Overview of Space Project LET Requirements

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Outline

- Environmental requirements in space projects
  - GEO : Operator and/or Satellite Manufacturer requirements
  - LEO - MEO : examples of requirements for CALIPSO (CNES) and GALILEO (ESA)
- Descriptions of SEE
- SEE requirements in Test Methods standards
- LET & SEE requirements in RHA Plan in space projects
  - GEO : Operator and/or Satellite Manufacturer
  - LEO - MEO : examples of requirements for CALIPSO (CNES) and GALILEO (ESA)
- Particular case of destructive events : reliability

GEO : Satellite Manufacturer

- HEAVY IONS GALACTIC COSMIC RAYS

Satellite Manufacturer	Model	Parameters
ASTRIUM [EUR3-SP-5060-MMT] 29/11/2001	CREME	Shielding : 1 gm/cm², Earth Shadow : yes Magnetosphere = quiet, Ion species : 1 < Z < 92, M=3
US 1	CREME	M=1
Alcatel Alenia Space	CREME - OMERE	Shielding : 1 gm/cm², Earth Shadow : yes Magnetosphere = quiet, Ion species : 1 < Z < 92, M=3
US 2	CREME	M=3
US 3	CREME	Shielding : 100 mils Aluminium, M=3
US 4	CREME	Shielding : 1 gm/cm², M=3

GEO : Satellite Manufacturer

- HEAVY IONS SOLAR FLARE

Satellite Manufacturer	Model	Parameters
ASTRIUM [EUR3-SP-5060-MMT] 29/11/2001	CREME	Shielding : 1 gm/cm², Earth Shadow : yes Magnetosphere = quiet, Ion species : 1 < Z < 92, M=8
US1	CREME	M=9, anomalously large solar flare generates peak flux lasting 6 hours. The heavy ion portion of the solar flare environment is affected by shielding. The increased flux through 100 mils and 300 mils of aluminium shielding as a result of anomalously large solar flares
Alcatel Alenia Space	Not considered	Only solar proton peak flux (Oct. 89 is considered)
US2	CREME	Anomalously large event behind 100 mils and 300 mils of aluminium shielding.
US3	MACREE	Model on October 1989 solar Flare.
US4	Not considered	Only solar proton peak flux (Oct. 89 is considered)

LEO – MEO : examples of requirements CNES (CALIPSO) and ESA (Galileo)

HEAVY IONS GALACTIC COSMIC RAYS

Space Agency	Model	Parameters
CNES (CALIPSO)	CREME - OMERE	M=3 – Polar orbit
ESA (GALILEO)	CREME 96	Quiet – The nominal solar minimum cosmic ray flux. Shielding : 1 gm/cm².

HEAVY IONS SOLAR FLARE

Space Agency	Model	Parameters
CNES (CALIPSO)	CREME - OMERE	No requirement
ESA (GALILEO)	CREME 96	Worst week : the average flux for a “worst week” Peak 5 minutes : the peak flux

Definition of Single Event Effects

- Non destructive event
  - Single Event Upset (SEU)
    - SEU is defined as a bit-flip in a bi-stable element, caused by charge collection in a sensitive circuit node of that cell after the transition of a heavily ionizing particle
  - Single Event Transient (SET)
    - Temporary change in output signal due to strike by heavy ions. Linear (analog) Integrated Circuits in bipolar technology can show this effect. The signal change in most cases is a voltage spike but with components like Pulse Width Modulators also changes in output signal frequency or duty cycle can occur. The sensitivity to SET is strongly dependent on the circuit the device is used in.

Definition of Single Event Effects

- Destructive event
  - Single Event Burnout (SEB)
    - Is defined as the breakdown and subsequent burnout of the parasitic bipolar transistor inherent in a power MOSFET resulting from a heavy ion hit of this parasitic transistor. Since the effect is basically an avalanche breakdown, only N-channel MOSFETs are affected. The effect is strongly dependent on the drain to source voltage.
  - Single Event Gate Rupture (SEGR)
    - This effect is the direct breakdown and subsequent rupture of the gate dielectric of a power MOSFET along the track of a heavy ion hit: The ionization density along this track is extremely high, which effectively represents a conducting plasma filament. So a current sufficiently high to destroy the dielectric starts flowing between the gate electrode and the transistor channel. The effect depends strongly both on drain to source as well as gate to source voltage, because of the superposition of both related electrical fields.

Definition of Single Event Effects

- Destructive event
  - Single Event Latch-up (SEL)
    - Is defined as the heavy ion induced firing of a parasitic structure exhibiting negative differential resistance inherent in some monolithic integrated circuits technologies. This causes uncontrolled increase of device currents which may lead to device burnout.
  - Other effects
    - Single Event Hard Errors (SHE)
    - Single Event Functional Interrupt (SEFI)

SEE requirements in Test Methods standards

- ASTM F-1192 - Standard Guide for the Measurement of Single-Event Phenomena from Heavy Ion Irradiation of Semiconductor Devices.
- EIA/JESD57 - Test Procedures for the Measurement of Single-Event Effects in Semiconductor Devices from Heavy Ion Irradiation.
- SINGLE EVENT EFFECTS TEST METHOD AND GUIDELINES ESCC Basic Specification No. 25100 ISSUE 1 October 2002

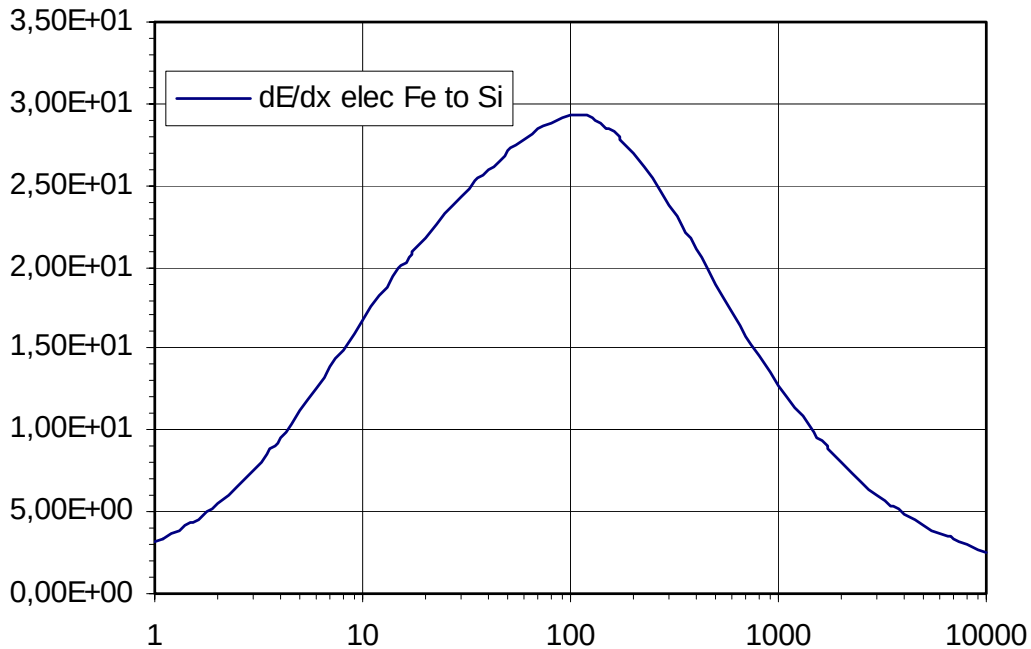
SEE requirements in Test Methods standards

- Tests methods are applicable
  in the Space Projects RHA requirements
- Final Goal
  - To obtain the SEE cross section versus LET curve with sufficient data points to have an accurate description of the complete curve with the LETth (threshold value) and the saturated cross section (σsat)
  - What is the LET value requirement ?
    - No requirement in [ASTM F-1192] and [ESCC N°25100]
    - **2 x LET required for the cross-section to saturate** and if this level is not possible, data should be taken up to **120 MeV.cm^2/mg**, as deposited in the sensitive volume **[EIA/JESD57]**

SEE requirements in Test Methods standards

- Other parameters
  - LET value is linked to Energy :
    - Influence of energy : LET value is not constant along the ion path

Then the range is
an important parameter



SEE requirements in Test Methods standards

- Other parameters
  - LET value is linked to range :
    - Range of ions : it's important to reach the sensitive node (volume) in order to trigger the SEE. The range or penetration of ion is important for SEL and SET.
      - Typically 30 µm [ESCC N°25100]
      - Some test requirements specify an ion range > 30 µm [ASTM F-1192]
  - Fluence :
    - Fluence level required to establish that an observance of no SEE corresponds to an acceptable upper bound on the upset cross section with a given confidence.
      - a fluence of 10^7 ions/cm^2 will often meet these requirements [ASTM F-1192]
      - For an insensitive device to accumulate a fluence of at least 10^7 ions/cm^2 for a sensitive device [ESCC N°25100]

LET & SEE requirements in RHA Plan in space projects

- SEU : non destructive

Satellite Manufacturer	SEU requirements
ASTRIUM [EUR-SPM-00000-0002-MMT] 19/12/2000	Irradiation must be performed up 100 MeV/mg/cm^2 . Categorization methodology. LET(SEP)th > 100 MeV/mg/cm^2 is not sensitive to SEP. SEU rate calculation.
US 1	No LET requirement. SEU rate calculation. Specifications provided if the total upset error rate of all digital IC that could cause critical (traffic perturbations, intervention of ground..) conditions.
Alcatel Alenia Space	No LET requirement. SEU rate calculation and effects must be analyzed (acceptable total upset rate are provided in the unit and system specifications)
US 2	No LET requirement. SEU rate calculation. Out of specification : no more than once per 300 years
US 4	No LET requirement. SEU rate calculation. Out of specification : no more than once per 3000 years

LET & SEE requirements in RHA Plan in space projects

- SEL, SEB, SEGR, SHE : destructive effects

Satellite Manufacturer	SEE requirements
ASTRIUM	SEL, SEB, SEGR sensitive part use shall be justified with a technical report providing : full device cross section versus LET curve (up to LET of **100 MeV.cm2/mg)**. All Destructive Single Event Effects could be acceptable only if the equivalent Destructive Single Event Failure Rate is 10 times lower than the **intrinsic reliability failure** rate of the part as defined in MILHDBK217.
US 1	SEL or SHE for Linear Energy Transfer (LET) of up to **100 MeV/mg/ cm2.**
Alcatel Alenia Space	SEL, SEB, SEGR sensitive part use shall be justified with a technical report providing : full device cross section versus LET curve (up to LET of **60 MeV.cm2/mg**). The sub-Contractor shall demonstrate the compliance to mission requirements in terms of reliability. All Destructive Single Event Effects could be acceptable only if the equivalent Destructive Single Event Failure Rate is 10 times lower than the **intrinsic reliability failure** rate of the part (@ 25°C).
US 2	No LET requirement. The unit level permanent SEE damage rate requirement is part of the unit's **reliability requirement in FITs**.
US 4	No LET requirement. Parts susceptible to destructive effects shall not be used, or the rate of destructive events shall be less than the device **reliability failure rate** and the destructive rate shall be included in the reliability analysis (I < 1 FIT for SEB and SEGR)

LEO - MEO : examples of requirements CNES (CALIPSO) and ESA (Galileo)

SEU : non destructive

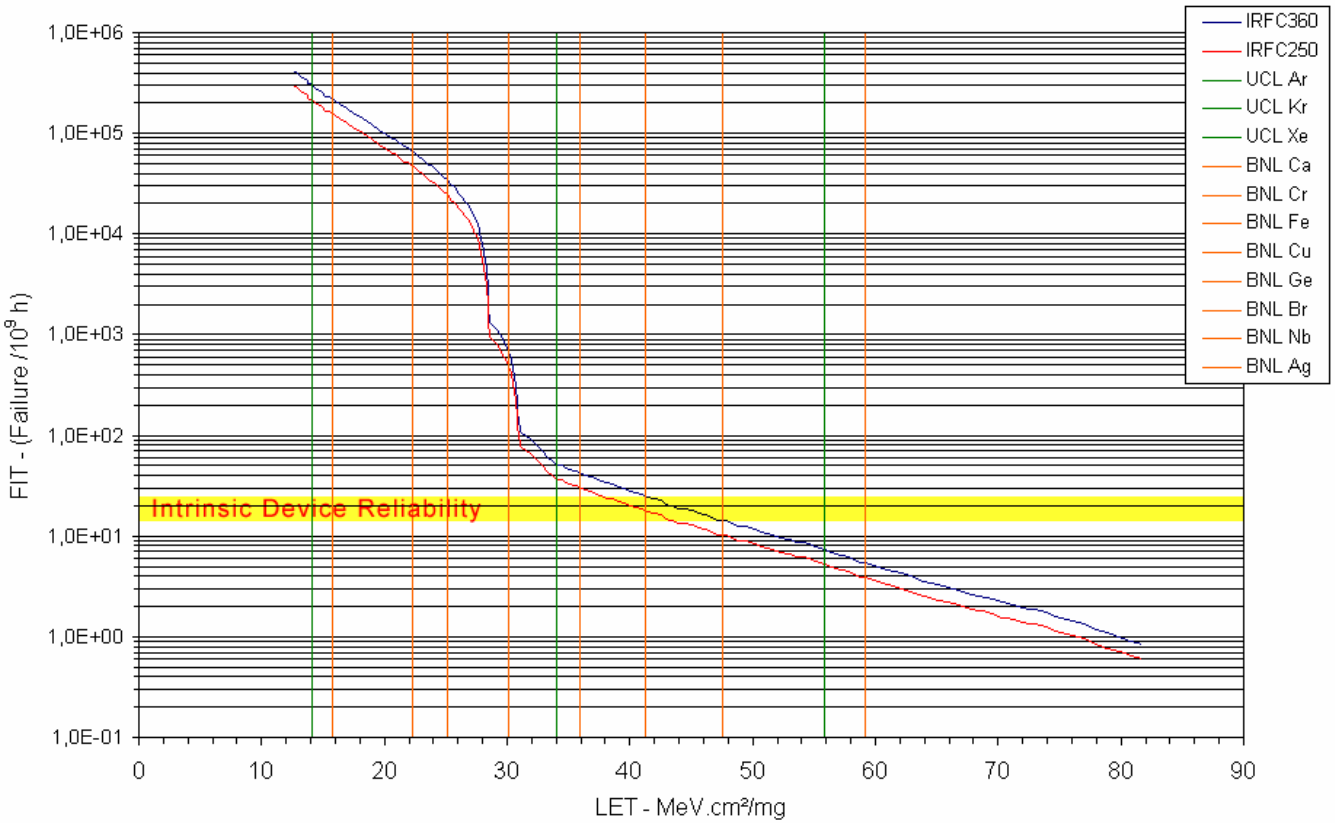
Space Agency	SEU requirements
CNES (CALIPSO)	Functionality requirement.
ESA (GALILEO)	Irradiation must be performed up **100 MeV/mg/cm^2 .** Categorization If LET < 70 MeV/mg/cm^2 : no further action. SEU rate calculation.

SEL, SEB, SEGR, SHE : destructive effects

Space Agency	SEU requirements
CNES (CALIPSO)	Destructive Single Event Failure Rate is 10 times lower than the intrinsic reliability failure
ESA (GALILEO)	Irradiation must be performed up **100 MeV/mg/cm^2 .** Categorization If LET < 70 MeV/mg/cm^2 : no further action. The sub-Contractor shall demonstrate the compliance to mission requirements in terms of reliability. All Destructive Single Event Effects could be acceptable only if the equivalent Destructive Single Event Failure Rate is 10 times lower than the **intrinsic reliability failure** rate of the part (@ 25°C).

LET impact for destructive events - A case study

- It is a reliability concern and event rate is then converted in FITs



Conclusions

Let’s go to the round table . . .

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