Van Allen Probes

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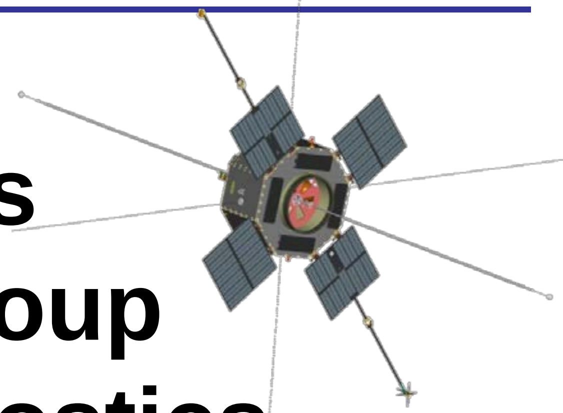
Science Working Group
ERM Spacecraft Diagnostics

March 12, 2014



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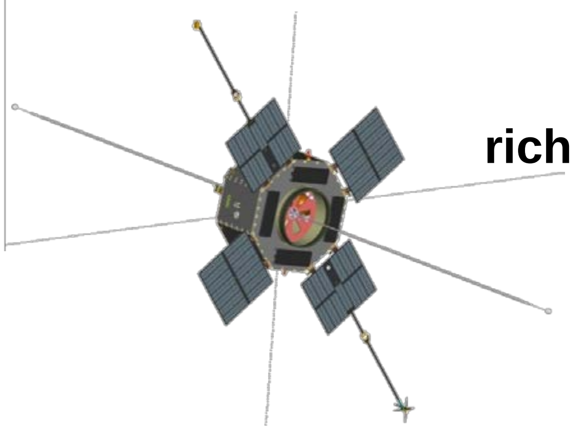
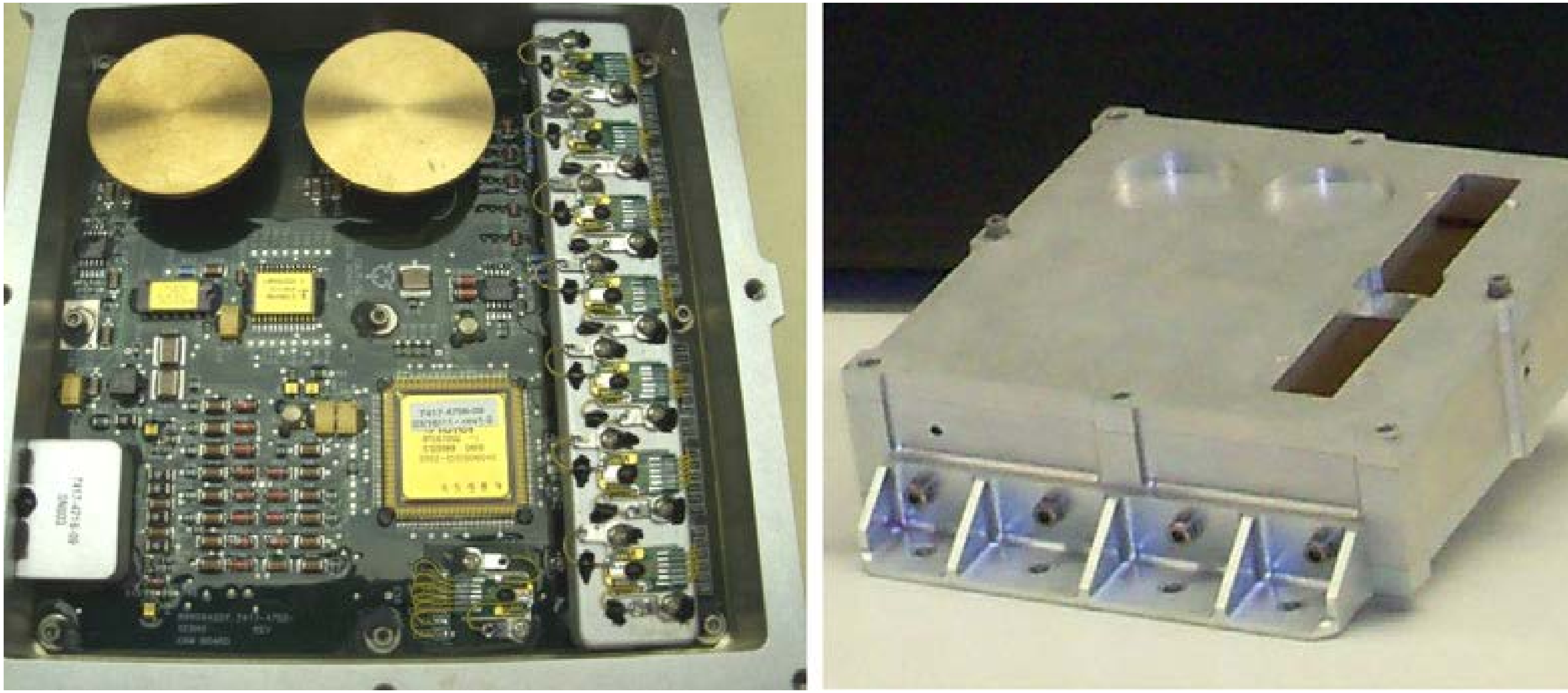


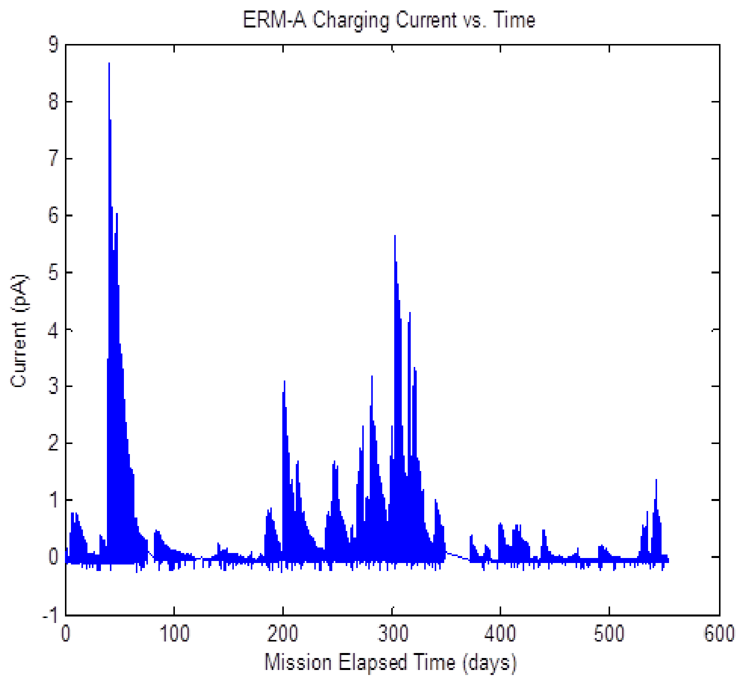
APL

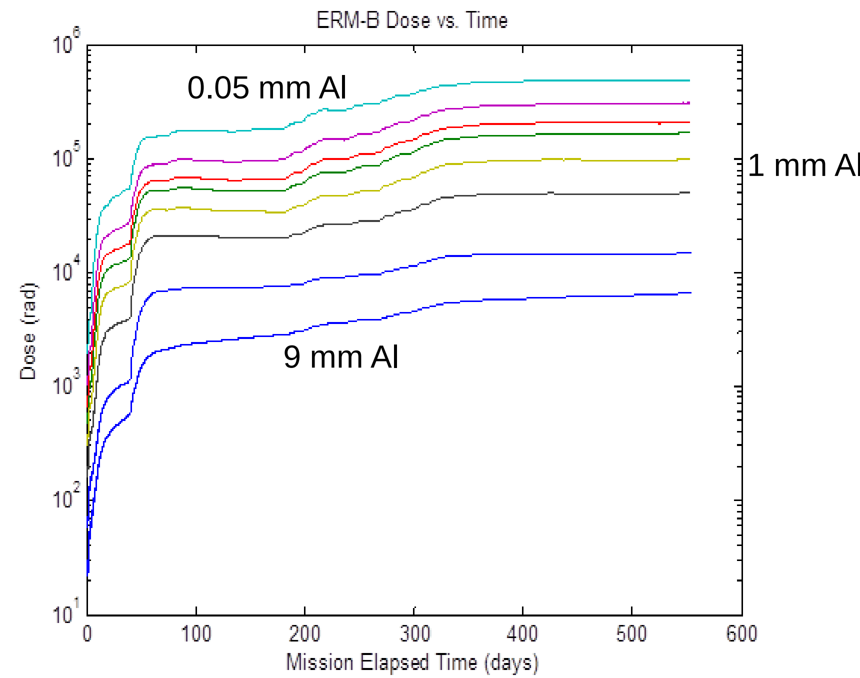
Engineering Radiation Monitor



Left: Flight ERM with its cover removed showing the locations of the individual RadFET dosimeters and the two charge monitors; the maximum shielded board-mounted RadFET is at the lower right next to and deeper than the RadFET bench; R*ight:* view with cover showing variable thickness absorber.

ERM Data at 548 Days (2/28/14)





Current monitor data from ERM-A behind 1mm Al.
Current was higher in late June/July 2013 time frame than during the Jan/Feb 2014 solar events

Dose data from ERM-B

9mm Al: 6.7 krads
1mm Al: 100 krads
0.05mm Al: 500 krads

ERM data at 427 Days (10/30/13)

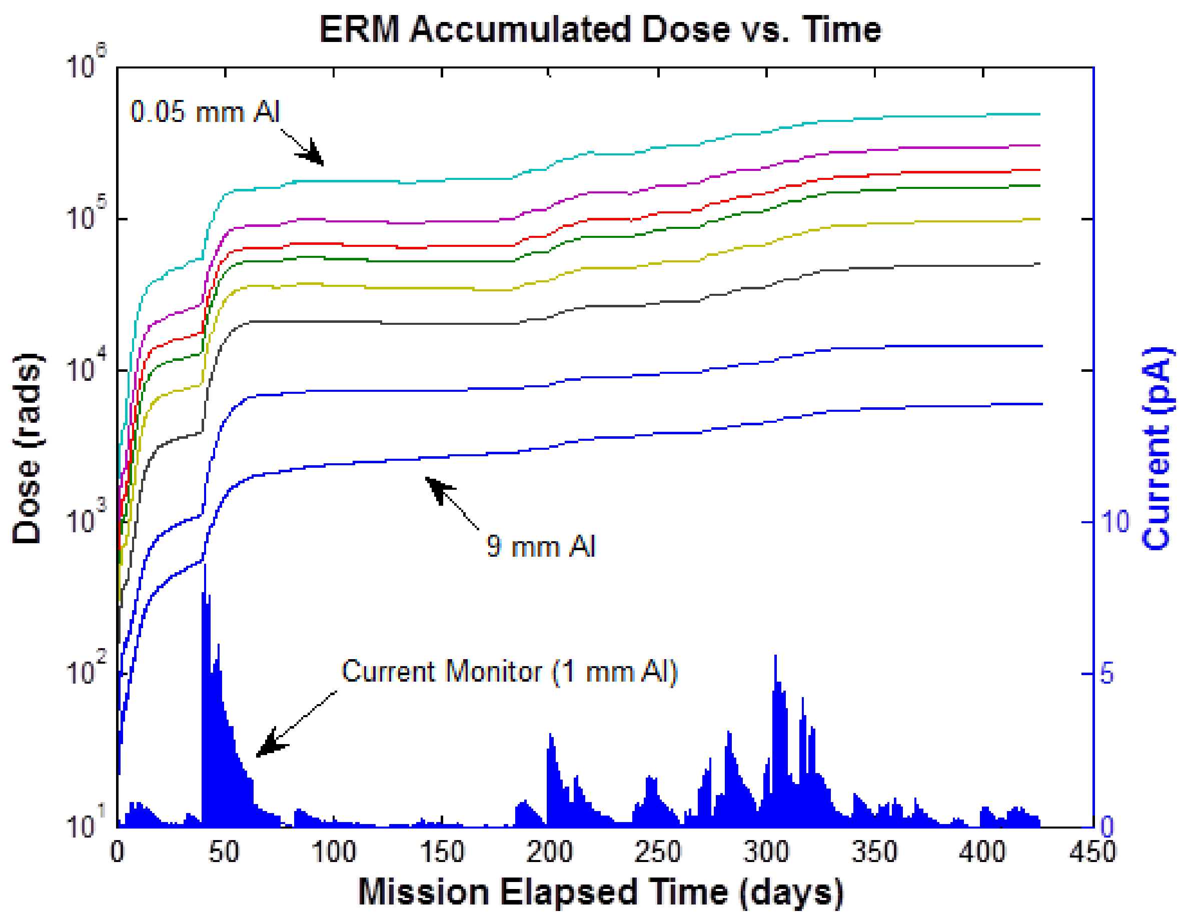
Current monitor data from ERM-A

Dose data from ERM-B

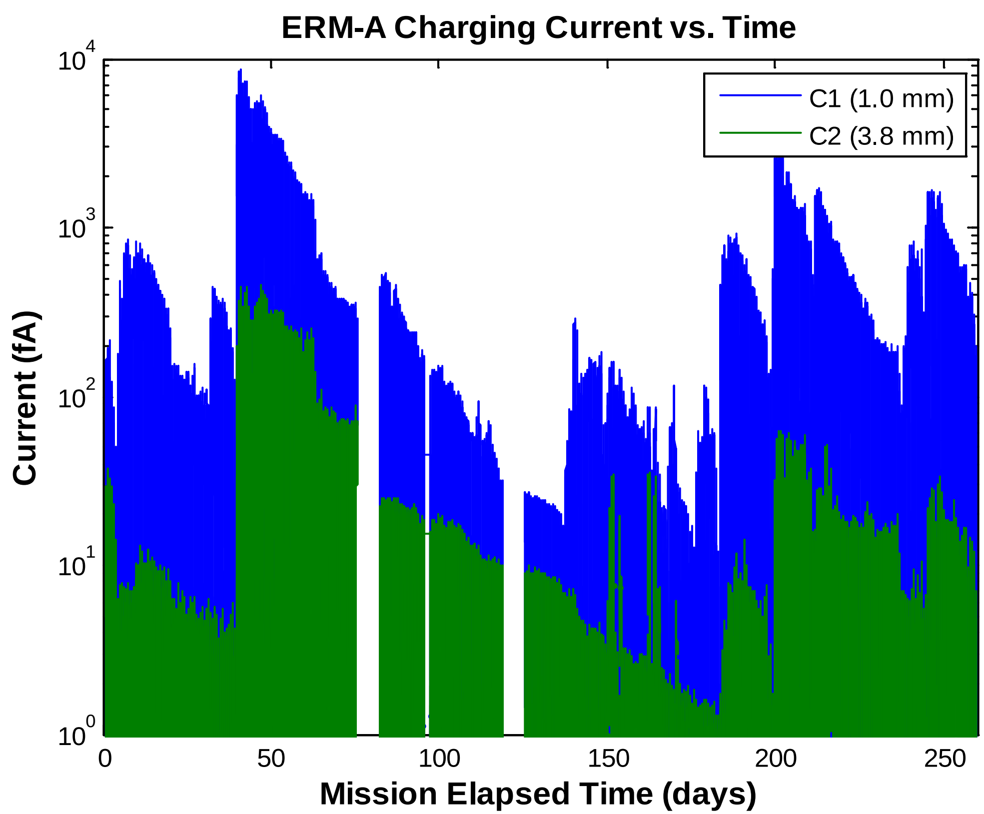
9mm Al: 6.154 krads

0.05mm Al: 489 krads

Current monitor data was higher in late June/July 2013 time frame

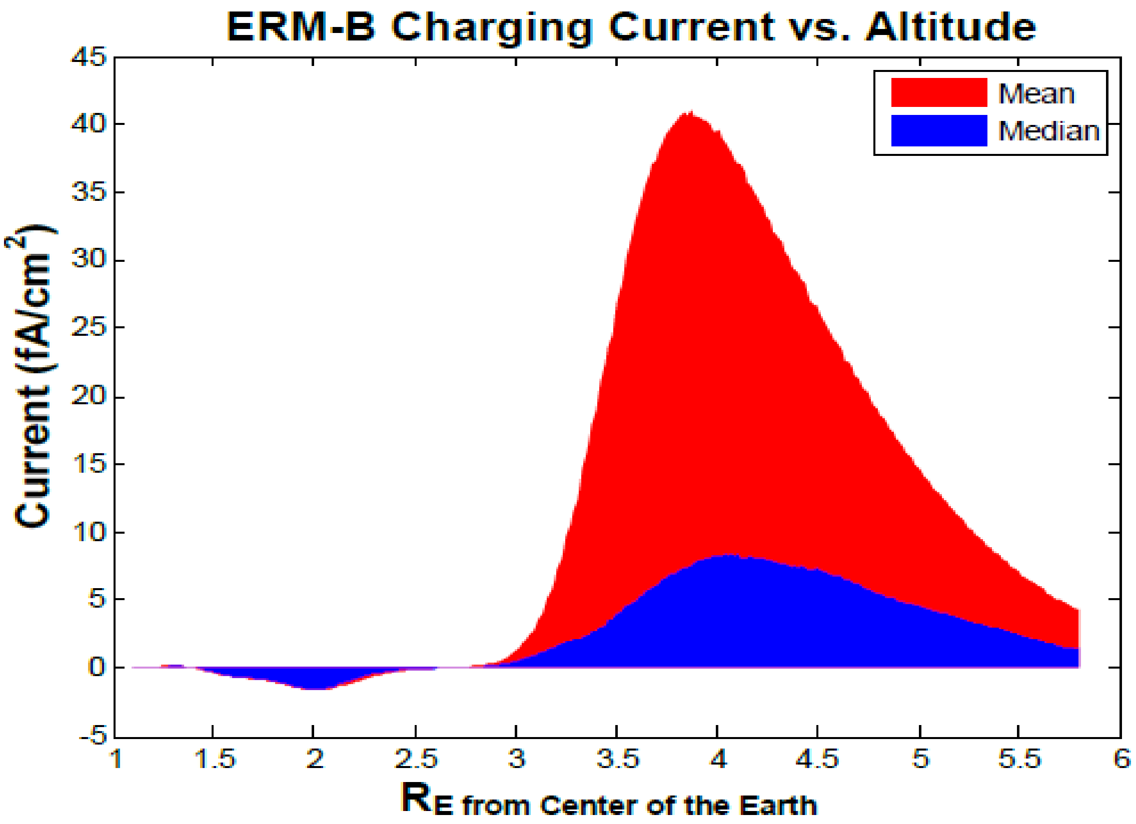


Charge Monitor Plate Currents for the First 260 Days



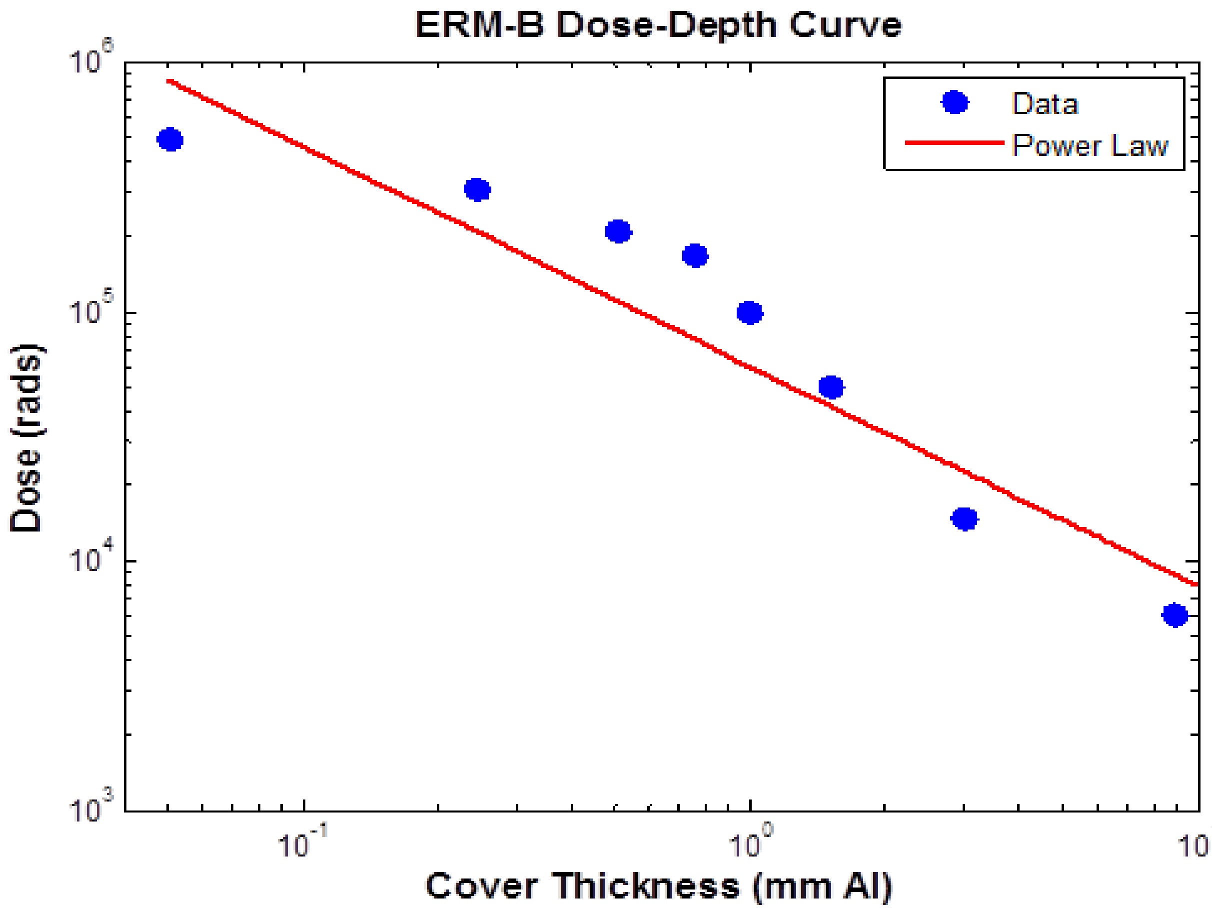
Charge monitor plate currents in femtoamps versus time for electrons > 0.7 MeV (upper blue) and > 2 MeV (lower green). Day 0 is August 30, 2012.

Charging vs Orbit Altitude



Charging current (electron current as positive) versus orbit attitude for more than 400 orbits below the 1 mm Al cover (electron energy >0.7 MeV; proton energy > 15 MeV). Below ~2.5 Re protons dominate and the median and mean plots are almost equal due to inner belt stability; above ~3 R_E, electrons dominate and the peak of the mean plot is ~8 times greater than the median plot due to outer belt variability.

ERM-B 427 Day Dose-Depth Curve



Back Up Slides for Mission Extension

Future operations

- **After 548 days, the measured dose behind 9 mm Al (representative of the electronics on the spacecraft) is 12.2 rad(Si)/day or 6700 rad (Si) versus 10,500 rad (Si) for the worst case prediction using NOVICE transport of the AP8/AE8 static environment models and an RDM of 2.**

- **A linear extrapolation of these results, assuming similar storm activity continues to the end of the 800 day primary mission, gives values of 9.78 krad (Si) versus the 15.4 krad (Si) prediction.**

- **The minimum shielded RadFET (0.05 mm Al) has seen 500,000 rad (Si) or 912 rad (Si)/day. A linear extrapolation in time for the mission yields 0.73 Megarad (Si) for near surface locations (surface materials were tested to 10 Megarad).**

Van Allen Probes Soft Part Survey I

- **Each observatory was originally designed for an on-orbit life of 2 years and 74 days. This encompasses a 60- day commissioning period, a 2-year science mission, and 14 days to disable the observatories.**
- **Mission extension necessitates the survey of the radiation hardness of the electronic parts to determine how long an extension could be tolerated by devices originally qualified for the ~800 day mission.**
- **Survey of all parts determined the five softest devices**
  - AD8012—solid 20krads (>= 20krads; < 50krads)
  - AD780---solid 20krads (>= 20krads; < 50krads)
  - AD620—solid 20krads at 2.3, 5 V; 100krads at 15V
  - PRIO-2---20-50krads
  - AD7943---15krads maximum

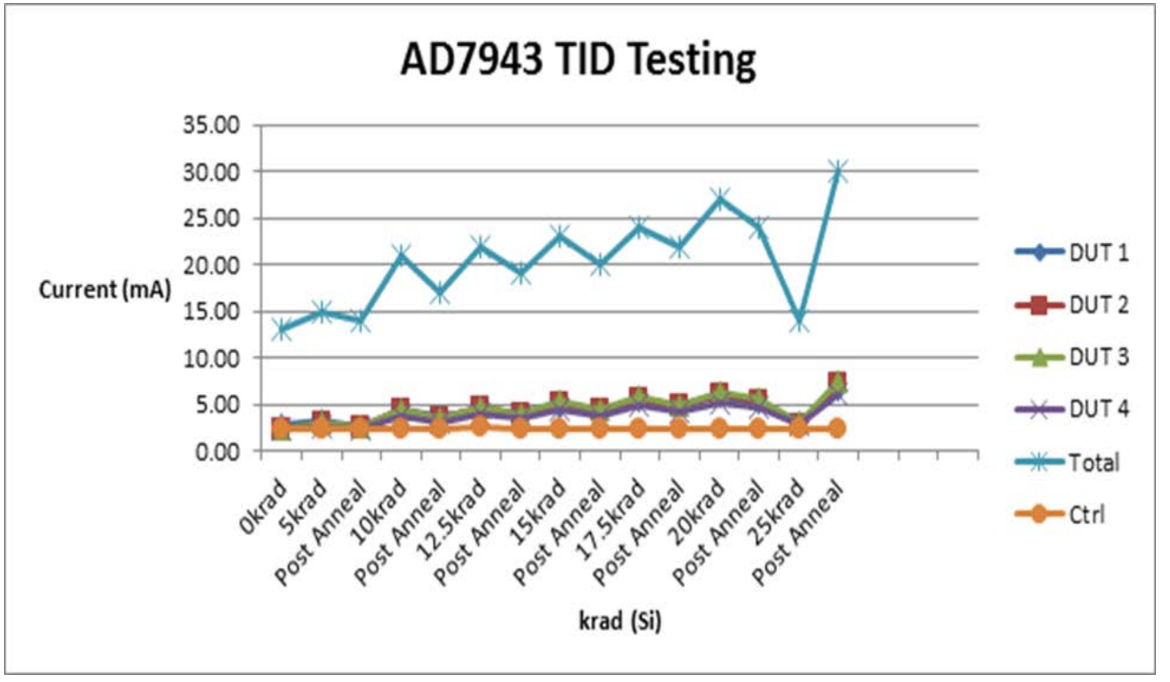
Van Allen Probes Soft Part Survey II

- **Detailed analysis of TID test results**
- **The AD8012 dual amplifier is hard to 20krads and functions at 50krads but DC parameters are significantly out of spec—so this device is probably hard to about 30krads (test intervals were 20, 50, 100krads).**
- **One of four AD780 high precision references was marginally out of a tight output voltage spec at 50krads so this device is probably hard to 40krads—same as the PRIO.**
- **The AD620 amplifier is used in the PSE shunt driver with a +15V supply voltage; thus it is hard to 100krads and comes off the "soft" part list.**
- **The PRIOs were hard to 20krads and one of four parts failed after 50krads. It was considered marginal at 50krads, but probably hard to 40krads (test intervals were 20, 50, 100krads).**
- **The AD7943 DAC is the softest part (15krad) by a factor of X2.**

Van Allen Probes Soft Part Survey III

A detailed TID evaluation in which anneal cycles were interleaved with 2500rad and 5000rad dose steps followed by a one week anneal at 100C was designed to simulate the orbit exposure scenario.

The AD7943 is heavily shielded and the dose is due to protons in the inner Van Allen Belt near perigee. It sees exposure in a roughly ~2 hour time period and then is free from proton flux for the roughly remaining 7 hours of the Van Allen Probes orbit.



Supply current versus accumulated total dose and anneal cycles for the AD7943 DAC completed in September 2013. The four devices under test survived <u>20krad</u>; functional behavior became erratic after 25krad.

Implications for Mission Extension

- **The 2013 high dose rate dose/anneal cycle radiation exposure determined that the AD7943 DAC was hard to 20,000rads (Si).**
- **The original NOVICE code pre-CDR prediction for the RF transceiver containing the DAC was 10,200 rads maximum with a shield depth of 9.9mm (390 mils) Al equivalent, 51% of the AD7943 hardness.**
- **The June 2013 FASTRAD simulation revealed that in the as-built configuration the median ray trace path length was 19.2mm (757mils) or almost twice the shielding as estimated pre-CDR. The consequent maximum dose with an RDM = 2 is 6000rads, 30% of the AD7943 hardness.**
- **We have much more shielding in the as-built configuration than originally modeled. A factor of 3.33 (20,000rads from test hardness/6000rads from FASTRAD simulation) X 800 days would be a 2667 day mission or ~5.1 year extension on the initial 2.2 year Van Allen Probes mission lifetime.**