Single Event Effects (SEEs) Specification Approach

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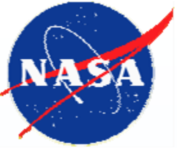
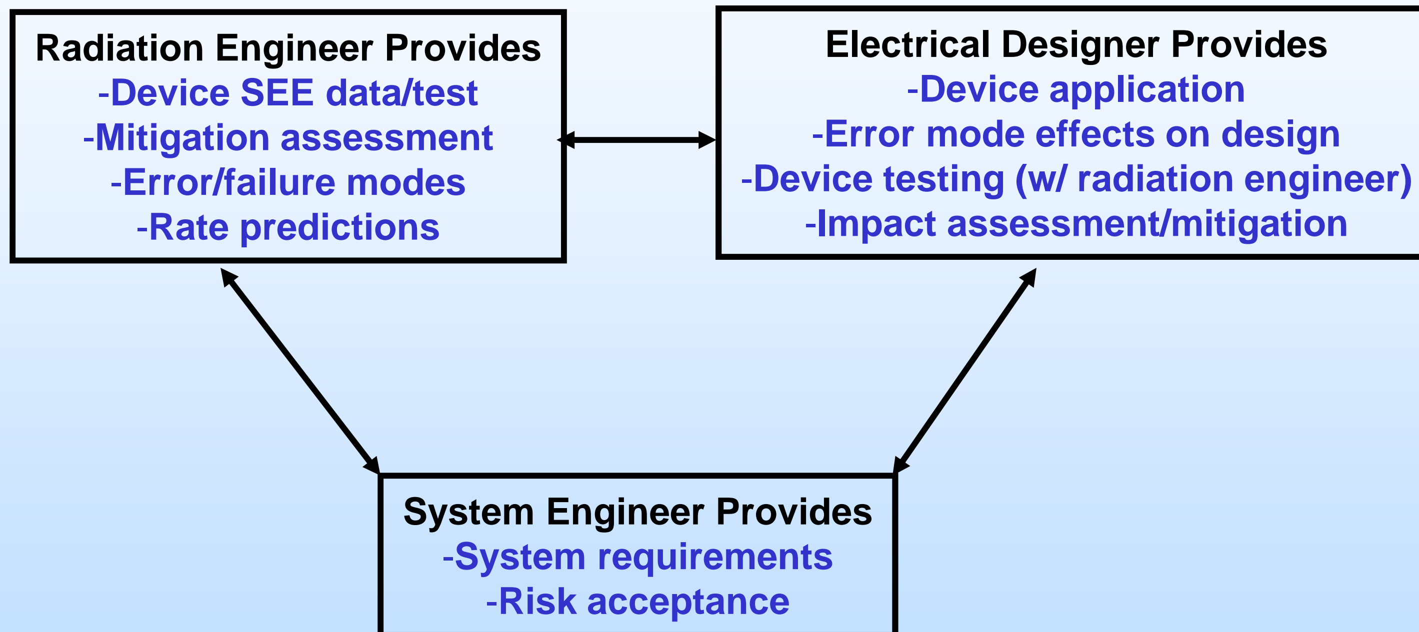
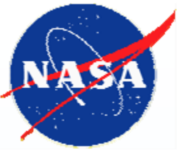


System Requirements - SEE Specifications

- For TID, parts can be given A number (with margin)
  - SEE is much more application specific
- SEE is unlike TID
  - Probabilistic events, not long-term
    - Equal probabilities for 1st day of mission or last day of mission
      - Maybe by definition!

Radiation Assurance Design Process - SEE





Sample Single Event Effects Specification (1 of 3)

1. Definitions and Terms

Single Event Effect (SEE) **- any measurable effect to a circuit due to an ion strike. This includes (but is not limited to) SEUs, SHEs, SELs, SEBs, SEGRs, and Single Event Dielectric Rupture (SEDR).**

Single Event Upset (SEU) **- a change of state or transient induced by an energetic particle such as a cosmic ray or proton in a device. This may occur in digital, analog, and optical components or may have effects in surrounding interface circuitry (a subset known as Single Event Transients (SETs)). These are "soft" errors in that a reset or rewriting of the device causes normal device behavior thereafter.**

Single Hard Error (SHE) **- an SEU which causes a permanent change to the operation of a device. An example is a stuck bit in a memory device.**

Single Event Latchup (SEL) **- a condition which causes loss of device functionality due to a single event induced high current state. An SEL may or may not cause permanent device damage, but requires power strobing of the device to resume normal device operations. Latent damage concern must be addressed for all SEL sensitive devices.**

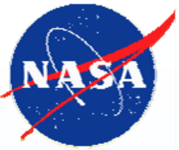
Single Event Burnout (SEB) **- a condition which can cause device destruction due to a high current state in a power transistor.**

Single Event Gate Rupture (SEGR) **- a single ion induced condition in power MOSFETs which may result in the formation of a conducting path in the gate oxide.**

Multiple Bit Upset (MBU) **- an event induced by a single energetic particle such as a cosmic ray or proton that causes multiple upsets or transients during its path through a device or system.**

Linear Energy Transfer (LET) **- a measure of the energy deposited per unit length as a energetic particle travels through a material. The common LET unit is MeV*cm^2/mg of material (Si for MOS devices, etc.).**

Onset Threshold LET (LET_{th0}) **- the maximum LET at which no effect is observed at a particle fluence of 1E7 ions/cm^2(per JEDEC). Typically, a particle fluence of 1E5 ions/cm^2 is used for SEB and SEGR testing.**



Single Event Effects Specification (2 of 3)

2. Component SEU Specification

2.1 No SEE may cause permanent damage to a system or subsystem.

2.2 Electronic components shall be designed to be immune to SEE induced performance anomalies, or outages which require ground intervention to correct. Electronic component reliability shall be met in the SEU environment.

2.3 If a device is not immune to SEUs, analysis for SEU rates and effects must take place based on LET_{th} of the candidate devices as follows:

Device Threshold	Environment to be Assessed
LET_{th} < 20* MeV*cm²/mg	Cosmic Ray, Trapped Protons, Solar Proton Events
LET_{th} = 20*-100⁺ MeV*cm²/mg	Galactic Cosmic Ray Heavy Ions, Solar Heavy Ions
LET_{th} > 100 ⁺ MeV*cm²/mg	No analysis required

2.4 The cosmic ray induced LET spectrum which shall be used for analysis is given in Figure TBD.

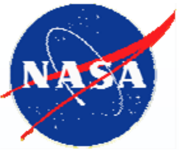
2.5 The trapped proton environment to be used for analysis is given in Figures TBD. Both nominal and peak particle flux rates must be analyzed.

2.6 The solar event environment to be used for analysis is given in Figure TBD.

2.7 For any device that is not immune to SEL or other potentially destructive conditions, protective circuitry must be added to eliminate the possibility of damage and verified by analysis and test. Latent damage must be addressed.

This number is somewhat arbitrary and is applicable to "standard" devices. Some newer technologies may require this number to be higher.

⁺A LET of 37 may be used for more risk accepting missions



Single Event Effects Specification (3 of 3)

2. Component SEU Specification (Cont.)

2.8 For SEU, the *criticality* of a device in it's specific application must be defined into one of three categories: error-critical, error-functional, or error-vulnerable. Please refer to the /radhome/papers/seecai.htm Single Event Effect Criticality Analysis (SEECA) document for details. A SEECA analysis should be considered at the system level.

2.9 The improper operation caused by an SEU shall be reduced to acceptable levels. Systems engineering analysis of circuit design, operating modes, duty cycle, device criticality etc. shall be used to determine acceptable levels for that device. Means of gaining acceptable levels include part selection, error detection and correction schemes, redundancy and voting methods, error tolerant coding, or acceptance of errors in non-critical areas.

2.10 A design's resistance to SEE for the specified radiation environment must be demonstrated.

3. SEU Guidelines

Wherever practical, procure SEE immune devices. SEE immune is defined as a device having an LET_{th} > 100 MeV*cm^2/mg.

If device test data does not exist, ground testing is required. For commercial components, testing is recommended/required on the flight procurement lot.

Notes on System Requirements

- **Requirements do NOT have to be for piecepart reliability**
  - **For example, may be viewed as a “data loss” specification**
    - **Acceptable bit error rates or system outage**
  - **Mitigation and risk are system trade parameters**
  - **Environment needs to be defined for *YOUR* mission (can’t use prediction for different timeframe, orbit, etc…)**