Engineering Radiation Monitor (ERM)

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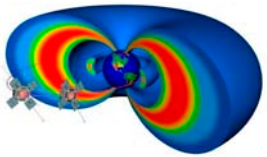
This document has been reviewed and approved for public release

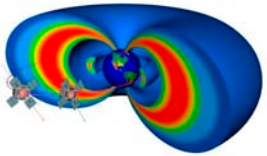
Purpose



The Engineering Radiation Monitor (ERM) will monitor total dose and deep-dielectric charging at each RBSP spacecraft in real time

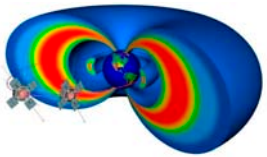
- In-situ monitoring enables correlation of spacecraft anomalies with space weather conditions
- IC RadFET sensors have same sensitive micro-volume as most s/c electronic devices and therefore “see” same effects
  - Sensitive to all types of ionizing dose
  - Unique opportunity to cross-compare with Aerospace dosimeter
- Spacecraft charging monitor detects penetrating electrons
  - Monitors potentially hazardous charge build up on dielectrics within the s/c (e.g., circuit boards and coaxial cables)
  - Reports energetic electron environment, which may be highly localized
- Provides valuable data for future missions
  - Validation of space environment models and transport codes
  - Design of other high radiation missions (e.g., Jupiter moons)

Origin



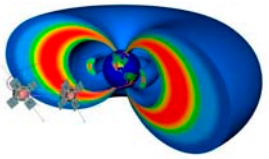
- Conceived as a balance mass experiment to recover S/C capability lost during early cost-cutting efforts
  - Dosimeter
  - Deep dielectric discharge monitor
- Power and data I/F available via RBSPICE test port
- Not required for mission success
  - No Mission Level 1 requirements
  - Waiver granted for relaxed parts and documentation requirements
  - Best practices followed where possible
  - Full pedigree parts for interface to RBSPICE (“do no harm”)
  - FMEA performed on first circuits
- Flight units successfully integrated on S/C A and B

Conops/Resources



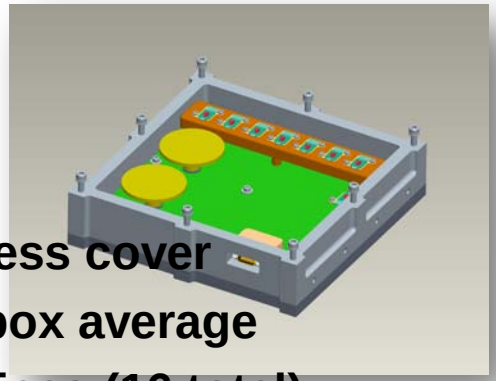
- ERM powered on/off via RBSPICE command
  - Off by default
  - RBSPICE autonomy will turn off ERM if current limit exceeded
- Dosimeter operated in unbiased mode; whenever ERM is powered off, it continues to accumulate dose accurately until the next time ERM is powered on
- ERM has only one operating mode: continuously cycle through readings every 3 minutes
  - RBSPICE reads and packetizes data with unique APID
  - Telemetry packets available via the MOC and RBSPICE SOC
- Telemetry fixed at 16 bps
- Mass: 2.9 kg
- Power: 250 mW
- Envelope: 18 x 18 x 6 cm^3

Measurement Objectives/Requirements



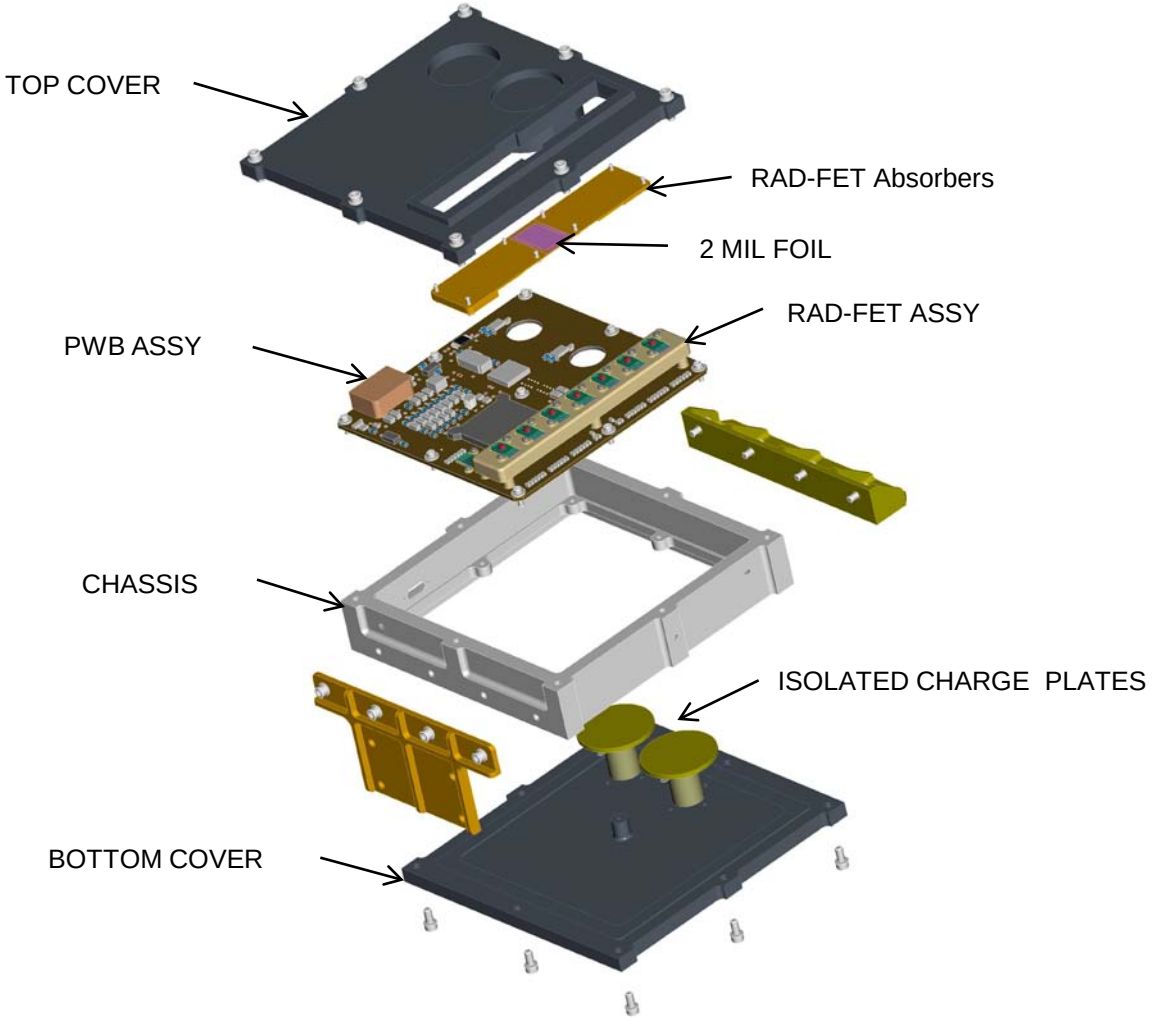
- Dosimeter
  - Provide multiple measurements along the dose depth curve
  - Sufficient dynamic range for >2-yr mission
  - Sufficient sensitivity and temporal resolution to profile orbit (electron vs. proton dose)
- Charge Monitor
  - Sufficient dynamic range to handle worst-case storm w/o saturating
  - Sufficient sensitivity to gauge quiescent conditions
  - Sufficient temporal resolution to monitor dynamics
  - Provide crude spectrometry using dual thickness cover

Sensors

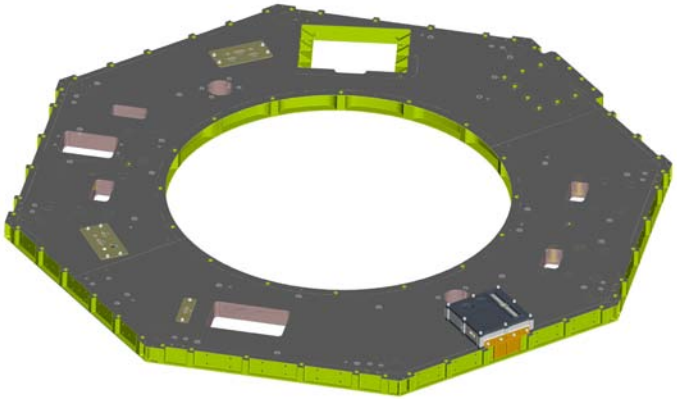


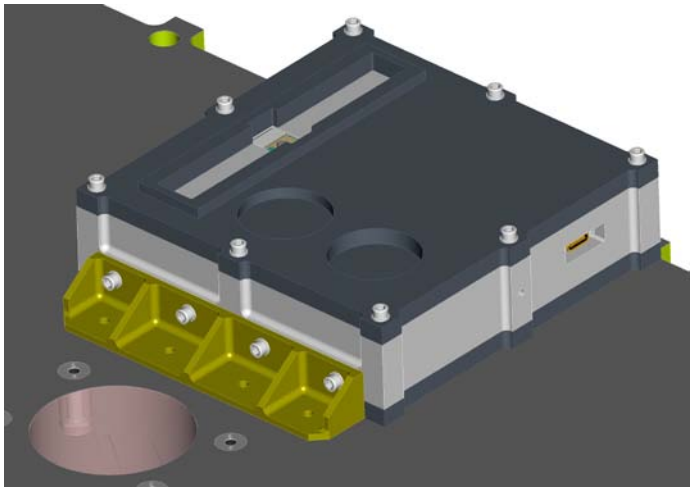
- **Dosimeter**
  - **Array of RadFETs provides dose depth curve**
  - **7 RadFET "pixels" mounted under varying thickness cover**
  - **8th RadFET mounted directly to board measures box average**
  - **Each RadFET die actually contains 2 RadFET devices (16 total)**
    - **Can average readings to reduce statistical uncertainty**
    - **Potentially improves calibration**
  - **Wide dynamic range (0 to 1000 krad) with <0.1 krad sensitivity**
  - **Initial sensitivity <0.01 krad is sufficient to profile orbit**
- **Charge Monitors**
  - **Two large-area sensors (~10 cm^2) behind different cover shielding**
  - **Wide dynamic range (0 to 30 pA) with < 0.01 pA sensitivity**
  - **High time resolution (5 sec) to characterize rapid changes in flux, or can be time-averaged to increase sensitivity**

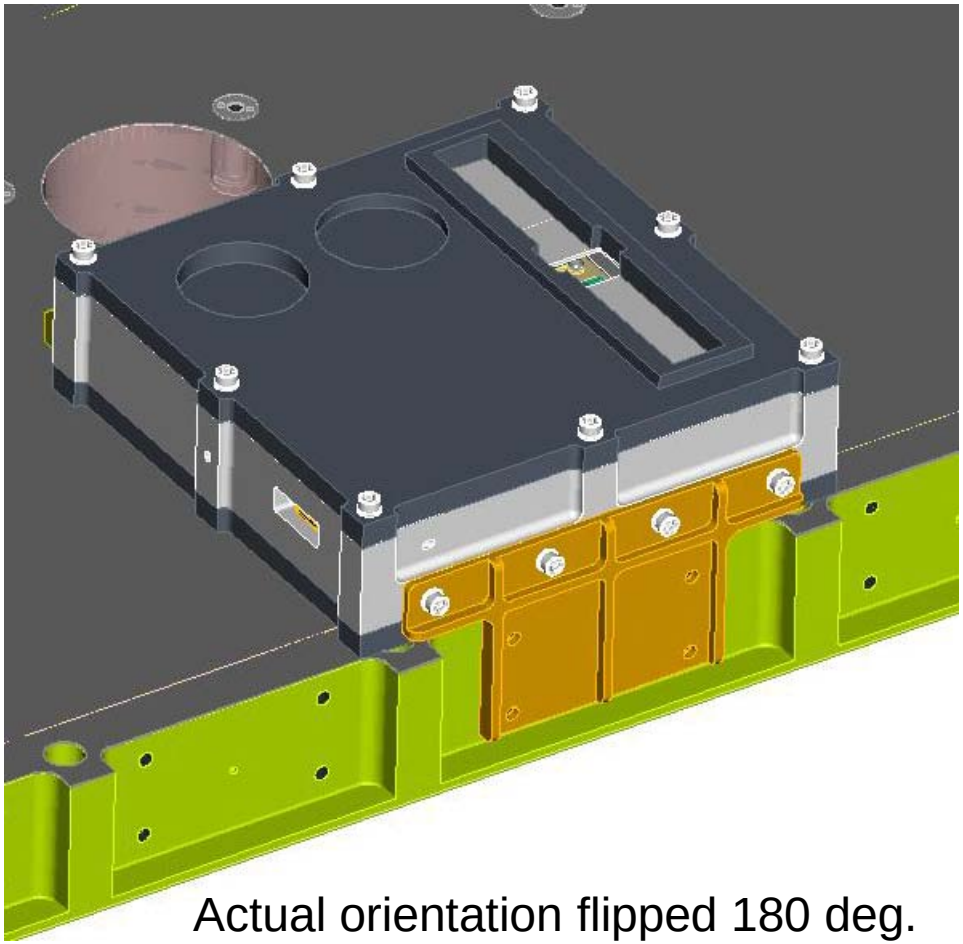
Assembly


TOP COVER
RAD-FET Absorbers
2 MIL FOIL
RAD-FET ASSY
PWB ASSY
CHASSIS
ISOLATED CHARGE PLATES
BOTTOM COVER

S/C Location

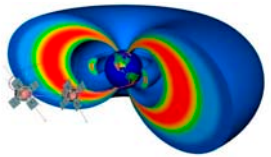




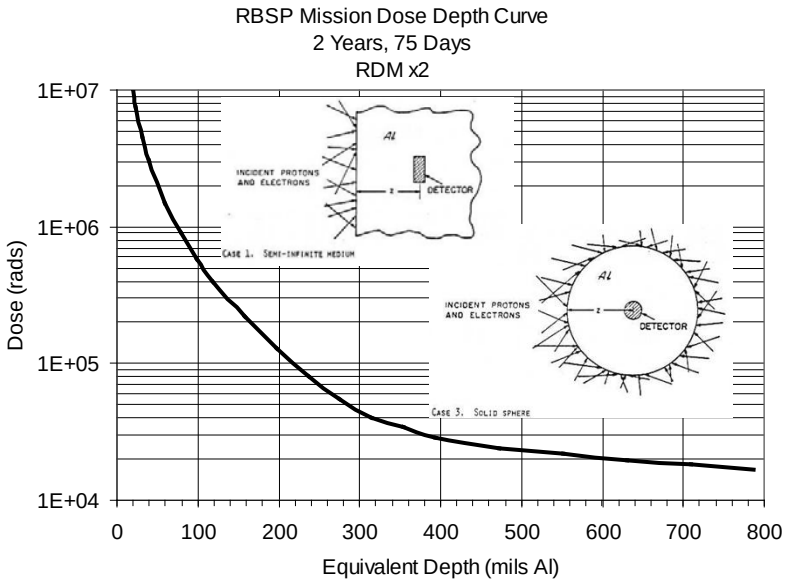


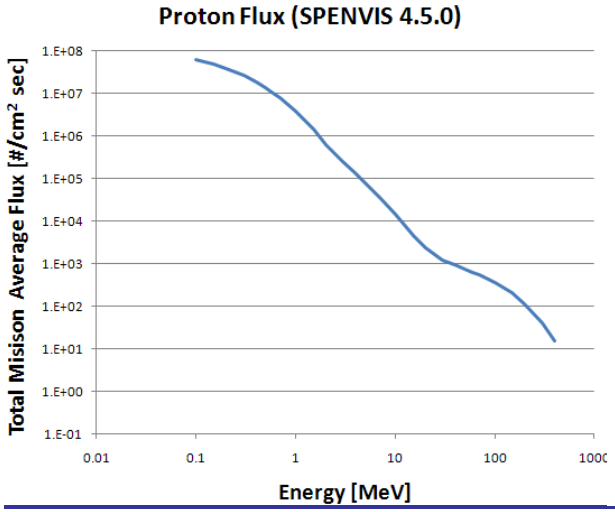
Actual orientation flipped 180 deg.
for easier cable access

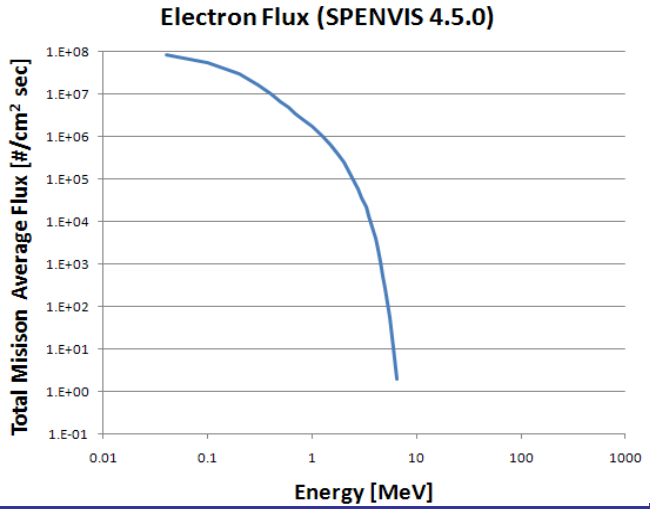
Simulating the ERM in the RBSP Radiation Environment

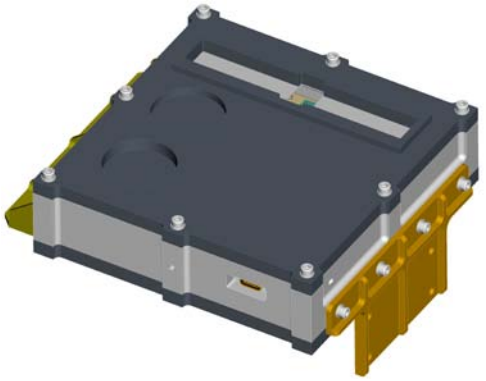


- Previous simulations assumed simple geometries (slab and sphere)
- Geant4 used to create a high fidelity simulation of the ERM to predict the actual response of the RadFETs and charge collection plates
- Simulation results used to optimize cover design

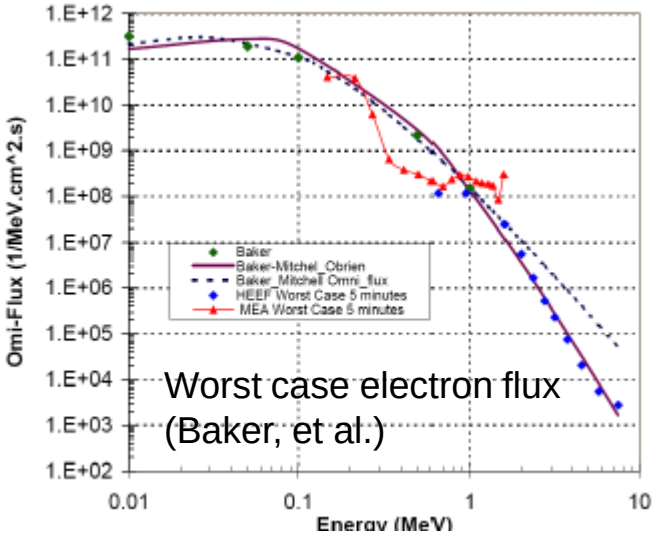


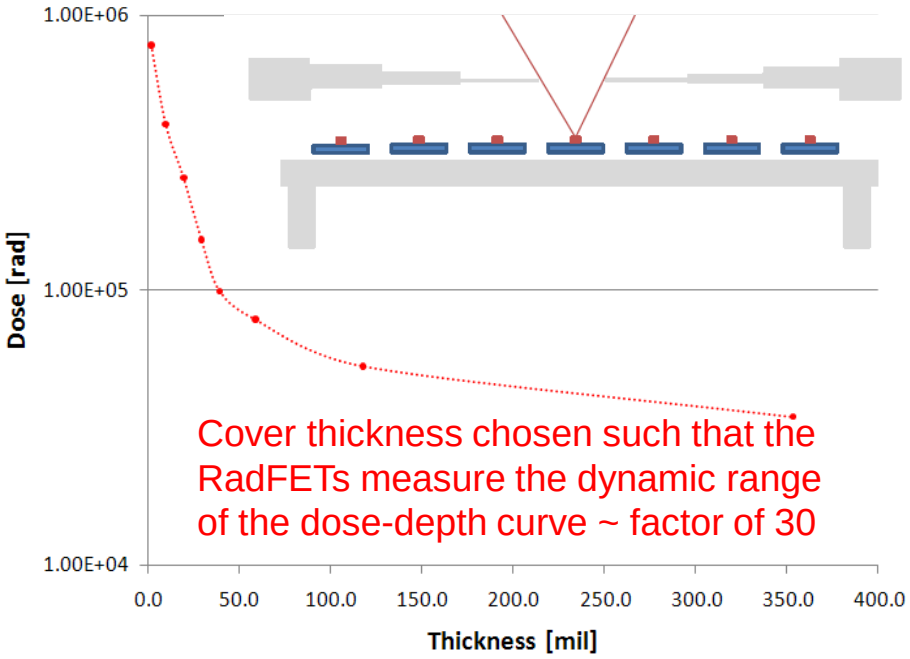




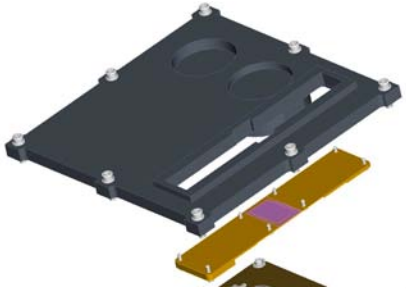


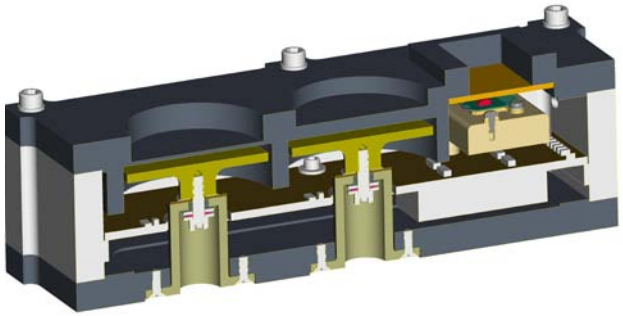
Cover Design





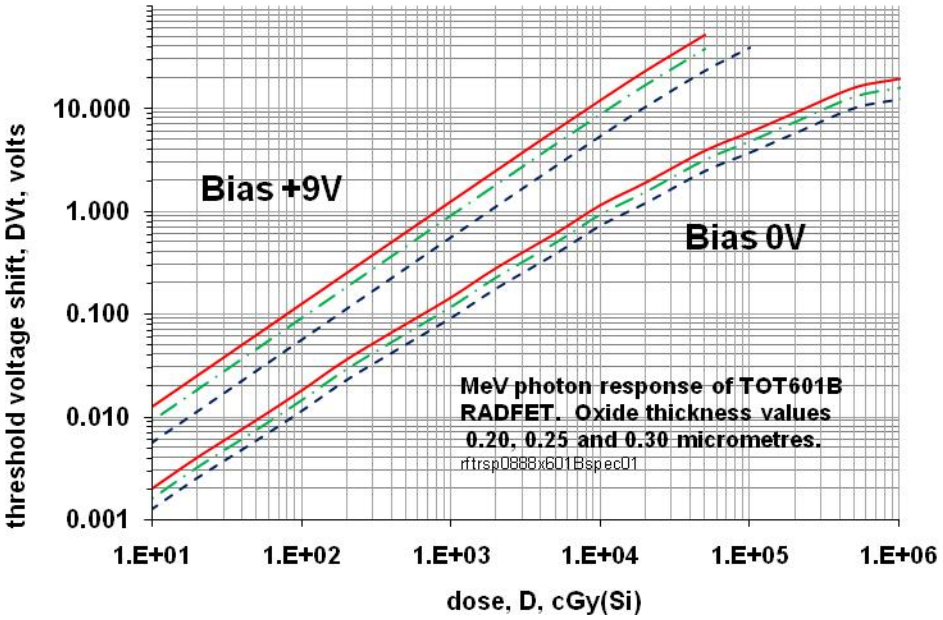
- Charge collection plates mounted close to cover to maximize solid angle (~50%)
- Side shielding added to reduce "background" electrons
- Collected signal ~10 pA for 3.8-cm dia. charge plate

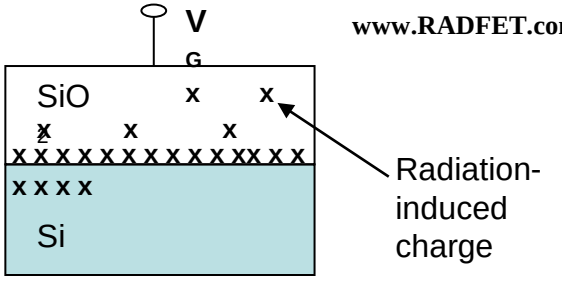




RadFET Response

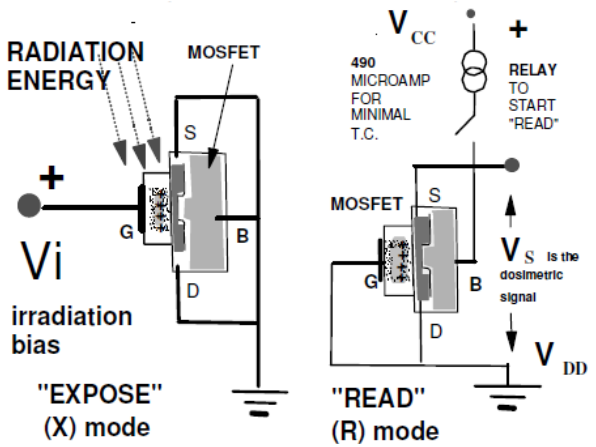
- **RadFETs are p-MOSFET transistors with thickened gate oxide region**
- **Radiation-induced charge in the insulated gate oxide (SiO2) region remains trapped**
- **Induced charge produces a threshold voltage shift vs. dose**
- **Thicker oxide region increases sensitivity; thinner one increases dynamic range**
- **LET response; Not overly affected by dose rate or particle species**
- **Long-term fade (self-annealing) is potentially a calibration issue, but may be less of a problem if operated cold**

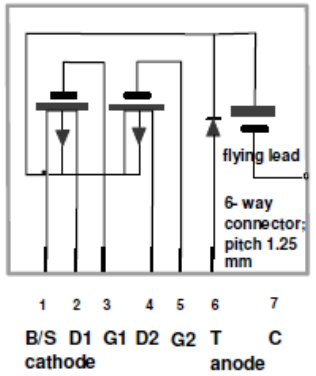




RadFET Operation

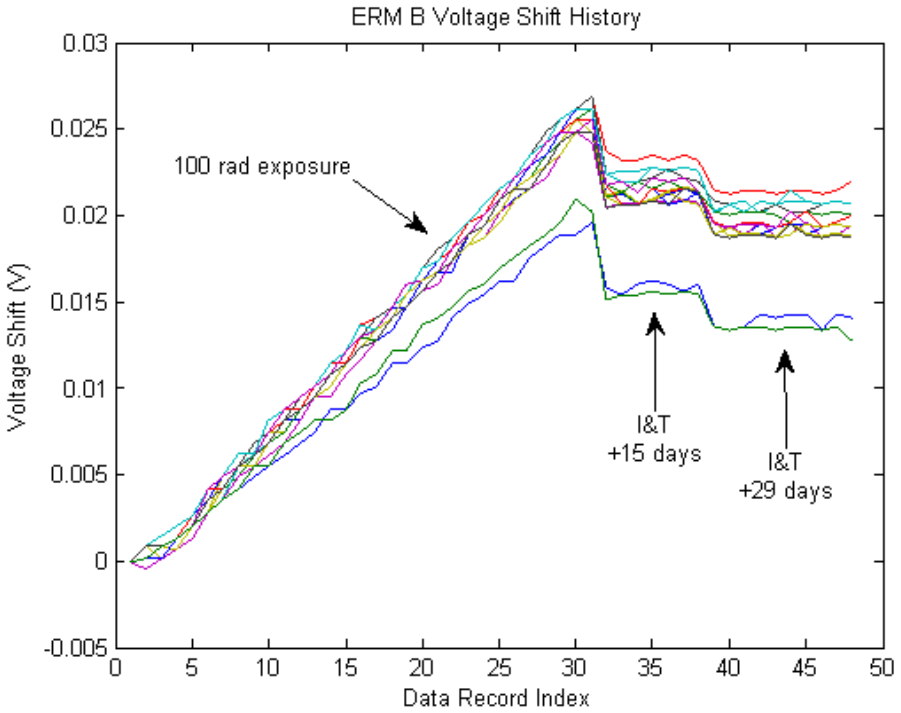
- **RadFET biased at 0V during exposure**
  - **Calibration accurate when powered off**
  - **Extends dynamic range to 1 Mrad w/ 30V supply**
  - **Response less linear than if biased**
- **Source pin connected to constant current source during read cycle**
  - **Read time kept to ~1% duty cycle to maintain calibration**
  - **Readings captured at 1 and 2 sec following application of bias to characterize “drift up” effect**
  - **Readings at two different currents to measure device gain**
  - **On-chip diode used to monitor die temp**
- **Everything changes with dose! Careful calibration required**
  - **All devices from same lot**
  - **EM unit can be used for additional ground calibrations post-launch**

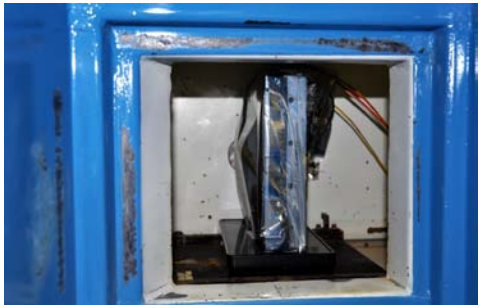




Calibration

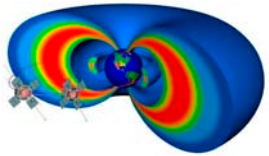
- Each flight unit irradiated w/o cover to expose all RadFETs
- Spread between bench-mounted RadFETs is +/- 5%.
- Initial data can be used to improve die-to-die matching and reduce spread further
- Long-term fade is clearly a cal issue for unbiased RadFETs at room temperature; Colder operation may help
- Low dose-rate test in progress using EM (60-day test at expected mission dose rate)
- Tests w/ particle beams planned next summer



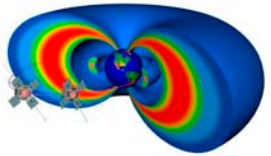


ERM-A in Co-60 Irradiator

Other Uses



- Possible uses of ERM data by the SWG



Backup

Block Diagram