The On-Orbit Performance of the HRBE (E1-P) CubeSat Nearing Nine Months in LEO

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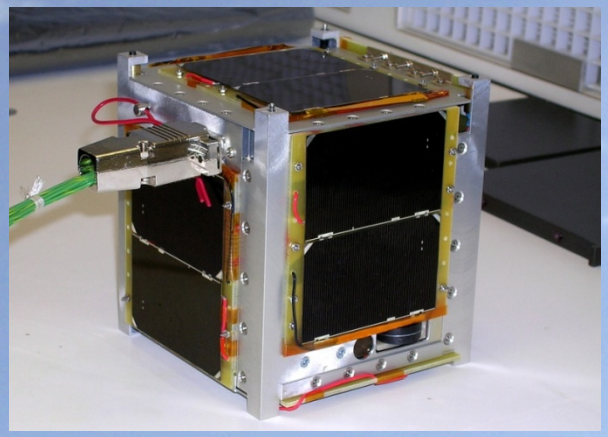
Prior Attempts

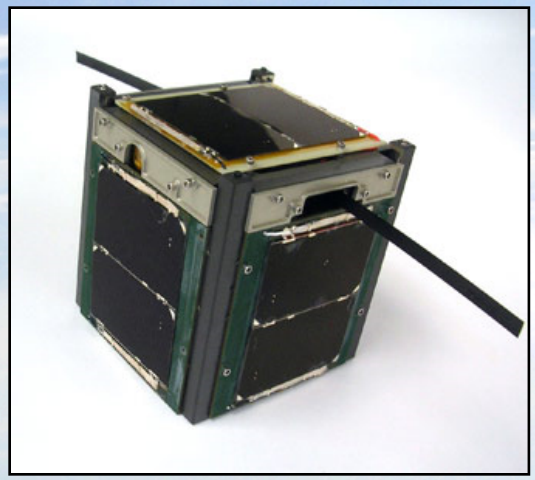
MEROPE



Failed launch on a Russian rocket, 2006

"crater-synchronous" or **extremely** low earth orbit.

Explorer 1 [Prime]-Flight Unit 1

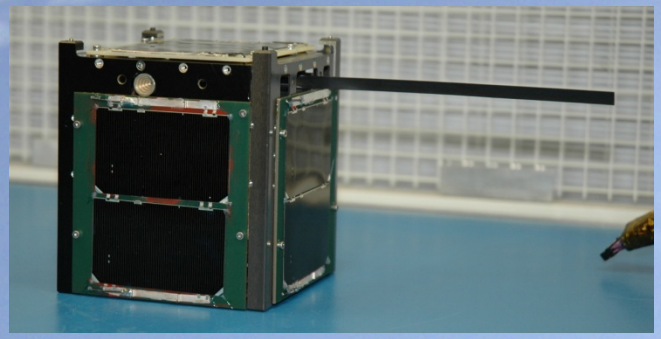


Failed launch on Orbital Taurus XL, March 4, 2011

Deployed at 500km Not enough ΔV to achieve orbit.

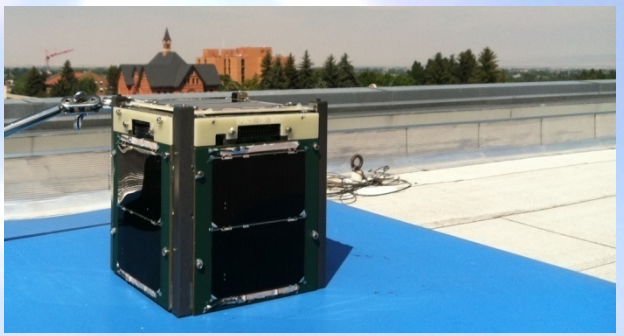
Likely to have burned up in re-entry.

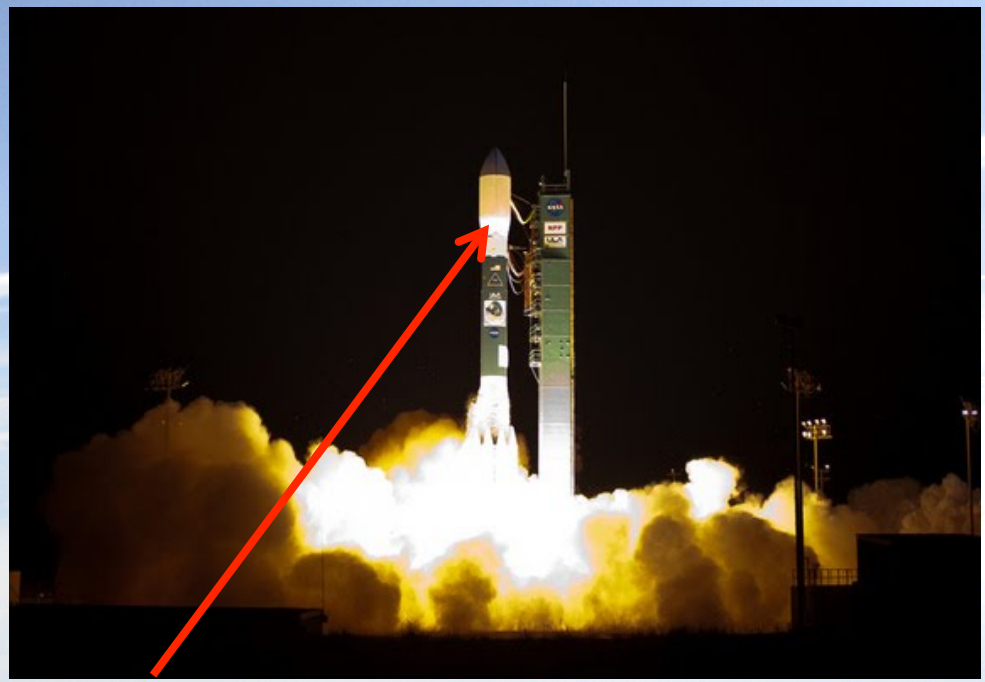
Explorer 1 [Prime]-FU2



HRBE!

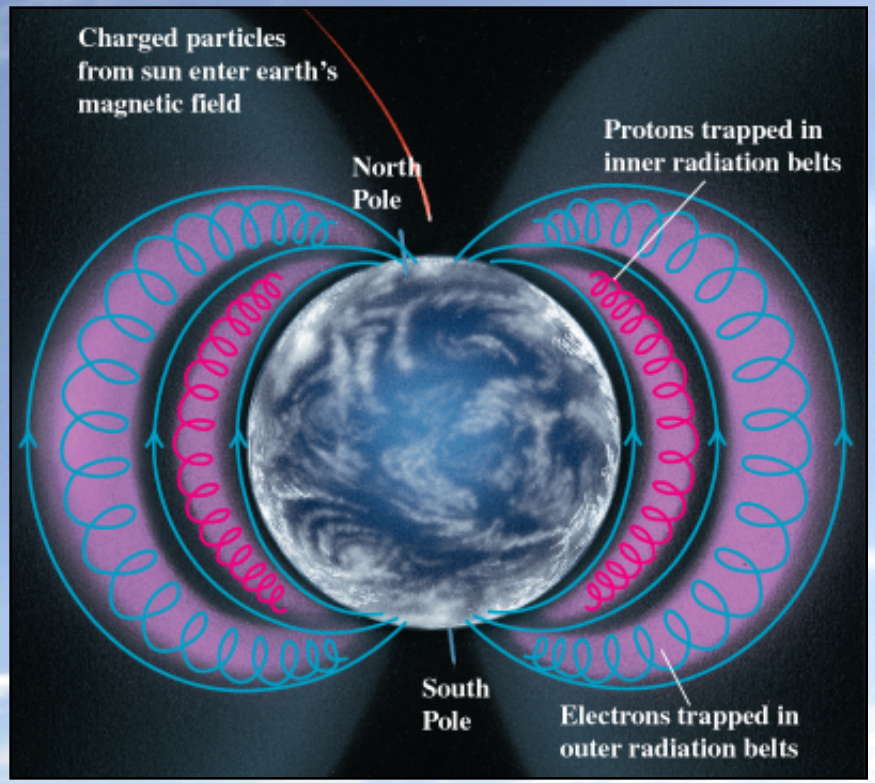
Hiscock Radiation Belt Explorer





PPOD location

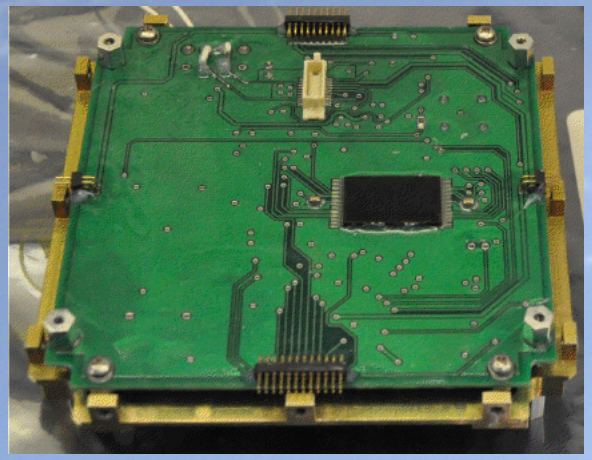
Mission



- Radiation belts consist of clouds of charged particles trapped in Earth's magnetic field.
- Belts come closer to Earth's surface at the "horns", located at northern and southern latitudes.

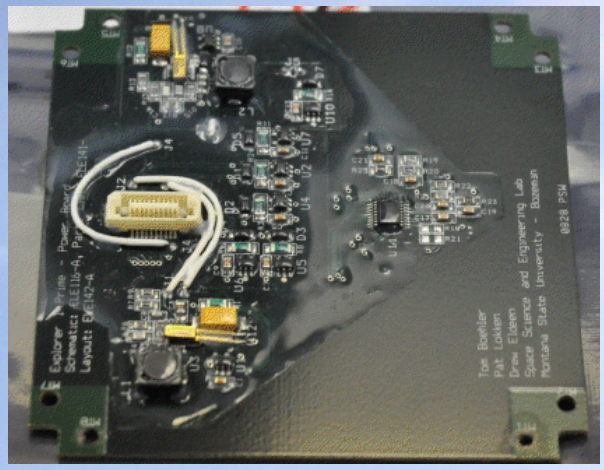
- The HRBE CubeSat mission demonstrates the utility of low-cost CubeSats to provide critical space weather observations for forecasting and specification
- Employs a simple Geiger Müeller tube to monitor the flux of trapped electrons in the horns of the inner and outer Van Allen radiation belts
- Contributes to the development of the aerospace workforce by involving university students in spacecraft design, development, and operations

Subsystems



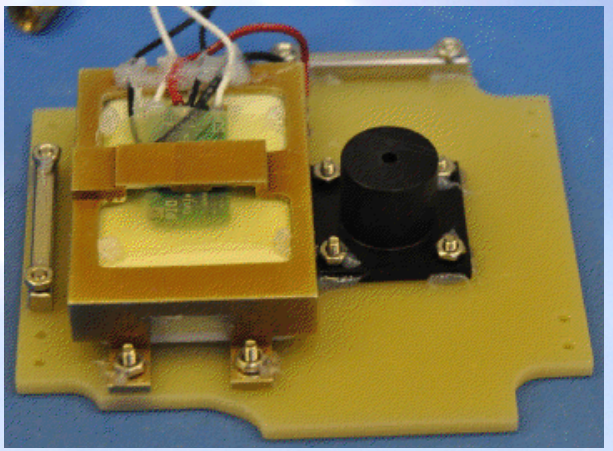
Command and Data Handling

- Freescale MCU (HCSX12)
- Onboard Flash data storage



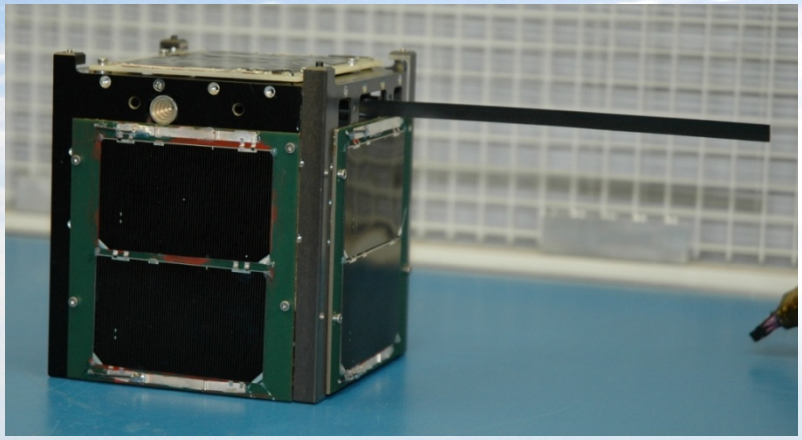
Power

- 3.3 and 5 V regulators
- 2 Rose Li-Ion Batteries
- 6 solar arrays



Attitude Control System

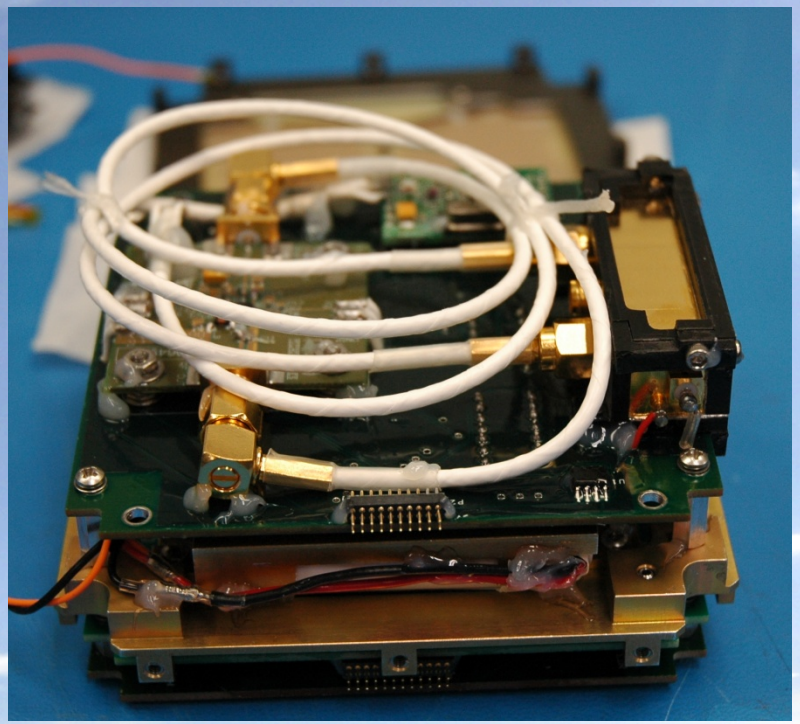
- NiB Earth Magnet
- HyMu80 dampening rod

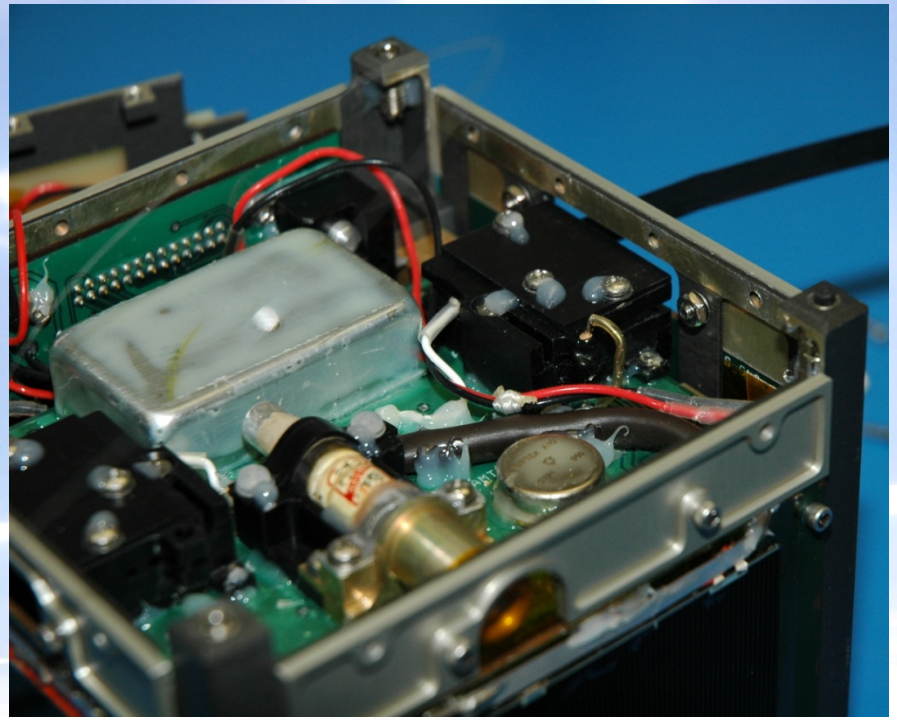


Structure

- Designed in-house
- Manufactured in Kalispell MT at Sonju
- Interfaces mechanically with all subsystems and solar arrays

Subsystems





Communications

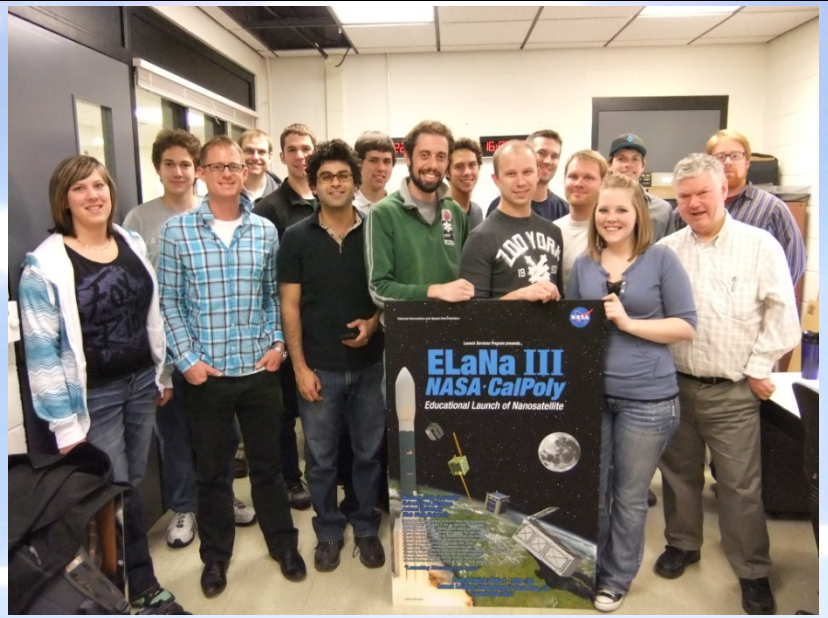
- Utilizes 2 CC1000 transceivers
- RF5110G Amplifier
- Monopole antenna
- Tx: 437.505 MHz
- Rx: 437.305 MHz

Science Payload

- Geiger tube donated by James Van Allen
- EMCO HVPS
- AmpTek amplifier
- Collimated tube to limit indirect particles from being counted

Post Launch Engineering

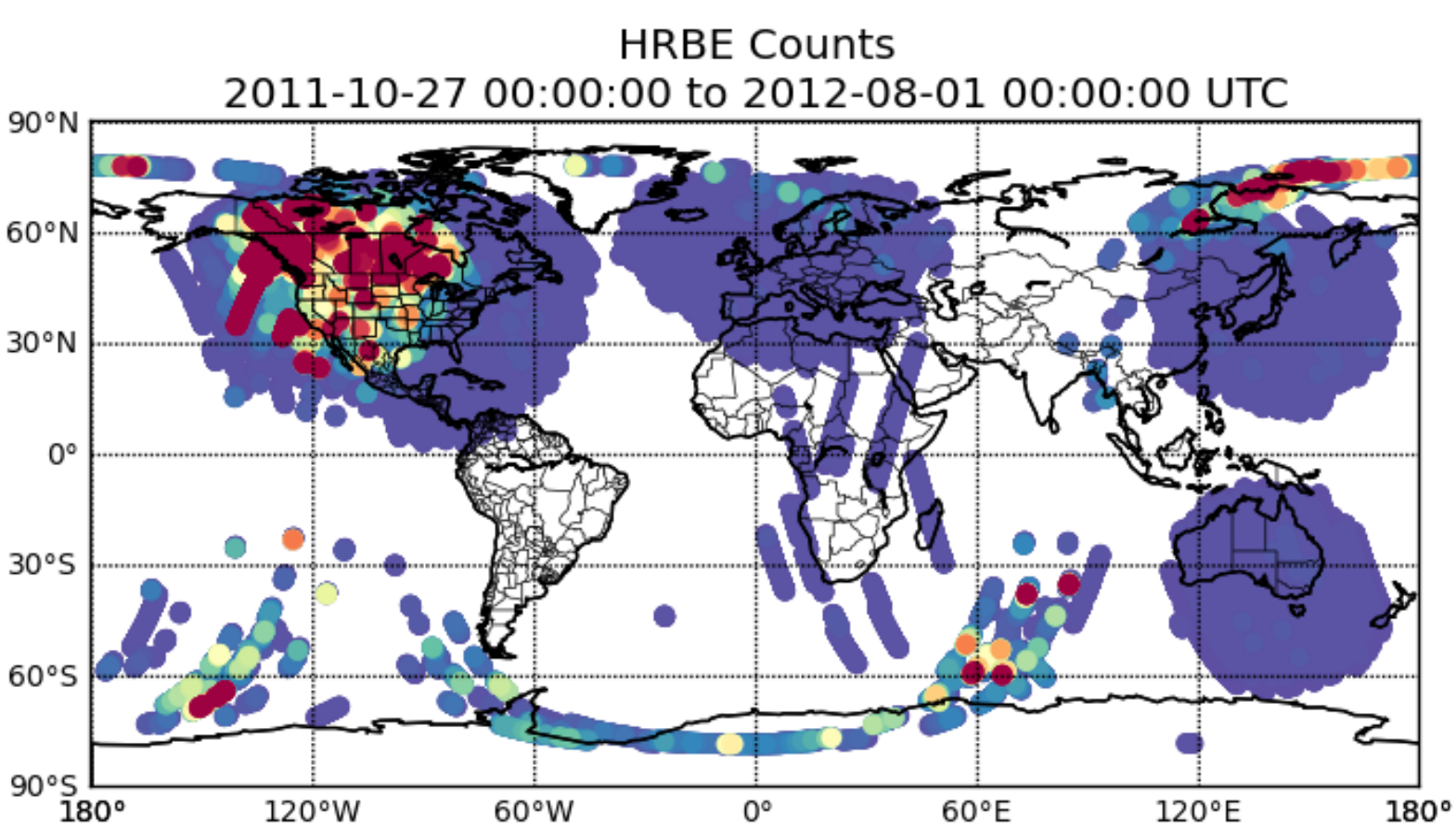
- Could not Establish Uplink:
  - HRBE Receiver BW ~ 600kHz
  - No science without uplink
- SRI 60ft Dish:
  - 1.3MW Max ERP
  - Established Uplink
- Upgraded K7MSU
  - 1.5KW UHF amplifier added
  - Uplink successful!



HRBE Ops Team

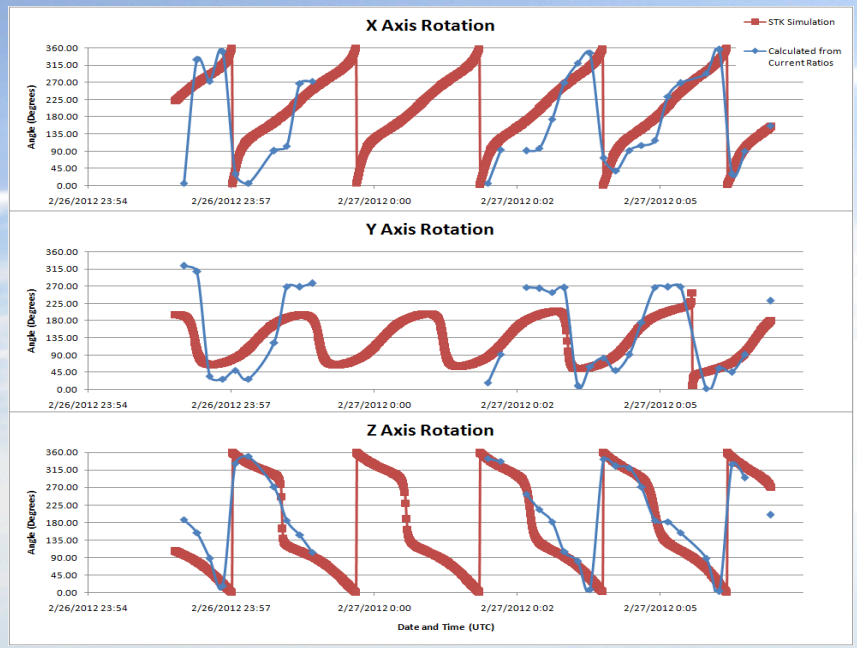
SRI International 60ft Dish

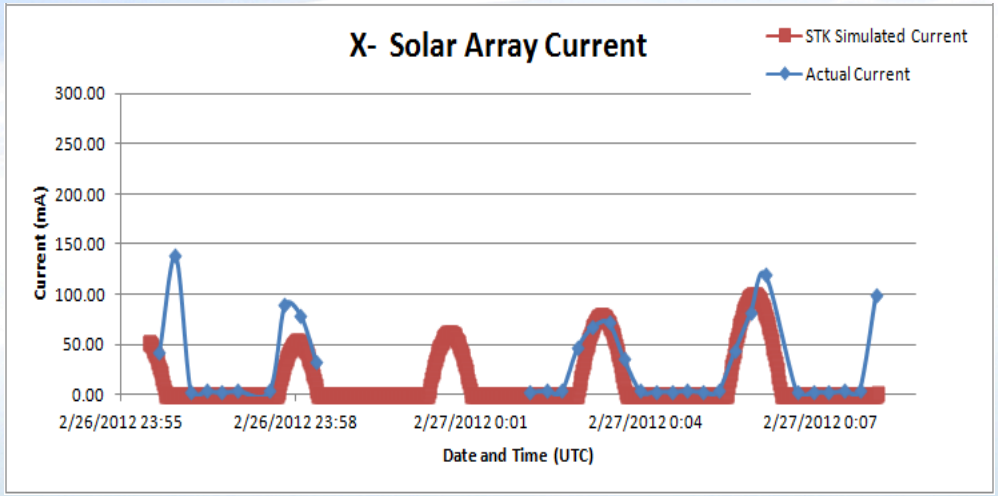
Science Coverage



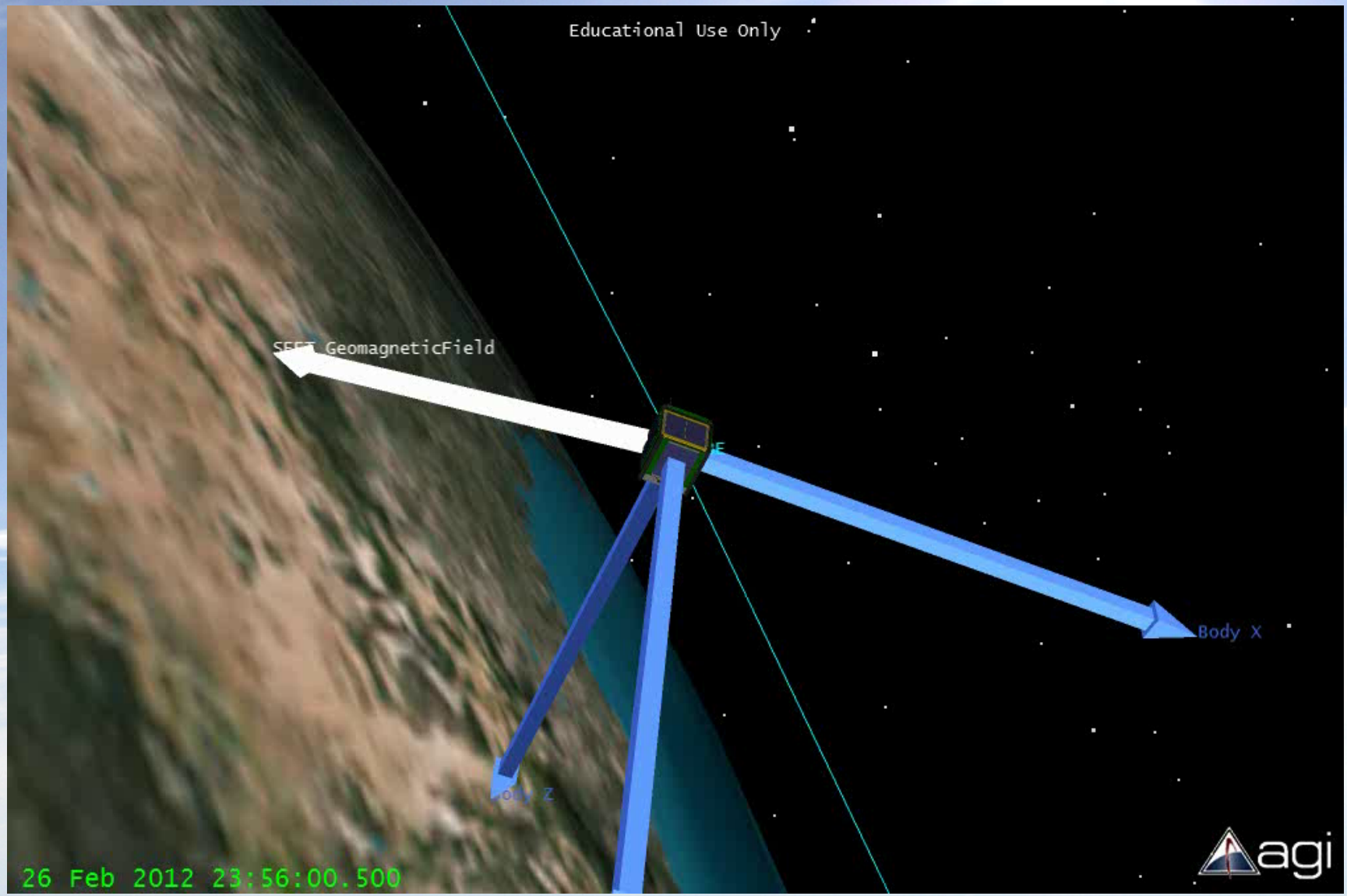
Attitude Determination

- Ratio of electrical current from adjacent solar panels used to find direction of sun
- Satellite Tool Kit (STK) simulation adjusted until it matches data





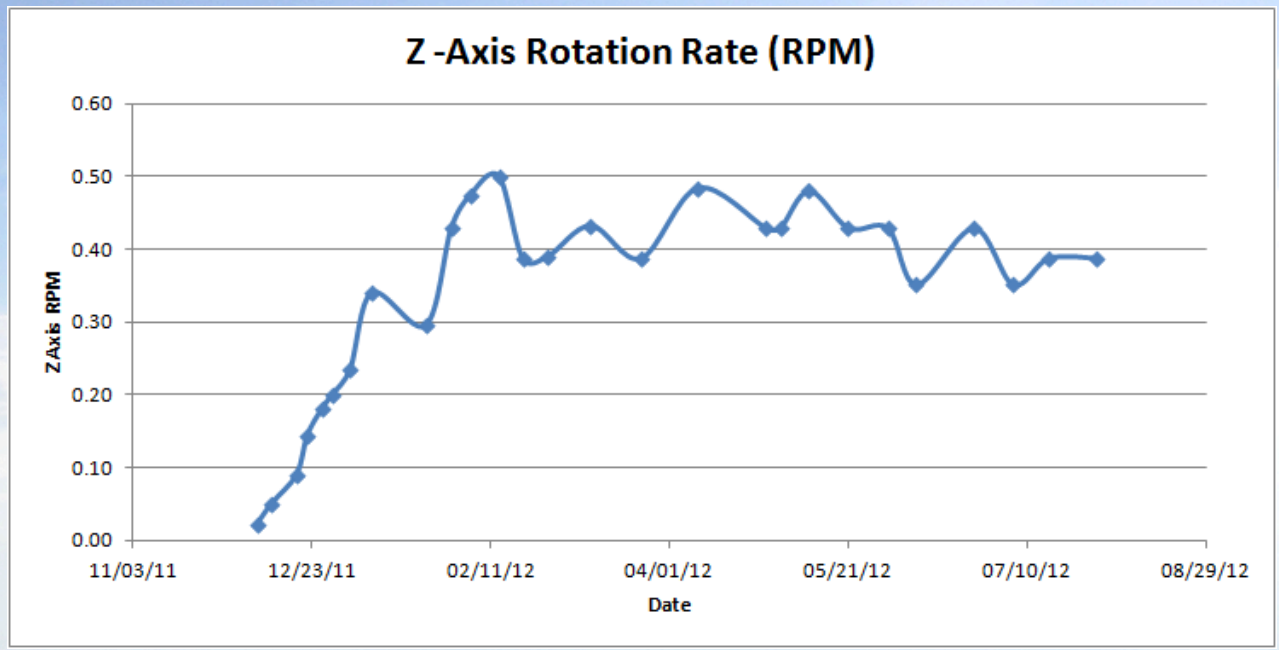
Attitude Simulation in STK



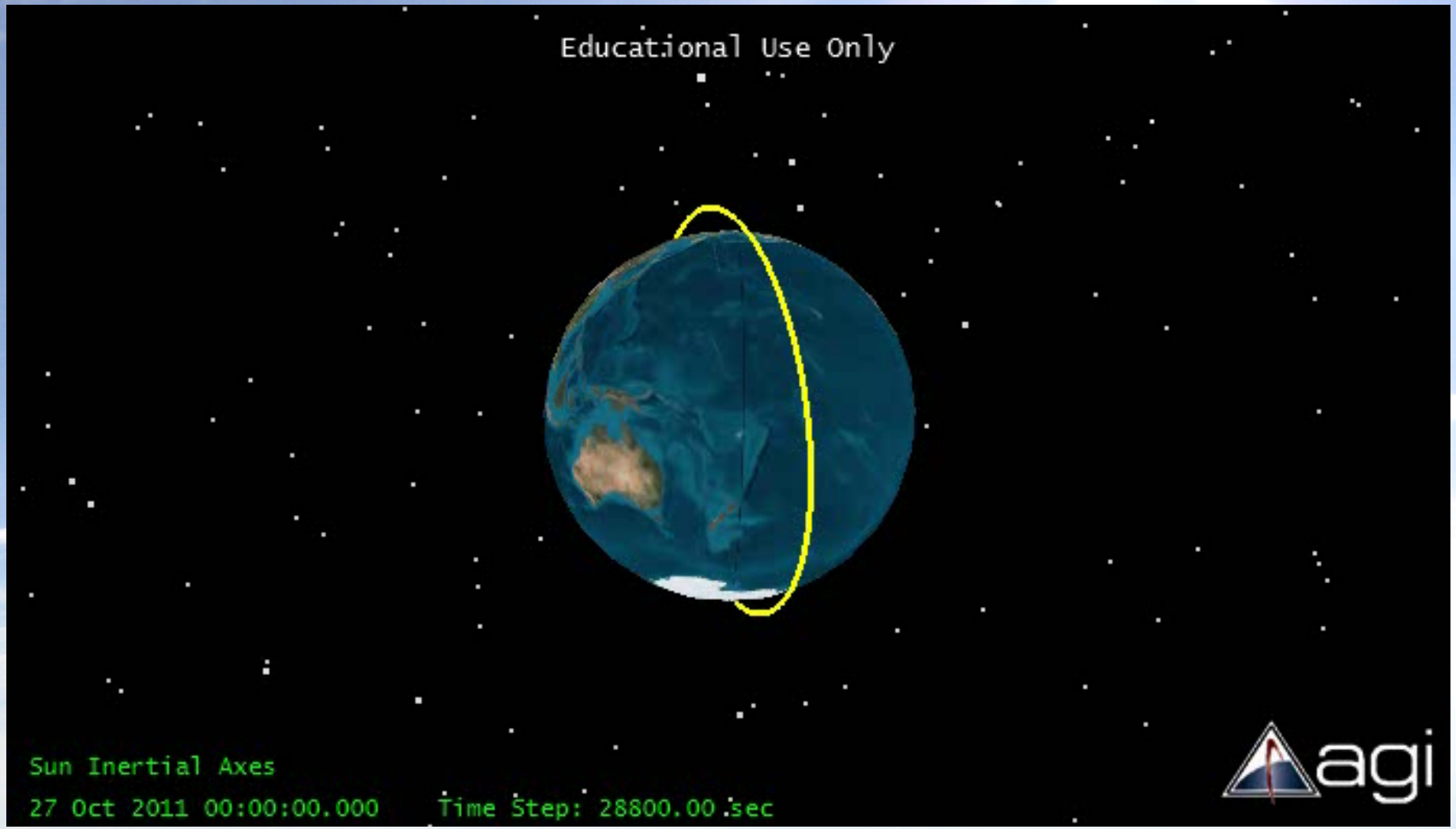
Attitude Determination

- Slower than expected de-tumble
- Off-axis spin

- Data aliased before Fed. 2012 due to 15 second sample rate

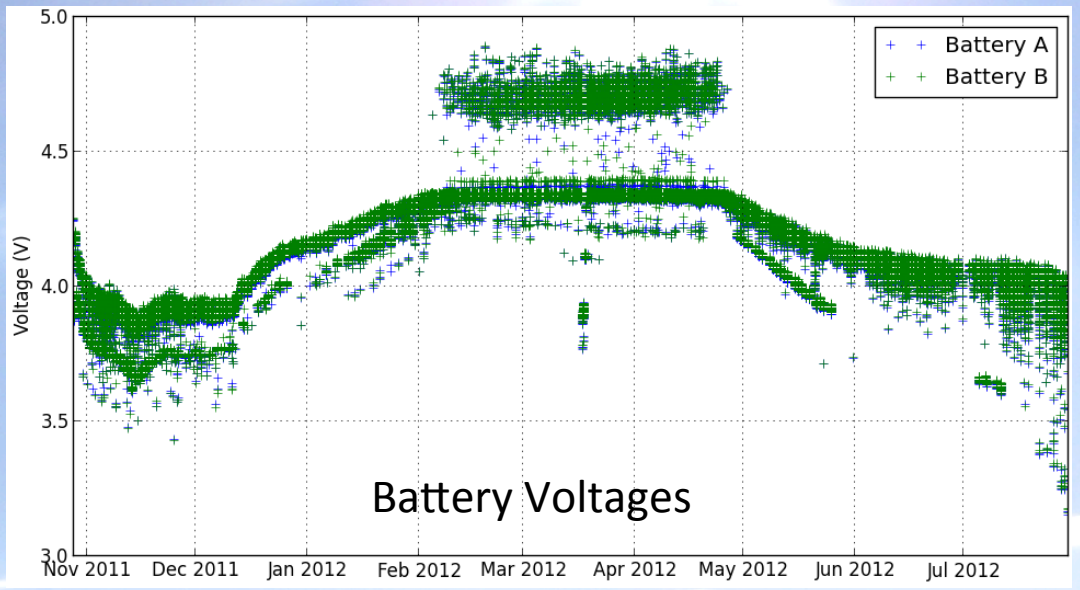


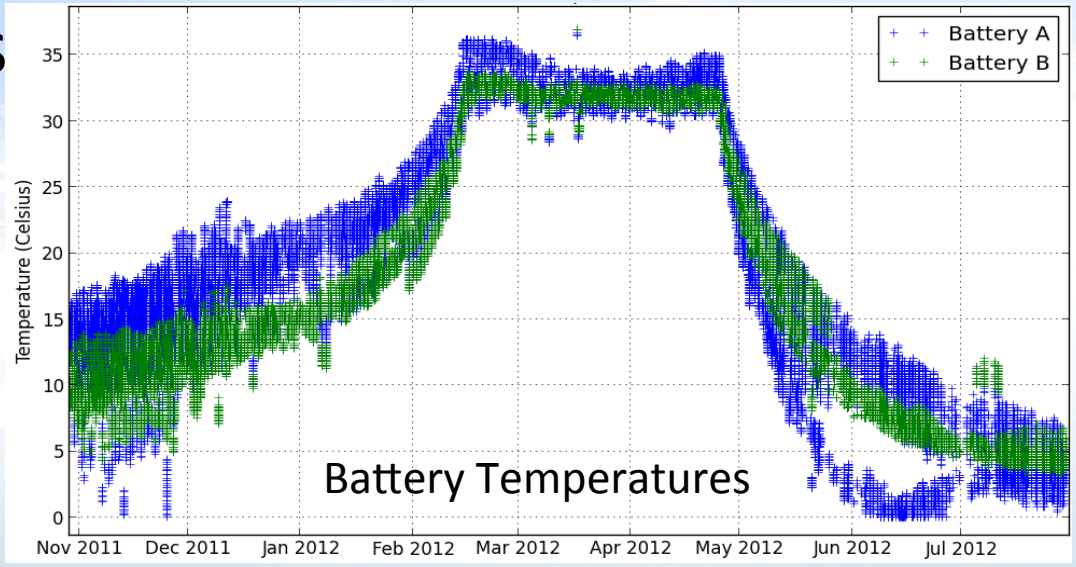
Transition to Sun-Sync. Orbit



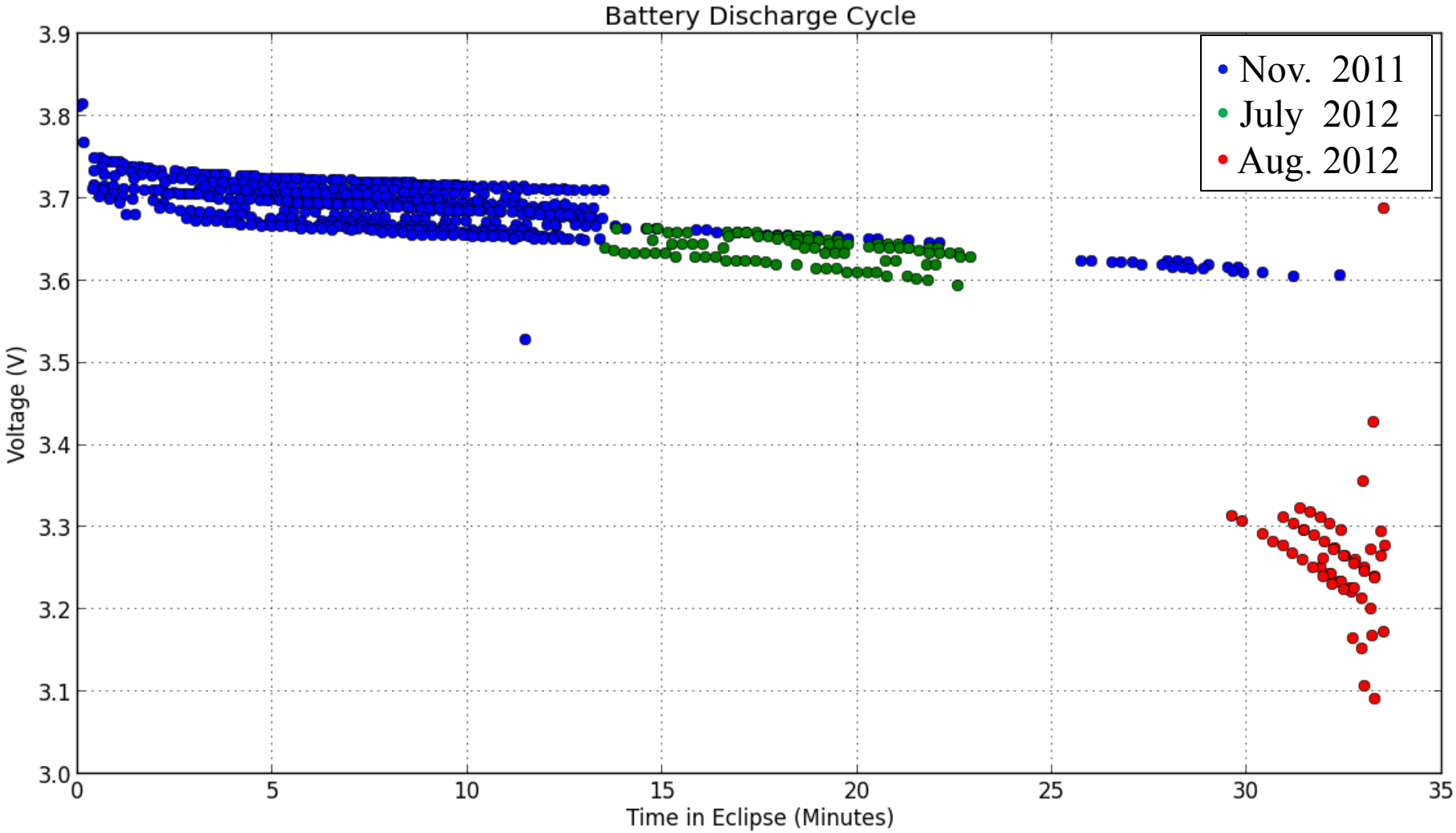
Effects of Continuous Sun

- Full Sun light from Feb. 27 to April 27
- Over-voltage protection circuitry used in full sun
- Voltages and temps at life-time low

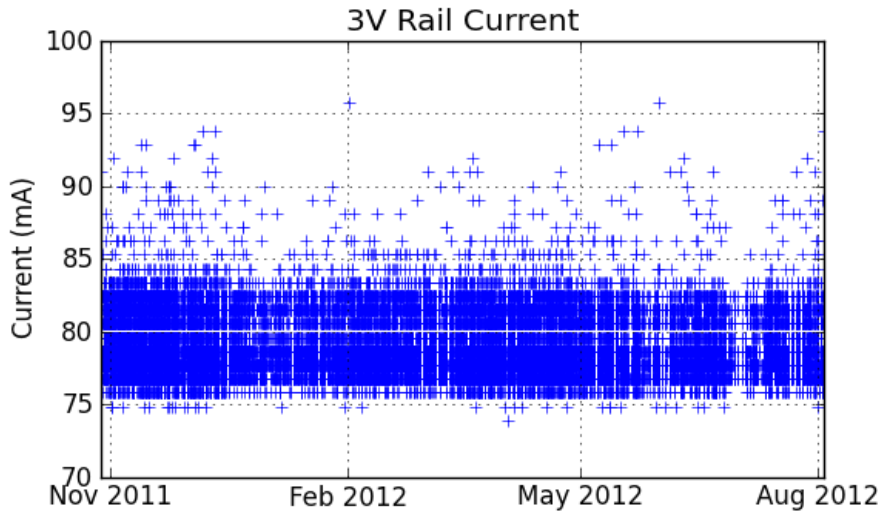


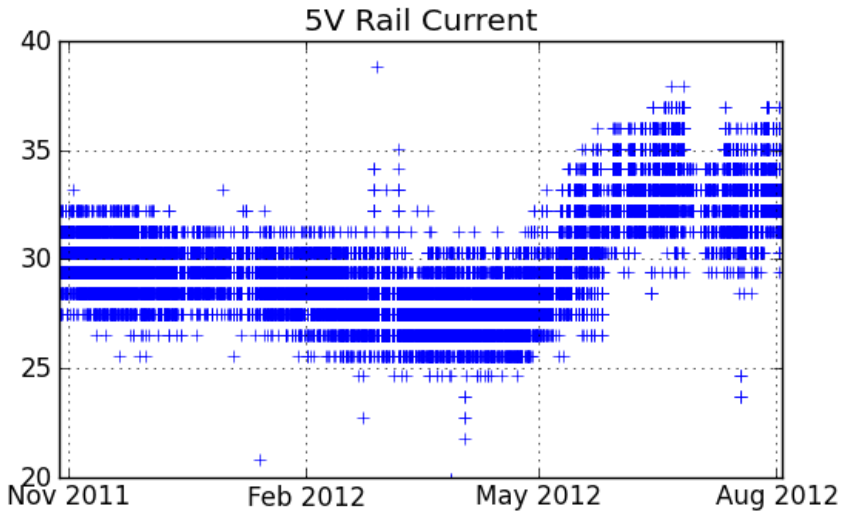


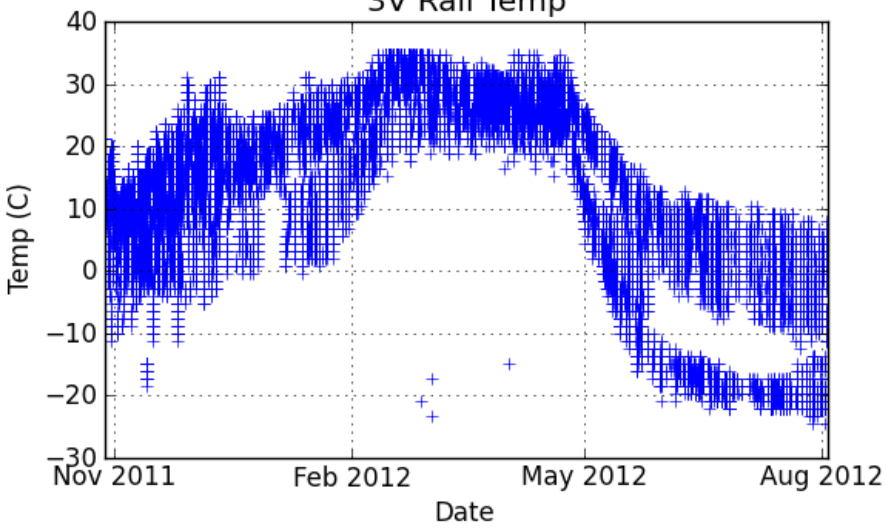
Battery Deterioration

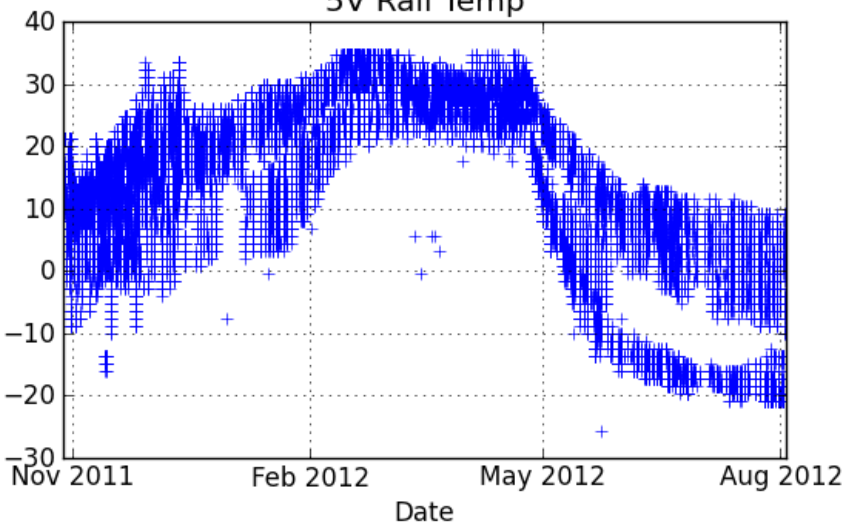


Increased Current Draw





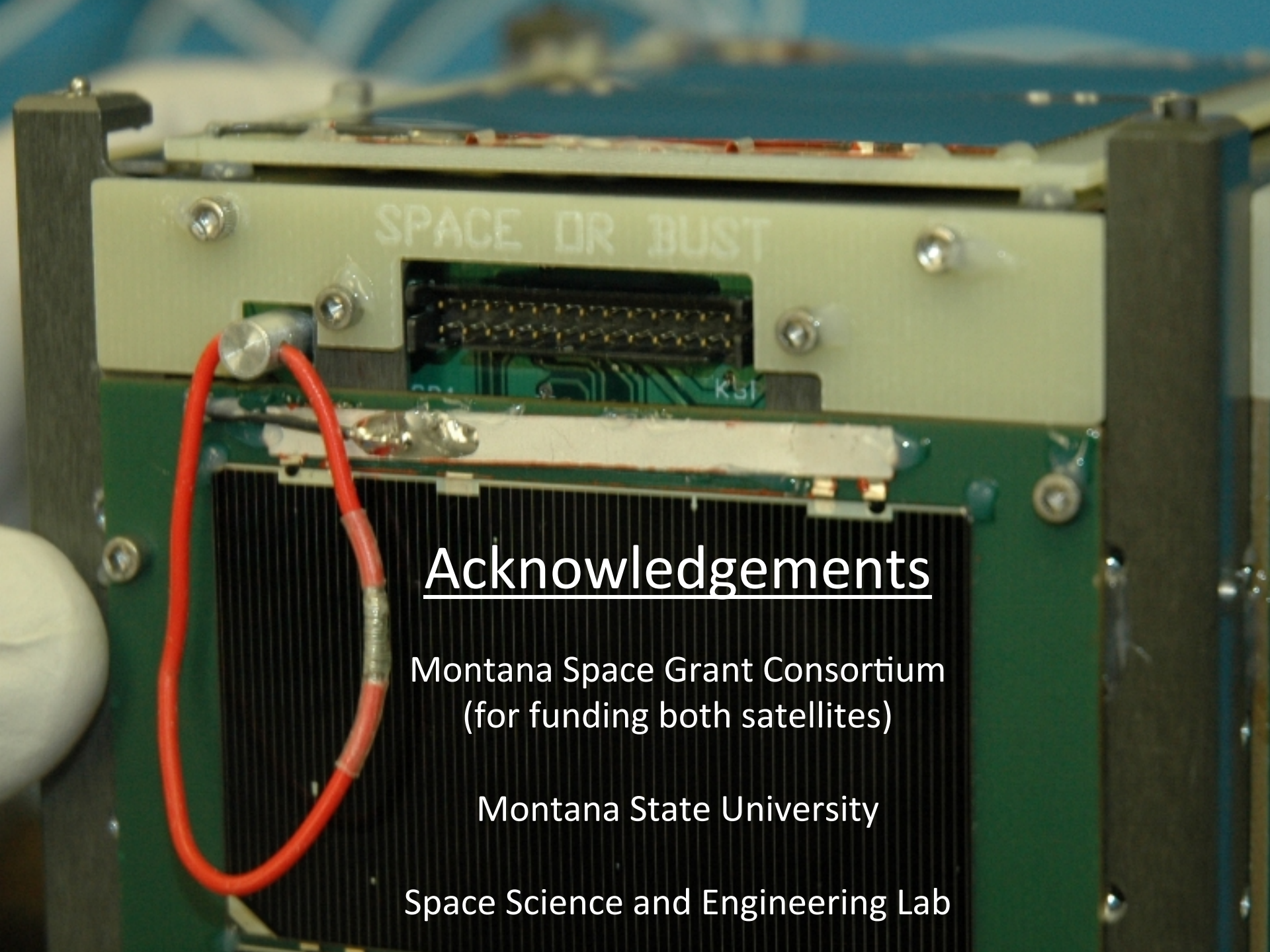




Conclusions

- HRBE Works!
- 100% Mission Criteria Success
- If batteries fail, still operational in Sun

- 47,000 beacons decoded, ½ from HAM community
- 210 hours of science data collected

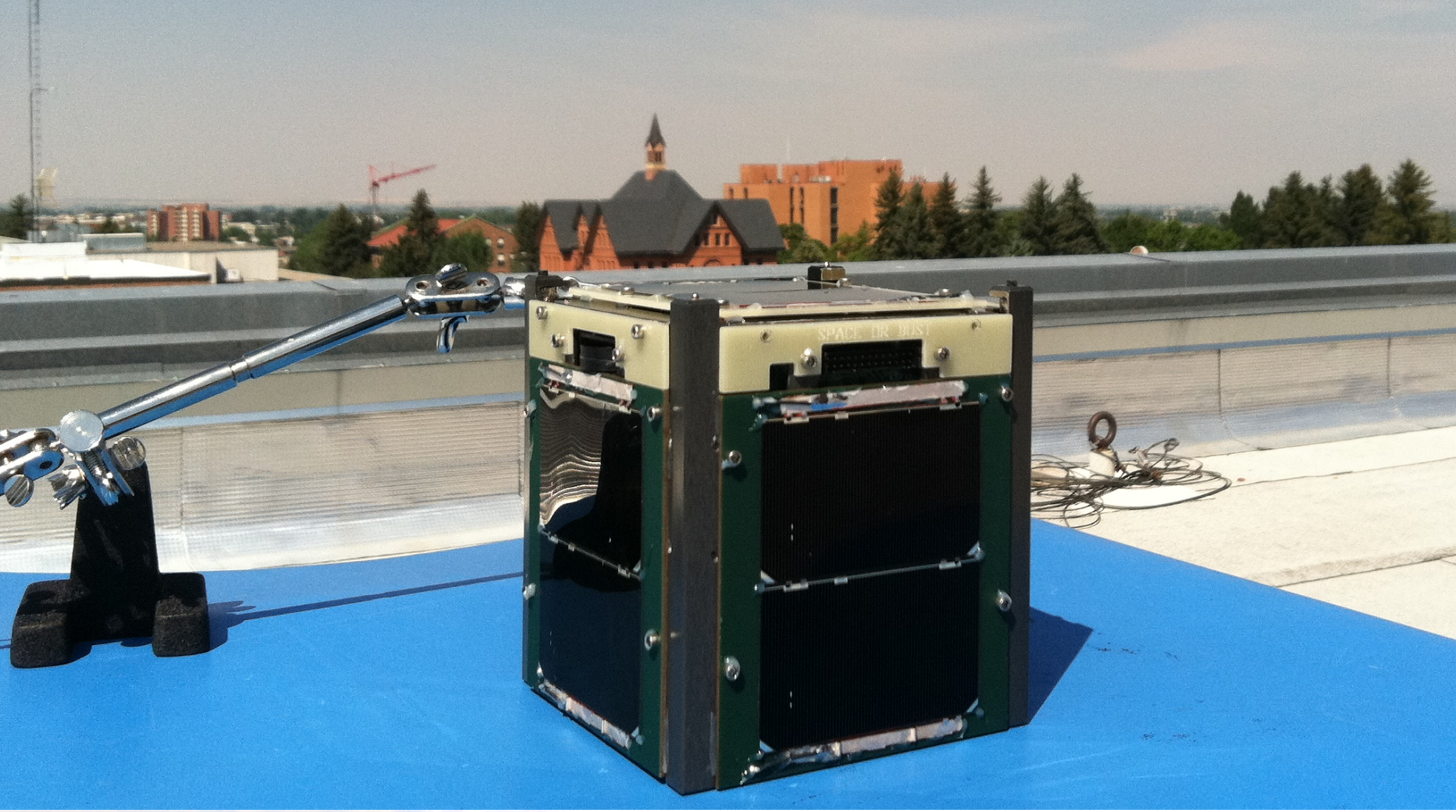


Acknowledgements

Montana Space Grant Consortium
(for funding both satellites)

Montana State University

Space Science and Engineering Lab



Questions?

http://ssel.montana.edu