3rd RADECS Thematic Workshop on "Single Event Transient" January 29th 2009

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SET rate prediction Critical issues – Realistic assumptions

All the space you need

EADS astrium

Content

- SET rate prediction : test data set reliability
- SET rate prediction : use of test data
- SET rate predictions: the dispersion
- SET rate prediction: influence of the environment
- Conclusion

Introduction

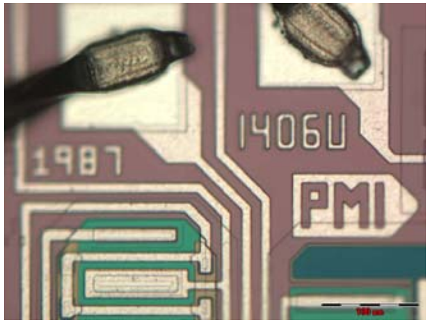
- For Single Event Transient (SET), the baseline of Radiation Hardness Assurance (RHA) approach shall be the analysis of the effect of a SET on equipment performance: it shall be demonstrated that a SET will not produce equipment out of specification.

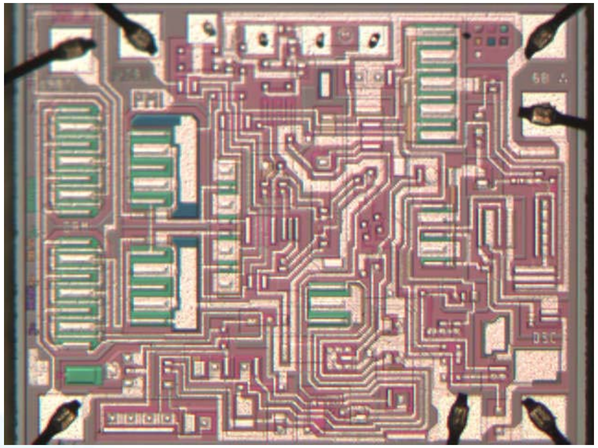
- However, in some cases, countermeasure by design can be difficult and it can then necessary to perform SET rate predictions

- The trust we put in these predictions relies on several aspects
  - Reliability of test data set
  - Hypothesis taken during SET rate calculation process
  - Radiation environment models…

SET rate prediction : test data set reliability 1/4

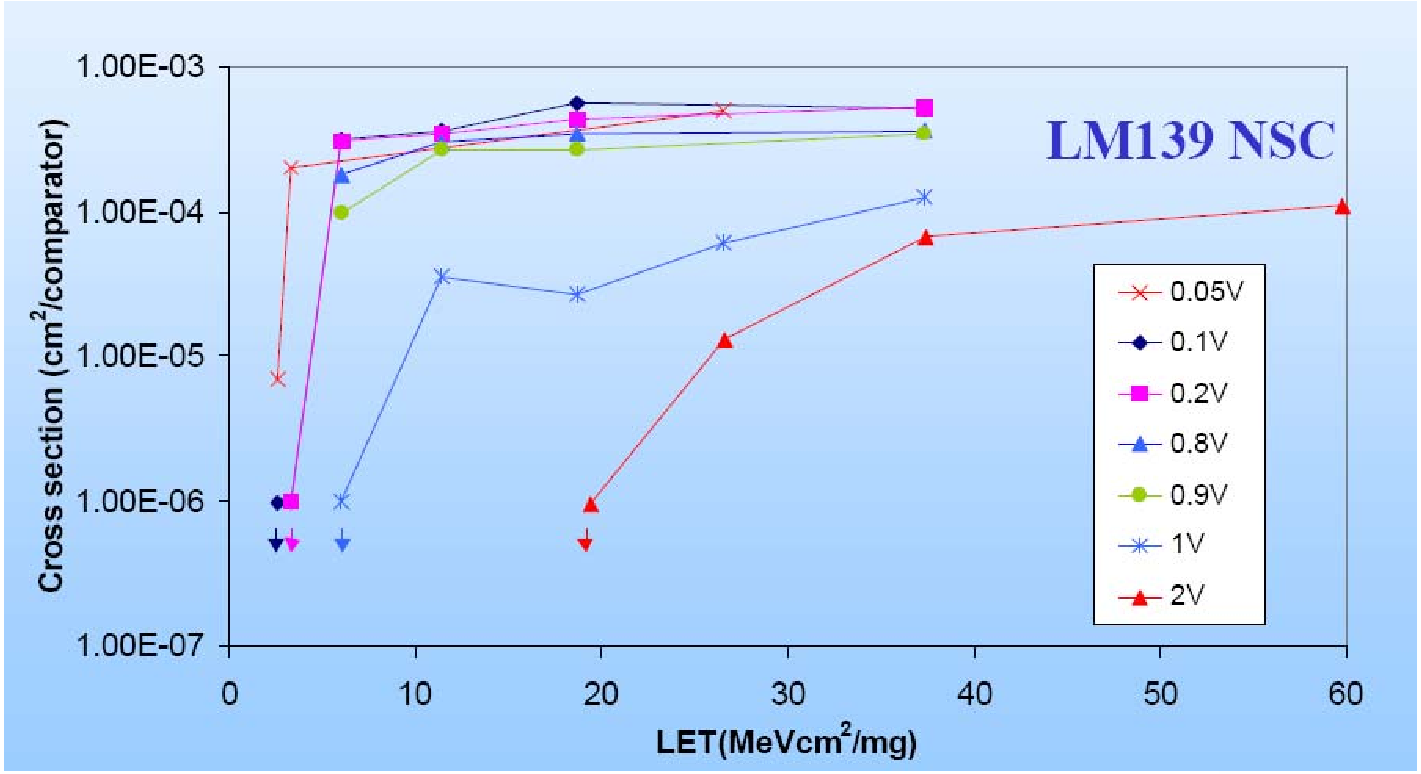
- To predict SET rate implies that ground test data are available
- First step is to insure that the test data are reliable
  - To insure that tested device is « identical » to the one that is going to fly
  - To insure that tested application is “identical” to the one that is going to fly
  - To insure that measured SET corresponds to event that will trigger outage
- Device traceability
  - Identical manufacturer and reference number is not enough





SET rate prediction : test data set reliability 2/4

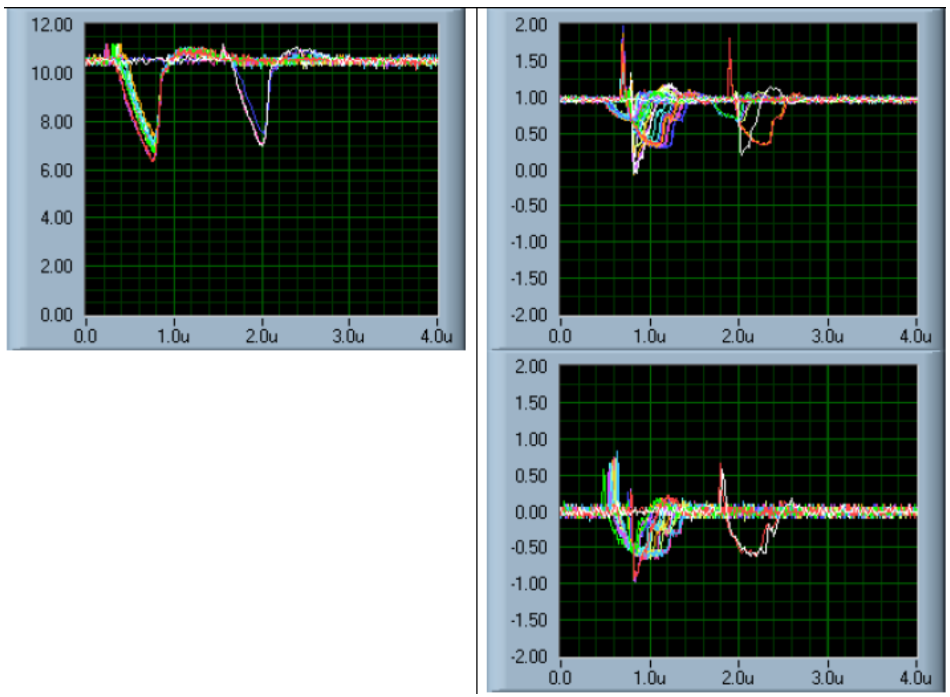
- Bias conditions have a significant effect on device sensitivity to SET

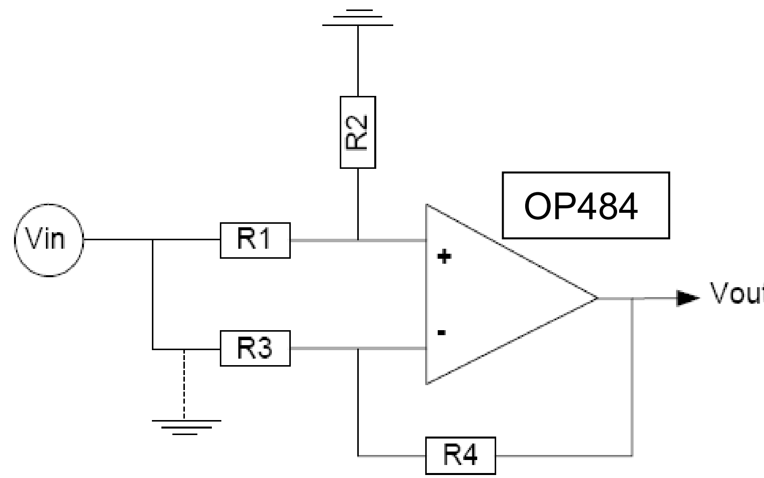


Buchner et al, 2002

SET rate prediction : test data set reliability 3/4

- Bias/operating conditions also have a significant influence on SET waveform and duration





Amp N°	*function*
1	Follower G=1
2	Follower G=1
3	Non inverting G=11
4	Inverting G=-10

SET rate prediction : test data set reliability 4/4

- For a given application condition, different SET waveform of various duration can occur
  - Probably not all of observed SET can trigger an outage

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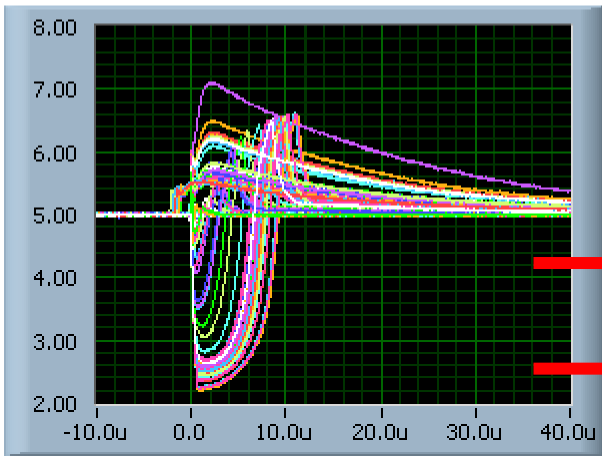
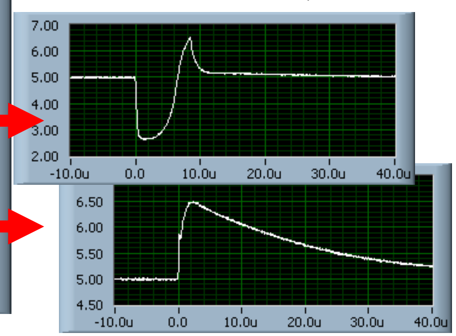
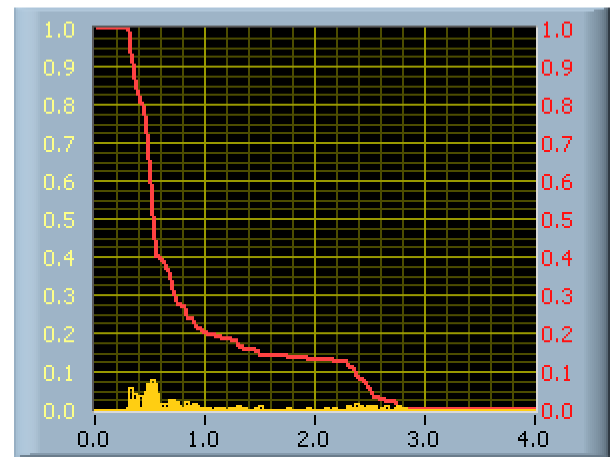


Cumulative plot of transients





Statistical repartition vs amplitude

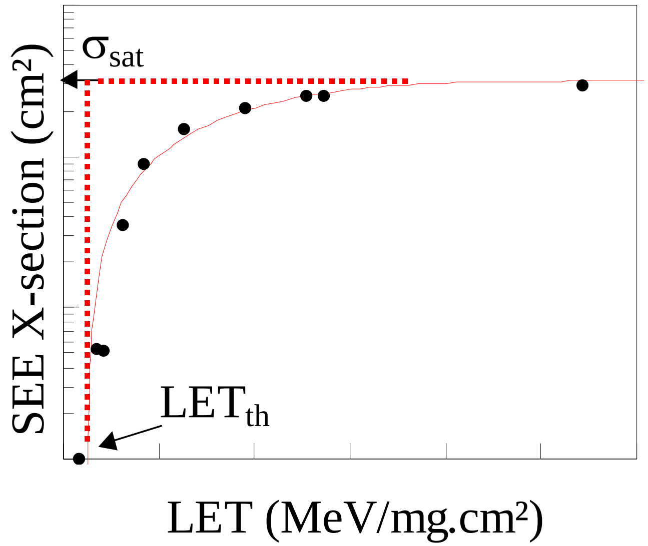
⇒ All this parameters strongly affect calculated SET rate

- SET testing outputs will likely be the CS curve that measures the LET-dependent sensitive area of the chip.

$$\sigma\left(LET\right) = \frac{Number\ of\ events}{Fluence}$$

$(units\ of\ cm^2)$

Protons => $\sigma(E_p)$



- Most of the devices exhibit a LET_{th} < 15 $MeV.cm^2/mg$
  - Are they sensitive to proton induced SET?

SET rate prediction : use of test data 2/5

- Not systematically
  - Example 1: Operational amplifier
    - Heavy ion SET test results
    - Proton SET test results

SET

σ sat (cm²)

LET th (Me

S

W (MeV cm

Transients characteristics

Ampl

Dura

X-section

1E-8 cm²	All transients
8E-9 cm²	Positive transients
<1E-10 cm²	Transient > 2V

Transients characteristics

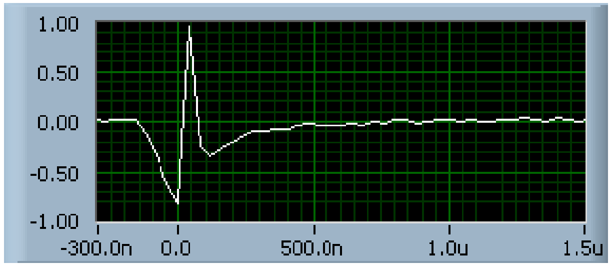
Amplitude	< 400mV Mean 150-200mV
Duration	2µs (positive) 4µs (negative)

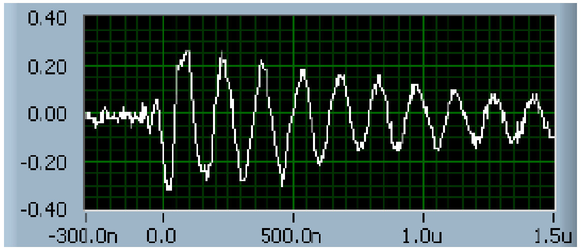
SET rate prediction : use of test data 3/5

– Example 2: high speed amplifier

– Heavy ion

***σ sat** (cm²)*	9,00E-05
***LET th** (MeV cm²/mg)*	7
S	1,4
***W** (MeV cm²/mg)*	42
Transient Characteristics	
Amplitude	-2.2V/+1V
Duration	1µs





– proton

SET	Not SENSITIVE up to 190MeV

SET rate prediction : use of test data 4/5

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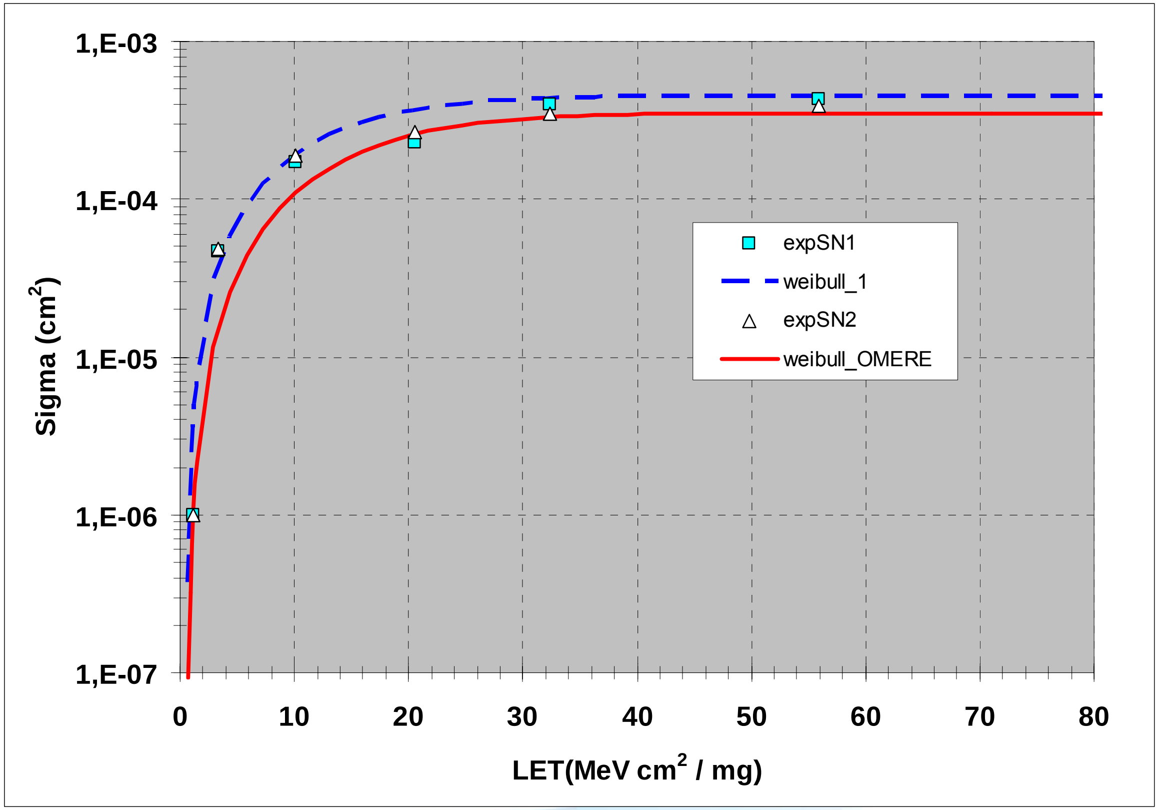
- Use of cross section curve
  - How do we use it: Weibull fitting?

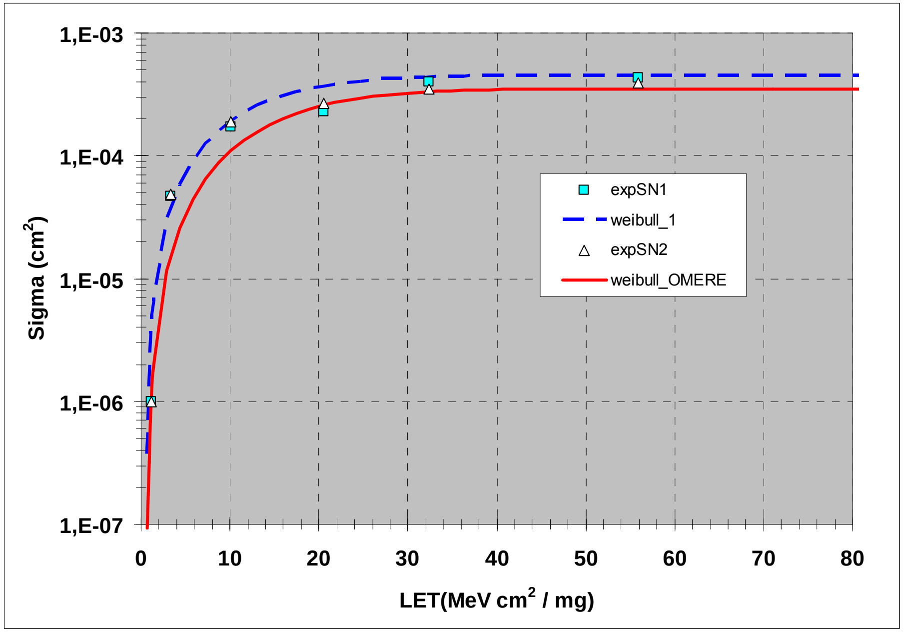


SET rate prediction : use of test data 5/5

- Other parameters to define
  - Number of nodes that constitute the sensitive area
    - Difficult to estimate, is variable with device type
      - Potential solution to determine it is to perform a laser mapping of the device
    - Assuming the sensitive area is a unique node will provide conservative rates
  - Thickness of the sensitive depth
    - It is expected that SET phenomenon is a “deep” one; as an example, NASA GSFC Testing Guidelines for Single Event Transient (SET) Testing of Linear Devices recommends to take an averaged value of 10 µm

SET rate predictions: the dispersion 1/4

- Variation of the SET rate
  - With weibull fit nature



	SET rate (/device/day)	Calculation conditions
Weibull 1	$3.3\ 10^{-3}$	Node x1 ; SET amplitude 1 ; depth 2µm ; GCRISO
Weibull 2	$1.6\ 10^{-3}$	Node x1 ; SET amplitude 1 ; depth 2µm ; GCRISO

SET rate predictions: the dispersion 2/4

- Variation of the SET rate
  - With sensitive depth

	SET rate (/device/day)	Calculation conditions
Depth 2µm	$3.1\ 10^{-3}$	Weibull1 ; Node x1 ; SET amplitude 1 ; GCRISO
Depth 10 µm	$3\ 10^{-3}$	Weibull1 ; Node x1 ; SET amplitude 1 ; GCRISO
Depth 30 µm	$2.6\ 10^{-3}$	Weibull1 ; Node x1 ; SET amplitude 1 ; GCRISO
Depth 50 µm	$2.3\ 10^{-3}$	Weibull1 ; Node x1 ; SET amplitude 1 ; GCRISO

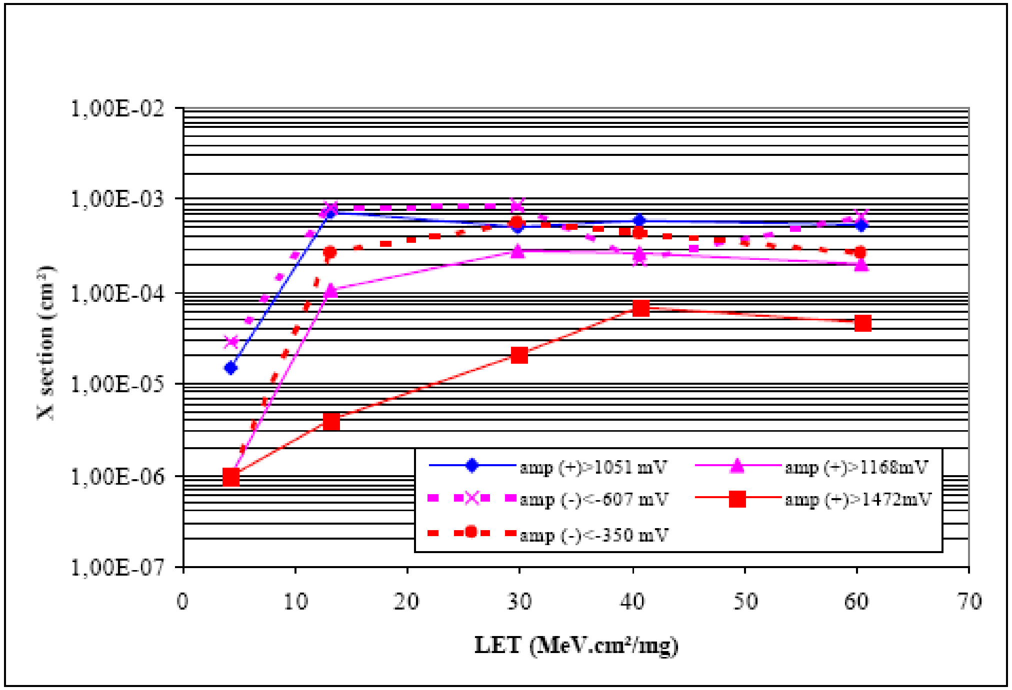
SET rate predictions: the dispersion 3/4

- Variation of the SET rate
  - With sensitive nodes quantity

	SET rate (/device/day)	Calculation conditions
Nodes x10	3.1 10^{-3}	Weibull1 ; SET amplitude 1 ; depth 2µm ; GCRISO
Nodes x25	3 10^{-3}	Weibull1 ; SET amplitude 1 ; depth 2µm ; GCRISO
Nodes x50	2.9 10^{-3}	Weibull1 ; SET amplitude 1 ; depth 2µm ; GCRISO
Nodes x10	1.3 10^{-3}	Weibull1 ; SET amplitude 1 ; depth 50µm ; GCRISO
Nodes x25	9.2 10^{-4}	Weibull1 ; SET amplitude 1 ; depth 50µm ; GCRISO
Nodes x50	6.7 10^{-4}	Weibull1 ; SET amplitude 1 ; depth 50µm ; GCRISO

SET rate predictions: the dispersion 4/4

- Variation of the SET rate
  - With SET amplitude



conditions
utput voltage = 33mV
utput voltage = 3.3V

SET rate prediction: radiation environment definition

- Topic not specific to SET, however to be also considered when performing SET rate prediction

- From in flight experience, we see that up to now almost all of the observed events are due to Galactic Cosmic Rays (GCR) (see also TAS presentation, this thematic day)

- However, when SET has an impact on a function of an equipment that can lead to a mission outage, prediction shall consider the various contributors of the radiation environment
  - GCR and Solar Particle Event (using the most “reasonable” model)
  - Trapped and Solar protons if device exhibit a sensitivity to proton induced upsets

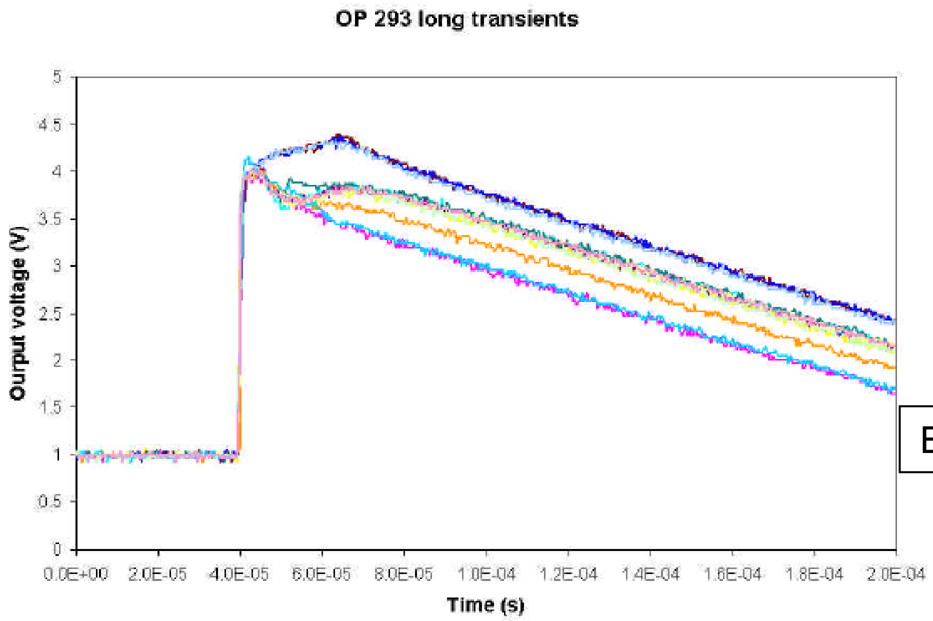
SET rate prediction: influence of the environment

- Variation of the SET rate

	SET rate (/device/day)	Calculation conditions
GCRISO sol min	$3.3\ 10^{-3}$	Node x1 ; SET amplitude 1 ; depth 10µm ; Weibull 1
CREME86 M=1 sol min	$2.9\ 10^{-3}$	
CREME86 M=8	1.5	

Conclusion 1/2

- Baseline of RHA for SET remains a design responsibility. However, in some cases SET rate prediction can be needed
  - Trade of between design countermeasure and risk linked to SET occurrence rate not in favour of design solution
  - Use of uncharacterized device in a critical function; some devices may exhibit very long transient duration



Buchner, 2002

Conclusion 2/2

- When performing SET rate prediction, one shall take care of
  - The reliability of the SET ground test data
    - Traceability of the device and the function/application
    - **Adequacy of SET threshold**
  - The reliability of calculation hypothesis
    - Fitting function used (if any)
    - Sensitive depth determination
    - Number of sensitive nodes
  - The definition of the radiation environment
    - Solar flare model for heavy ions
    - The particle type that can trigger a SET, for the considered application (need to include proton calculation?)