



The
most
beautiful
sound in
the world

The on-orbit Performance of HRBE (aka Explorer-1 [Prime] FU2

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LAUNCH: October
28, 2011; Delta-II;
Vandenberg Air
Force Base, Calif.



Image credit: Montana State University

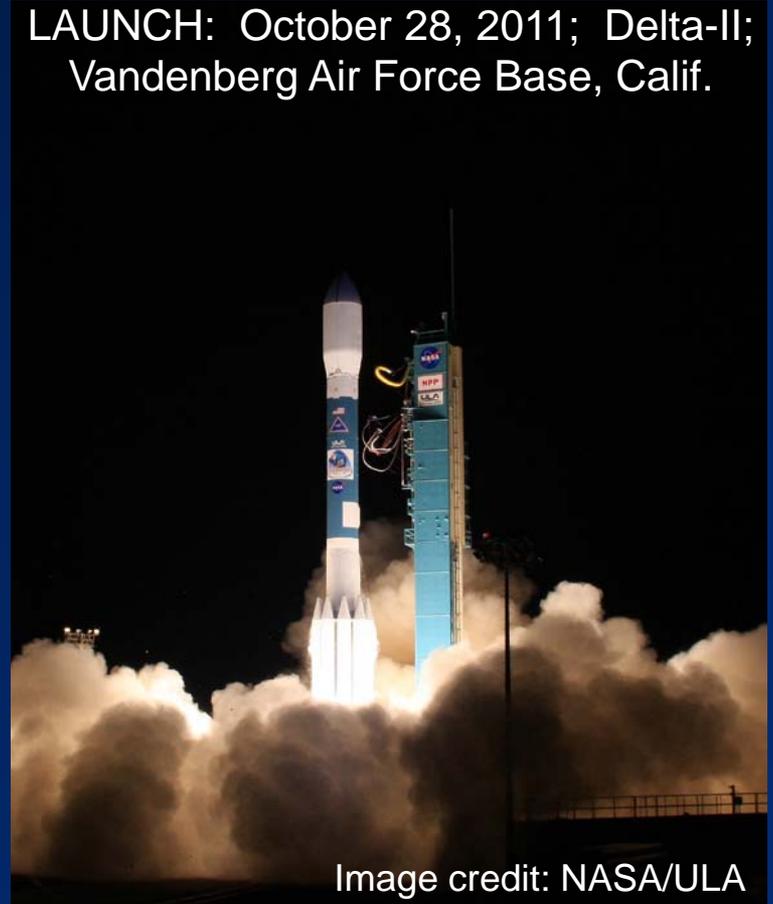


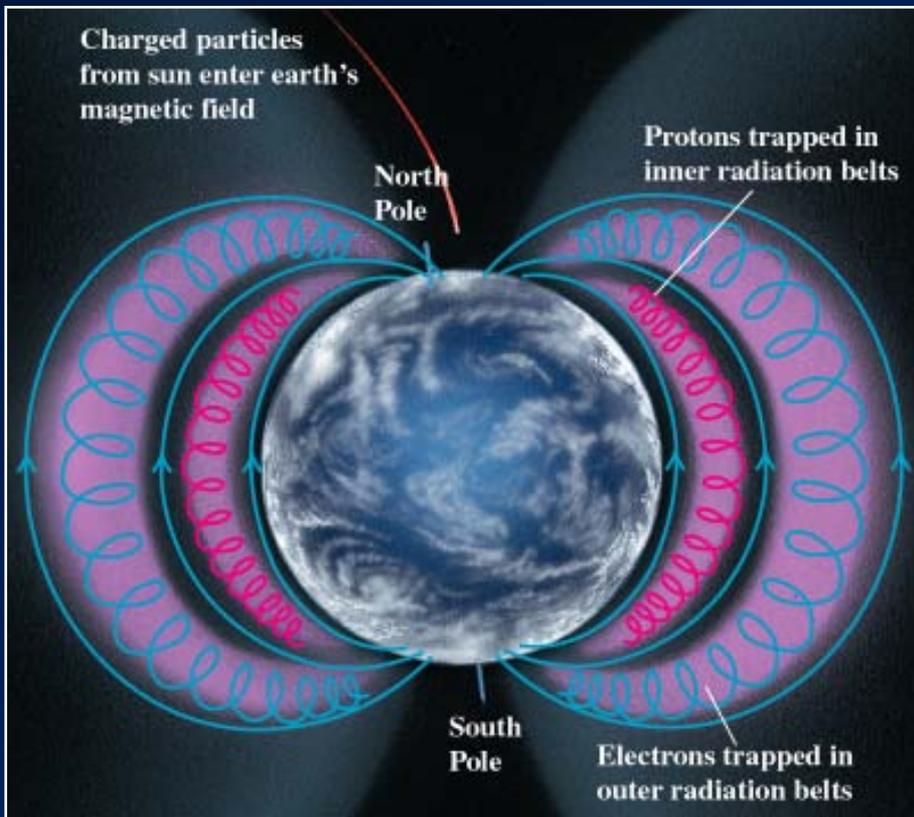
Image credit: NASA/ULA

One week following launch Explorer-1 [Prime] was formally dedicated as The William A. Hiscock Radiation Belt Explorer (HRBE) in honor of Bill Hiscock, founding Director of the Montana Space Grant Consortium, who had the vision to support university-built CubeSats in Montana

Mission Statement: 1) The Explorer-1 [Prime] mission (HRBE) will measure variations in the location and intensity of energetic electrons trapped in the Van Allen Radiation belts. 2) University students (undergrads) will have major responsibility for its design, fabrication, testing, and flight operations

- HRBE is an entirely “in house” build.
- The space segment is a 1U CubeSat designed, built, tested and operated by students supported by staff of the Space Science and Engineering Laboratory at Montana State University.
 - No kit parts were used
 - Low cost COTS components
 - Fully designed, built, tested, and now operated by more than 100 university students
- Carries a scientific payload built upon an original Van Allen Geiger counter to measure energetic electrons in the near-Earth environment.

HRBE' scientific mission is to monitor variations in the intensity and location of energetic charged particles in the near-Earth environment in response to solar activity.



Van Allen Radiation Belts

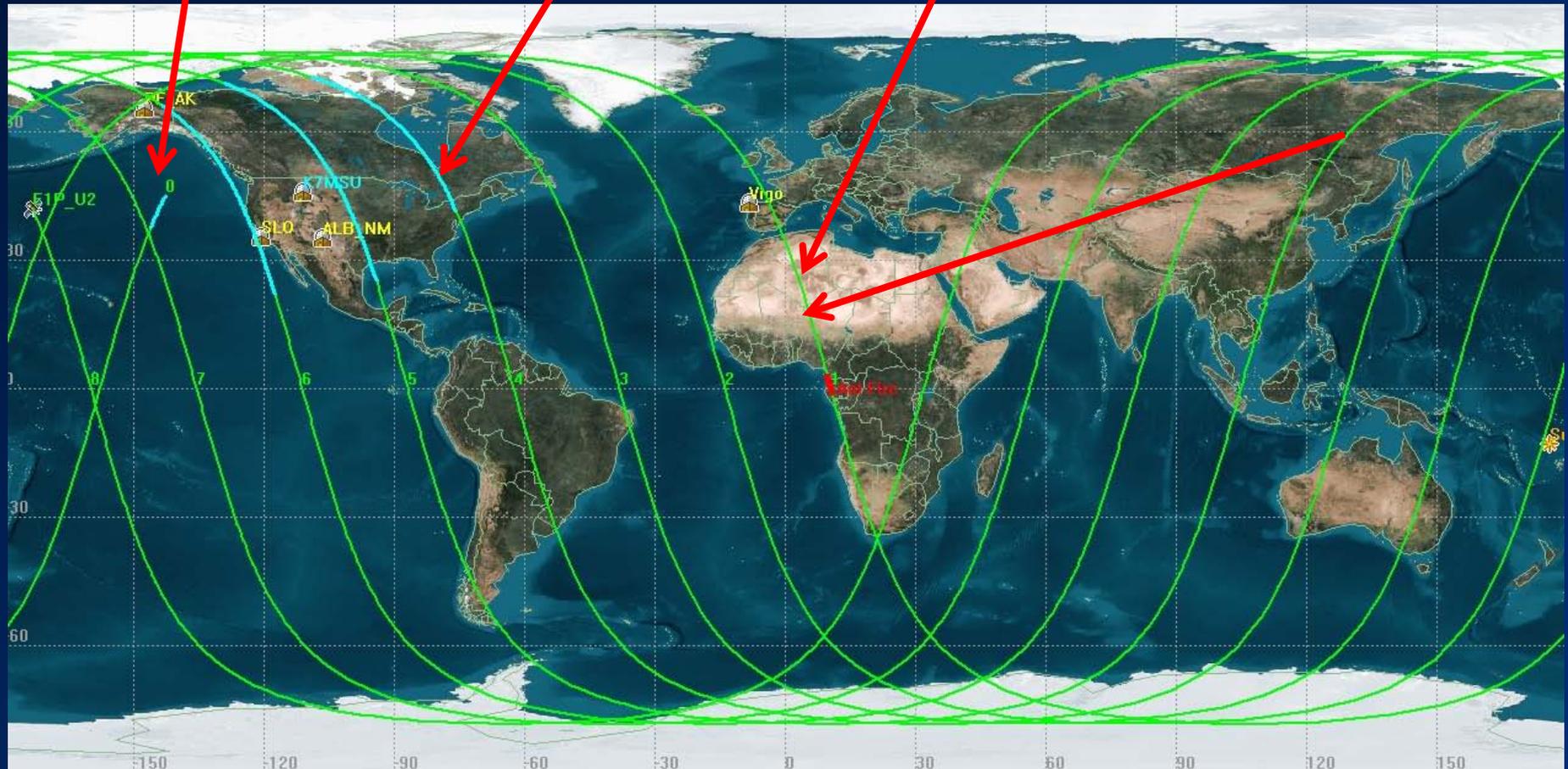
- Consist of clouds of charged particles trapped in Earth's magnetic field
- Radiation belts come closer to Earth's surface at the "horns", located at northern and southern latitudes
- Location of "horns" fluctuate due to solar influence

1) Deployment as a free-flying satellite
5:27am MDT

4) MSU Decodes Packets
11:15am MDT

3) First Signal Received
Vigo Spain
06:29 am MDT

2) Antenna Deployment;
autonomous operations
begin
6:27am MDT



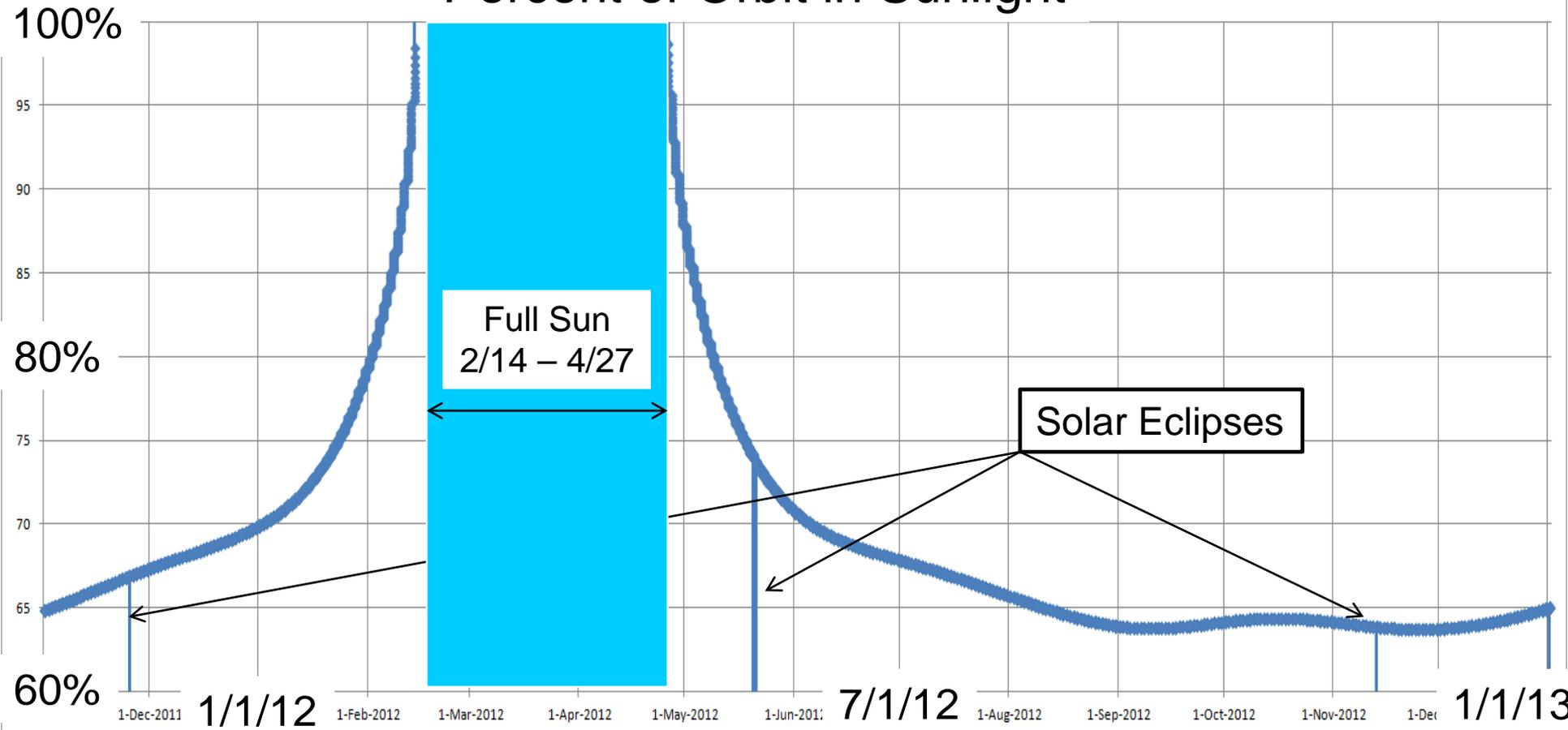
- Launch of Explorer-1 [Prime] Flight Unit 2 (E1P-FU2): 28 October 2011, 03:48:31 a.m. MDT; 0948:31 GMT
 - Deployment into orbit from the P-POD: L+ 98 minutes, 45 sec
 - Autonomous turn-on (over central Africa): L+159 minutes
 - First reported receipt of beacon telemetry: L+162 min. University of Vigo, Vigo, Spain
 - First downlink and decoding of beacon data from K7MSU: L + 7 hours 27 minutes.
-
- Dedication to William A, Hiscock: The Hiscock Radiation Belt Explorer (HRBE): L + 1 week
 - Successful Commanding demonstrated from 60' SRI dish: November 20, 2011
 - Successful commanding from upgraded MSU Space Operations Center: January 13, 2012. Routine since January
 - "Turn-off" HRBE for M-cubed/COVE commanding: January, 2012
 - Mission Success achieved: February 15, 2012: 111-days in orbit
 - Continued operations of HRBE on orbit
 - As of April 28, 2012: 2563 orbits completed

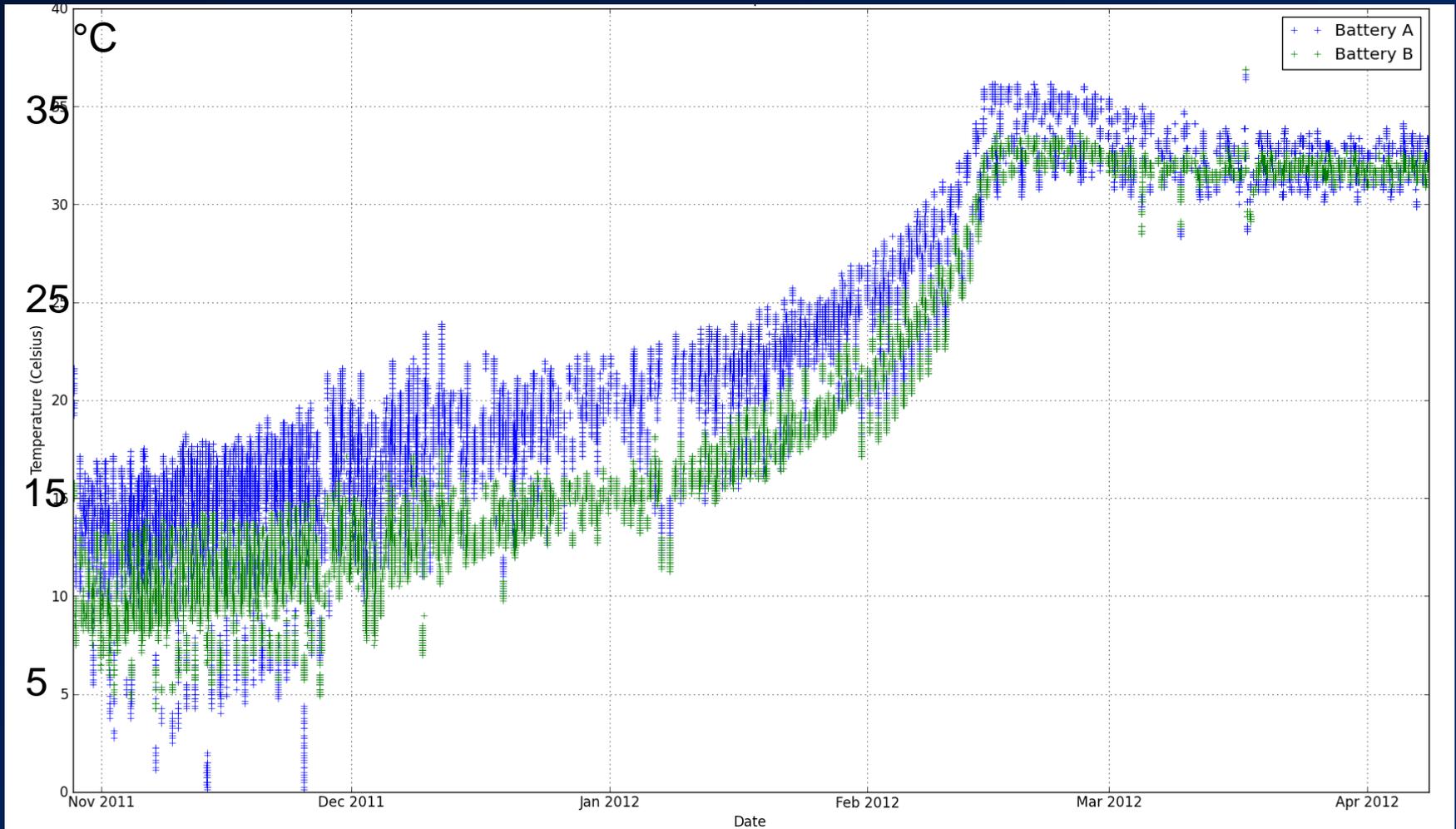
Apogee: 803 km;

Perigee: 439 km;

Inclination: 101.7°

Percent of Orbit in Sunlight





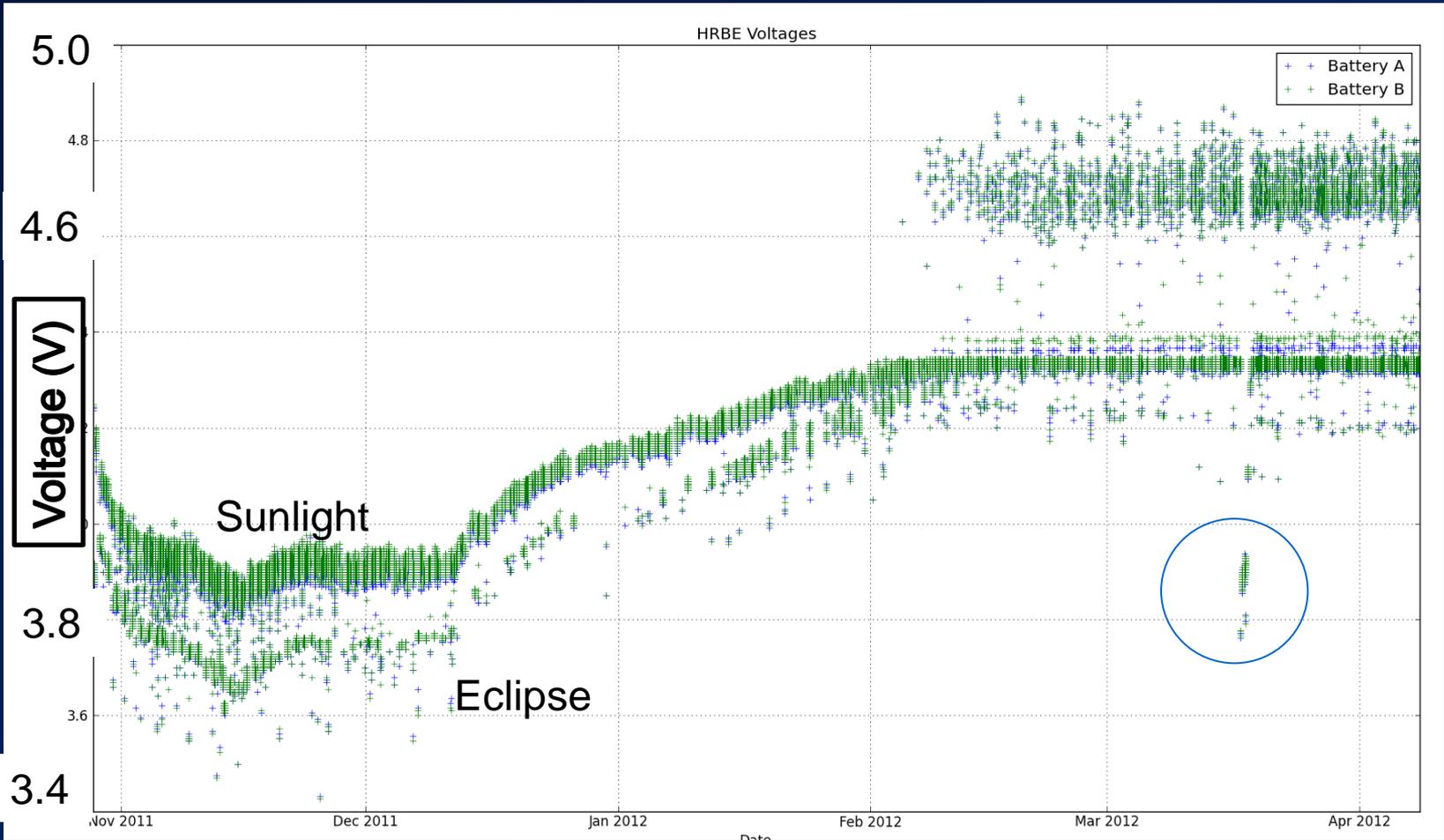
1 Nov 2011

1 Jan

1 Feb

1 Mar

15 Apr. 2012



1 Nov 2011

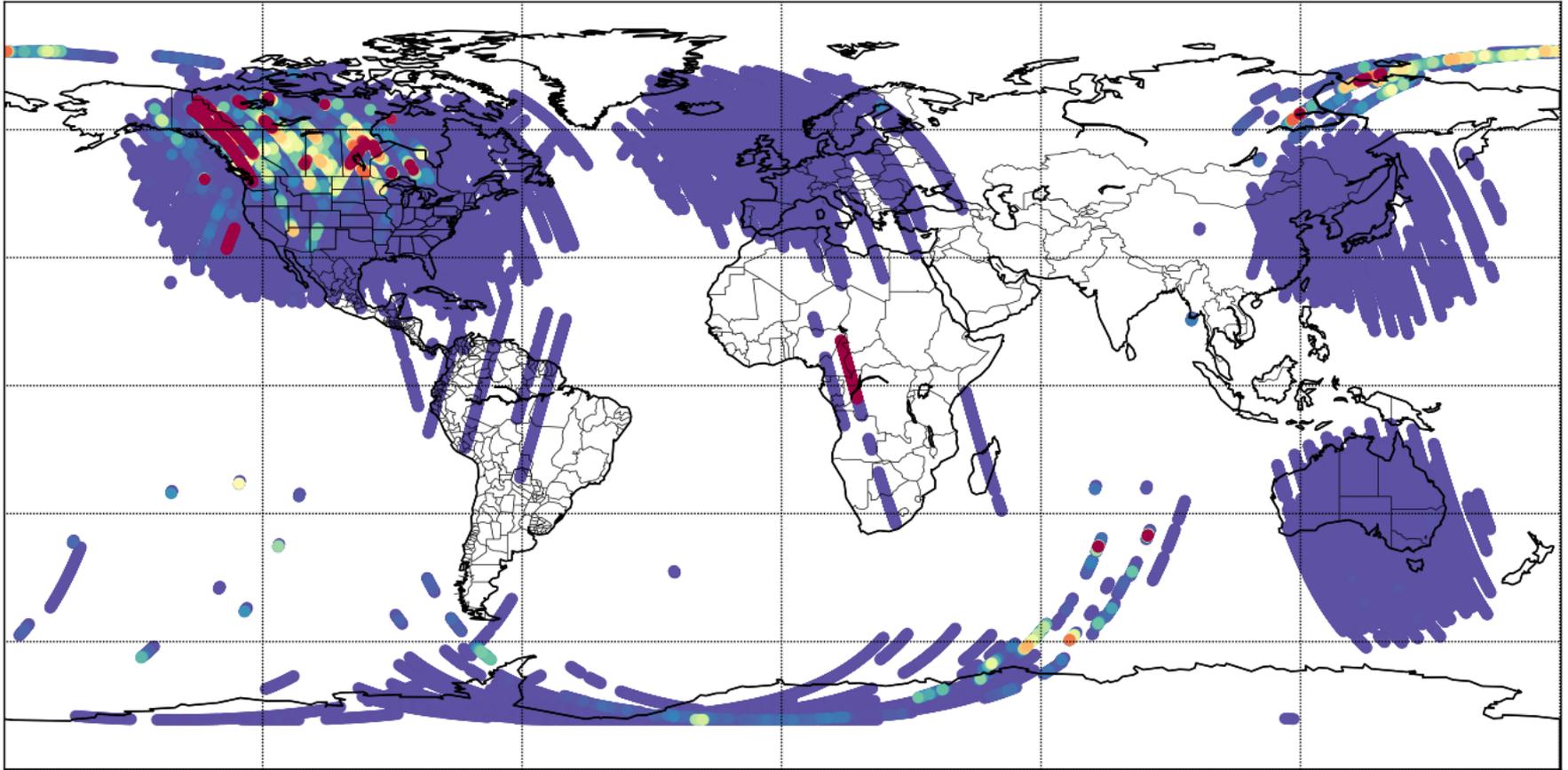
1 Jan

1 Feb

1 Mar

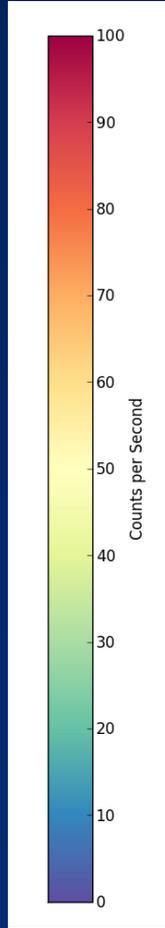
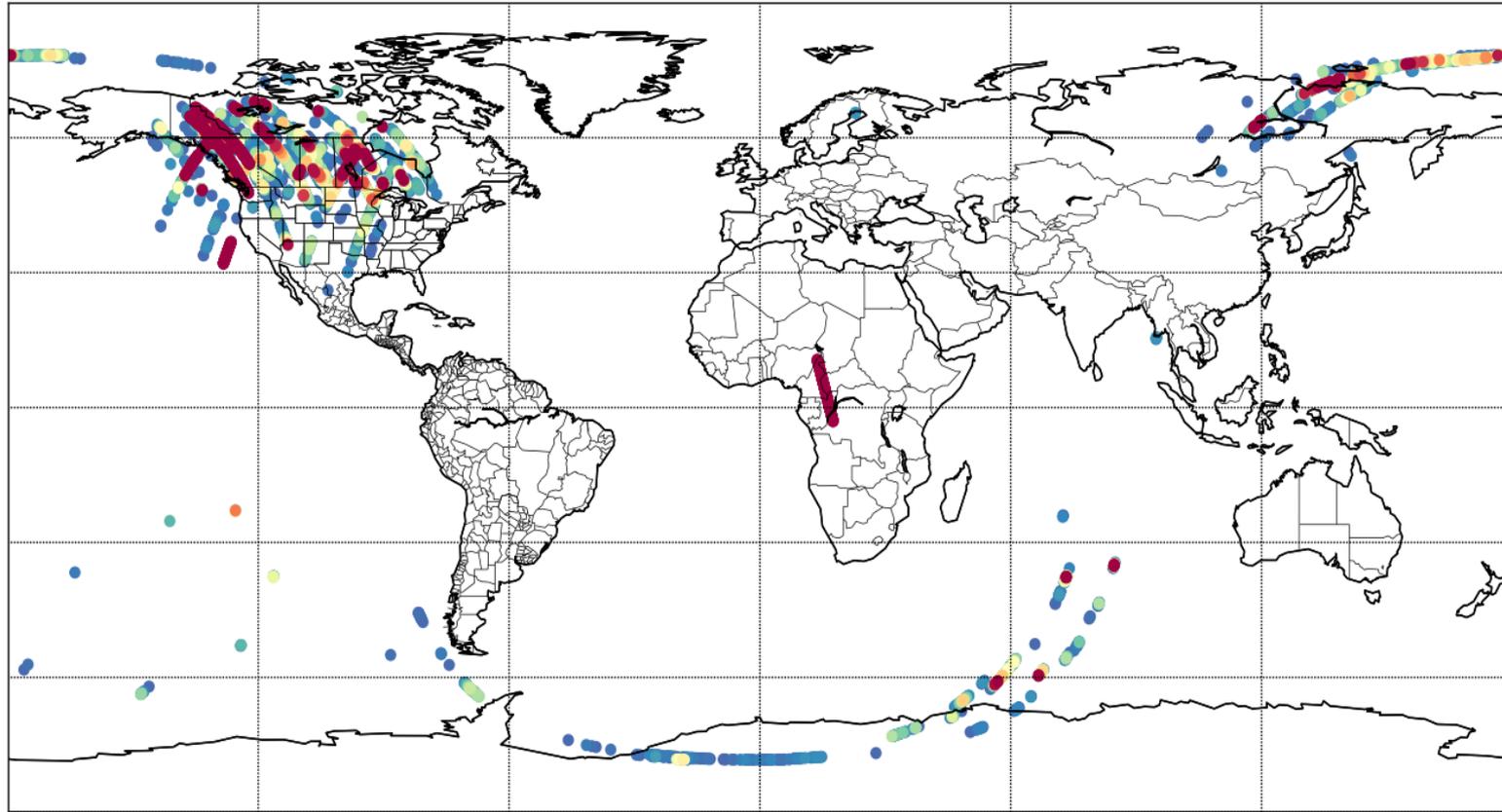
15 Apr. 2012

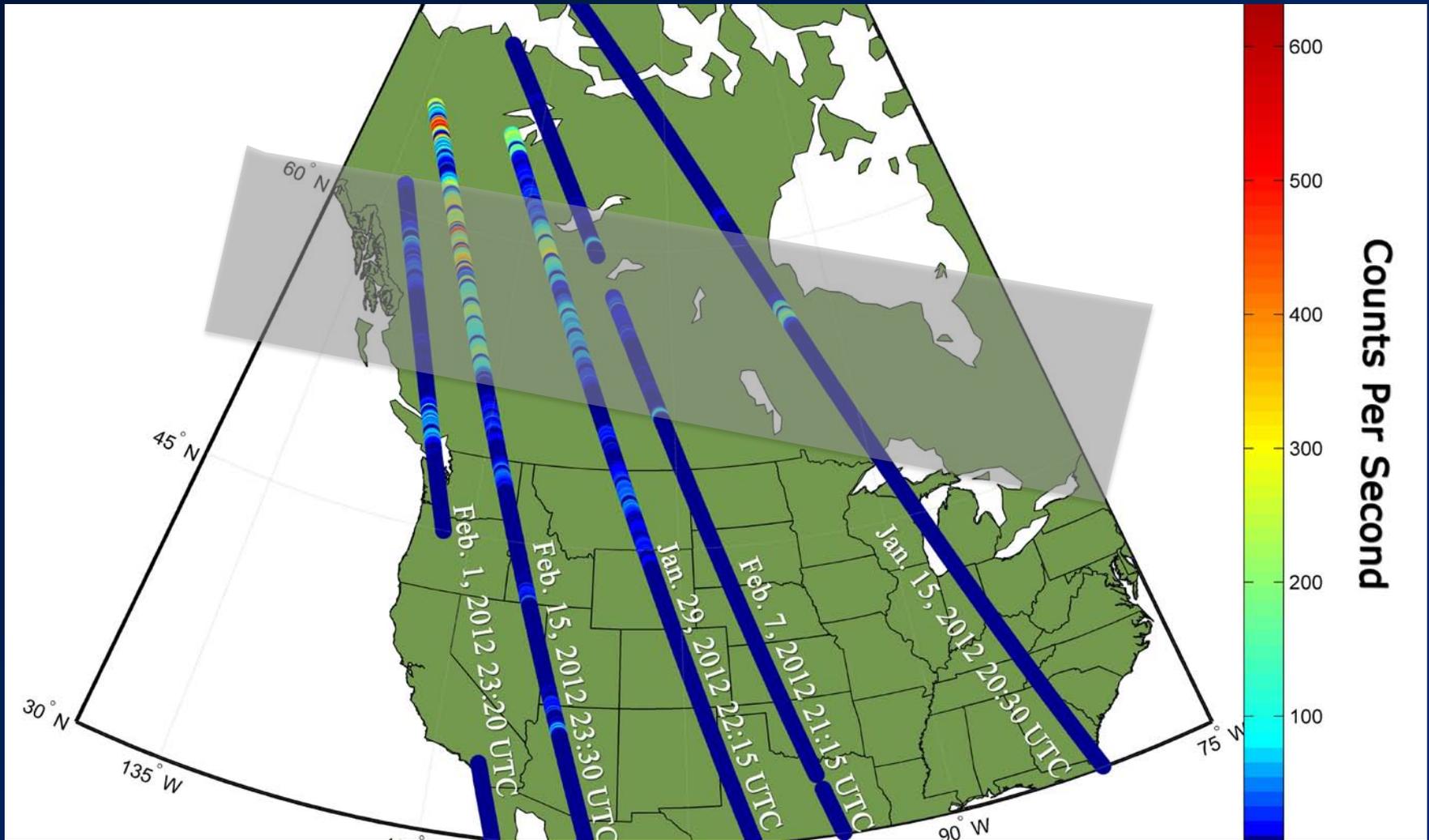
HRBE Total Data collected world-wide 11/01/11 – 04/16/12
 (each point represents a 1-second science data sample)



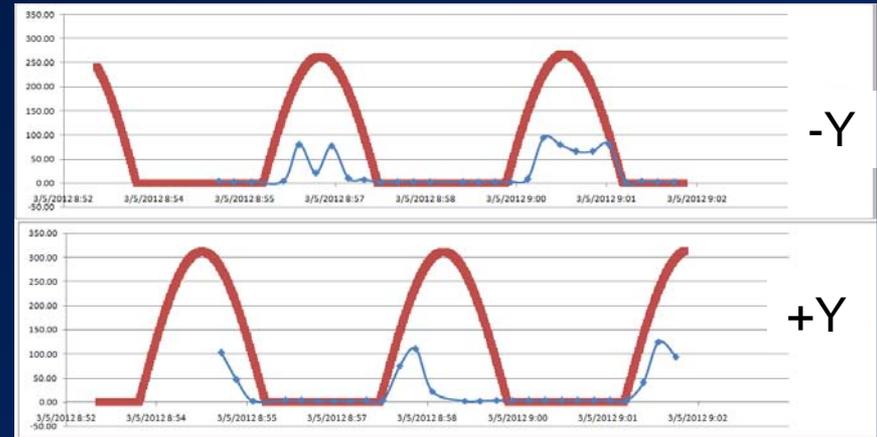
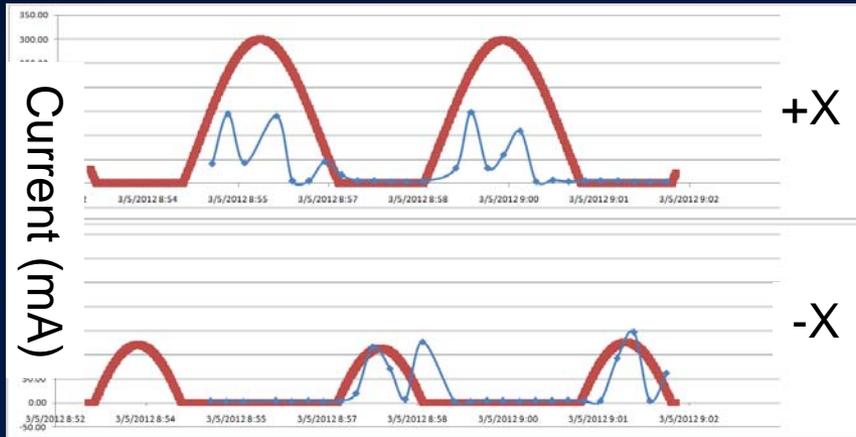
Statistics: 520,858 sec; 33,677 beacons; 61% collected by 16 different Hams

HRBE Counts Above Background (≥ 5 c/sec)
 2011-10-27 00:00:00 to 2012-04-15 00:00:00





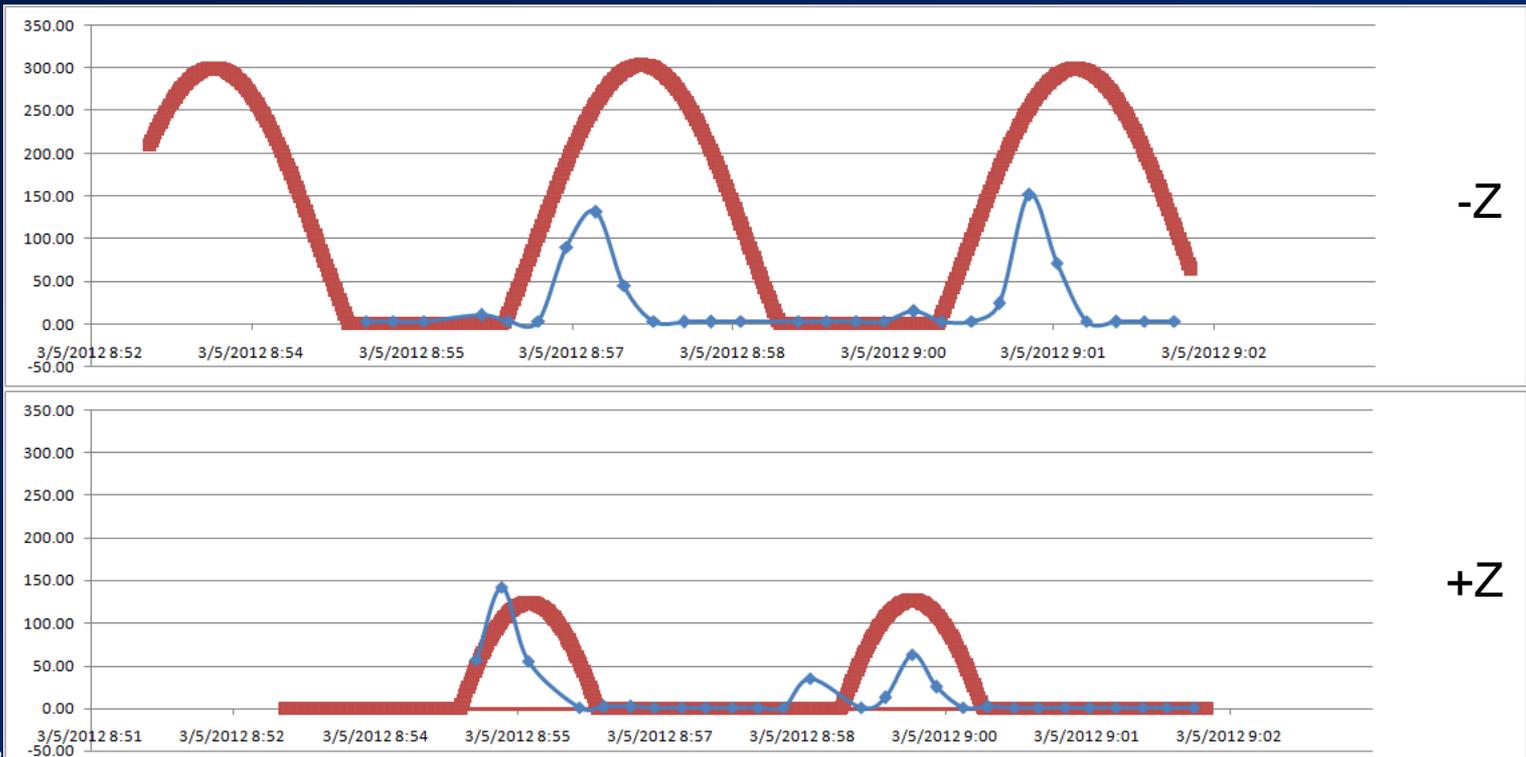
- Resets -- the ability to restart by command; recovering from latch-ups, autonomous restart
- The importance of having a beacon for acquisition and back-up data
- Commanding can be elusive
- The Amateur Radio Community is your friend
 - Special Thanks to Mike Rupprecht in Germany (DK3WN) and Colin Hurst in Australia (VK5HI)
- Use bench and environmental testing to verify your software implementation in every detail
 - Our boo-boo – truncated high order bits (e.g. solar panel data)
- Exhaustively test your flight ready system – in a space simulation environment.
 - MOST IMPORTANTLY: Meticulously evaluate that test data for unexpected behavior. (You will be surprised at how many things need to be fixed before launch).



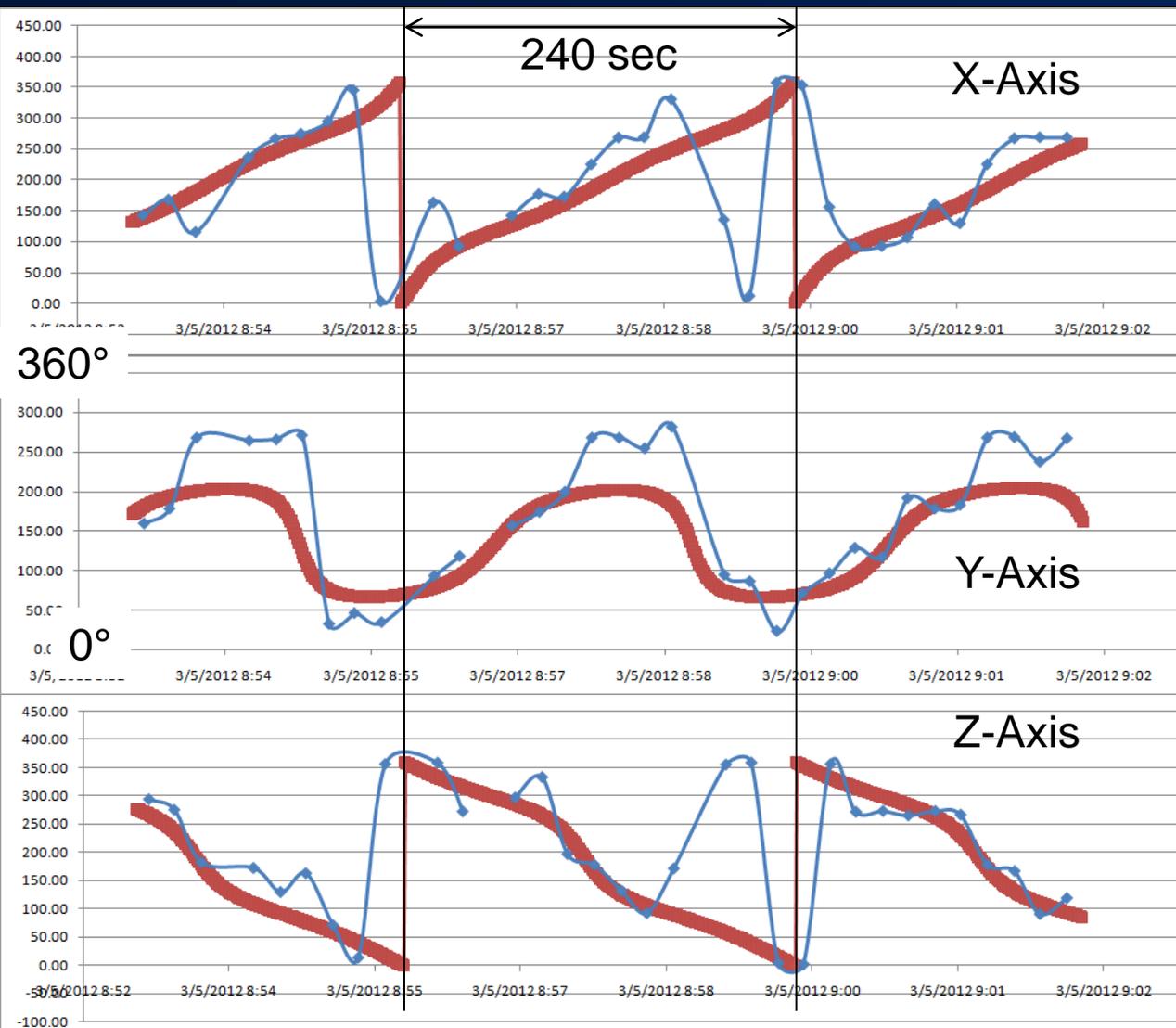
Predicted:
 Red

Measured:
 Blue

Limitation:
 Lost two most
 significant bits



Mar 5, 2012



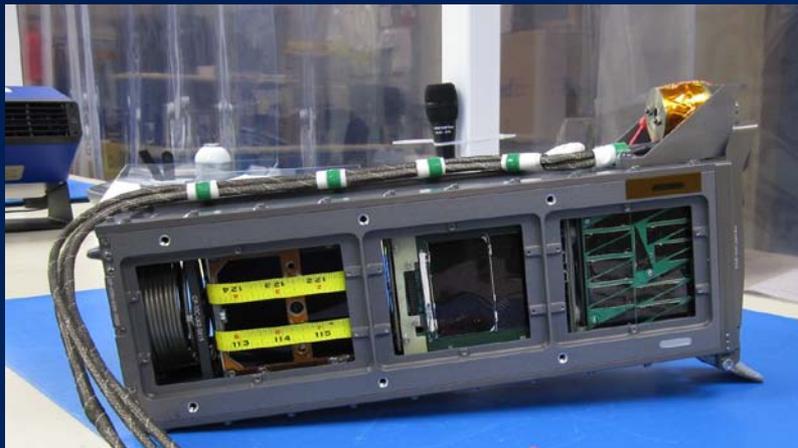
Plot shows the direction of the sun with respect to each axis

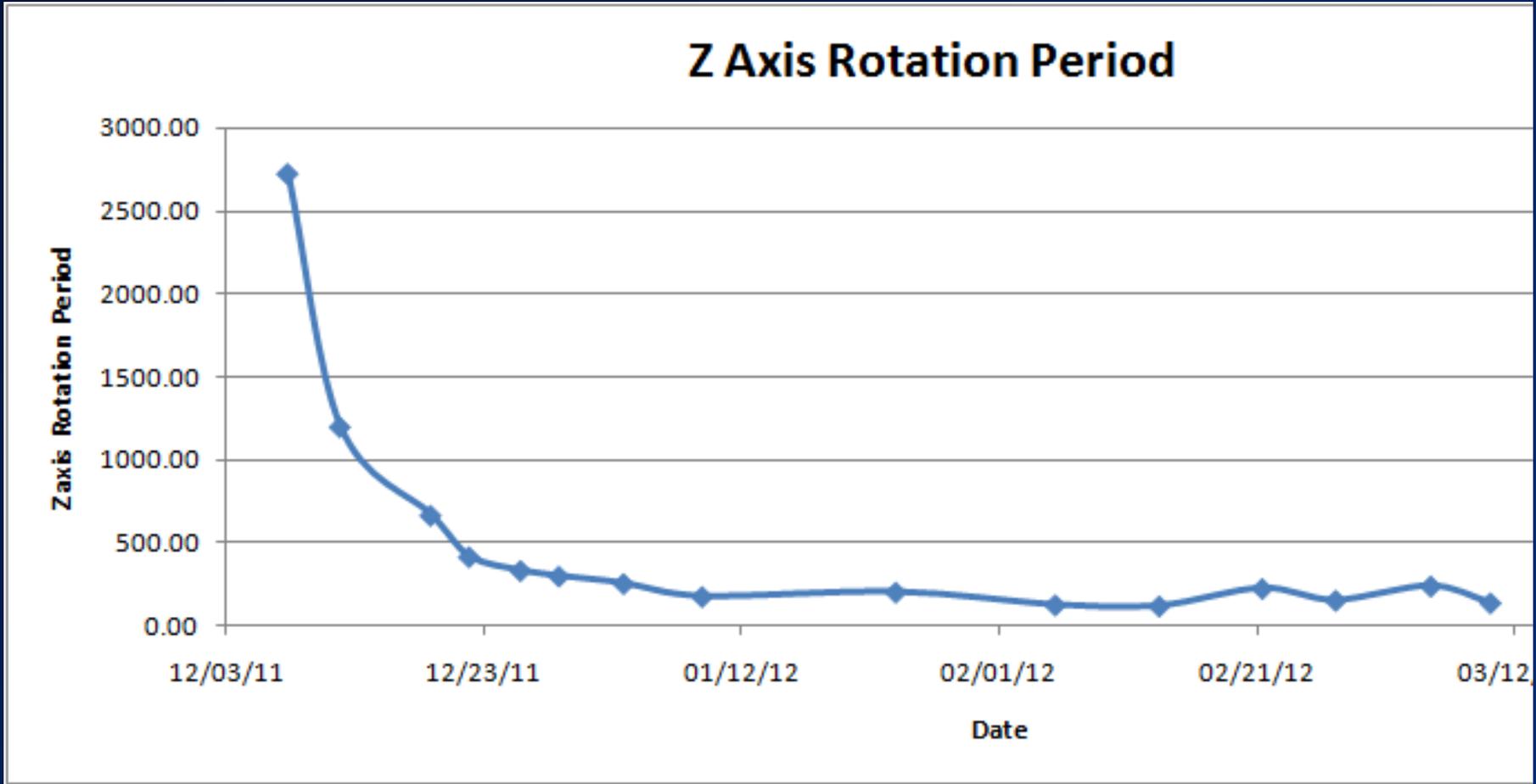
- Blue: analysis from HRBE telemetry

- Red: STK

- Result: Spin period: 240 seconds about a coning axis 40° off of the z-axis

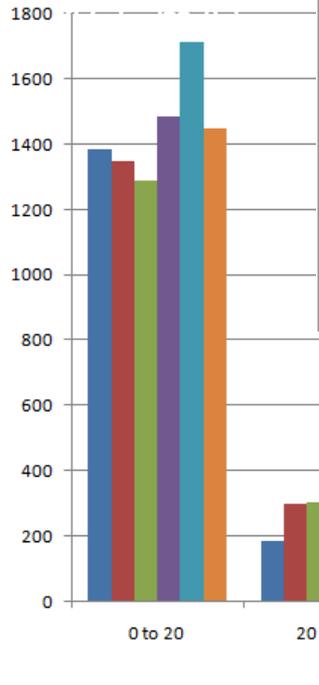
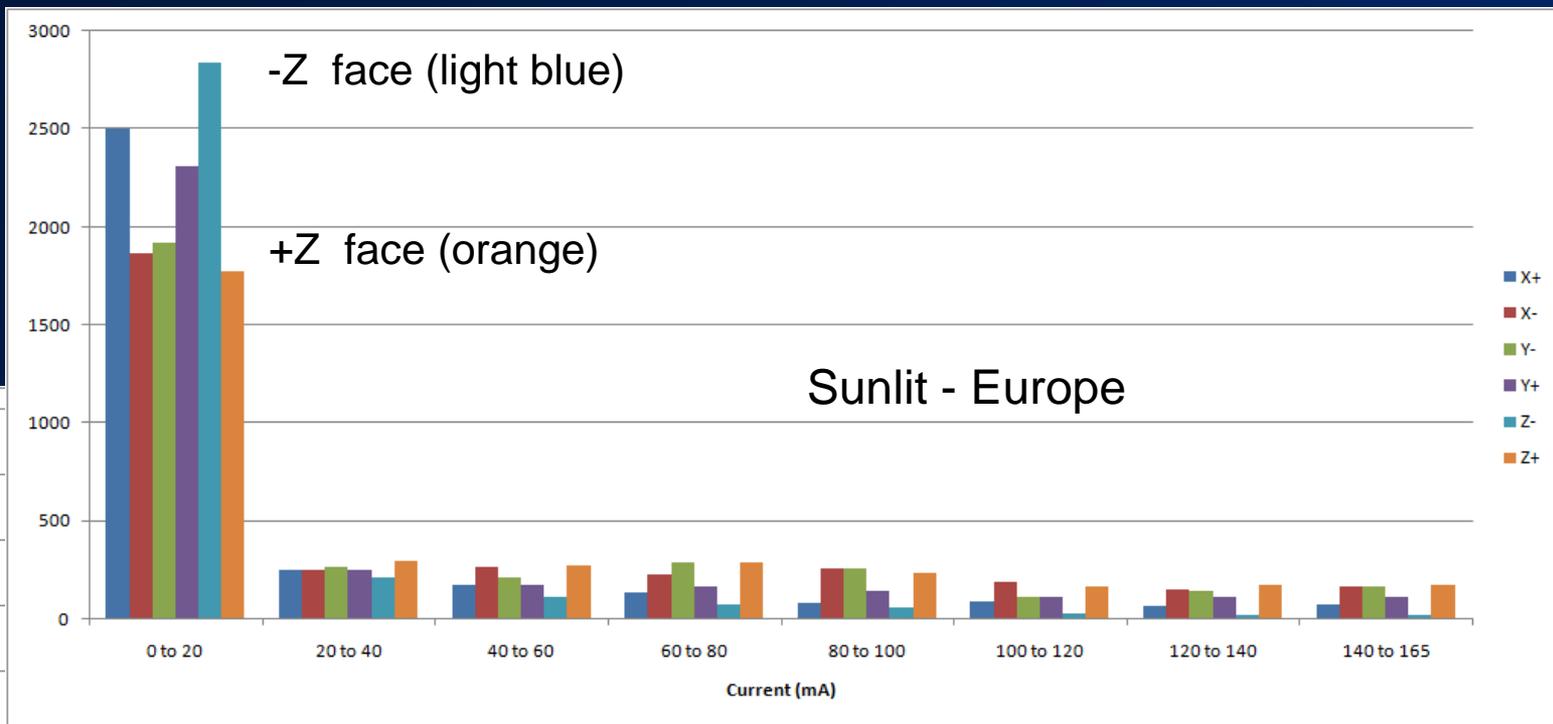
- Do we have evidence from HRBE's data or on-orbit performance that M-Cube is physically in contact in orbit that can be presented here?
- Solar Array Performance (data from all 6 panels)
- This is an ongoing endeavor and we are working with Michigan/JPL to better understand the physical relationships between these two independent CubeSats
 - Body motion analysis – continuing
 - Ballistic Coefficient – Drag – AubieSat as a surrogate





Spin Period about the s/c magnetic axis has stabilized to ~200 sec since January 2012

Occurrence histograms of SA currents (20 mA “buckets”; 0-



- HRBE has been a complete success
 - ... as an educational tool. More than 100 students, and continuing
 - ... as a demonstration of the utility of very small CubeSat satellites
 - ... as a scientific platform
- HRBE as completed more than 2500 orbits, and continues to operate in low Earth orbit and return scientific data on the Earth's radiation environment
- No discernable evidence has been found in HRBE's operation or performance that would support the hypothesis of close proximity to another object.
- Advice: test, test, test your satellite before launch and carefully scrutinize the test data for any anomalous behavior.
- Thanks, NASA/KSC/LSP ELaNa Program; Montana Space Grant Consortium, Countless students at Montana State University