In flight observed Single Event Effects
Introduction

- Necessity to assess the system robustness against space radiation environment induced effects
  - Total Ionising and Non Ionising Dose calculation (TID, TNID also called Displacement Damage), Single Event Effects (SEE)
- This is possibly done for SEE through Space radiation environment modelling together with error rate prediction
  - Use of static models representing dynamic events
    - Very often, a “potentiometer” is integrated in the model (confidence level for JPL91 or ESP, weather index for CREME86...)
    - Prediction calculation process uses some hypothesis (sensitive volume definition for example)
- Comparing predicted error rates with in flight ones is a mean to acquire confidence in the applied process.
Case under study

- Observed Single Event Upsets (SEU) rates recorded on a SRAM are compared to predicted ones.

- Such device is protected by an EDAC (Error Detection and Data Correction), and cyclic scrubbing is performed. Therefore, SEUs have no consequence on equipment functionality.

- Device has been fully characterised for SEU at ground level (heavy ion and proton SEE testing).

- In orbit observation period represent more than 20 years.
Radiation ground characterization 1/2

- Heavy ion SEE test data are available
Protons test data are available as well, up to a proton energy of 60 MeV
Specified heavy ion models are obtained thanks to CREME86 with the “M” weather index set to 3 for GCR and 8 for Solar Ions.
Specified flare proton models are based either on October 89 or August 72 flare.

On top of flare protons, galactic proton model from CREME96 has been used.
In flight observation of SEUs

- More than 100 SEUs recorded, averaged SEU rate is about $10^{-9}$/bit.day
SEU rate prediction method

- SEU rate prediction performed, using radiation environment models presented in previous slides
  - OMERE tool used
  - Sensitive volume assimilated to a parallelepiped whose thickness is 2 µm
  - Heavy ion Test data fitted by Weibull function
  - Proton test data fitted by Bendel 2 parameters function

- SEU rate obtained in this configuration is about 10^{-8} SEU/bit.day
  - Specified rate is one order of magnitude above observed rate, even though proton SEE testing is potentially not conservative.
First example, LET value influence on testing data

- Case 1: LET up to 112 MeV.cm\(^2\)/mg (tilted device),
- Case 2: 2 last data point removed, LET up to 55.9 MeV.cm\(^2\)/mg, new fit

SEU rates obtained with such characterization curves are

- About 7 \(10^{-11}\) SEU/bit.day for the first case
- About 4 \(10^{-11}\) SEU/bit.day for the second case
Second example, LET value influence on LET spectrum (M=3)

- Case 1: LET spectrum up to 100 MeV.cm²/mg
- Case 2: LET spectrum up to 60 MeV.cm²/mg
- Case 3: LET spectrum up to 30 MeV.cm²/mg
- Case 4: LET spectrum up to 10 MeV.cm²/mg
- Case 5: LET spectrum up to 1 MeV.cm²/mg

SEU rates obtained with case 1 testing data and such spectra are:

- About 7 \times 10^{-11} \text{ SEU/bit.day} for cases 1 to 3
- About 5 \times 10^{-11} \text{ SEU/bit.day} for case 4
- About 1 \times 10^{-12} \text{ SEU/bit.day} for case 5
Conclusion

- When using specified models, SEU rates are in this case overestimated by about one order of magnitude.

- About the LET influence
  - When removing the high LET test data point, the impact on SEU rate is a decrease of about 40%.
  - From the second example, it turns out that contribution of heavy ion whose LET is above 30 is negligible regarding SEU rate.
    - 40% decrease observed in the first case is due to the modification of the fitting function in the very low LET values (< 5 MeV.cm²/mg) regardless that testing data are unchanged.
LET influence - follow on

- SEU rates obtained with 1/ full spectrum, 2/ LET < 15 MeV.cm²/mg
  - 1/ \(8 \times 10^{-6}\) SEU/bit.day \(1.65 \times 10^{-7}\) SEU/bit.day
  - 2/ \(7.6 \times 10^{-6}\) SEU/bit.day \(1.34 \times 10^{-7}\) SEU/bit.day