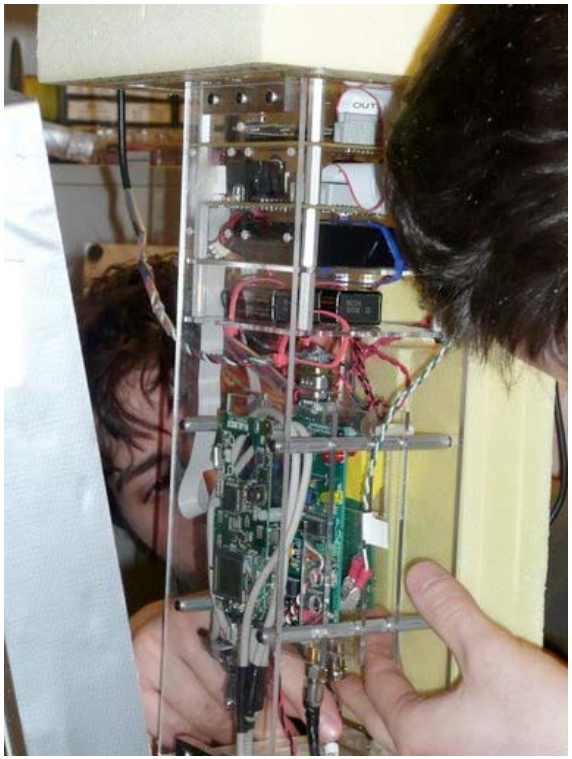


Flight Day Lessons

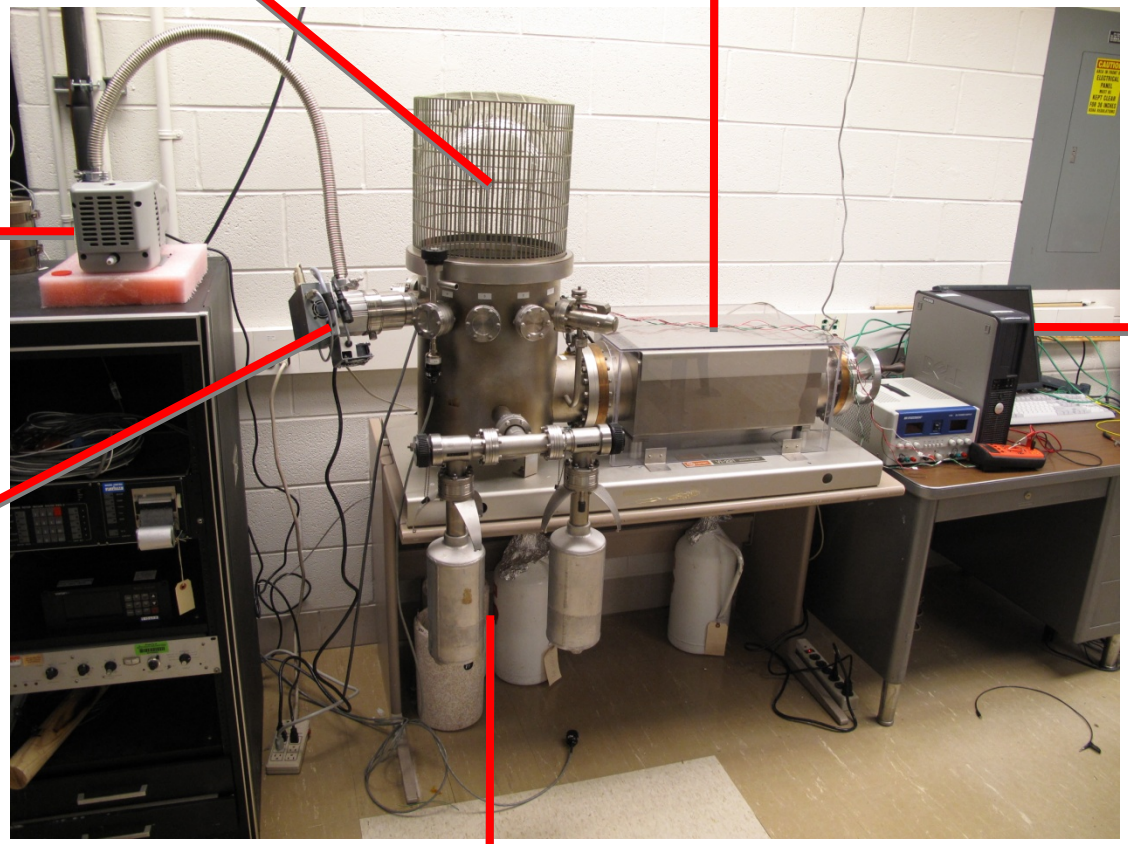
- Have backups for everything
  - Balloon, Helium, subsystems, computers, harness…
- Do a full dry run prior to flight day
- Clear/Easy communication between chase teams & permanent GS
- Be prepared for any landing spot
- Murphy's law always applies!

Balloon Future Plans

- Continued effort primarily through Student Space System Fabrication Lab (S3FL)
  - Students already dedicated for Spring/Summer
- General recommendations:
  - Understand failures and make according design changes
  - Configuration alternatives and improvements
  - Data downlink capabilities
  - FTU alternatives

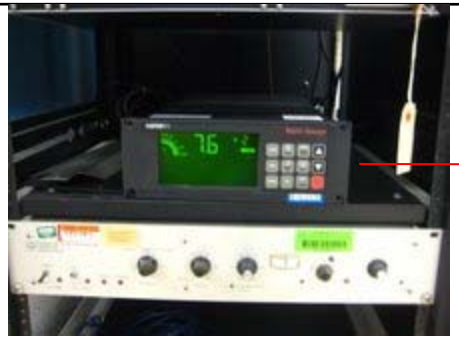


Student Thermal Vacuum

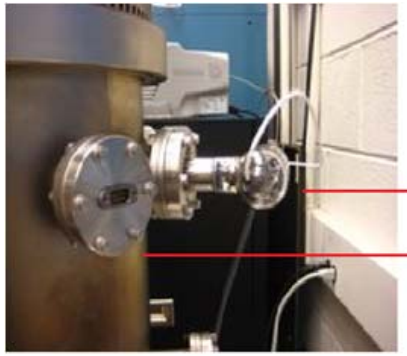


System Characteristics

- Baseline Pressure
  - $2*10^{-6}$ Torr
  - Approximately 2 hours for pump down
- Pressure Gauges
  - Thermocouple Gauge
    - Atmospheric to $2*10^{-2}$ Torr
  - Ion Gauge
    - 10^{-3} Torr – 10^{-8} Torr
  - Varian Multi-gauge
- Temperature Environment
  - Type K Thermocouple Probe
  - Temperature Range: -30°C to 70°C
  - Accomplished using liquid nitrogen and patch heaters
- Electrical Input
  - DB-9 Interface
- ~Additional $15 K Cost
- ~15 hours of training for proficiency

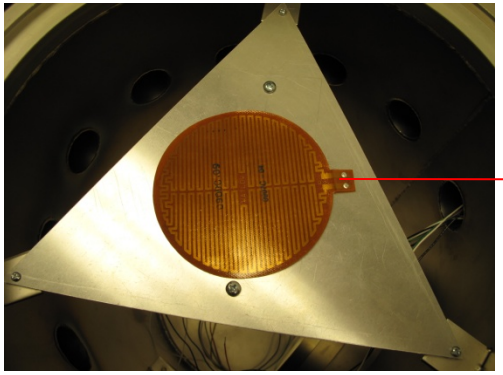


Varian Multi-Gauge



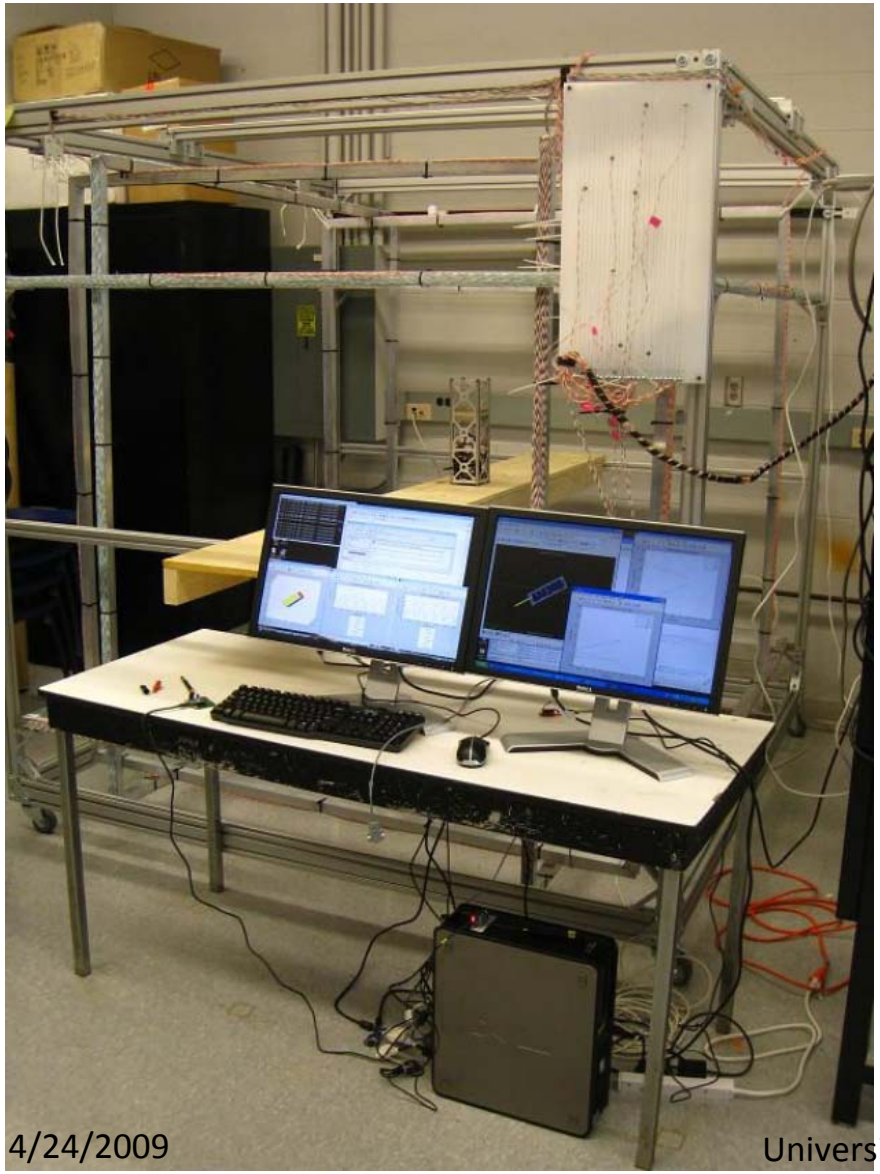
Ion Gauge

DB-9 Interface



Patch Heater

Helmholtz Cage



- Operation:
  - Matlab driven power supplies
  - 60,000 feet of copper wire
  - Loops generate magnetic field
- Capability:
  - Calibration and characterization of magnetometers
  - Analogue-Orbit simulator with IGRF referenced magnetic fields
  - Verification of magnetic attitude determination
- Submitted technical paper to the American Aeronautical Society to be released in August 09

Thank you! Questions?

Kiko Dontchev

CubeSat Developers Workshop
Cal Poly San Luis Obispo
4/24/09