

Simultaneous multi-point space weather measurements using the low cost EDSN CubeSat constellation

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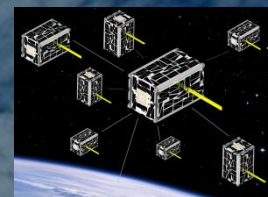
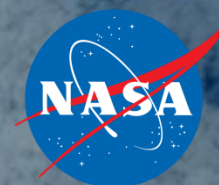
NASA Ames

James Cockrell

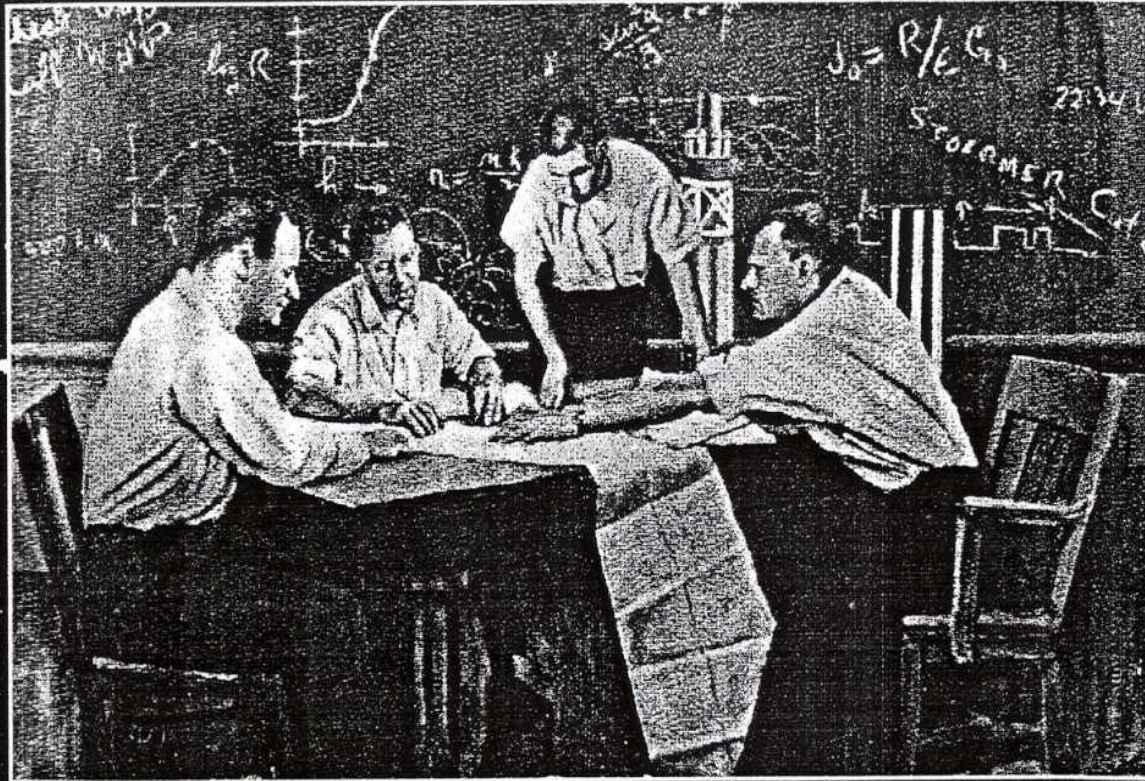
Hugo Sanchez

Harrison Smith

27th Annual AIAA/USU
SmallSat Conference
August 29, 2013



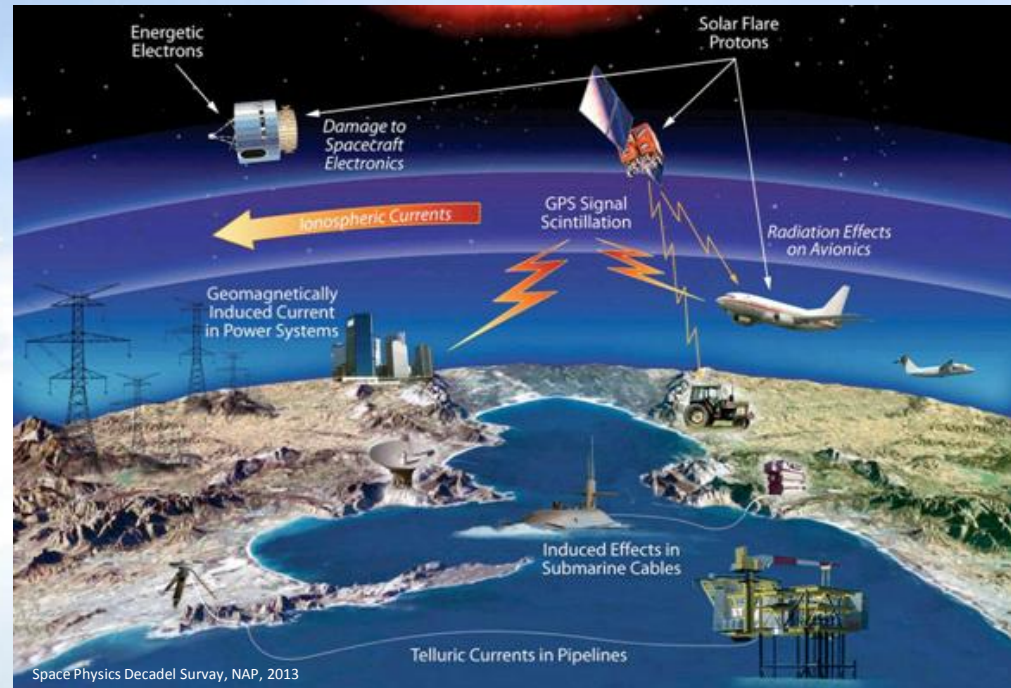
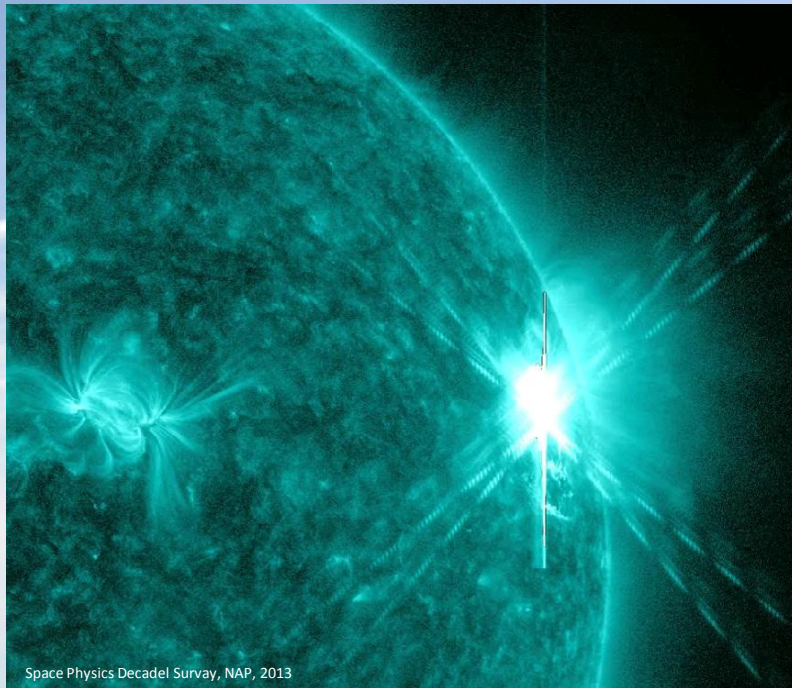
- EDSN Mission
- Instrument Motivations
- Mission Objectives
- Instrument Design
- Instrument Characterization
- Instrument Testing
- Mission ConOps
- Mission Status
- Future Work

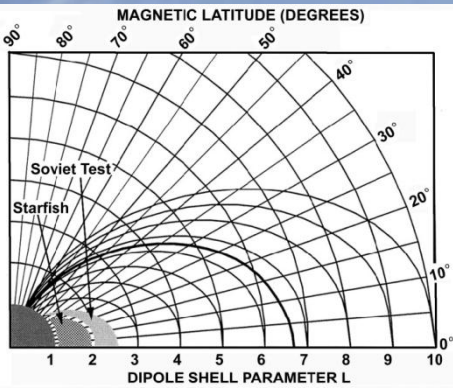


"My God, space is
radioactive!"

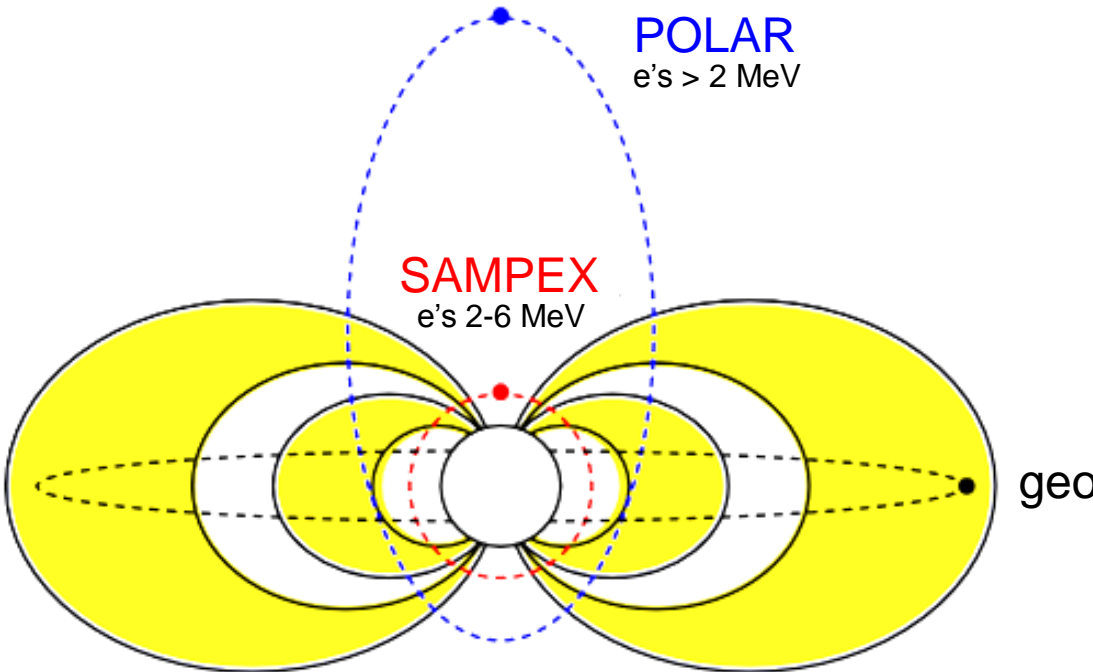
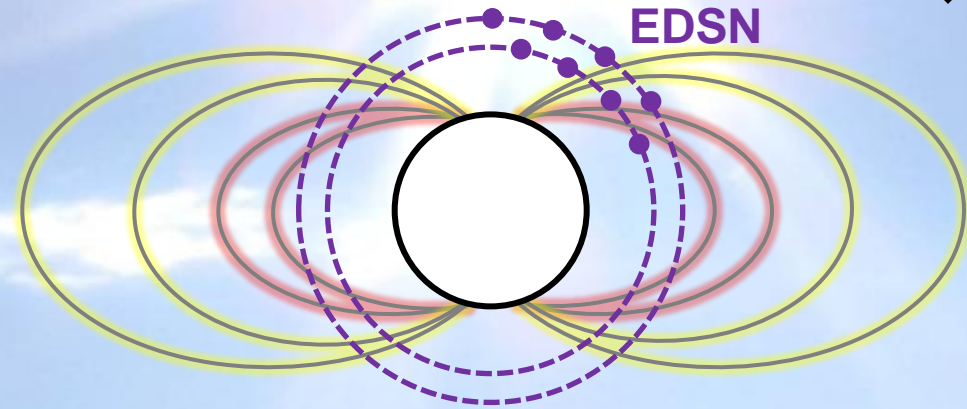
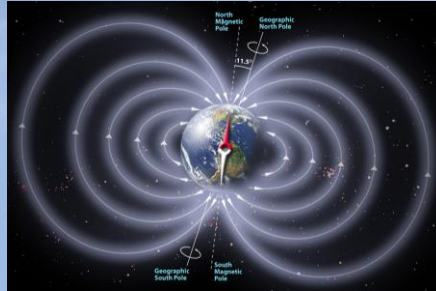
Dr. Ernest C. Ray
March 28, 1958

- 2003 Space Physics Decadal Survey:
 - Multipoint measurements are needed in the ionosphere, where global changes occur on short time scales and small spatial scales.
- 2013 Space Physics Decadal Survey:
 - The study of the heliophysics system requires multipoint observations to develop understanding of the coupling between disparate regions and to resolve temporal and spatial ambiguities that limit scientific understanding.





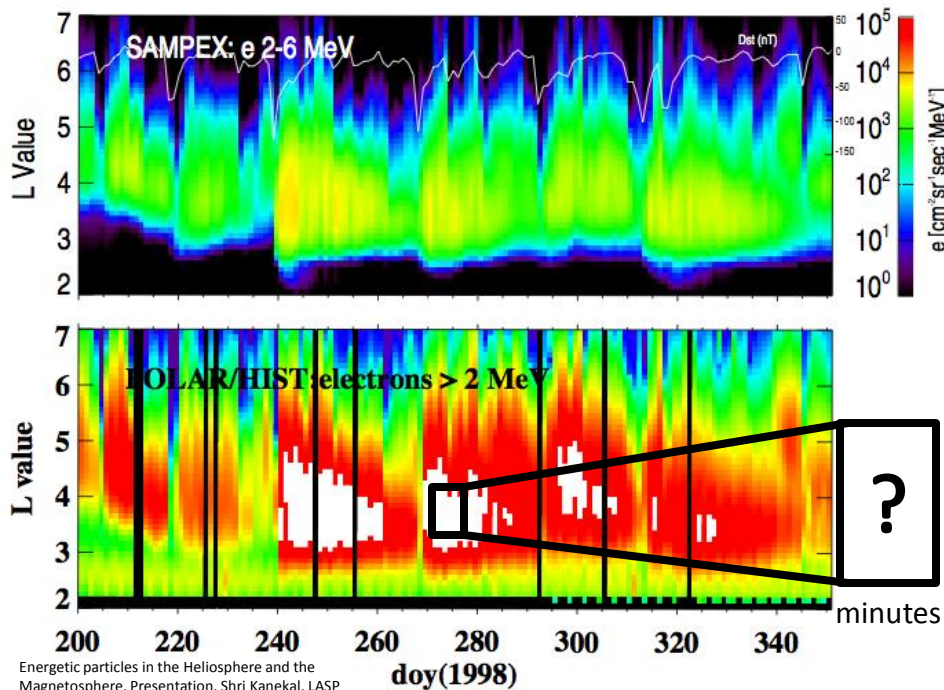
L-shell Concept



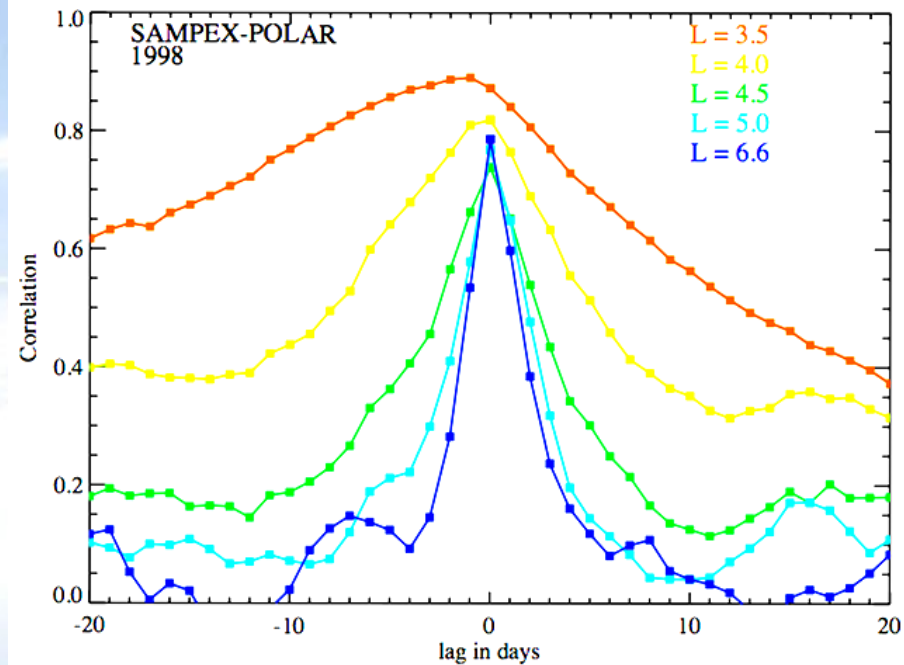
- EPISEM (above) will measure omnidirectional integral flux concurrently at each spacecraft
- POLAR/SAMPEX (left) evaluated electron flux at large spatial and temporal distributions
- Spatial variations may occur at scales undetectable by a large spatial distribution.
- Temporal variations may occur over periods of minutes to hours.

How are the spatio-temporal distribution and temporal variability of penetrating electrons and high-energy protons characterized?

- Previous correlations show distributions that appear isotropic in nature when lag time is less than one day, across large spatial/temporal distributions.
- Small spatial/temporal scales accomplished with co-temporal measurements across the EDSN array.



Energetic particles in the Heliosphere and the Magnetosphere, Presentation, Shri Kanekal, LASP

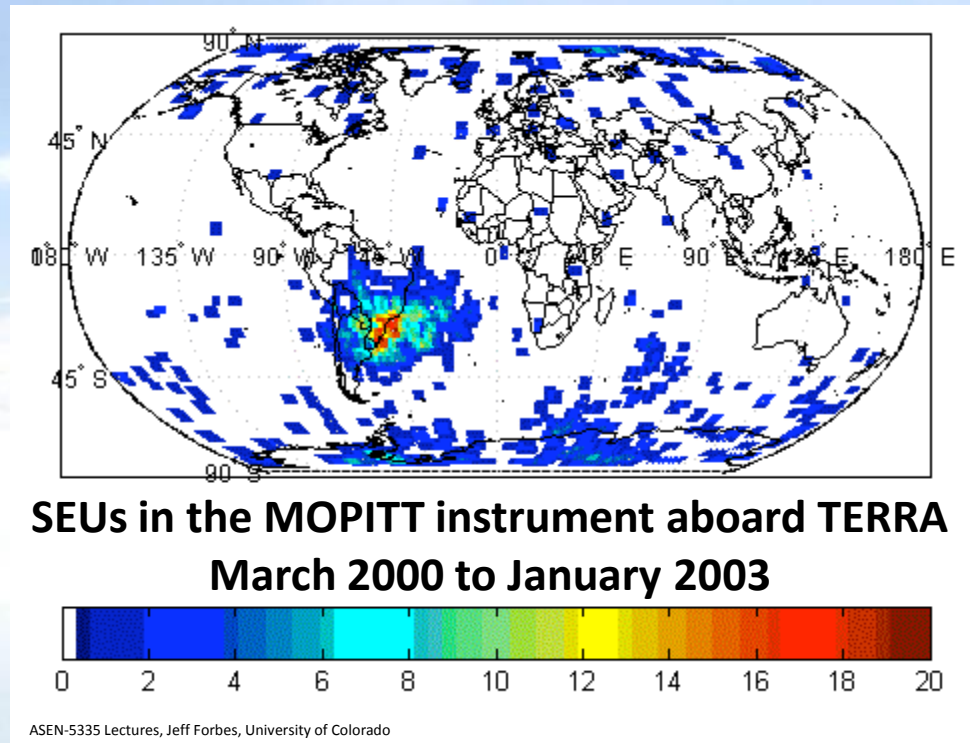


Multisatellite measurements of Relativistic electrons: Global coherence, S. Kanekal, J. Blake, Journal of GeoPhys Research, Dec 2001

EPiSEM will provide the first measurements of coherence at small spatial and temporal scales.

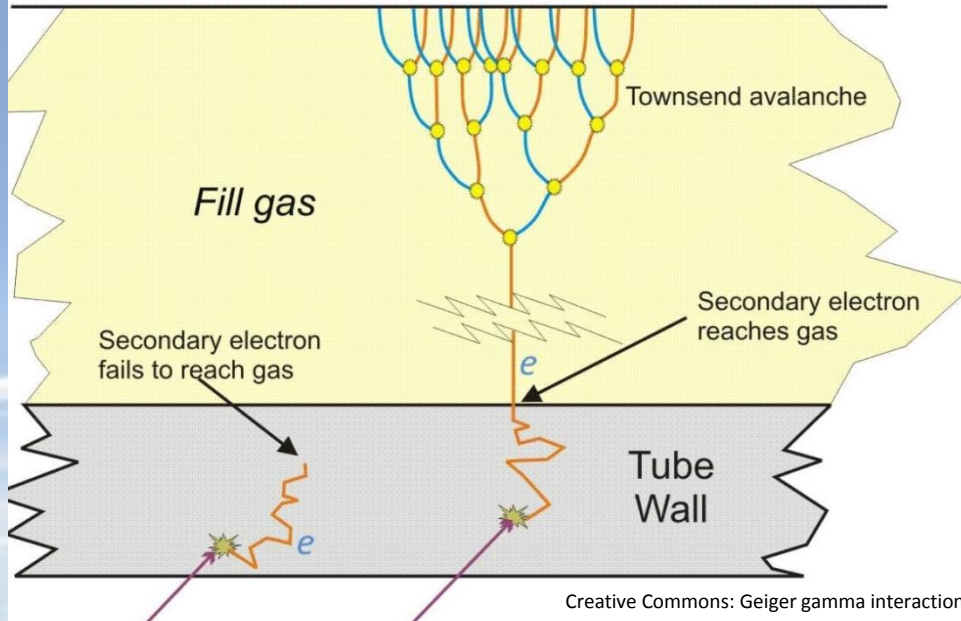
What are the fundamental exposure rates of spacecraft avionics to radiation from penetrating electrons and high-energy protons in Low Earth Orbit?

- EPISEM provides constant radiation measurements for each identical spacecraft
- Single event upsets on all or each spacecraft may be correlated to the radiation flux measured by each EPISEM.
- 54% in the South Atlantic Anomaly
- 26% in the Polar Regions
- 20% Galactic Cosmic Rays
- What are the temporal dependencies?
- What are the small scale spatial dependencies?

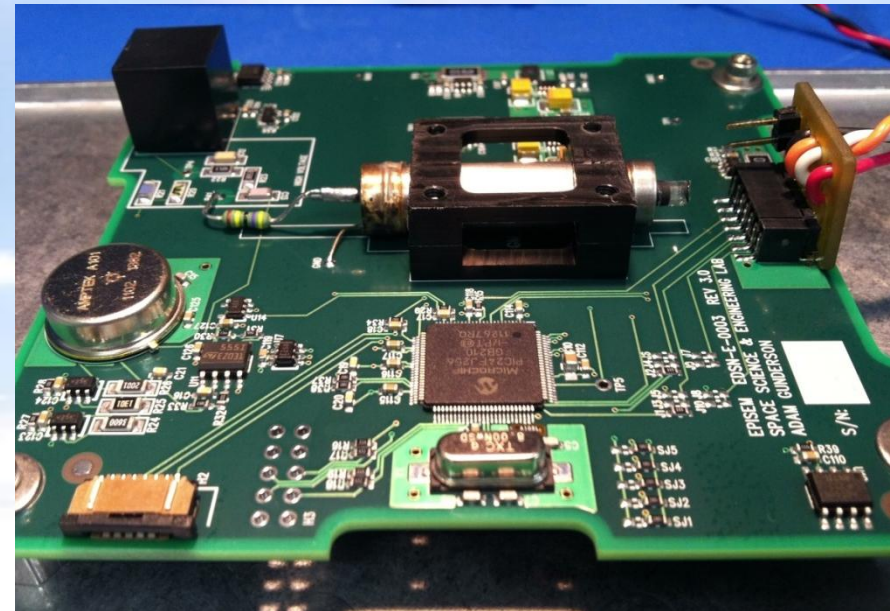


- Employs an thin-walled Geiger-Müller tube located inside the spacecraft structure.
- Detects penetrating beta/gamma radiation from energetic particles above a certain energy threshold.
- Specific energy threshold is different for electrons and protons.

Anode: ~550V



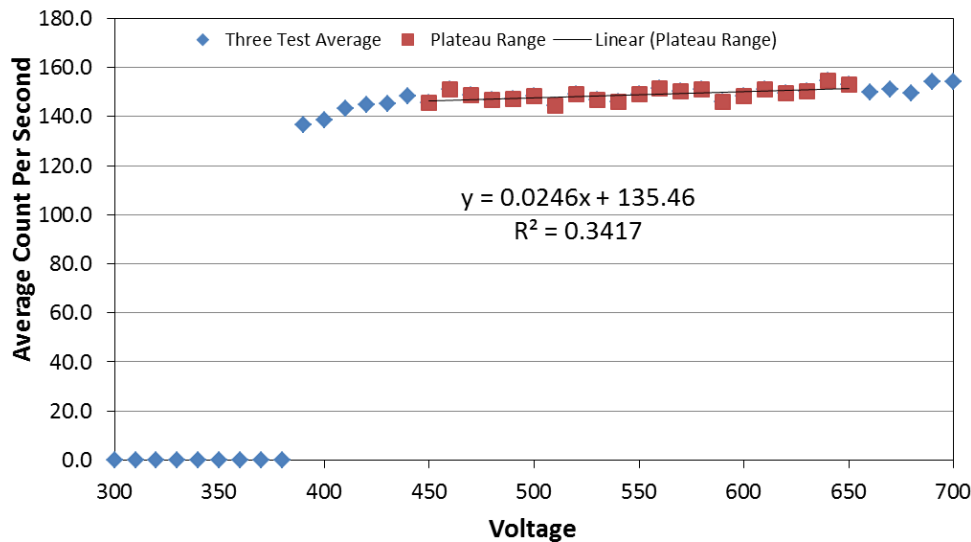
- Incoming radiation knocks electron off of the Neon fill gas
- Neon becomes Ne^+ and free electron avalanches toward anode



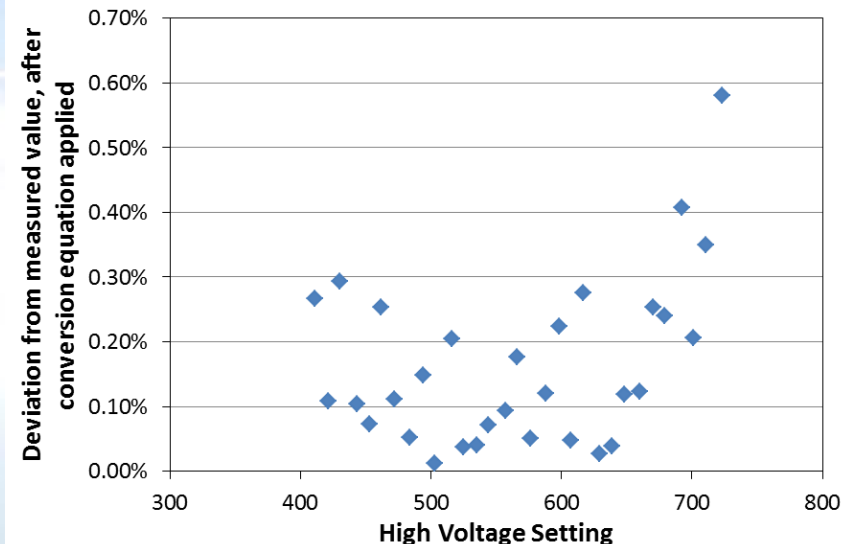
- Requires <100 mW of power draw at 8.4V
- Hard-coded serial numbers for all units
- Reports last 60 seconds of counts at 1 second time resolution

- Plateau curves completed twice for each instrument.
 - After GM tube installed and before shipment (prior to staking / coating).
- High voltage monitor circuit calibrated against a high voltage probe to reduce circuit measurement error.
 - 2nd order curve-fit approximation
- Each board tested using the same procedures.
- Test results compared to ensure no large outliers between boards.

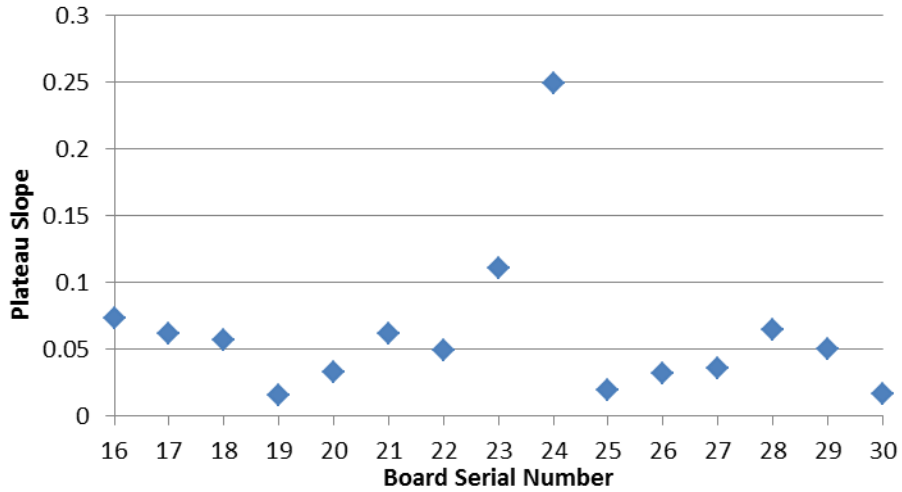
Flight Board Rt = 2000, Temp = 25C



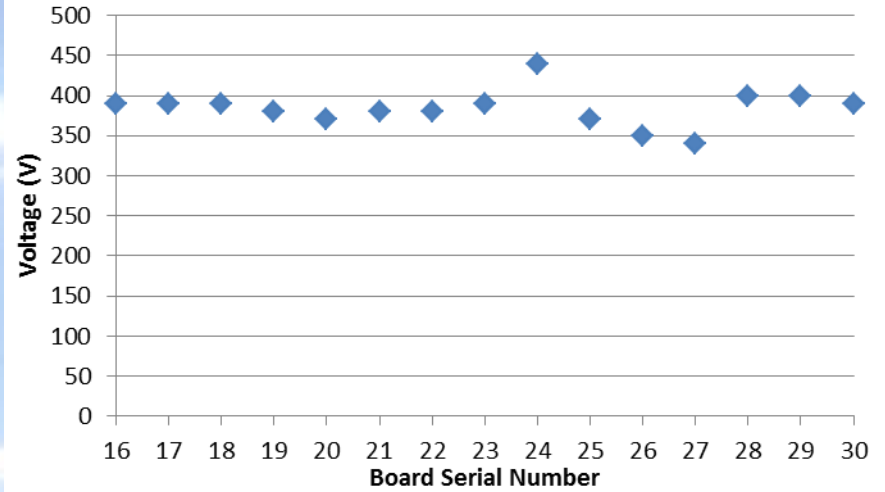
Error in High Voltage Monitor Circuit



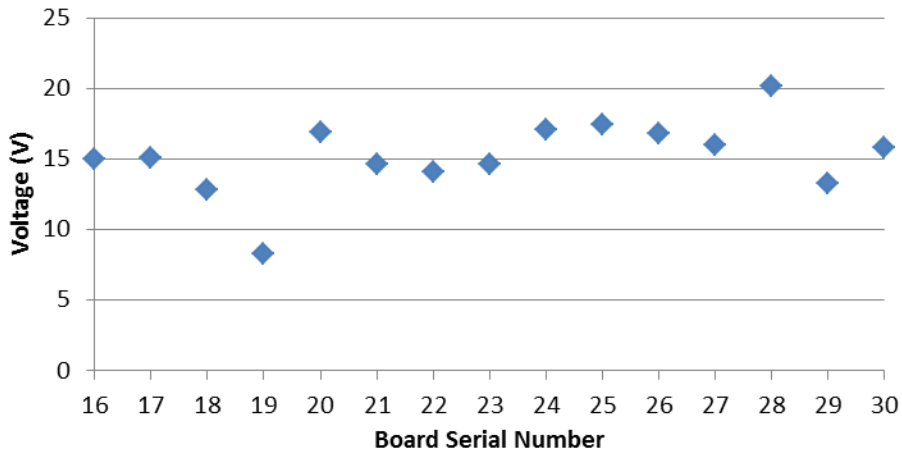
Final Plateau Curve Slope



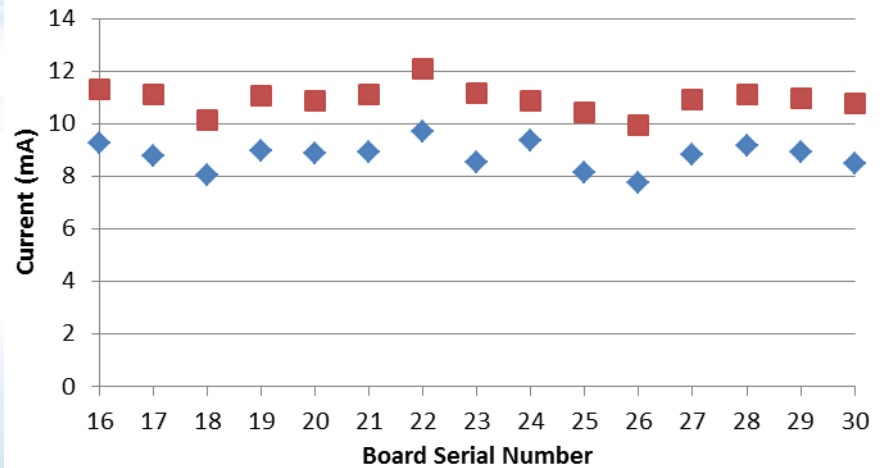
Turn On Voltage



High Voltage Ripple

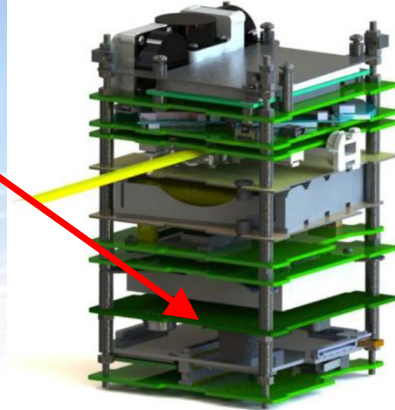
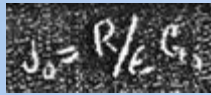
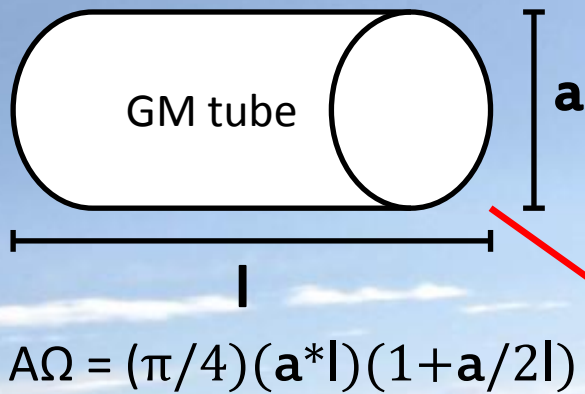


■ IBATTat700V ◆ IBATTat300V



EPISEM measures omnidirectional integral flux in counts per second per throughput (GF or AΩ).

- EPISEM: LND71320 Tube, $A\Omega = 1.94 \text{ cm}^2 \cdot \text{sr}$
- Explorer-1: Anton302 Tube, $A\Omega = 17.4 \text{ cm}^2 \cdot \text{sr}$
- Omnidirectional flux (ϕ_{part}) = count rate / ($\xi \cdot A\Omega$)



EPISEM detects particles with energy greater than some threshold energy.

- $E > E'$
- Found using the CSDA range.
- Approx to the average path length traveled.
- Rate of loss at every point along particles path assumed to be equal to total stopping power.
- Density Cu = 9.0 g/cm^3 , Density Al = 2.7 g/cm^3
- Bottom/Side Entry \rightarrow 2 MeV e- and 25 MeV p+

Integral flux, I(E):

J is a particle flux in $\text{counts} \cdot \text{sec}^{-1} \cdot \text{cm}^{-2} \cdot \text{sr}^{-1}$

J has a variation in energy $J(E)dE \propto E^{-\gamma}dE$

EPISEM measures integral flux I(E) above a certain kinetic energy $J = -dI/dE$

Top of Stack Entry

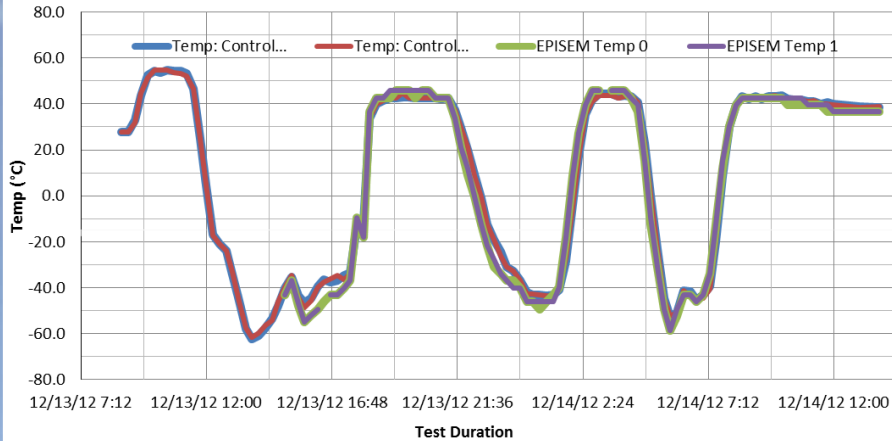
Material

E' for e- (MeV)

E' for p+ (MeV)

Top of Stack Entry	Material	E' for e- (MeV)	E' for p+ (MeV)
S-Band Patch	Copper	2.00	25.00
Router Assembly PCB	Copper	2.00	25.00
S-Band Heatsink	Aluminum	4.50	13.00
MHX2420 Shield	Aluminum	4.50	13.00
MHX2420 PCB	Copper	2.00	25.00
ACS PCB	Copper	2.00	25.00
Phone PCB	Copper	2.00	25.00
EPS PCB	Copper	2.00	25.00
18650 Liions	Various	8.00	60.00
Stensat Radio PCB	Copper	2.00	25.00
GPS Aluminum Housing	Aluminum	4.50	13.00
GPS Card	Copper	2.00	25.00
GPS Heatsink	Aluminum	4.50	13.00
GPS Interface PCB	Copper	2.00	25.00
EPISEM PCB	Copper	2.00	25.00
Geiger Tube Wall	Aluminum	0.08	2.20
Total Thicknesses	Copper	20.00	95.00
Total Thicknesses	Aluminum	1.75	27.50

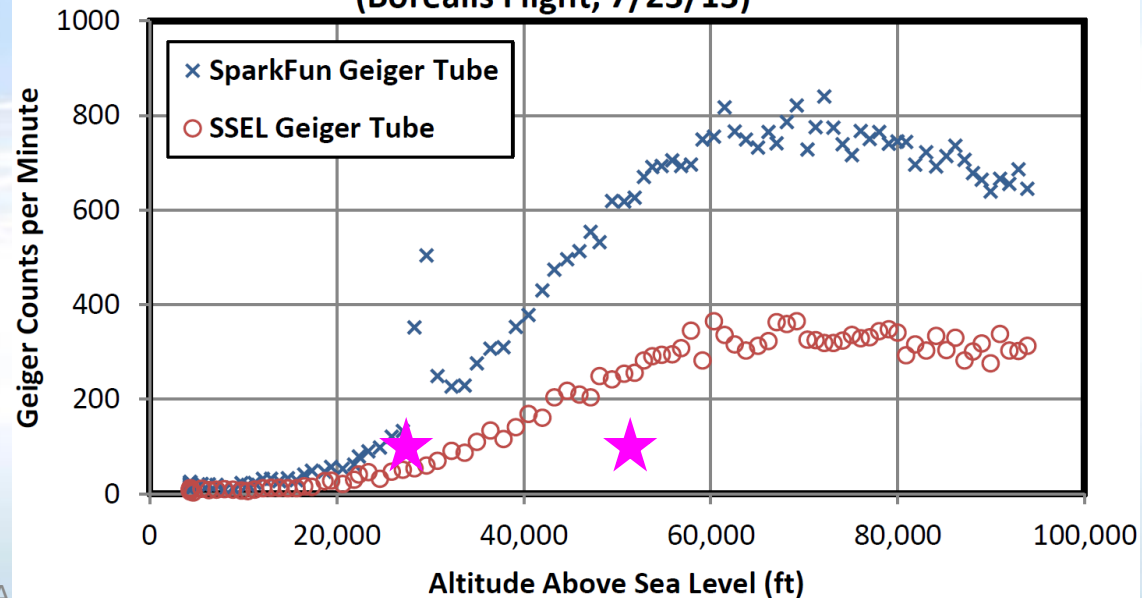
EPISEM Thermal Vacuum Test Profile



- TVAC chamber test:
 - Hot soak at 50C
 - -40C to 40C cycles
- High Altitude balloon flight:
 - Flight had two other detectors
 - Maximum altitude of 28 km

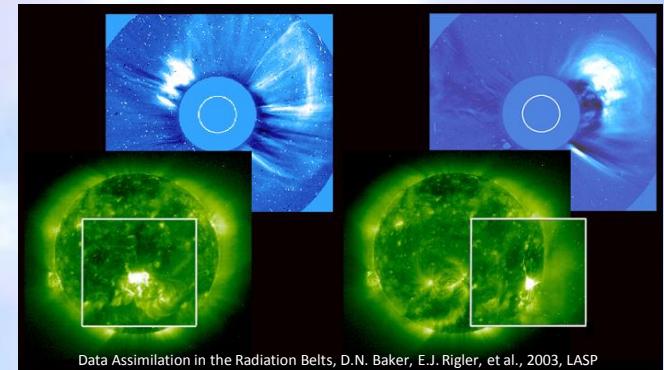
★ Suspected heavy ion strike from measurements with a silicon detector set to a threshold of >40 MeV

Geiger Counter Data (Borealis Flight, 7/23/13)

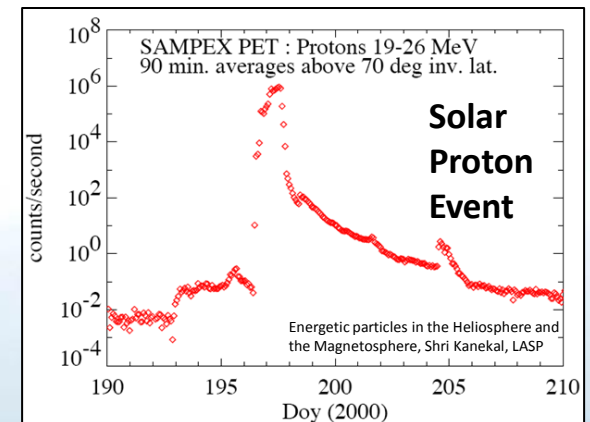
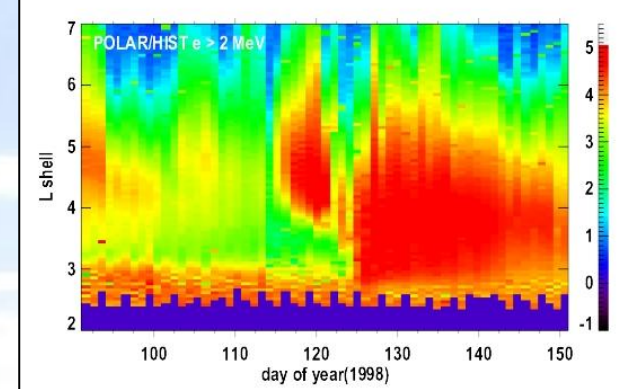
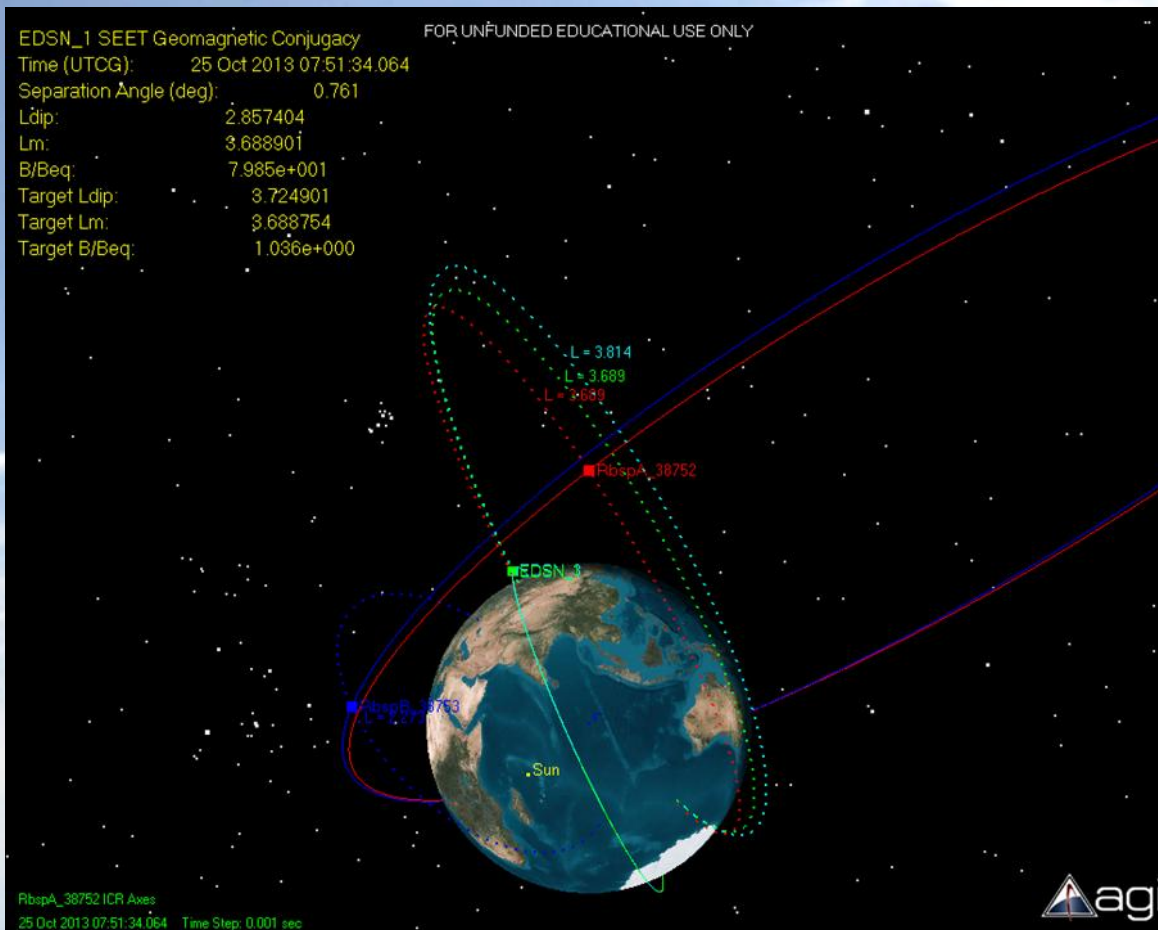


- Targets of interest
 - L-shell conjunctions: RBSP, BARREL
 - Flares, CME's, solar proton events
- South Atlantic Anomaly passes

Flare initially blamed for the Galaxy IV satellite failure



Data Assimilation in the Radiation Belts, D.N. Baker, E.J. Rigler, et al., 2003, LASP



- All instruments delivered to Ames
 - QA inspection passed
 - 8 μ C, Cs-137 radiation source procured at Ames
 - Awaiting pre and post integration performance tests
- Launch mid-2014 on ELaNA VII



Questions?

Acknowledgements

NASA Ames Research Center
Andrew Crawford, Matthew Handley,
Jerry Johnson, David Klumpar, Larry
Springer, Keith Mashburn, and
Ehson Mosleh

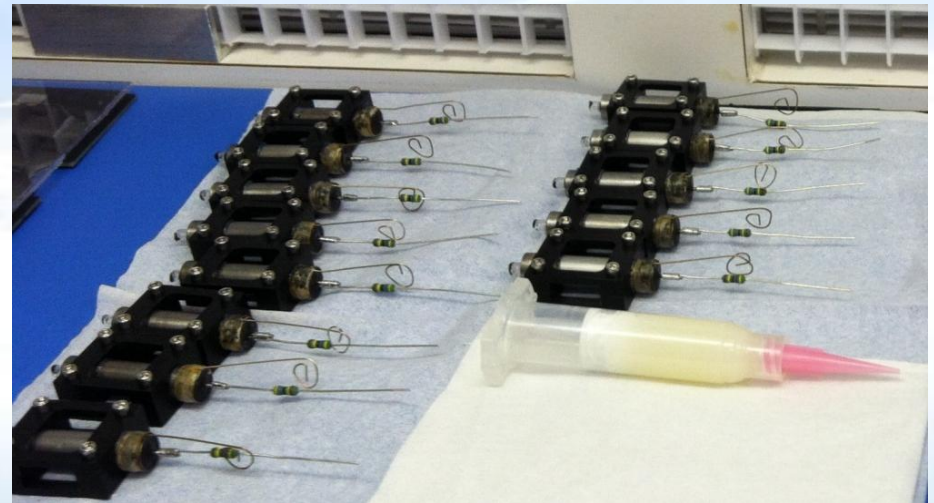


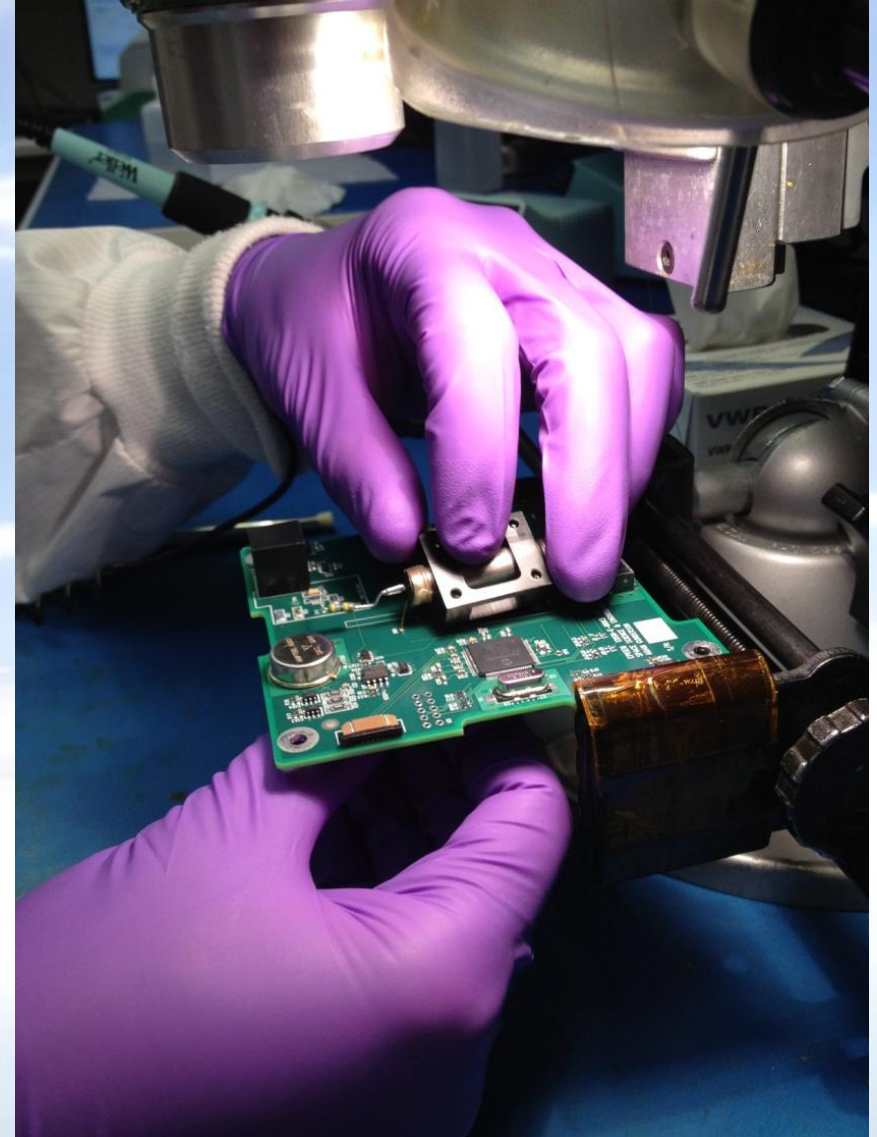
Symposium

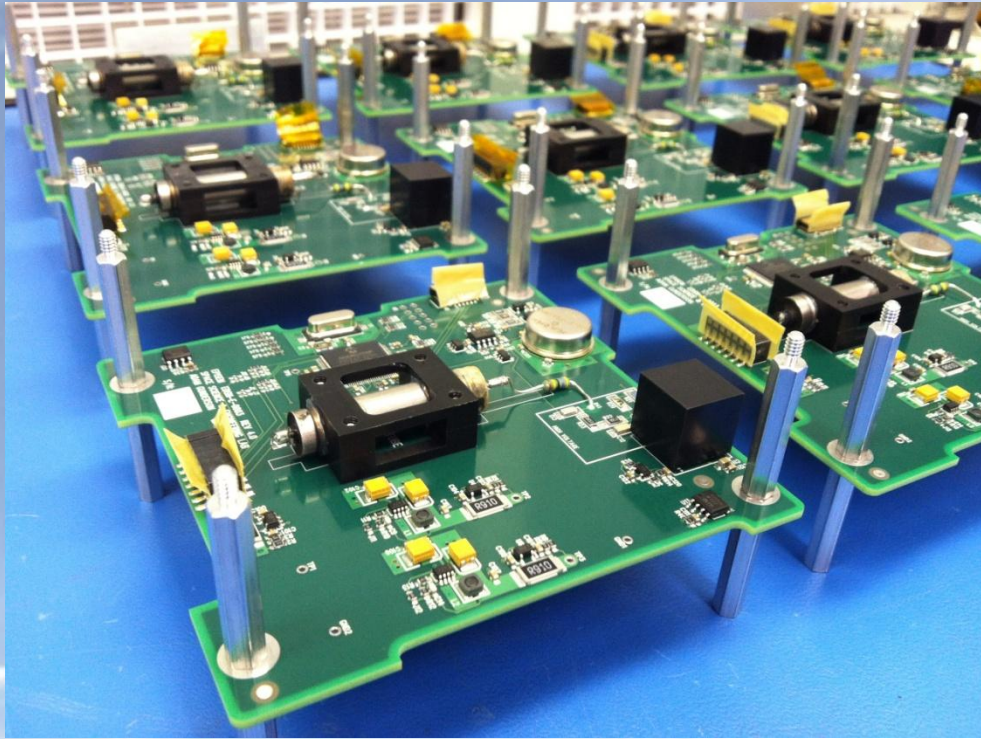


Backup Slides

Fabrication



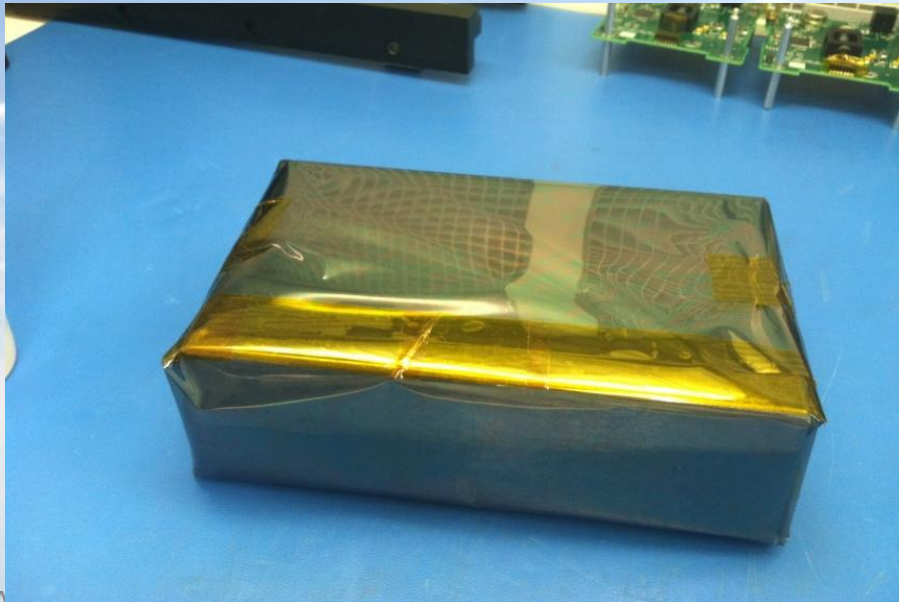




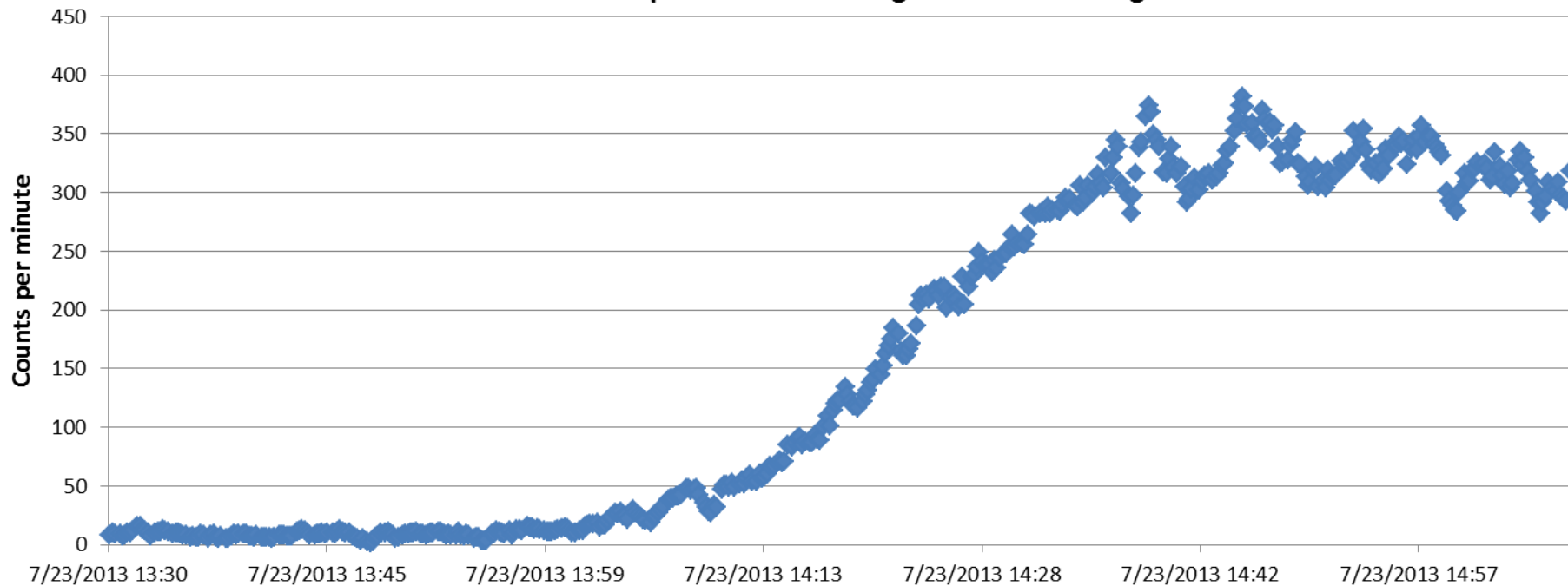
- All circuit boards cleaned, cleaned, and then cleaned again
- Boards staked and coated before final testing and shipment



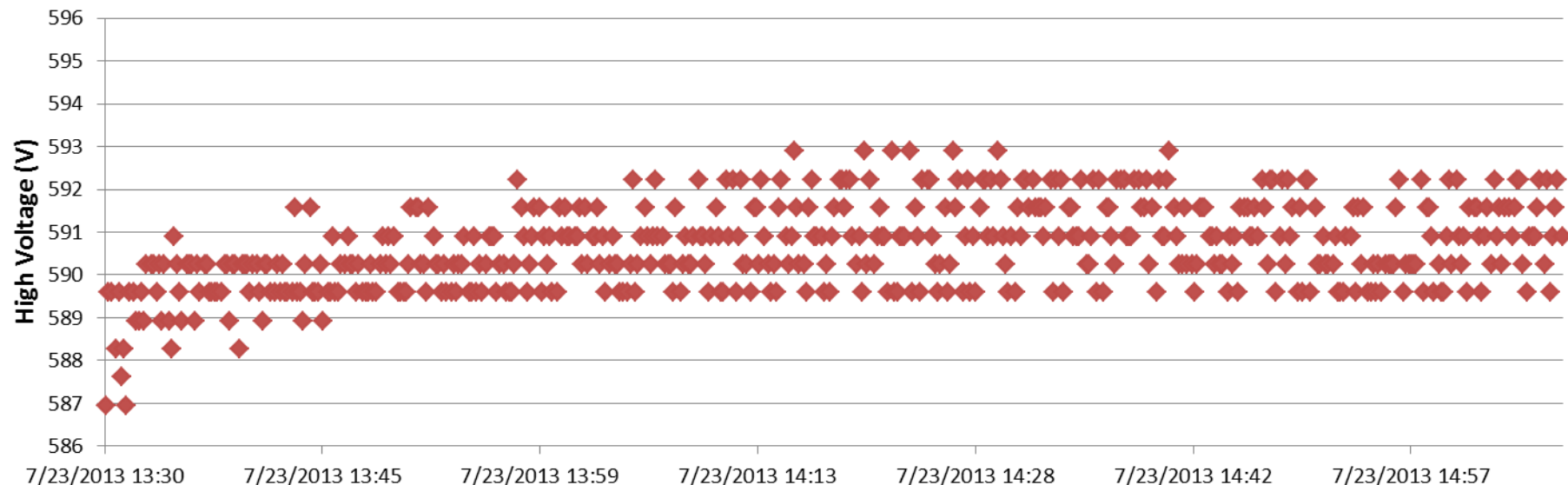
- Mounted and packaged in an aluminum shipping container
- Double-wrapped in aluminoloy
- Packaged and shipped in lots of two to four



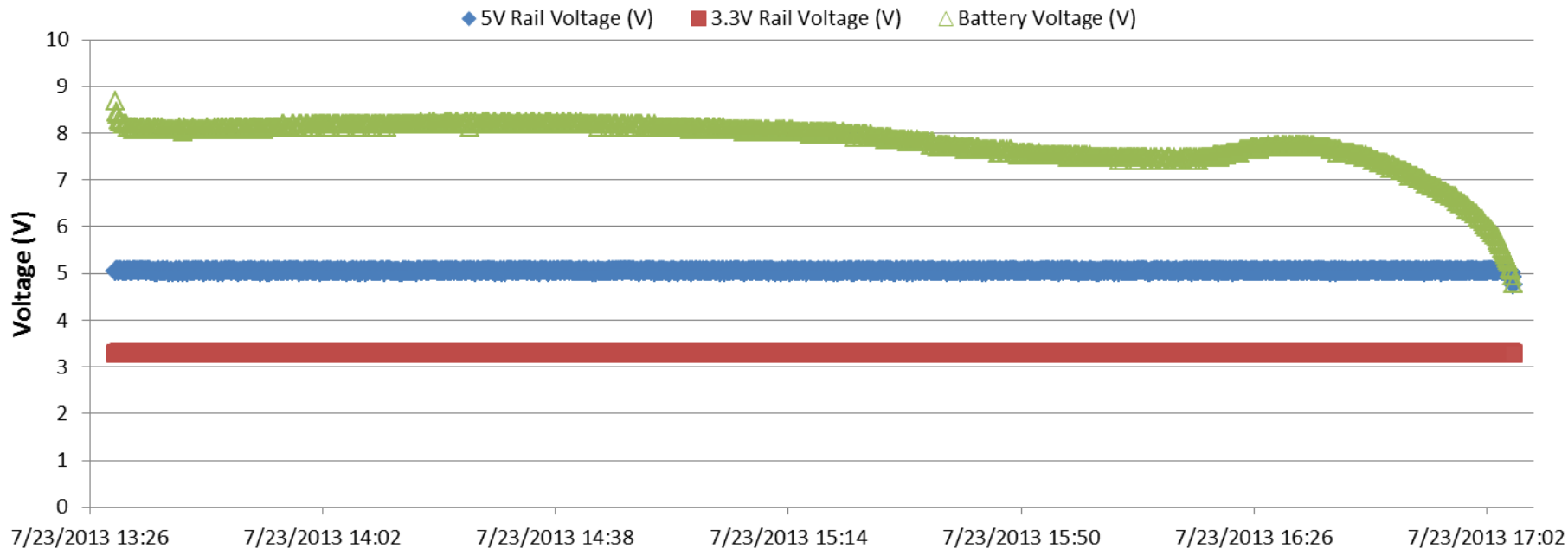
EPISEM BOREALIS Flight
Counts per minute moving 10 second average



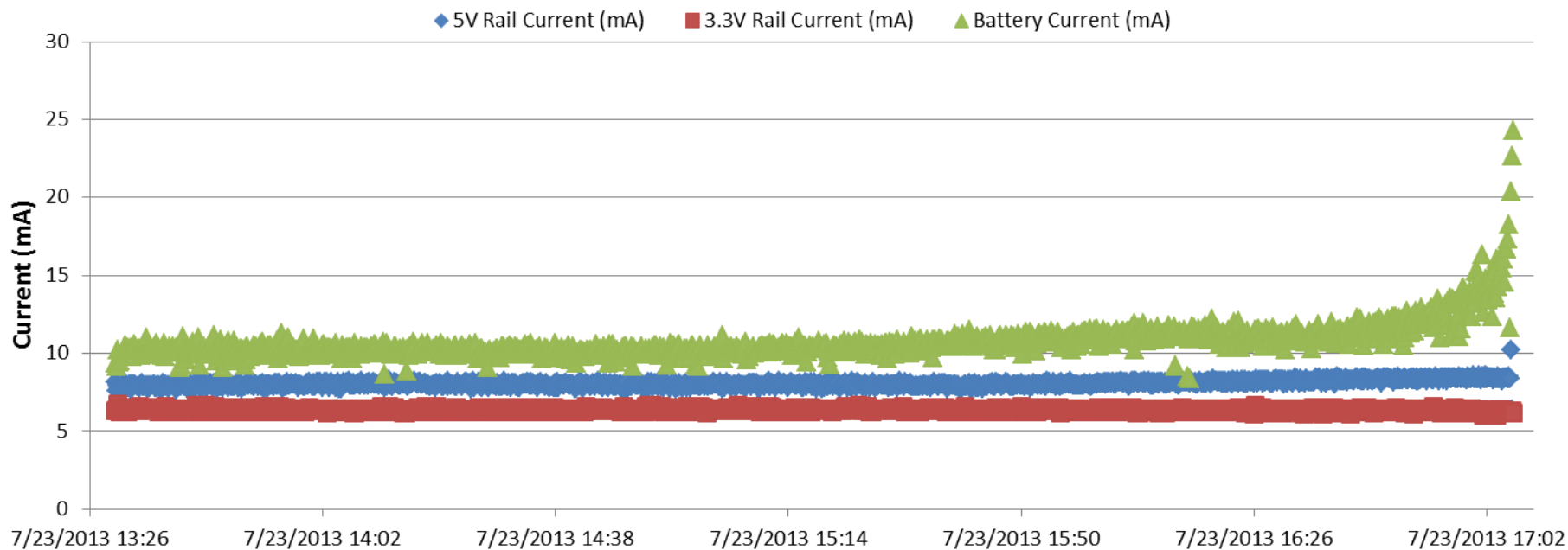
EPISEM BOREALIS Flight
High Voltage Power Supply Monitor



EPISEM BOREALIS Flight Voltages

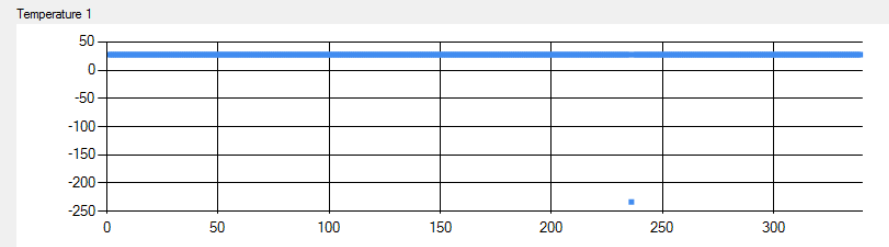
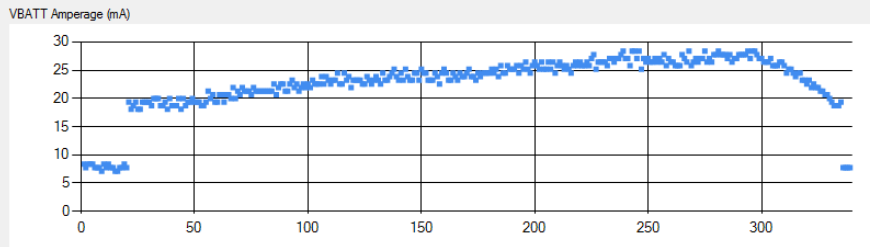
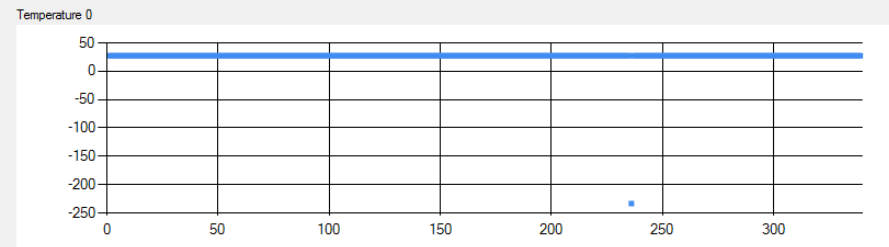
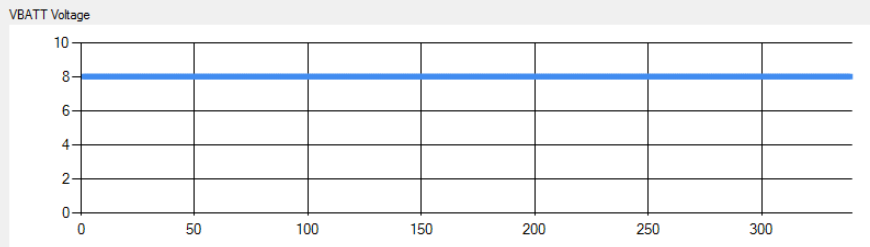
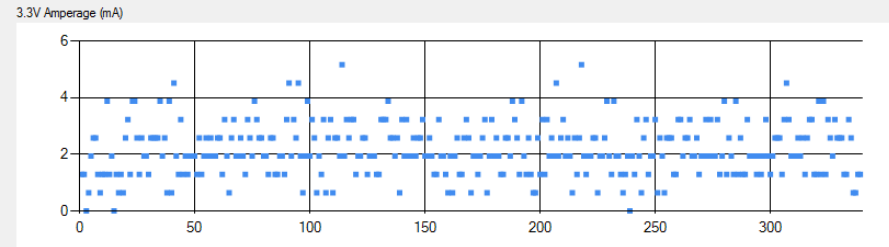
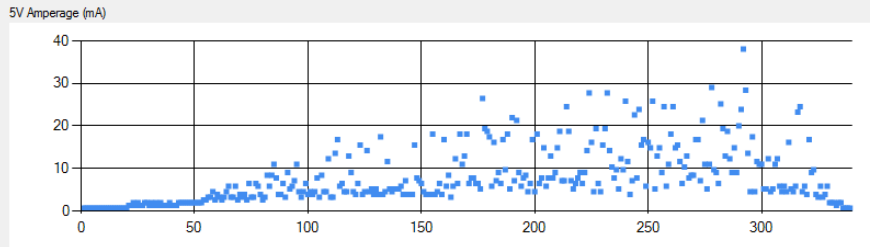
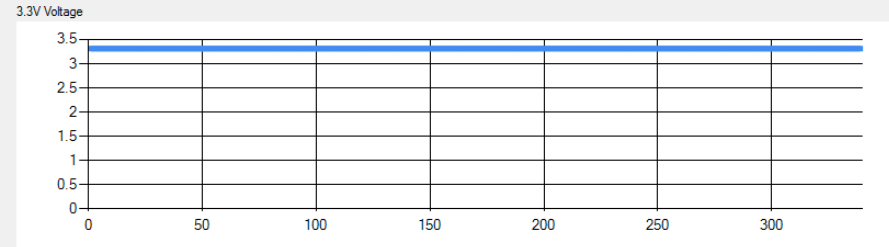
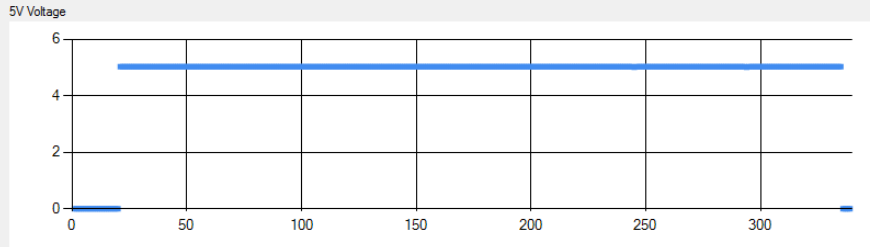


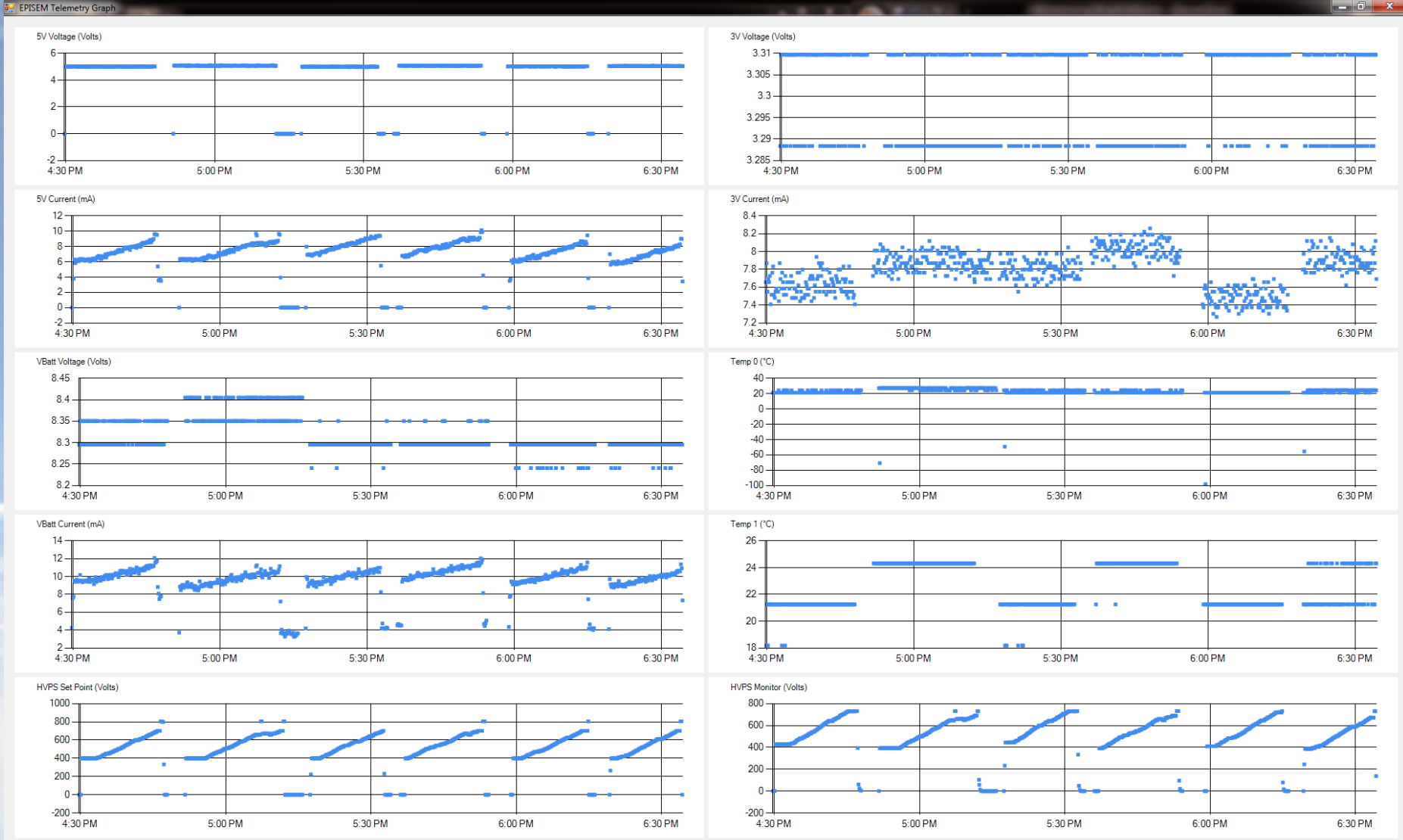
EPISEM BOREALIS Flight Currents



Design Iterations

EPISEM Telemetry Graph





Customer Growth SWPC Product Subscription Service

