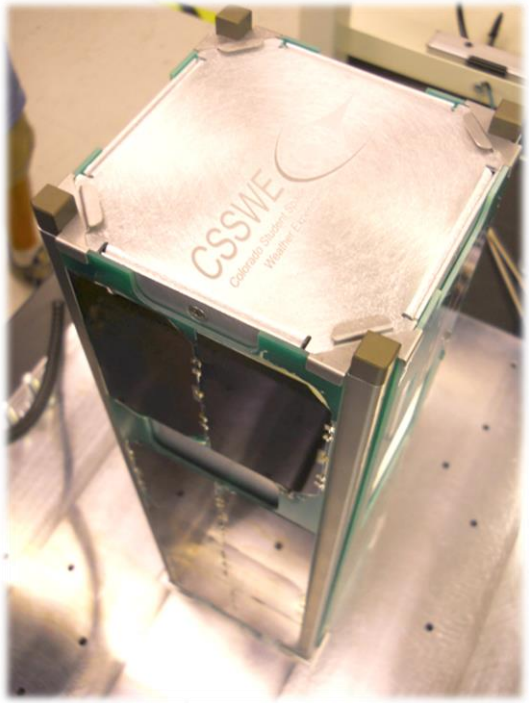
The Colorado Student Space Weather Experiment (CSSWE) On-Orbit Performance



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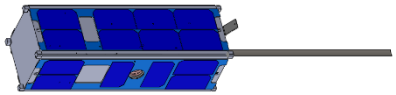
http://lasp.colorado.edu/home/csswe/

CSSWE CubeSat

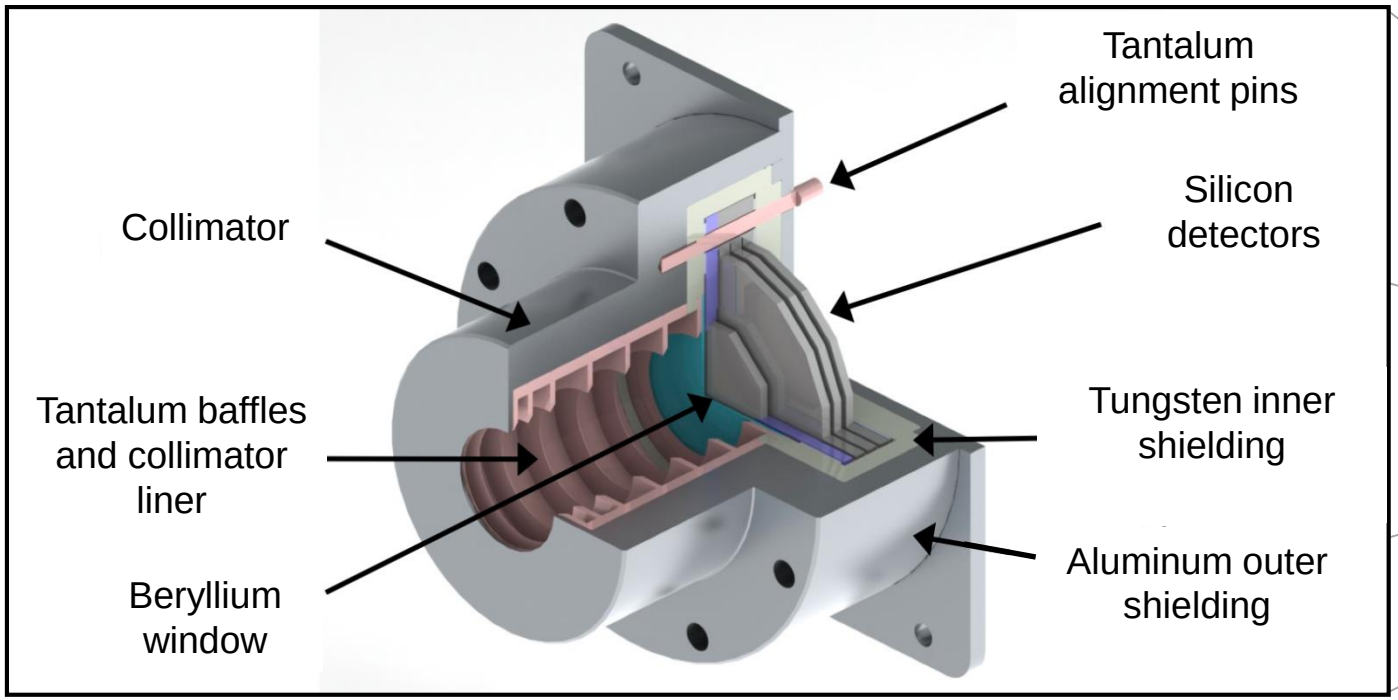


Science mission: Improve our understanding of the relationship between solar energetic particles (SEPs) and flares, as well as the Earth's radiation belt electrons

Science Payload:	Energetic Particle Telescope
Funding:	National Science Foundation
Organization:	Student-led, professionally advised
Delivery:	January 9th, 2012
Orbit Insertion:	September 13th, 2012 (ELaNa VI)
	480km x 780 km, 65° inclination
Expected Lifetime:	120 days (full success)
Actual Lifetime:	330 days (and counting)

Science Instrument: REPTile

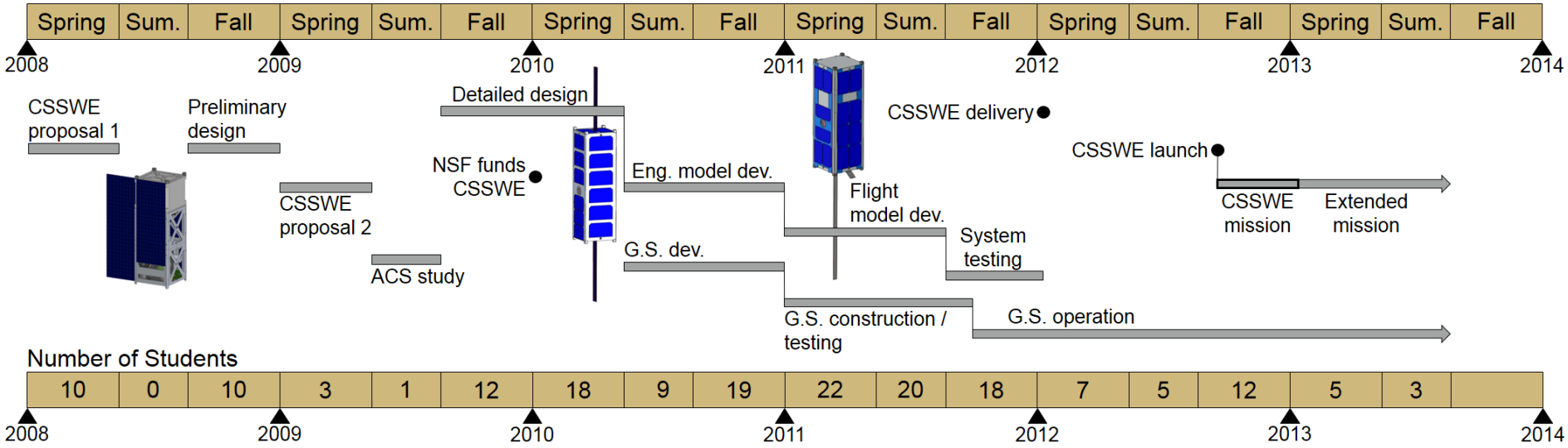
Relativistic **E**lectron and **P**roton **T**elescope **i**ntegrated **l**ittle **e**xperiment



Measures directional differential flux of 9 to 40 MeV protons & 0.5 to >3.3 MeV electrons with 6 sec. time resolution

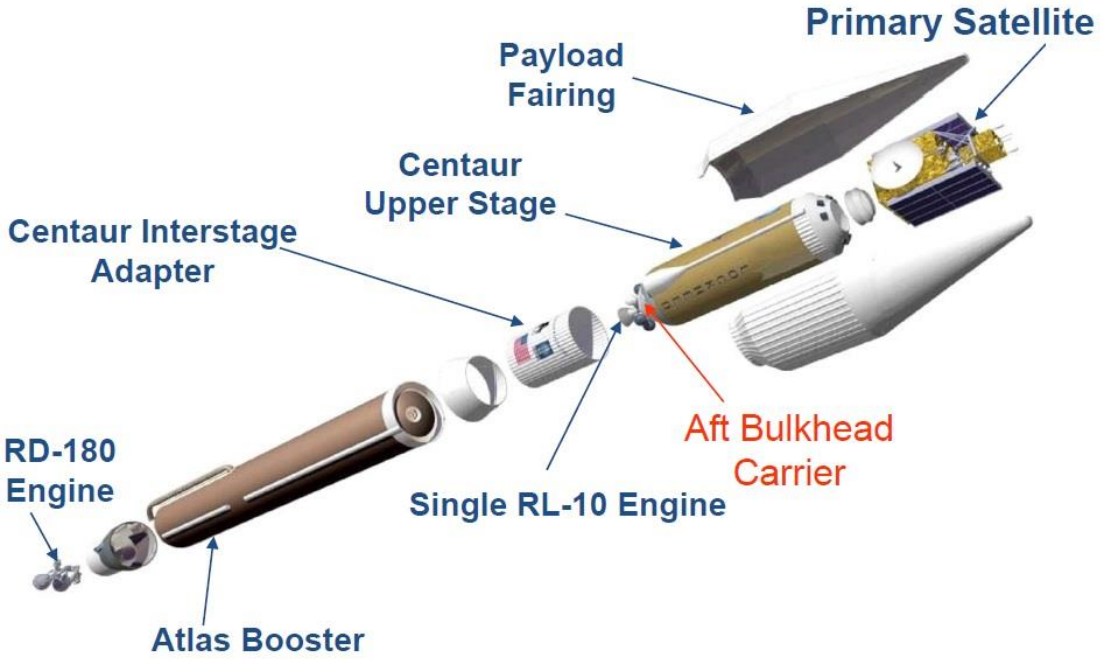
Field of view:	52˚
Dimensions:	4.6 cm (diameter) x 6.0 cm (length)
Total mass:	1.25 kg

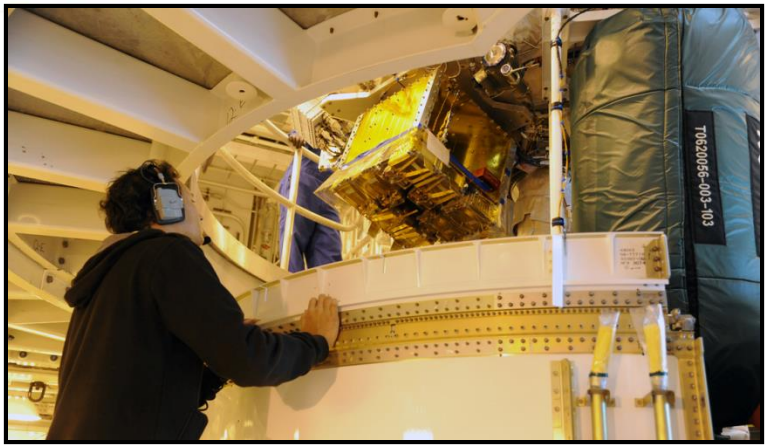
Timeline

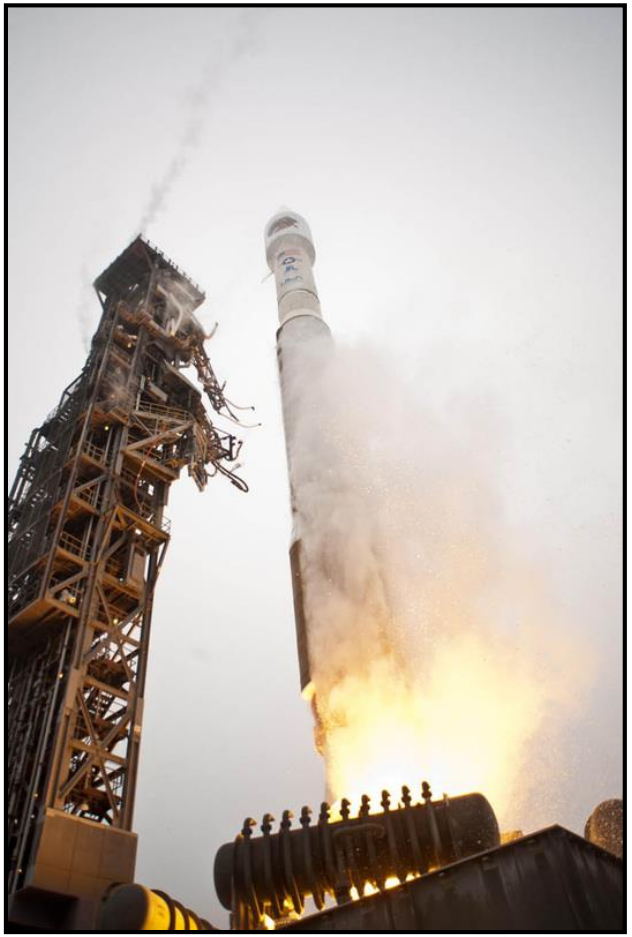


- Education
  - Satellite hardware experience for 60+ students
  - Masters project for 50+ students
  - Data will be in 3+ PhD dissertations

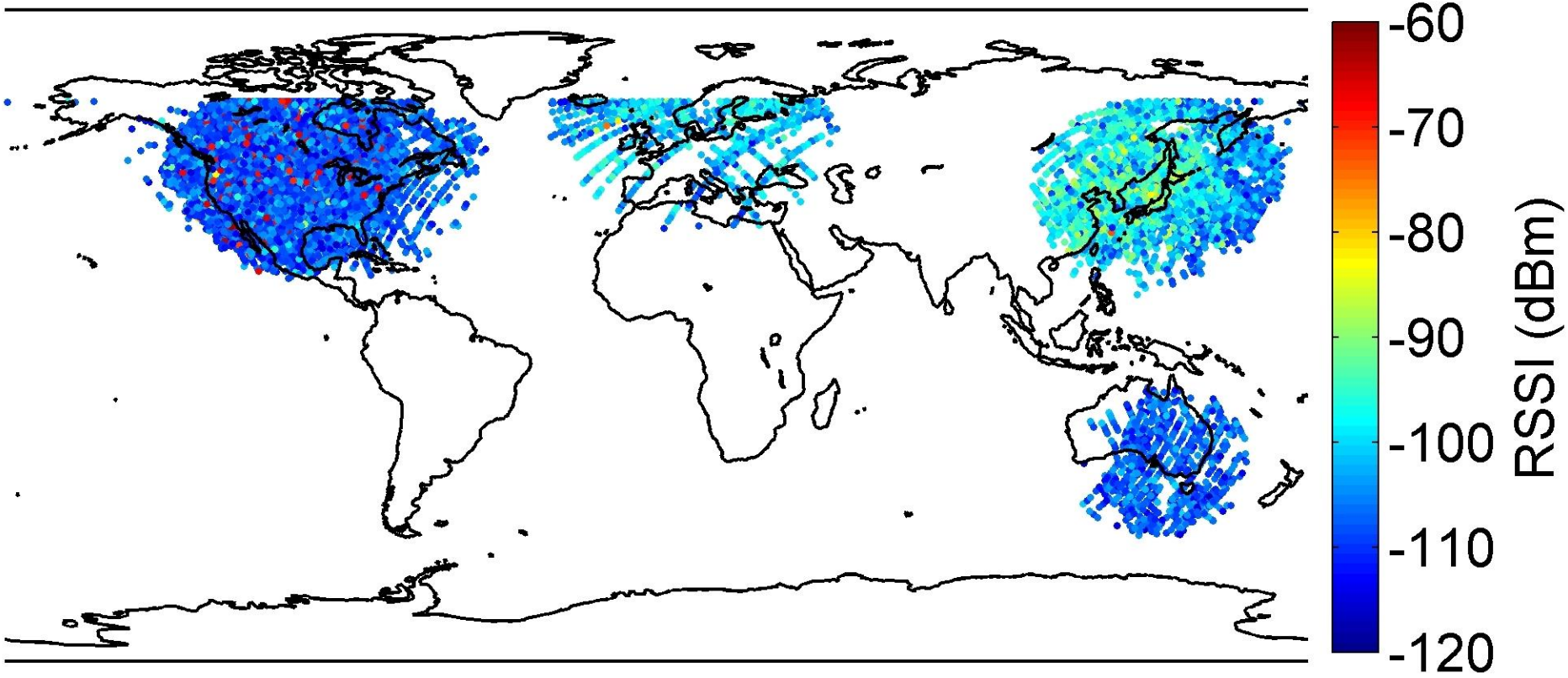
Launch


Primary Satellite
Payload Fairing
Centaur Upper Stage
Centaur Interstage Adapter
Aft Bulkhead Carrier
RD-180 Engine
Single RL-10 Engine
Atlas Booster



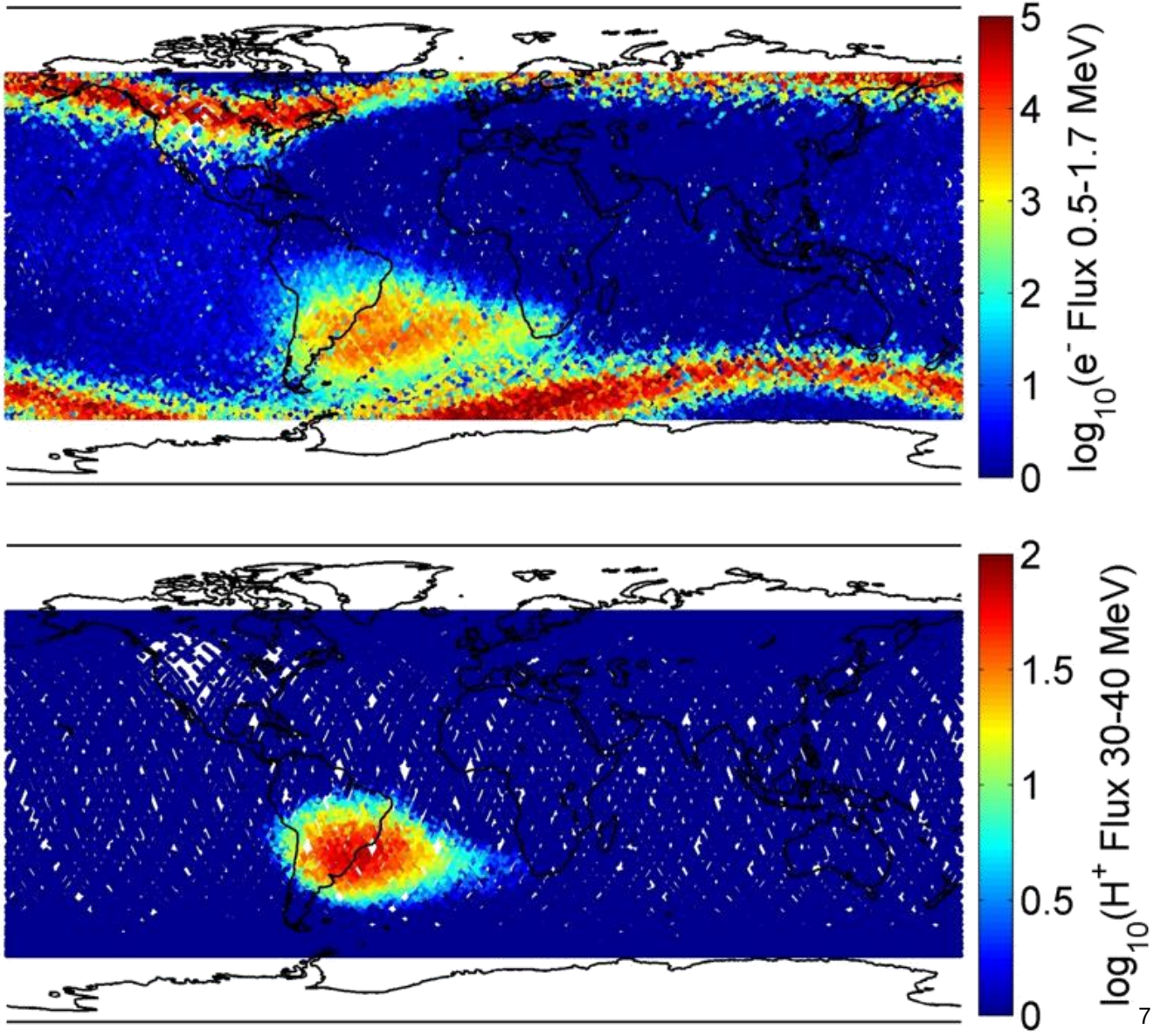


Commissioning

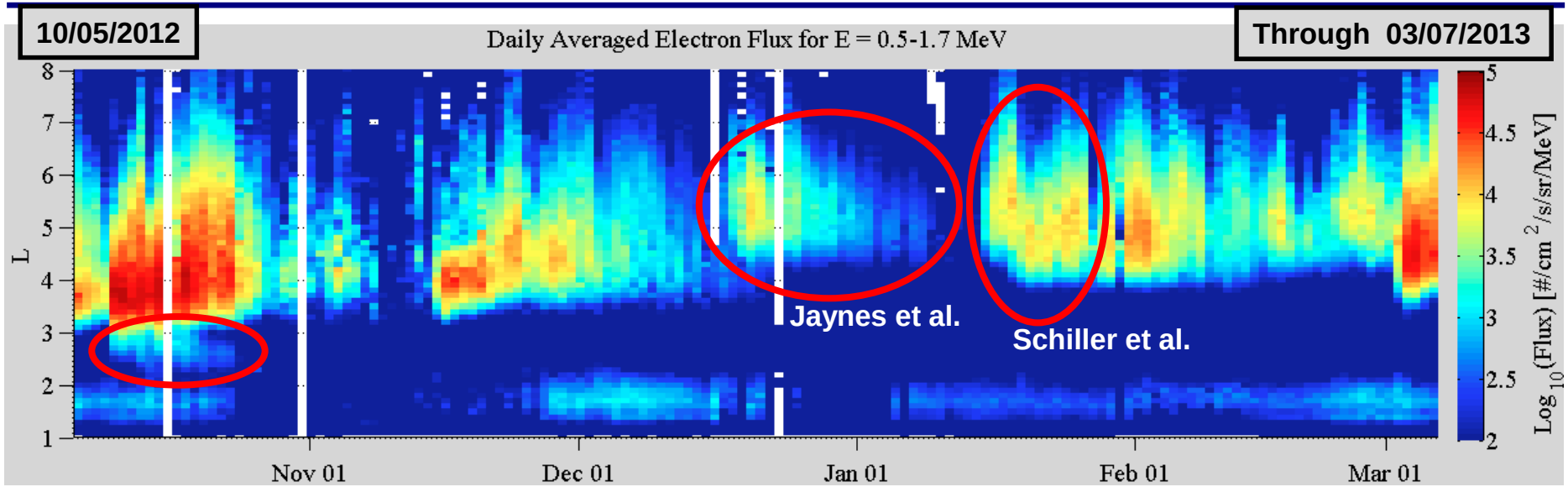


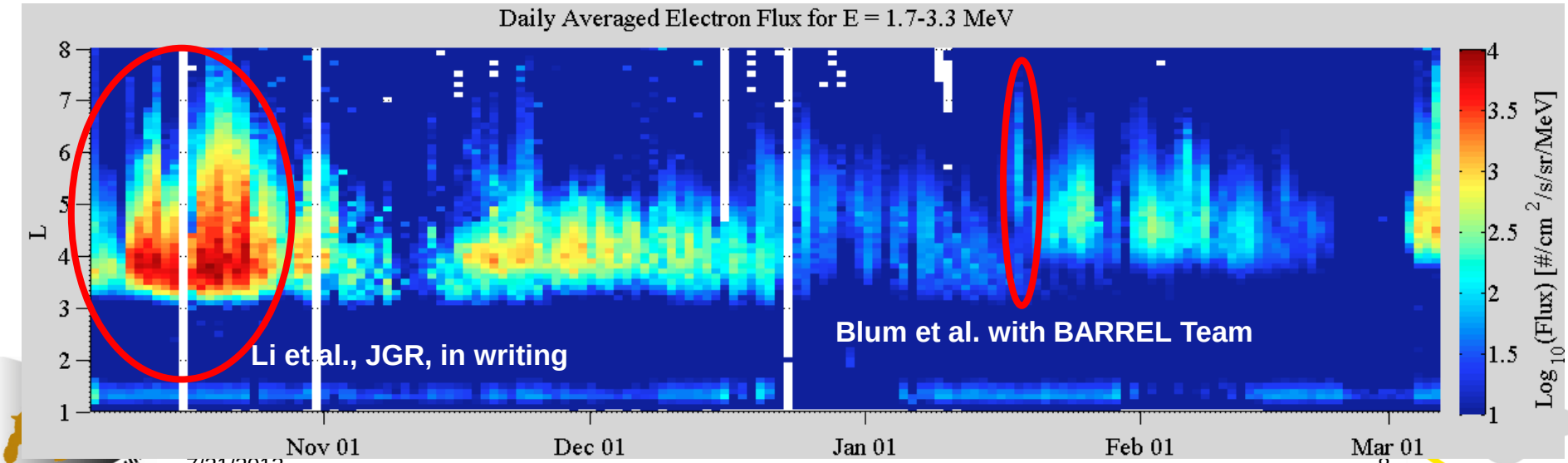
- Antenna deploy / beacons start at 2012.09.14 02:51
- First contact at 07:11 (Germany) / 10:14 (Boulder, CO)
- REPTile enabled on 2012.10.04

Science Results: First 20 Days



Science Results: Daily Average Flux





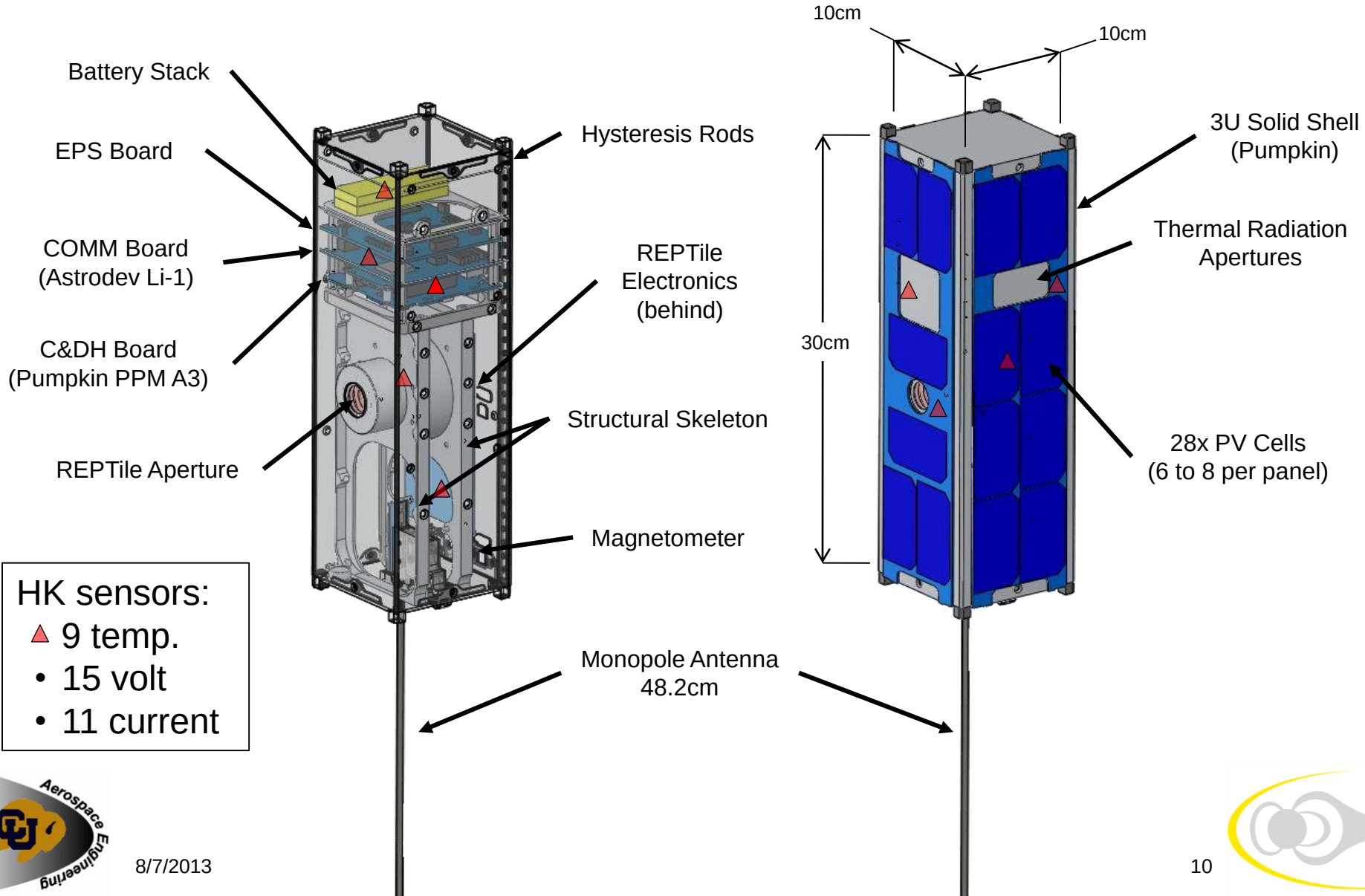
Full Mission Success: 2013.01.05

"The success of the CSSWE mission exemplifies everything we hope to achieve with the NSF CubeSat program. The CSSWE CubeSat has provided unique and highly valuable scientific data for space weather research.

At the same time, the project is an extraordinary demonstration that this can be done successfully with a student-built satellite in an educational setting. This data is an outstanding resource that will be aiding scientific advances for years to come."

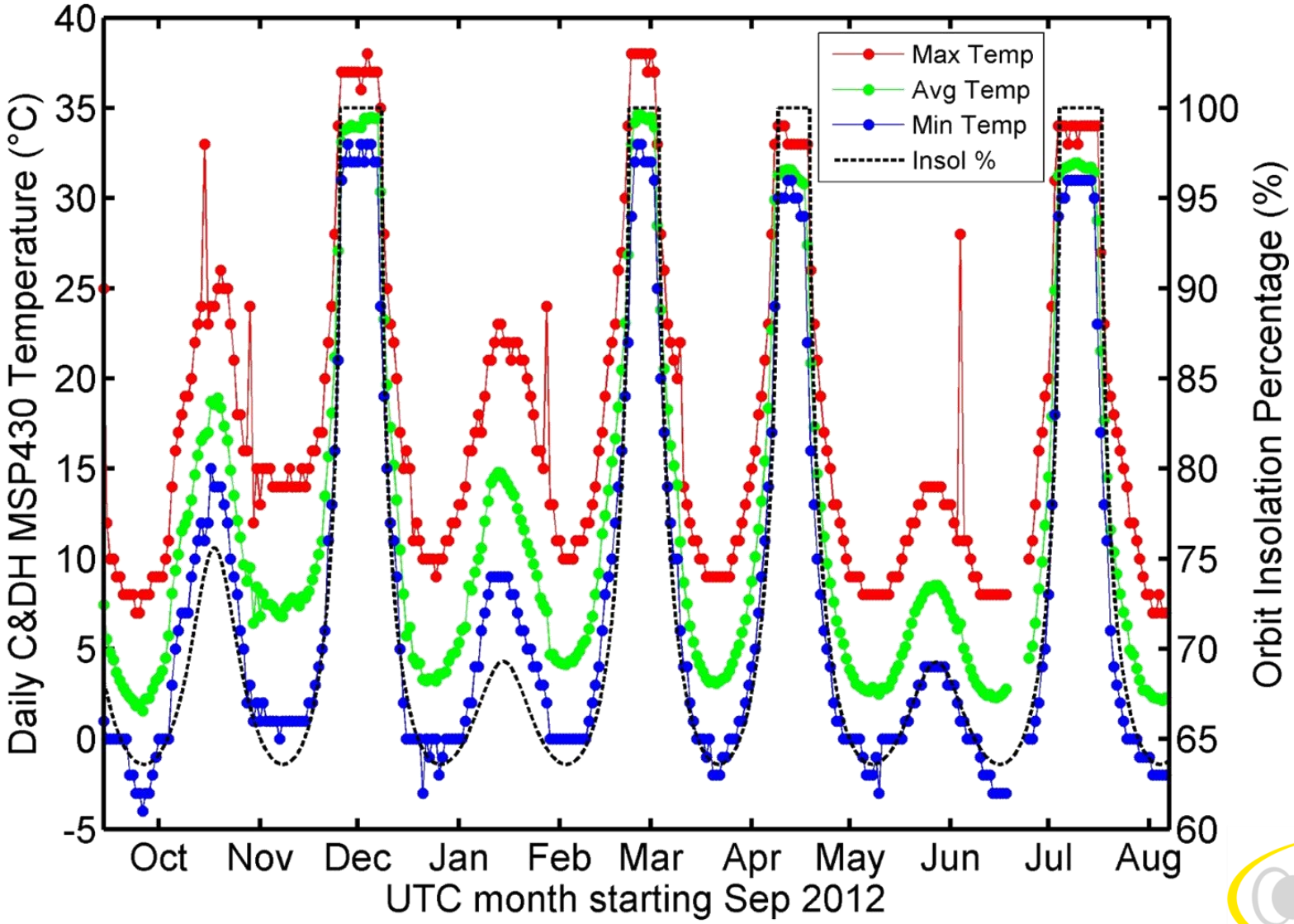
Therese Jorgensen
Program Director, Space Weather Research
National Science Foundation

System Overview



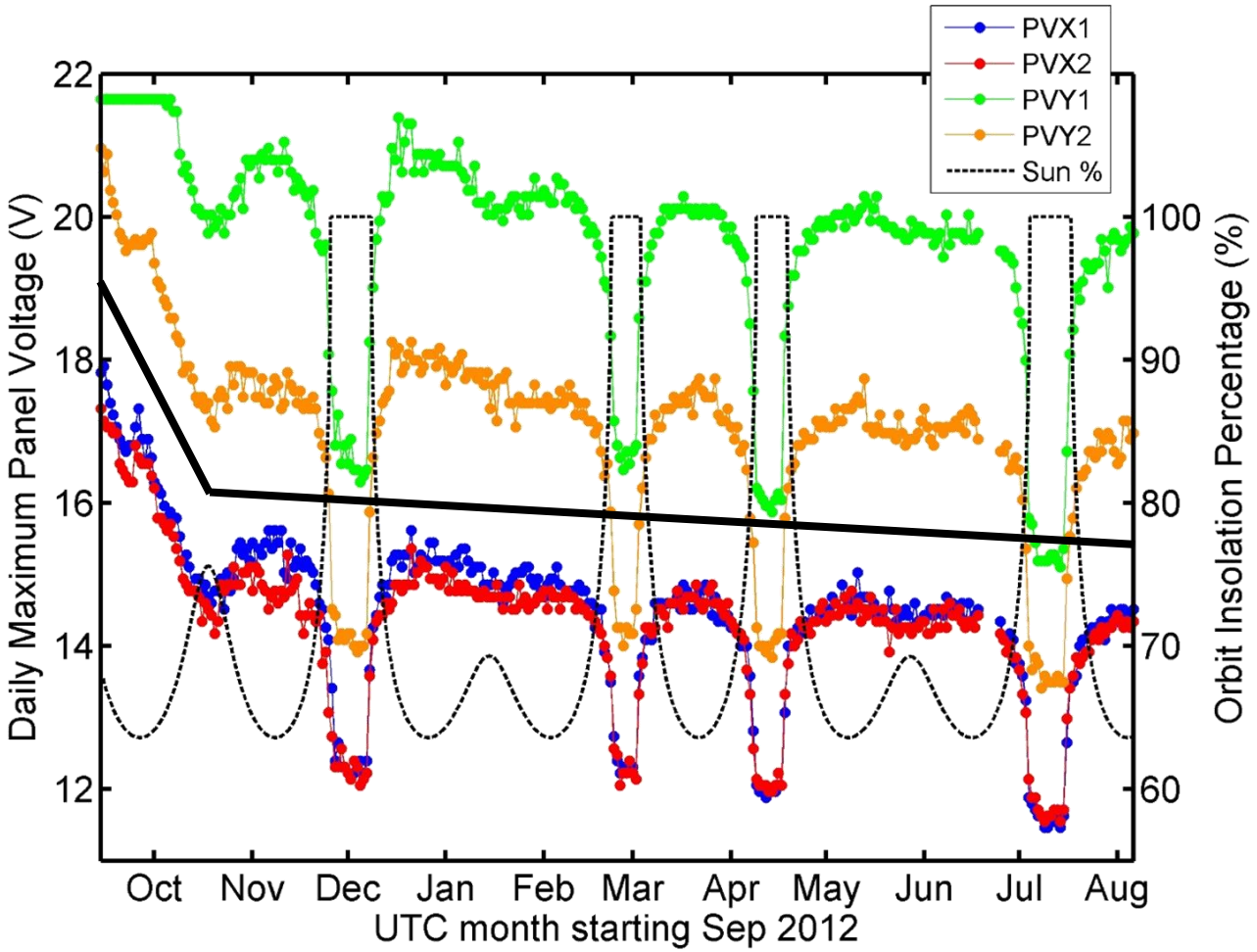
HK sensors:
- 9 temp.
- 15 volt
- 11 current

Nominal Operations: Temperature



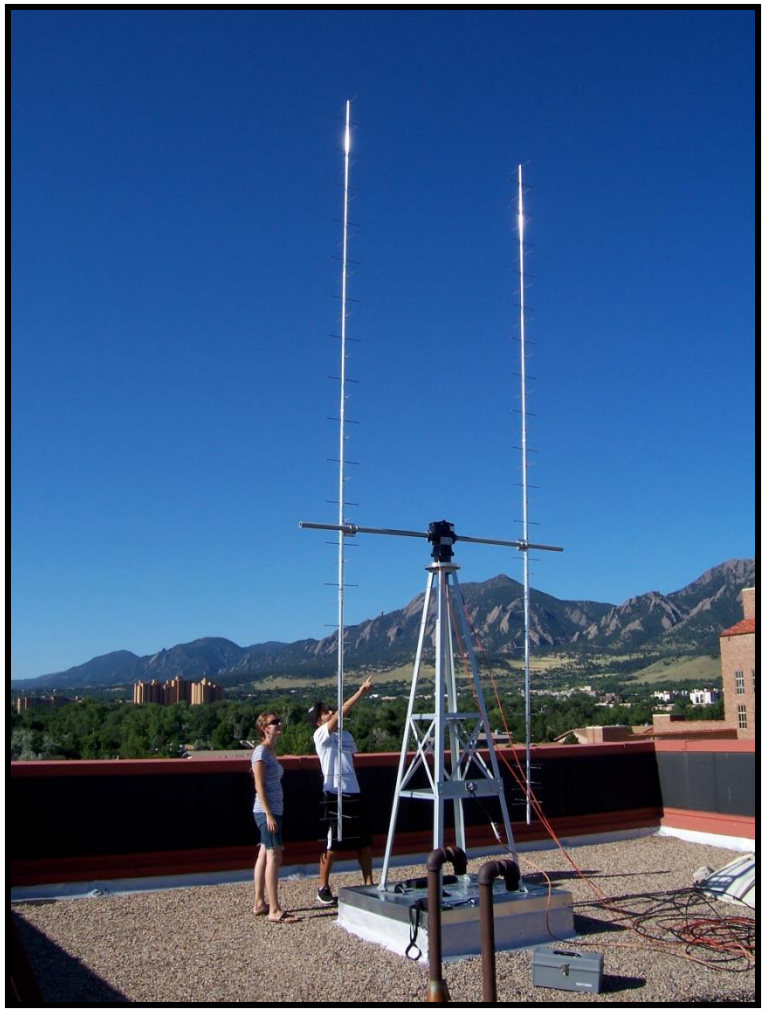
Nominal Operations: Solar Panels

- Degradation due to atomic oxygen slows after first month
- Solar panel efficiency decreases with temp

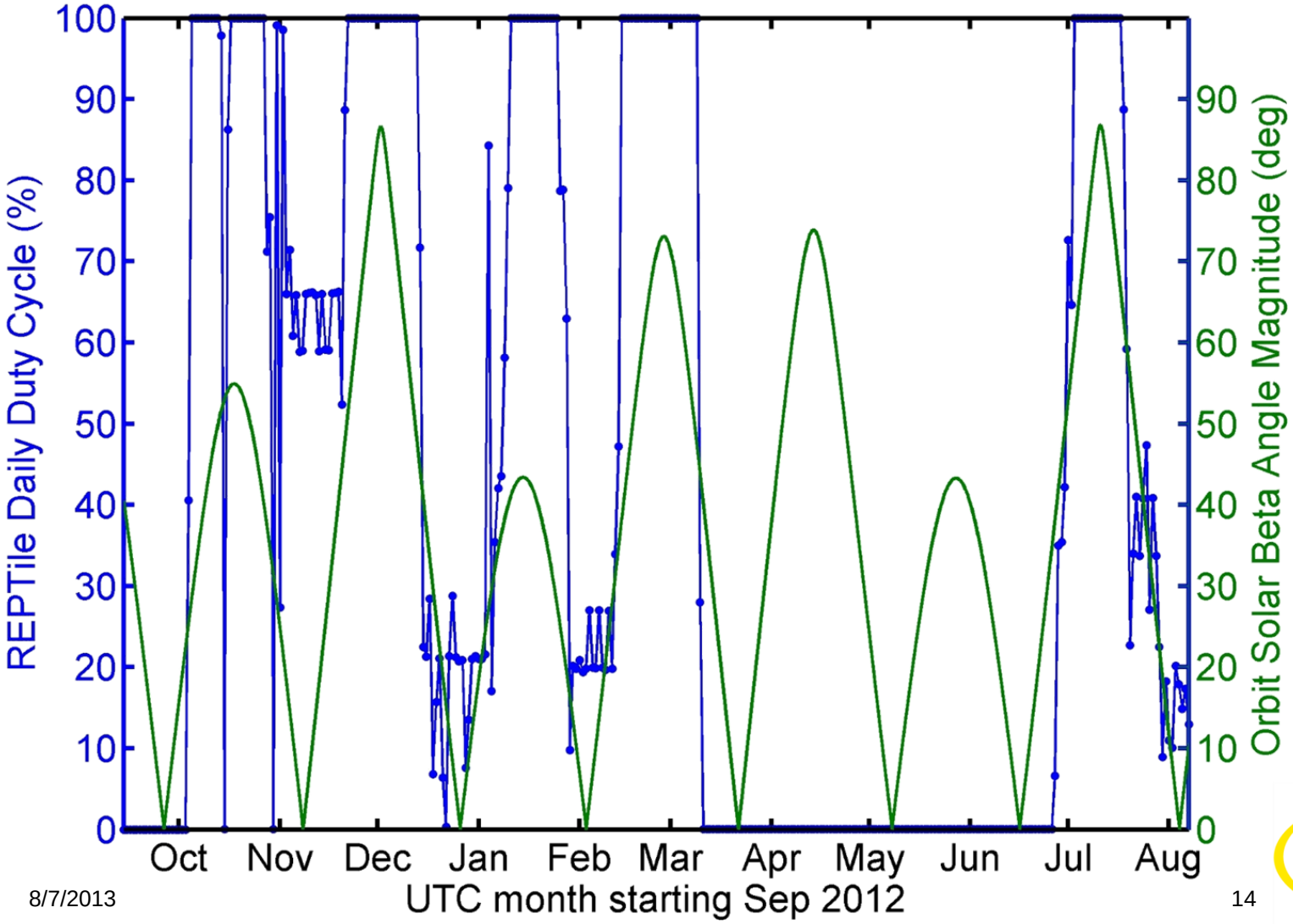


Nominal Operations: Commanding

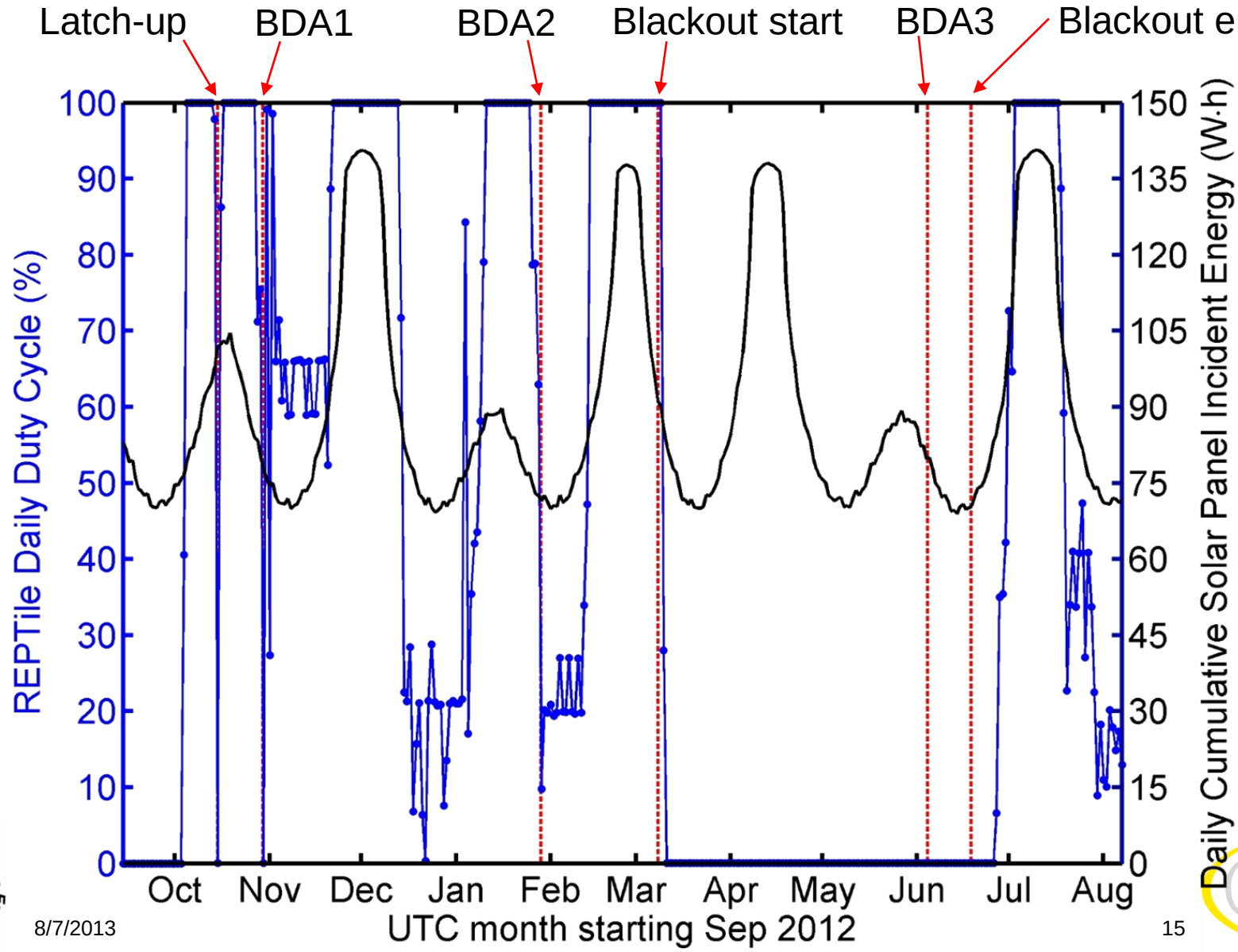
- Boulder ground station
  - Built for CSSWE operations
- Automated commanding system enabled Dec 2012
  - Enables data gather / monitoring during all 8+ passes per day
  - Analyzes received data to determine future requests
  - Requests data dumps based on satellite health
  - Plots received data to internal website for review
  - Email / text updates of each pass



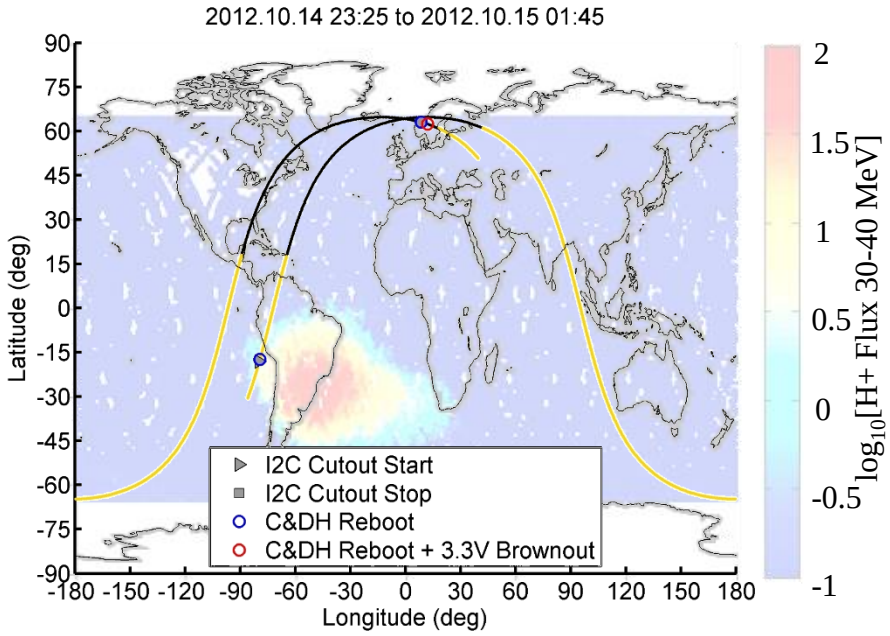
Nominal Operations



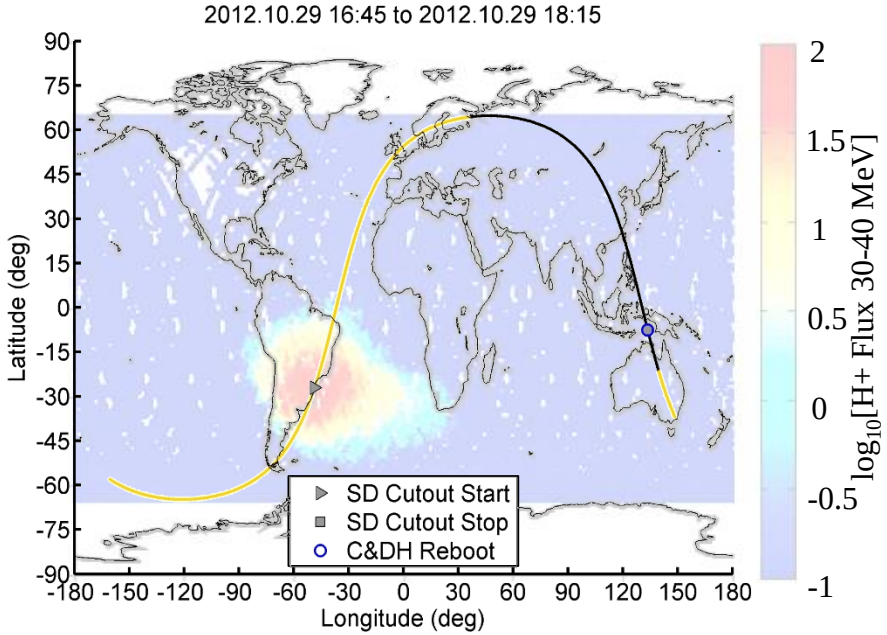
Nominal Operations



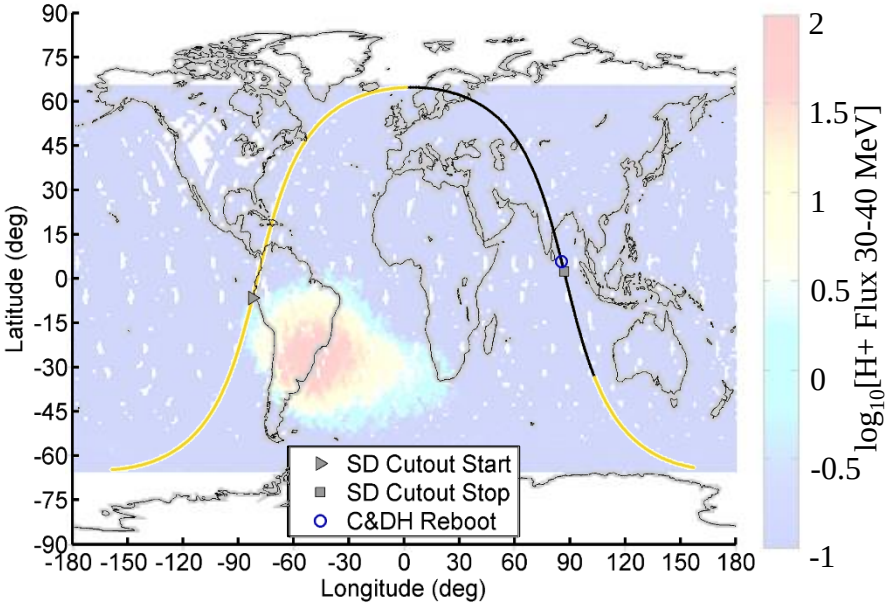
Latch-up



Battery Drain Anomaly #1



Battery Drain Anomaly #2



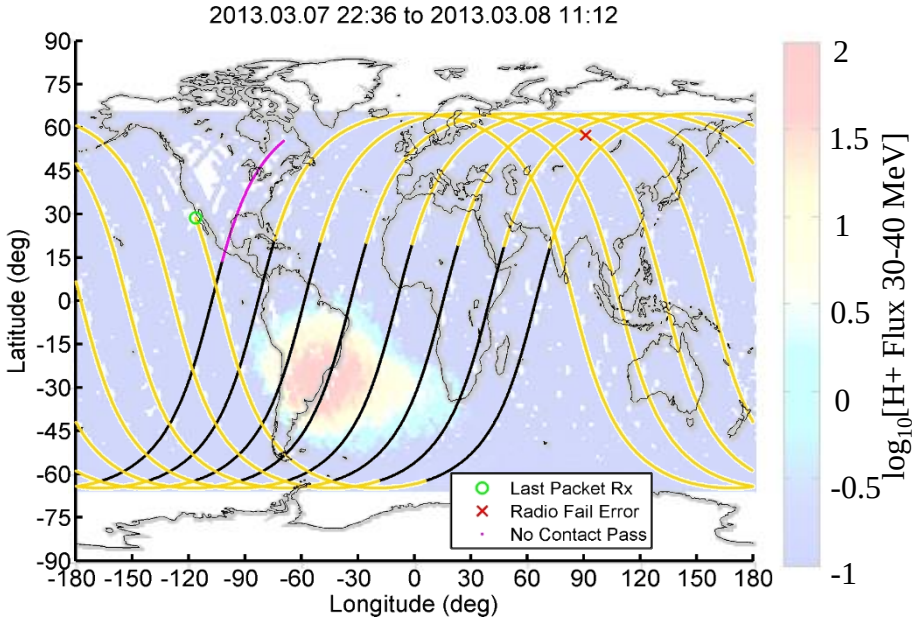
Anomalies

- Latch-up (2012.10.14)
  - HK I2C line held for 2 hours, cleared by low-voltage reset
  - Result: destroyed 1 HK ADC & damaged 2 others on same HK I2C line
- Battery Drain Anomalies
  - Unknown load in system for ~1 hour, cleared by low-voltage reset
  - After event, battery low & temps high but no permanent damage to system

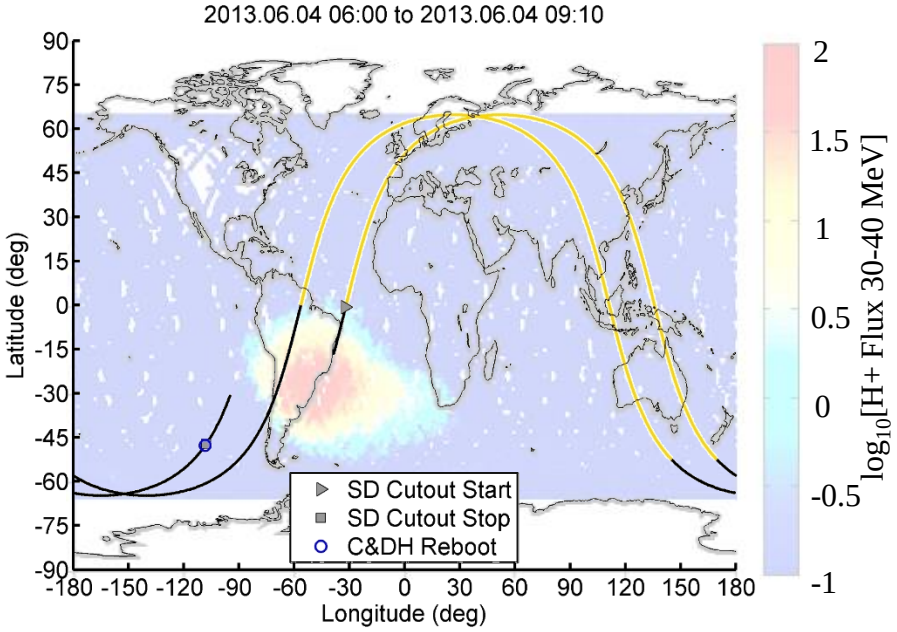
Comm. Blackout

- At 2013.03.08 06:33:07
  - C&DH ←→ COMM non-operational
  - 40mA increase on 3.3V line
  - C&DH continues logging data normally
- 2013.06.04: C&DH Reboot (5V only)
  - Battery heater thresholds increase
  - Antenna deployment attempts begin
- 2013.06.18: Full Reset (5V + 3.3V)
  - Caused by increased system load & β=0°
  - C&DH ←→ COMM operational

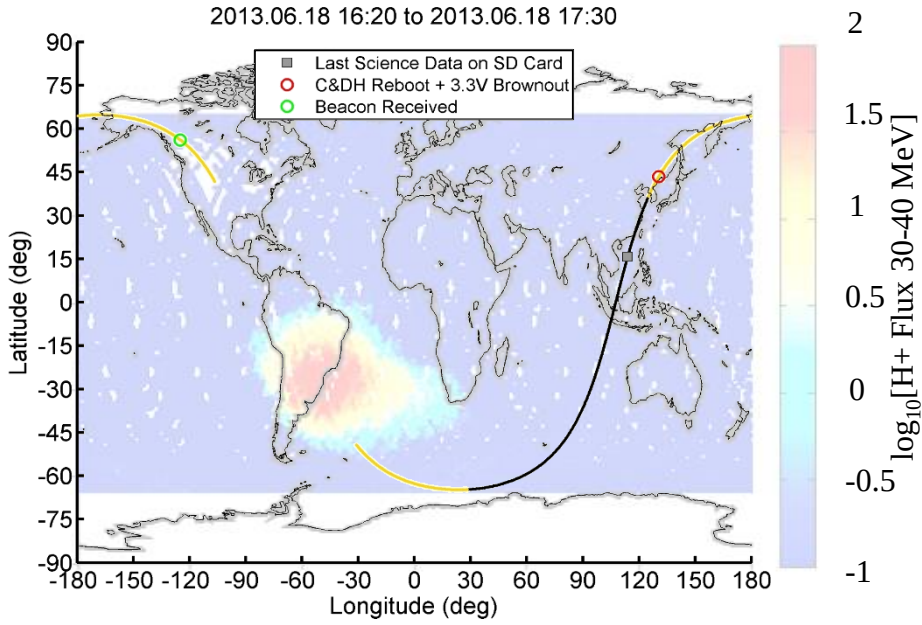
Loss of Contact



Battery Drain Anomaly #3

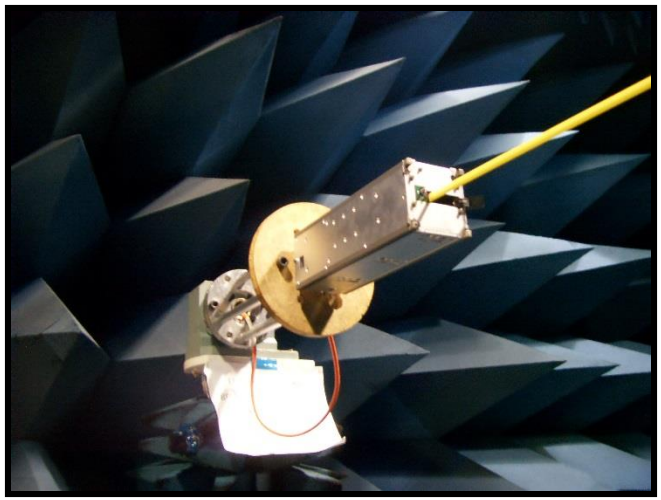


Restoration of Contact



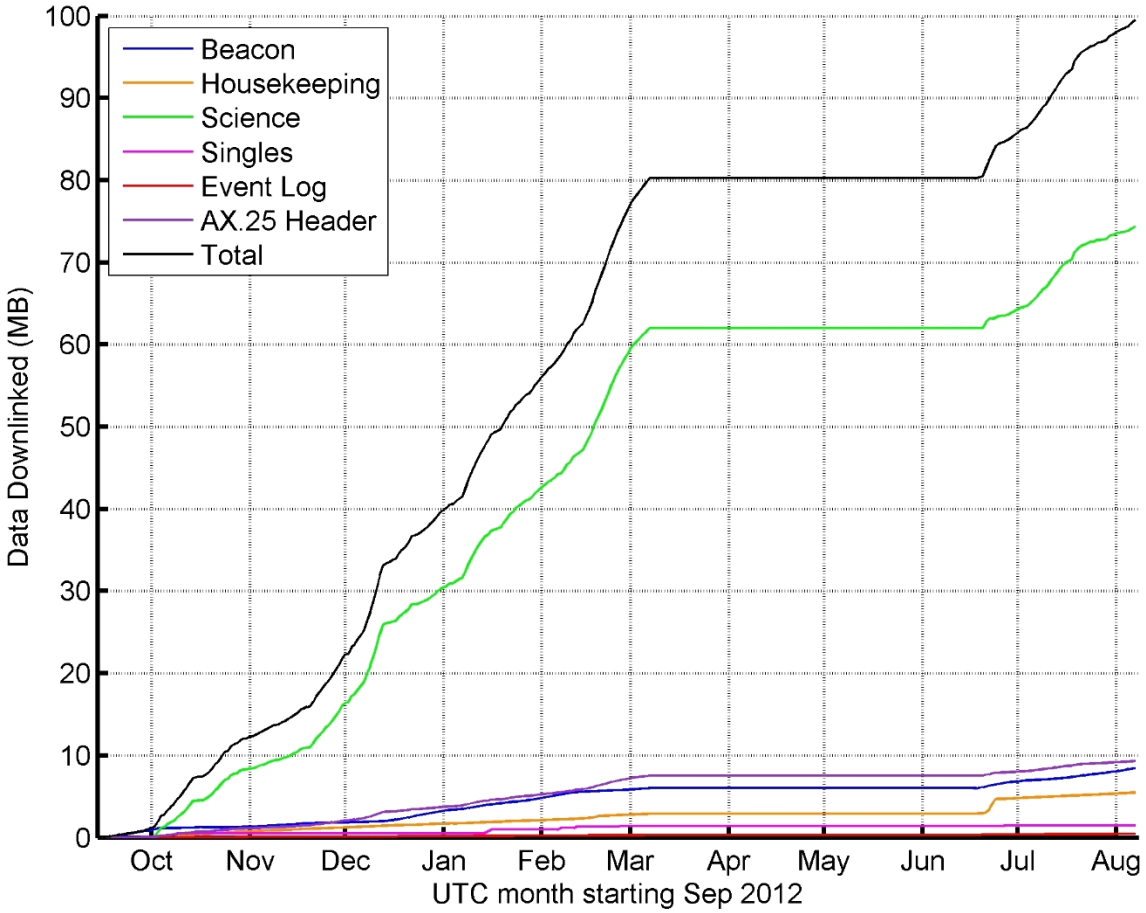
Lessons Learned

- Make it simple – then simplify
  - Applies to overall design, software, requirements, etc.
- Consider latch-up protection scheme
  - Our problems were due to latch-up, not total dose
- Design with analysis in mind
- Leverage team strengths
- Use only what you can test
- Error robustness is key



CSSWE Current Status

- Achieved full mission success
- To date:
  - 3 journal papers
  - 6+ invited talks
- **CubeSat collecting publication-quality science every day**



Questions?