



CENTRE NATIONAL D'ÉTUDES SPATIALES

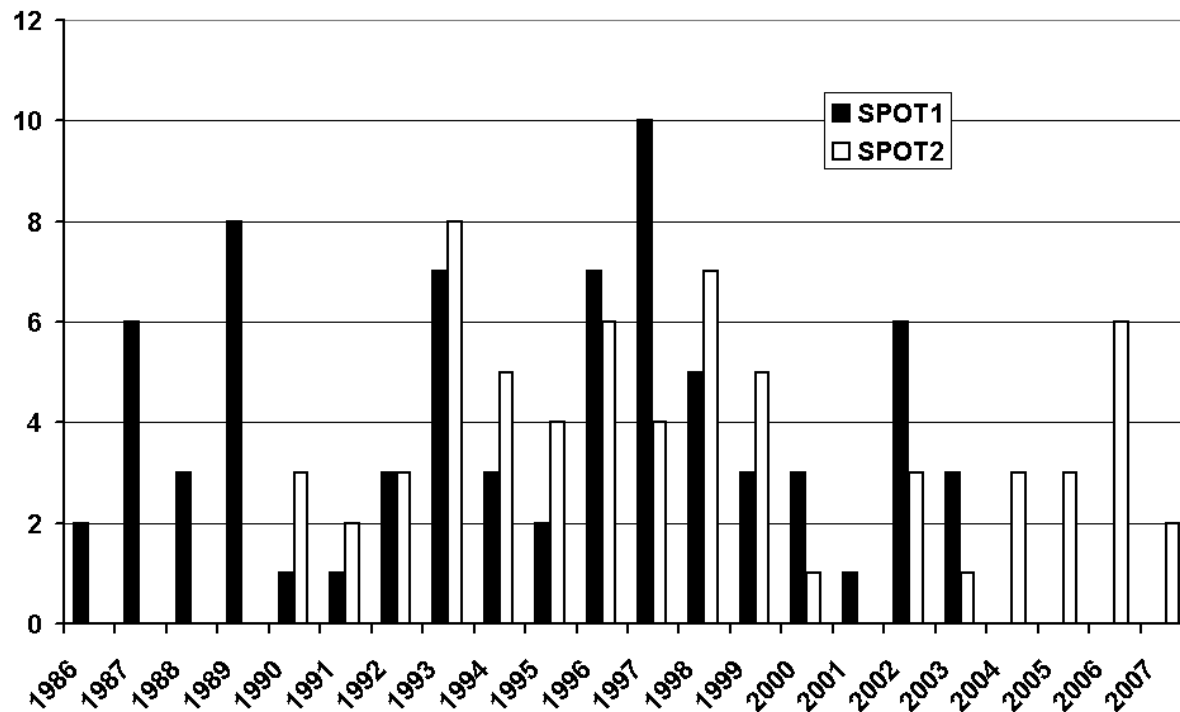
SEUs on SPOT-1, -2, -3 on-board computers

R. Ecoffet, CNES, France

Some elements for the discussions on LET needs for component testing

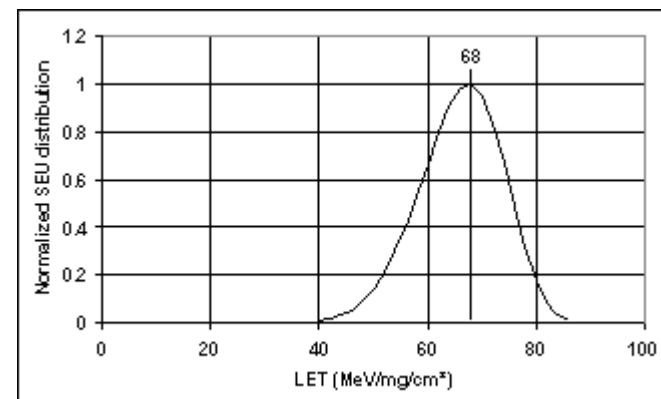
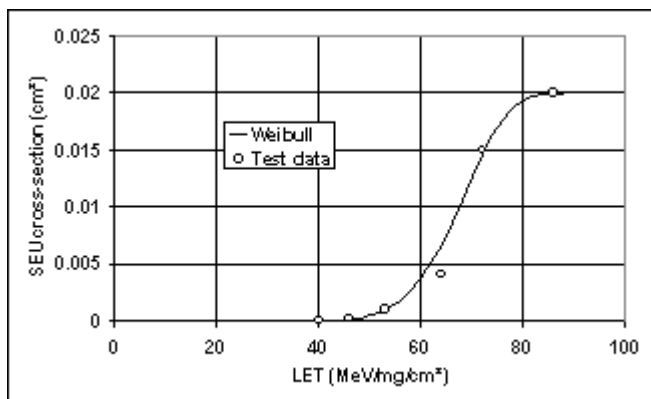
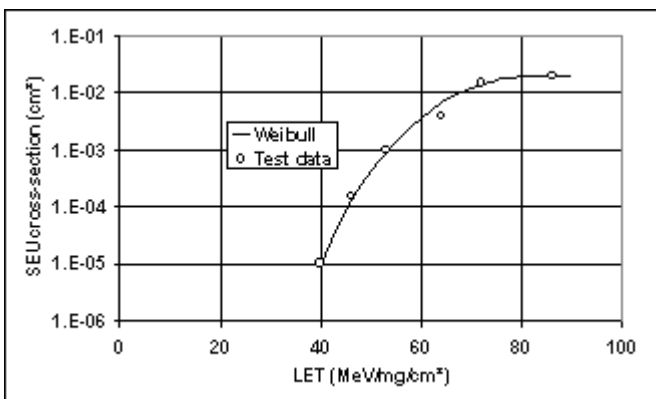
The components

- SRAM HEF4736 Phillips 1 kbit
- 1088 active components
- SEUs recorded since 1986 – now (~2 solar cycles)
- 74 records for SPOT-1 and 66 for SPOT-2 (end January 2007)

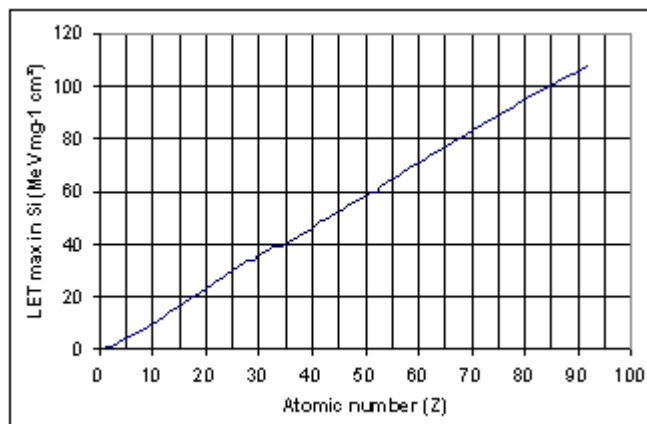
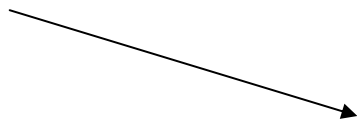


HEF4736 ground test results

- Heavy ion (IPN) and proton (SATURNE) tests
- $LET_{th} \sim 40 \text{ MeV/mg/cm}^2$
- Test results could let one believe that SEUs are only due to very high LET heavy ions



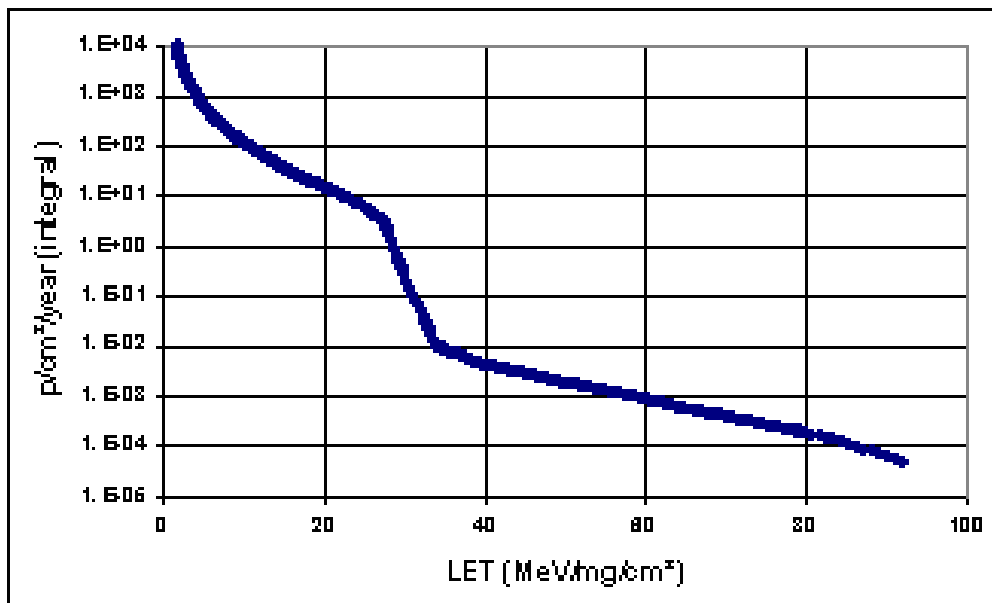
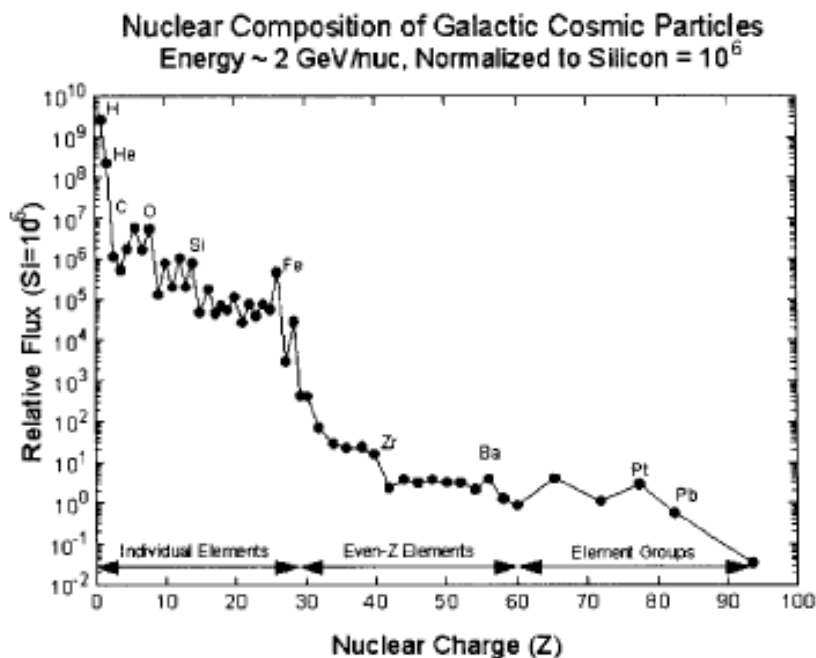
- $LET > 40 \rightarrow Z > 45$



Seen like that one could believe coping with an LET detector with maximum efficiency around $LET \sim 70$

High LET ions in space

- « There are no (extremely few) high LET ions ion space »
- Indeed, but we do observe SEUs in SPOT OBCs !



Periodic Table of Elements

IA	IIA											IIIA	IVA	VA	VIA	VIIA	VIIIA	0	
1	2											3	4	5	6	7	8	9	10
Li	Be											B	C	N	O	F	Ne		
3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20		
Na	Mg	Al	Si	P	S	Cl	Ar												
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74		
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104		
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Mn	Uu	Uu	Uu		

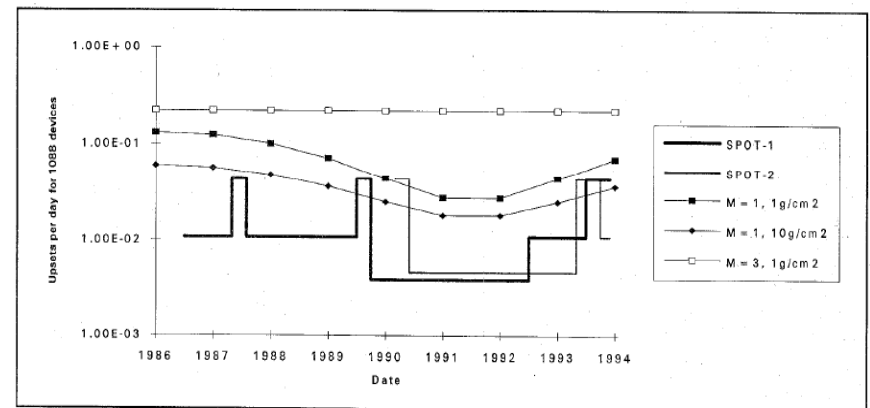
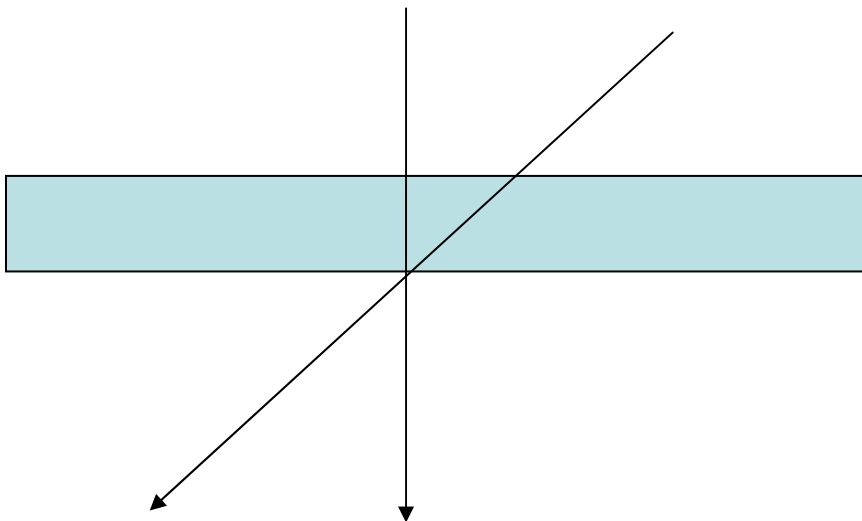
• Lanthanide Series
• Actinide Series

Legend - click to find out more...

■ Gas
 ■ LI - solid
 ■ Br - liquid
 ■ Tc - synthetic
■ Non-Metals
 ■ Transition Metals
 ■ Rare Earth Metals
 ■ Halogens
■ Alkali Metals
 ■ Alkali Earth Metals
 ■ Other Metals
 ■ Inert Elements

Why this discrepancy ?

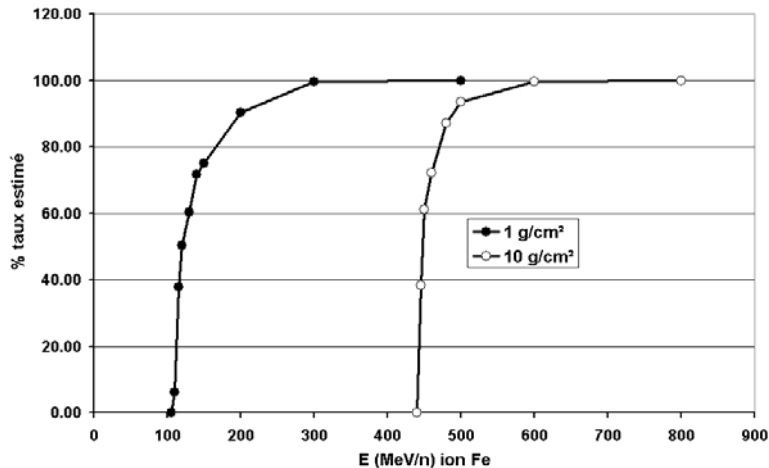
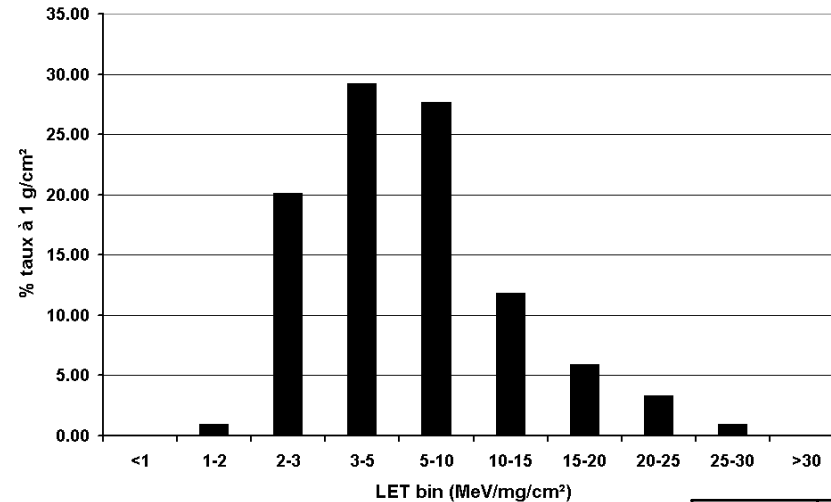
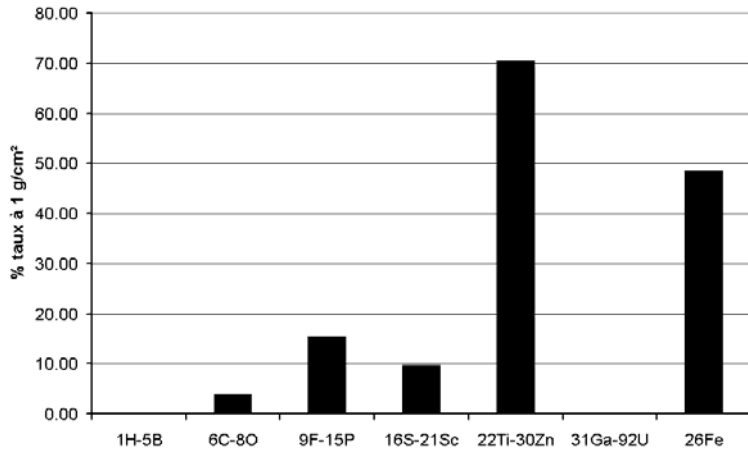
- LET (dE/dx) is an engineering “trick” , the right parameter governing SEU behavior is the deposited charge inside the sensitive volume.
(we stay here within the full classical sensitive volume theory)
- $Q_{\text{dep}} \sim \Delta E \sim \text{LET} \times z$
- For SPOT memories this volume is taken as $44 \times 44 \times 2 \mu\text{m}$



Simple convolution = $5 \text{ E-}5 \text{ event / day}$

Parametric study using OMERE

- As a function of Z, of LET, of energy : contributions to the estimated rate



Critical charge =
 $40 \text{ (accelerator LET}_{th}) \times 2 \mu\text{m (SV depth)}$

We'll have an upset if
 $\text{LET} / \cos(\text{incidence}) > 40 \text{ MeV/mg/cm}^2$

i.e. minimum incidence = $\arccos(\text{LET}/40)$.
 and path in SV = $2\mu\text{m} / \cos(\text{incidence})$.

LET max	Incidence (°)	Path in SV (μm)
1	88.57	80.00
2	87.13	40.00
3	85.70	26.67
5	82.82	16.00
10	75.52	8.00
15	67.98	5.33
20	60.00	4.00
25	51.32	3.20
30	41.41	2.67

Conclusions

- **In the case of HEF4736, the SEU sensitivity :**
 - ◆ Is characterized **on ground** with **very heavy ions** ($Z > 40$), **of low energy** (few MeV/n) **high LETs** (> 40), and **low incidences** ($< 60^\circ$)
 - ◆ Is revealed **in flight** by **much lighter ions** (Fe group and below), **of high energy** (few 100 MeV/n), **low LETs** (some MeV/mg/cm²) and **high incidences** ($> 60^\circ$).
28Fe alone contributes to nearly 50% of the rate.
- **The “ground” and “flight” domains are completely disjointed**
- If we had to limit SEU testing at e.g. LET=37 MeV/mg/cm² because “there are no high LET ions in space” we would have completely missed the issue
- It would be wiser to think about test criteria in more elaborated manner and eventually adapt them to the effect to be studied
- The SPOT technology is rather old for SEU, but the considerations above may still be true for other SEEs (SEL, SET,...)
- **→ Proposed 09 R&D : given {LET, sigma curve and sensitive volume} : on what ions (Z, LET, E) does this “detector” triggers in space ?**