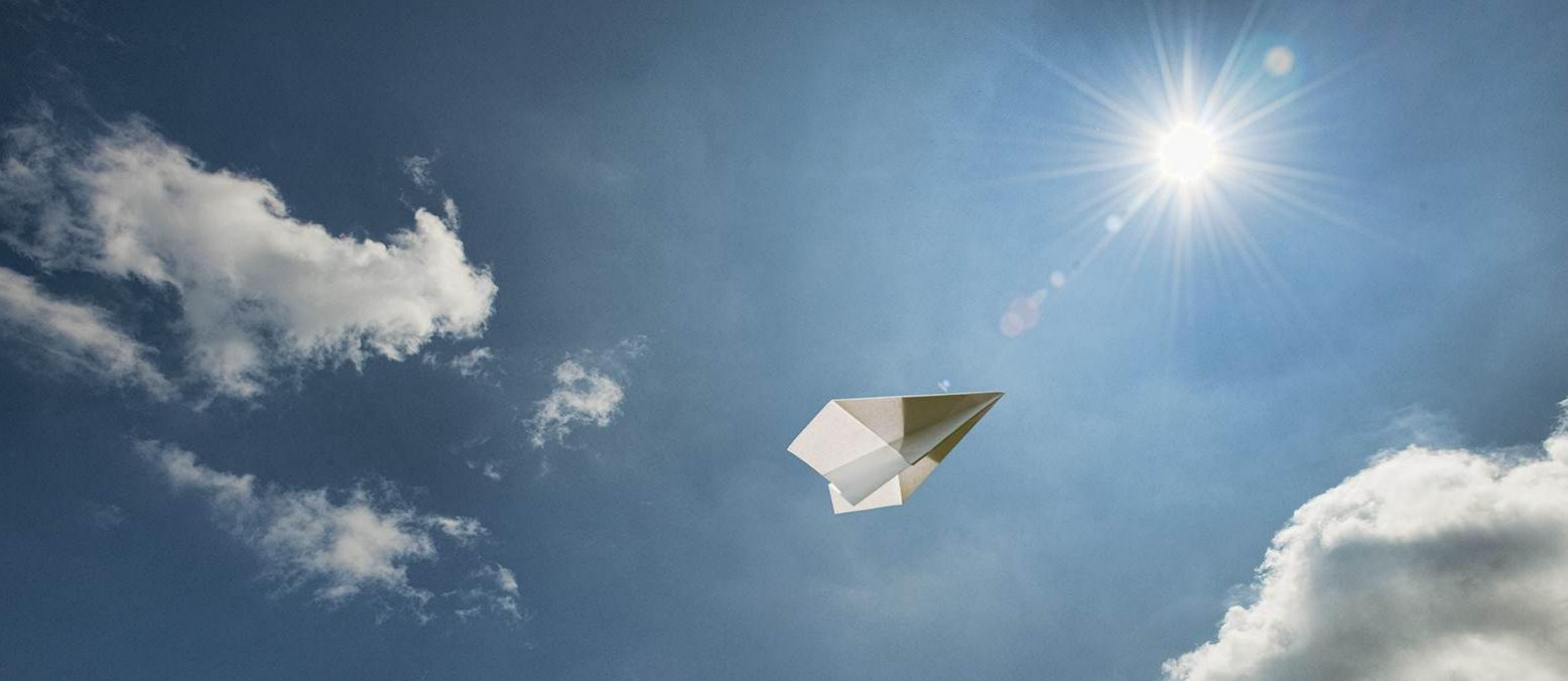


Application of two wavelengths laser testing for SETs prediction

Presented by Sébastien Morand, Airbus Defence and Space

Acknowledgment

- Cecile Weulersse,
- Florent Miller,
- Thierry Carrière,
- Renaud Mangeret.

Context

Inputs required for the prediction of analog SET rate	

Inputs required for the prediction of analog SET rate

- Heavy ion cross-section characteristics (depend on device biasing, circuit configuration, SET critical domain)
- Radiation environment for the mission
- RPP calculation (OMERE*…) based on
  - **a number of sensitive volumes**
  - their **thickness**

Challenges

- No determination of the number of sensitive volumes (SV) and their thickness by radiation tests in accelerators (large beams).
- Assumptions are currently made to ease the SER definition (typical values: 2 µm of thickness & 1 SV sensitive volume) .

How to better determine these 2 parameters ?

*http://trad.fr/OMERE,14.html

Context

1. Two wavelengths laser test
2. Determination of SET sensitive thicknesses
3. Heavy ion SER calculation
4. Conclusion

Two wavelengths laser test
Principle

- If λ < 1.1 µm, then laser generates charges in silicon by photoelectric process

- Laser loss of energy
  Beer-Lambert law (neglecting 2e order terms)

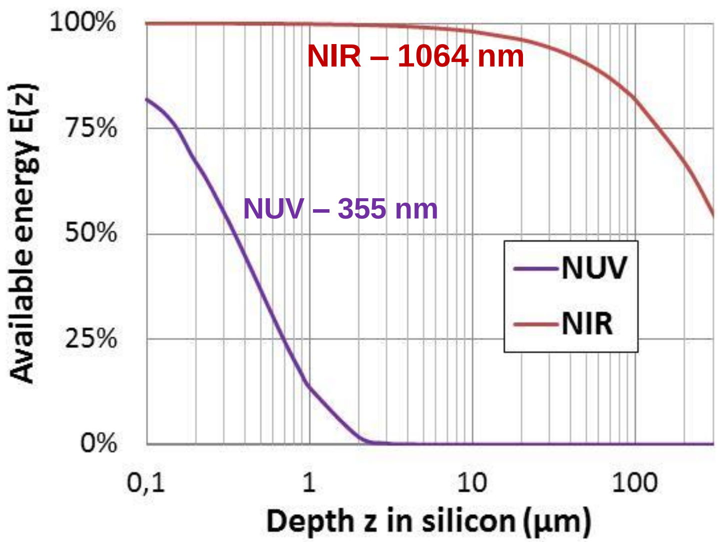
$$E(z) = E(0).\exp(-\alpha.z)$$
$$dE/dz = -\alpha.E(z)$$

- Previous study (2006) using **850 nm < λ < 1064 nm** for the estimation of the sensitive **depth***

➔ Using one laser with a large penetration depth and another one with a low penetration depth to determine the thickness of SET sensitive volumes

Near UV and Near IR laser beam properties (silicon)

	NUV	NIR
Wavelength	355 nm	1064 nm
Pulse duration	350 ps	600 ps
Quantum efficiency	0.2	1
Optical absorption α	~20 000 cm^{-1}	~20 cm^{-1}
Penetration depth	~0.5 µm	~500 µm



*C. Weulersse *et al*, "Probing SET Sensitive Volumes in Linear Devices Using Focused Laser Beam at different wavelengths," IEEE TNS, 2007.

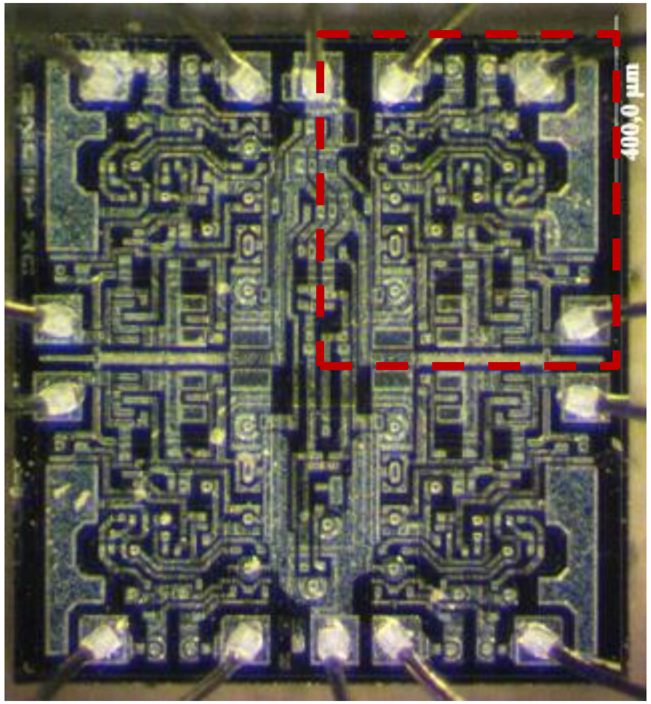
RADLAS 2017

Two wavelengths laser test
Test case: LM124 Operational Amplifier

Laser tests parameters

- **Threshold energy mapping**
- SET threshold: 150 mV amplitude.
- Objective magnification: x100
- Mapping size: 540 µm x 740 µm (1 Op. Amp)
- Mapping step size: 6 µm

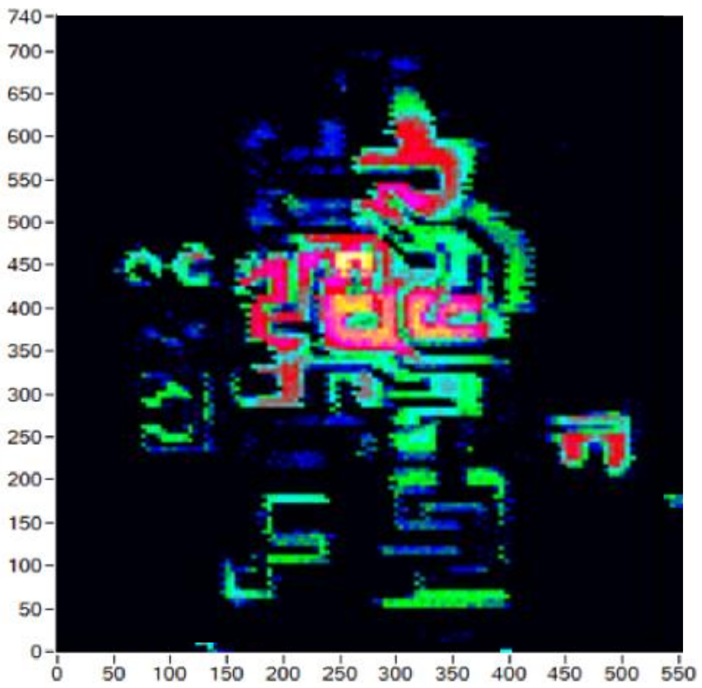
Parameter	Value
Circuit	Follower
Gain	1
$+V_{cc} - V_{cc}$	+15 V -15 V
V_{in}	0 V
DC load	50 Ohms



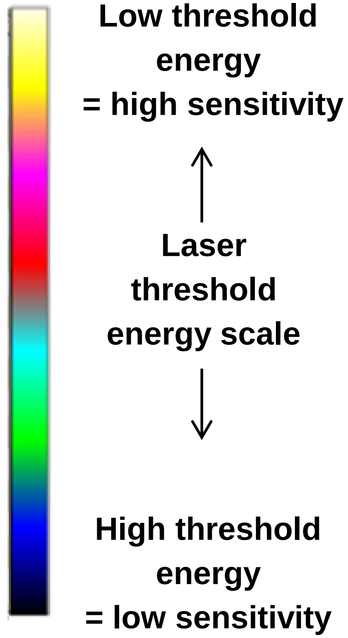
RADLAS 2017

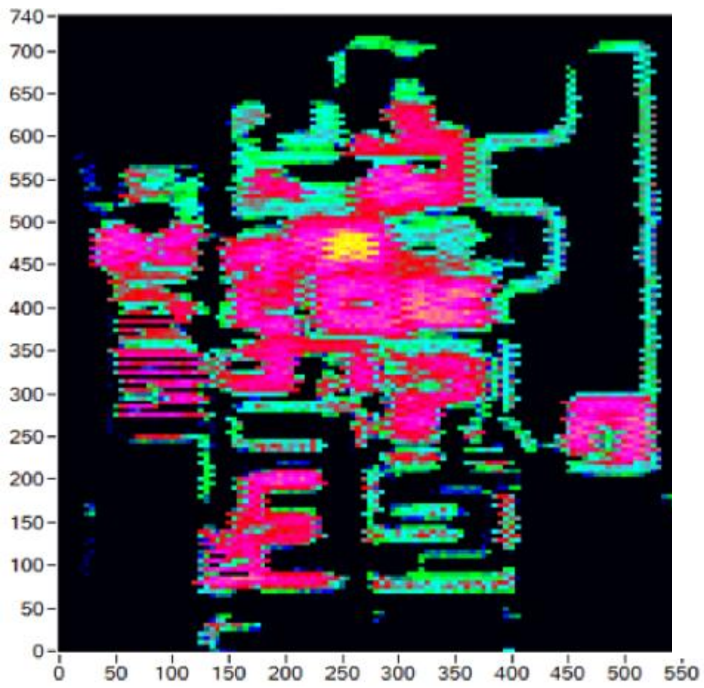
Two wavelengths laser test
Comparison of NUV and NIR threshold mapping (frontside)

not similar color scale (different energy)



NIR SET mapping





NUV SET mapping

Observations

- NIR & NUV laser could not cross metallization
- Similar surface sensitivity
- No missing area of sensitivity during NUV testing

➔ All sensitive volumes should start from the surface, no buried ones.

RADLAS 2017

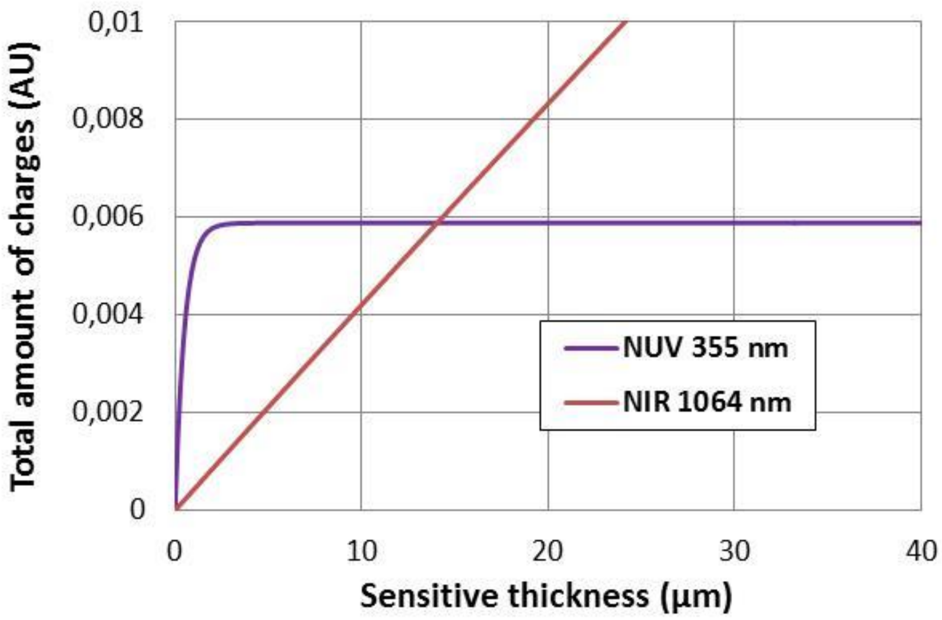
Determination of SET sensitive thicknesses Methodology

Thickness extraction

- At threshold, quantity of generated charges is equal

$$n_{IR} = n_{UV}$$
$$n_{IR} = k_{IR} \times (1 - \exp(-\alpha_{IR} z))$$
$$n_{UV} = k_{UV} \times (1 - \exp(-\alpha_{UV} z))$$

- By knowing the threshold energy for both wavelengths, a graphical solving can determine the z thickness for which $n_{IR} = n_{UV}$

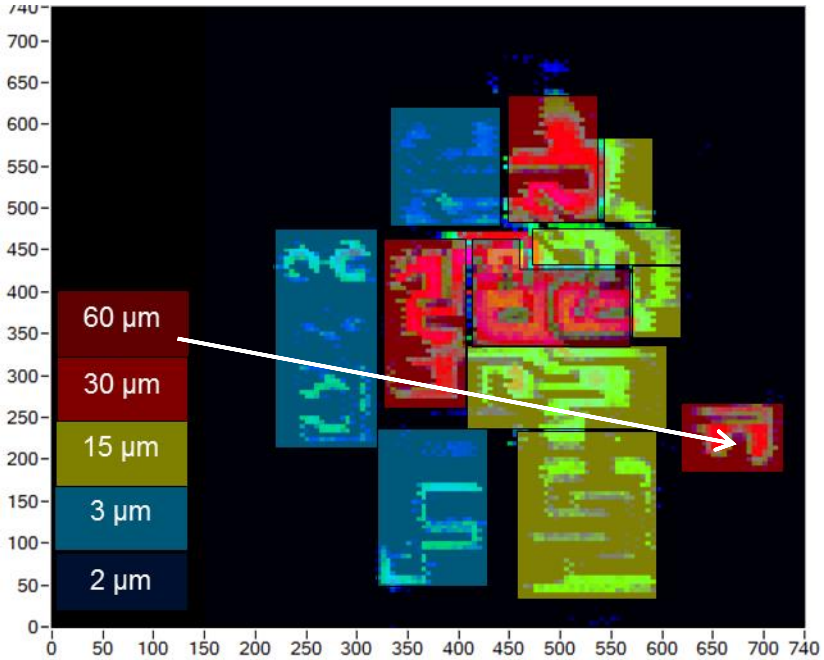


➔ Each sensitive volume presents a non-zero thickness value that equals the 2 carrier generation quantities.

RADLAS 2017

Determination of SET sensitive thicknesses
Results

The extraction of each sensitive volume is based on the laser threshold energy obtained during NUV and NIR laser tests.

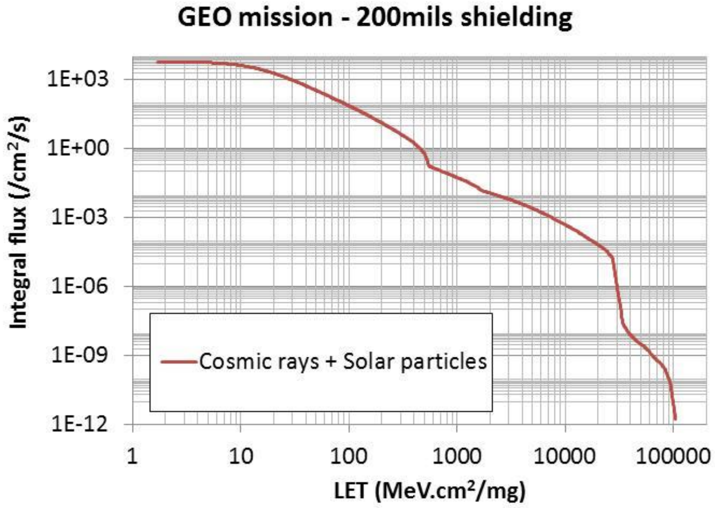


➔ The thickness of 10 sensitive volumes have been determined from 2 µm up to 60 µm, approximated by rectangular shape.

➔ 10 Weibull fits have been defined using the heavy ion SET cross-section.

RADLAS 2017

Heavy ion SER calculation



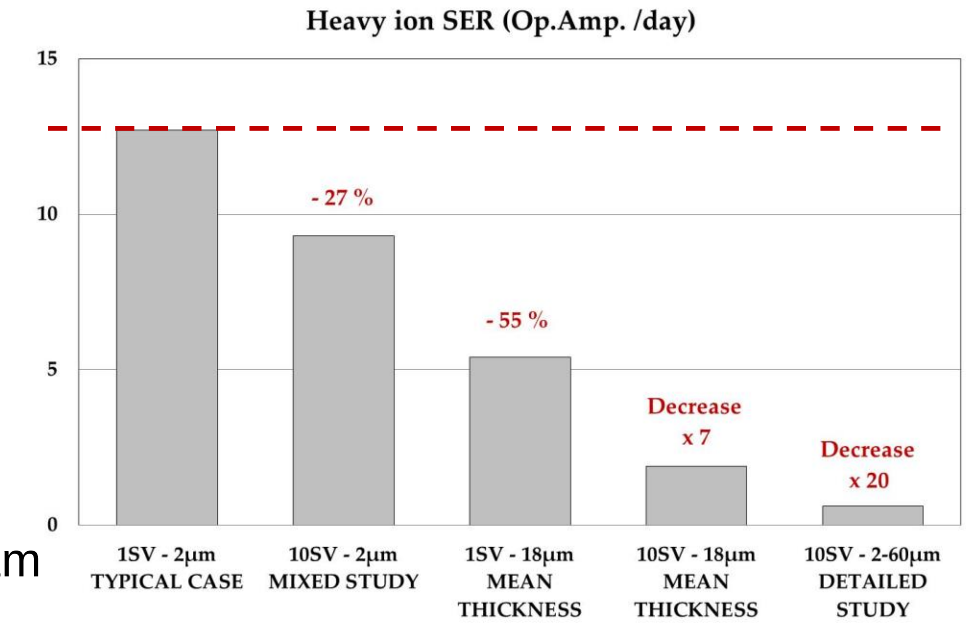
SER using OMERE* tool

- GEO mission, 200 mils shielding
- Cosmic rays, CREME96, solmin.
- Solar particles, CREME96

worst case 7 days (heavy ions)

Calculation strategies

- Conventional approach: 1 SV - 2 µm
- Mean thickness: 10 SV - 18 µm
- Mixed studies:
  - 10 SV - 2µm
  - 1 SV - 18 µm
- Detailed study: 10 SV – from 2 to 60 µm



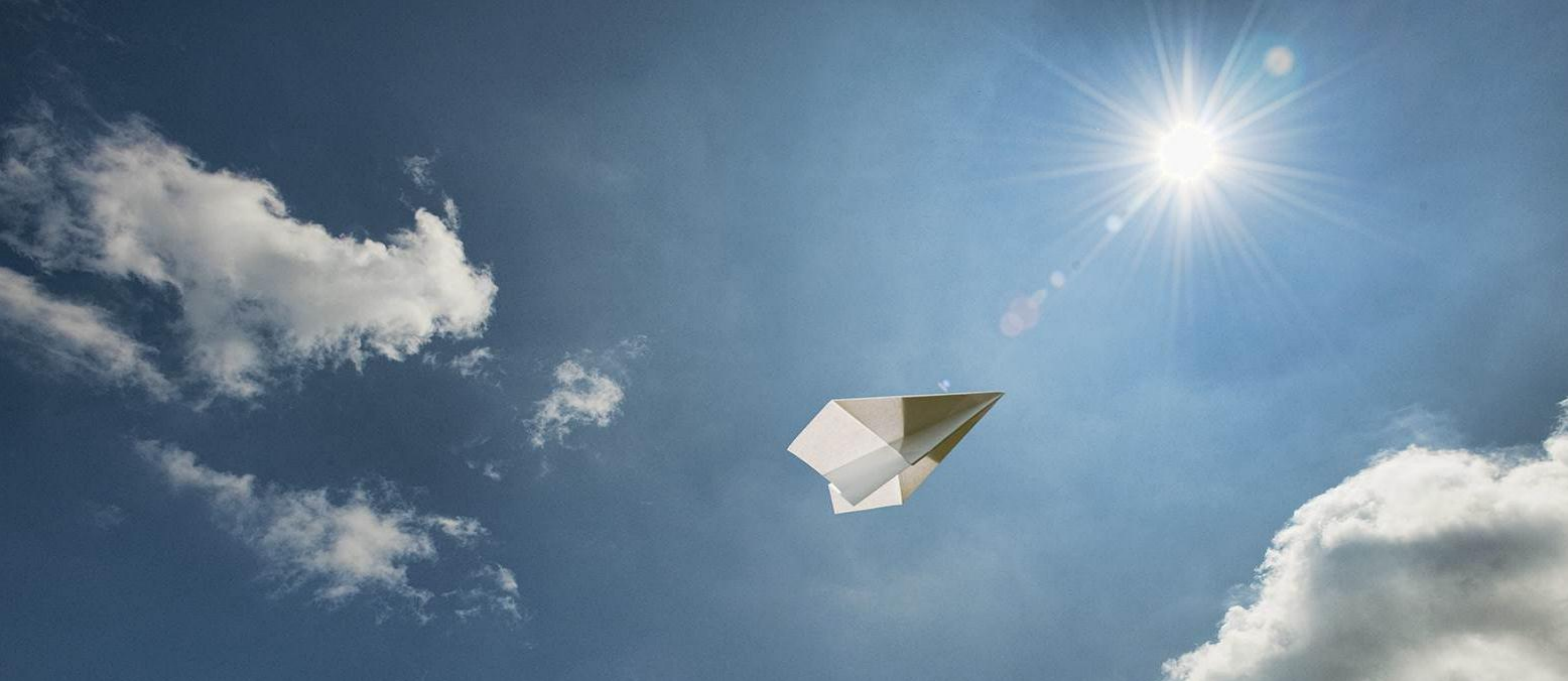
➔ Significant impact (decrease by a factor of 20) of the detailed analysis
➔ Conventional approach confirmed as conservative

*http://trad.fr/OMERE,14.html

RADLAS 2017

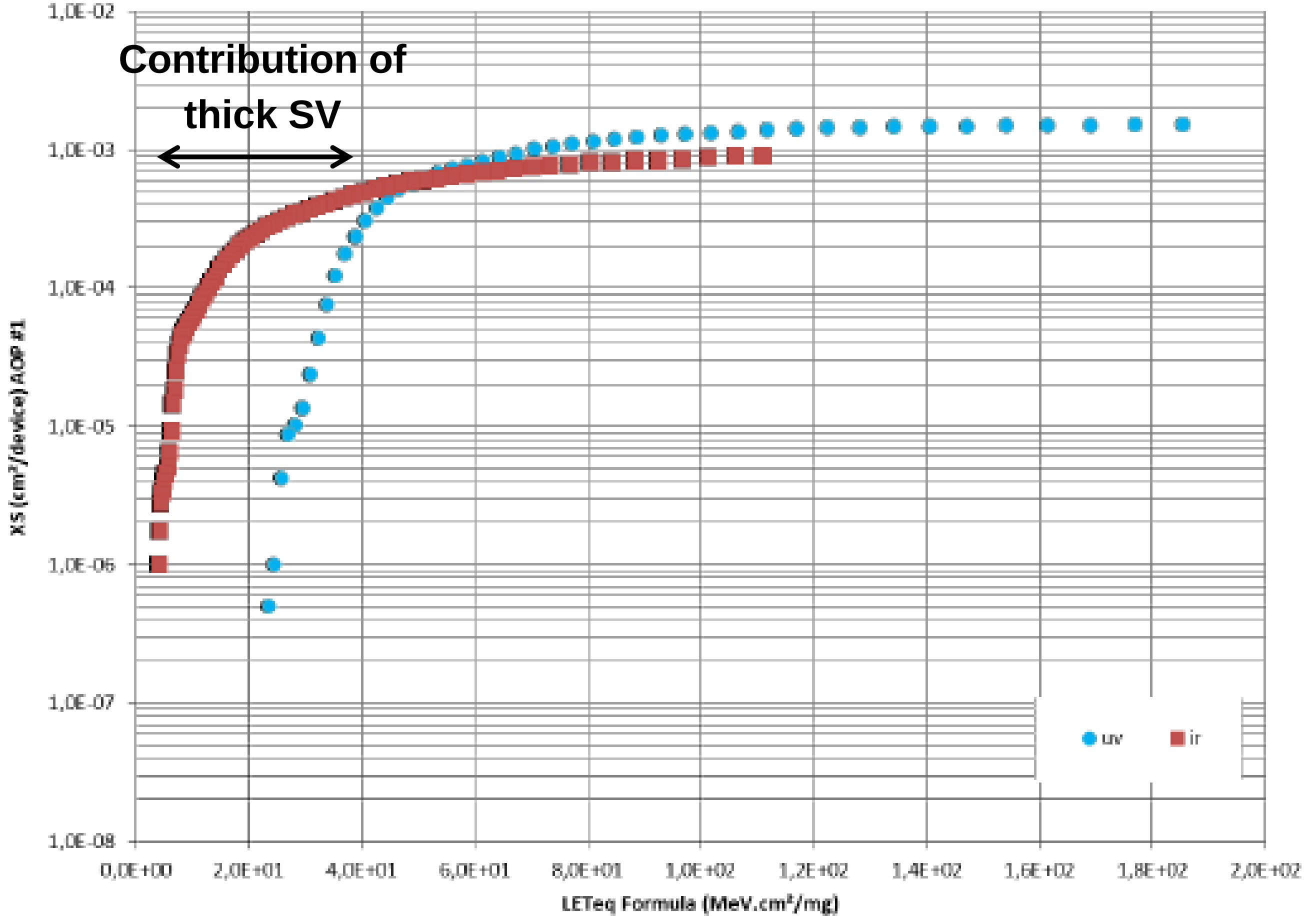
Conclusion

- Laser testing at different wavelengths allows the determination of the sensitive thicknesses inside a linear component.
- Interest in UV wavelengths (when testing from the frontside)
- The thickness values are consistent with previous studies (Airbus Group / CNES 2006)
- For SER calculation, the detailed analysis reveals the conservative approach currently used.
- Margin refinement can be achieved by testing with laser at two wavelengths and by using multiple sensitive volumes in a Soft Error Rate prediction tool.



Thank you.

BACK-UP


Contribution of thick SV
1,0E-02
1,0E-03
1,0E-04
1,0E-05
1,0E-06
1,0E-07
1,0E-08
XS (cm²/device) AOP #1
0,0E+00
2,0E+01
4,0E+01
6,0E+01
8,0E+01
1,0E+02
1,2E+02
1,4E+02
1,6E+02
1,8E+02
2,0E+02
LETeq Formula (MeV.cm²/mg)
uv
ir

Heavy ion SER calculation Methodology

10 elementary volumes - Weibull fit on the SET cross-section

$$\Sigma_0 \times (1 - exp(-(\frac{L-L_0}{W})^S))$$

	Xs_{sat} (cm^2)	LET_{th}	W	S	Thickness (µm)
total	8.2×10^{-4}	0.6	9.7	1.4	2
SV 1	1.3×10^{-4}	4.8	6	1.3	3
SV 2	8.7×10^{-5}	4.8	6	1.3	3
SV 3	1.3×10^{-4}	3.8	9	1.7	15
SV 4	9.2×10^{-5}	3.1	4	1,.1	15
SV 5	3.6×10^{-5}	1.9	7	1.2	30
SV 6	7.9×10^{-5}	3.1	7	1	15
SV 7	6.5×10^{-5}	1.2	3	1,1	30
SV 8	7.3×10^{-5}	19.3	3	0,5	2
SV 9	7.3×10^{-5}	1.5	3	1,1	30
SV 10	6.6×10^{-5}	0.6	2	1,1	60