CENTRE NATIONAL D'ÉTUDES SPATIALES

Lessons learned on IASI / METOP SEU sensitivity of rad-hard SRAMs

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IASI Memories

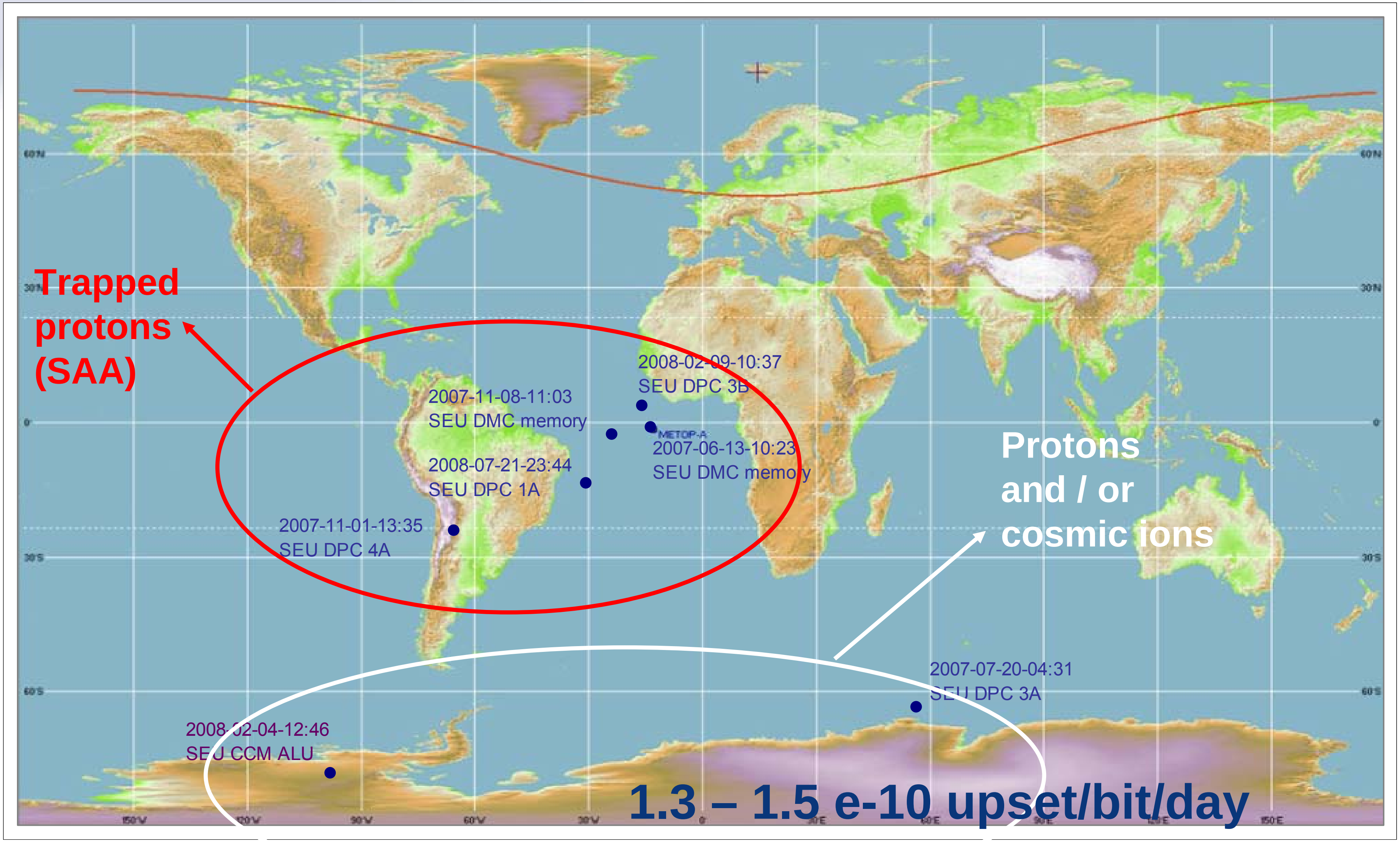
- ~ 130 rad-hard 1-Mbit Honeywell HX6228 SRAMs
- Procured in 1998 and « guaranteed » at < 1 e-10 upset/bit/day in GEO (→ heavy ions only)
- Not supposed to be proton sensitive at this time

- METOP launched 19 Oct. 2006
- IASI in full operational configuration since May 2007

- In flight we do observe upsets in SAA and polar zones
- May 2007 – January 2009
  - 5 upsets in SAA
  - 2 upsets in South Pole region

- Upsets lead to operational problems (whose impact is now limited due to great work at EUMETSAT)

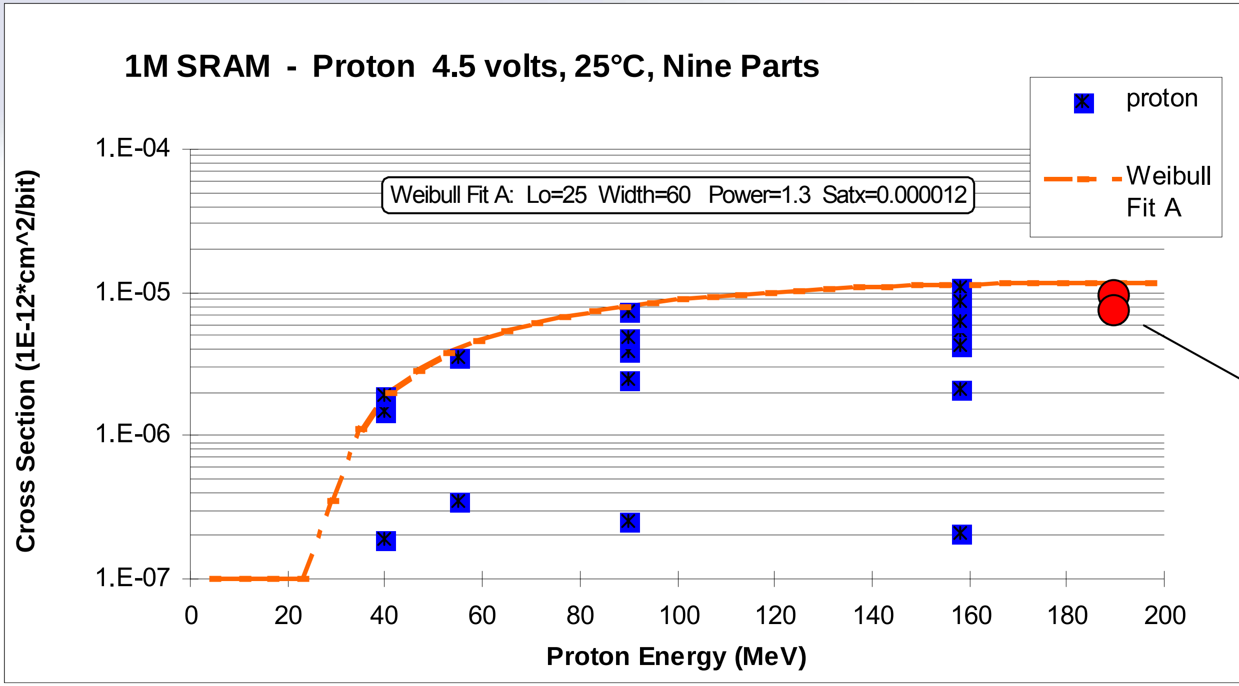
SEU anomalies



SEU sensitivity data

- A 2002, Honeywell application note stated a proton sensitivity on HX6228 and gave proton sensitivity Weibull parameters
- CNES obtained a proton test report from Honeywell (dated 2001)
- Heavy ion data were obtained from ESA / ESTEC
- Components from flight lots were tested by CNES :
  - Heavy ions : November 2008 at GANIL, F
  - Protons : January 2009 at KVI, NL
- Honeywell – ESA – CNES data are consistent even if obtained in different lots
- During our exchanges with Honeywell they stated that
  <u>The problem is still there today</u>

Proton sensitivity

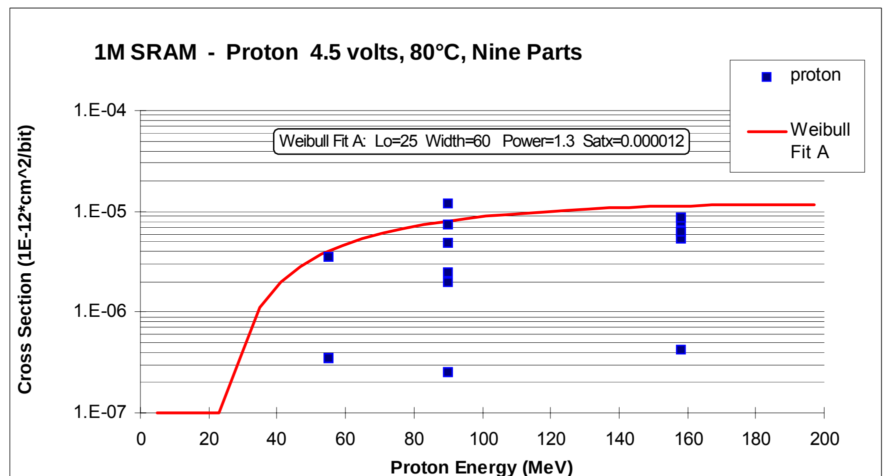


Proton Weibull parameters for 1M SRAM

onset	25	MeV
width	60	MeV
power	1.3	dimensionless
plateau	0.000012	1e-12cm2/bit

KVI results, 2 parts (lid on and off), 5 V, ambient T°

- **Note :**
- **Very low threshold of Weibull fit**
- **Neutron level when using degraded beams crashed FPGA test controller → lesson learned for proton testing at high flux / fluence levels**
- **Only 190 MeV tests were possible (primary beam without degradors)**



Flight rate estimation for IASI orbit

Trapped protons

- AP8, solar minimum, OMERE implementation
- Reference period 01 May 2007 to 01 January 2009 (611 days)

- The actual rate on the reference period (5 SEUs in SAA) is pretty well consistent with predictions given hypothesis in shielding and statistic fog.

	Rate (SEU / day)		Rate (SEU /year)		Rate (SEU / reference period)	
	1 memory	130 memories	1 memory	130 memories	1 memory	130 memories
3 mmAl	6.41E-05	8.33E-03	2.34E-02	3.04	3.92E-02	**5.09**
10 mmAl	5.50E-05	7.15E-03	2.01E-02	2.61	3.36E-02	**4.37**
30 mmAl	3.96E-05	5.15E-03	1.45E-02	1.88	2.42E-02	**3.15**
100 mmAl	1.69E-05	2.20E-03	6.17E-03	0.80	1.03E-02	**1.34**
200 mmAl	7.83E-06	1.02E-03	2.86E-03	0.37	4.78E-03	**0.62**
300 mmAl	4.60E-06	5.98E-04	1.68E-03	0.22	2.81E-03	**0.37**

Flight rate estimation for IASI orbit

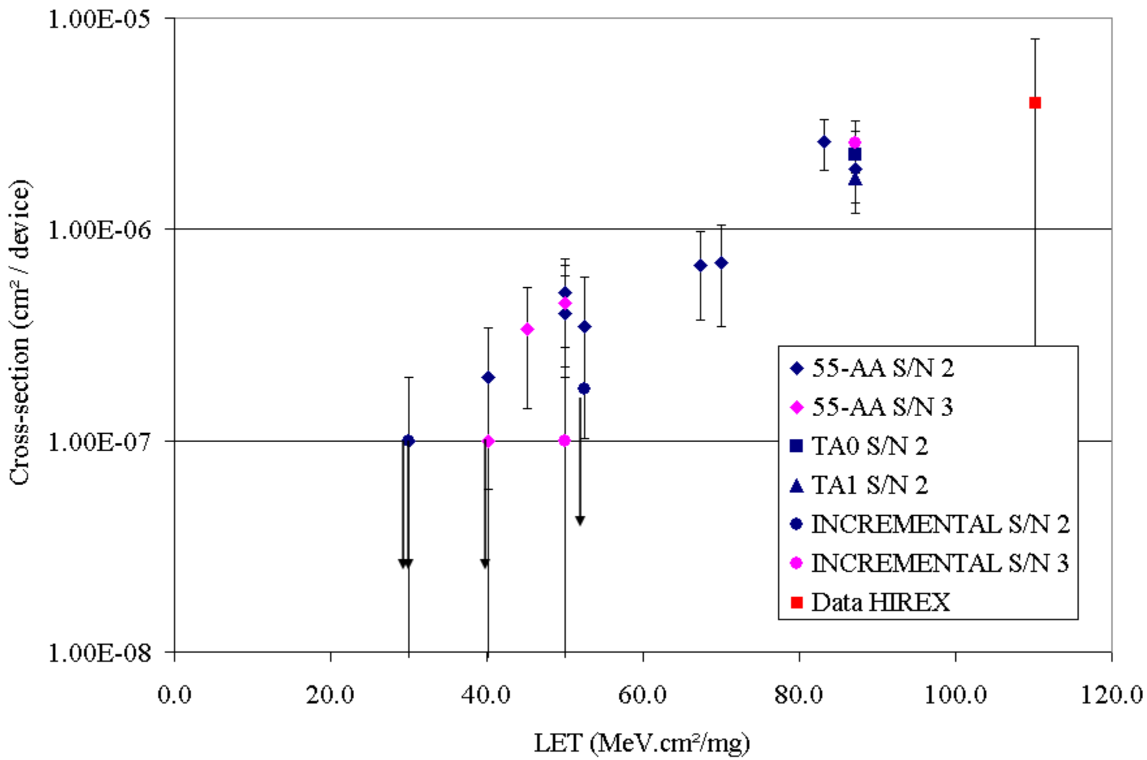
Flare protons

- Case solar events, OMERE implementation
- Depending on case (event spectrum, shielding hypothesis) risk ranges from quasi null to quasi certain
- In Events of the coming new solar maximum will not change a lot the statistics

	1 memory (SEU / day)				130 memories (SEU / day)			
	August 72	October 89	July 2000	October 03	August 72	October 89	July 2000	October 03
3 mmAl	7.00E-03	4.57E-03	2.18E-03	1.45E-03	0.91	0.59	0.28	0.19
10 mmAl	4.54E-03	2.82E-03	7.52E-04	6.08E-04	0.59	0.37	9.78E-02	7.90E-02
30 mmAl	1.93E-04	1.19E-04	7.94E-05	1.36E-04	2.51E-02	1.55E-02	1.03E-02	1.77E-02

Heavy ion sensitivity

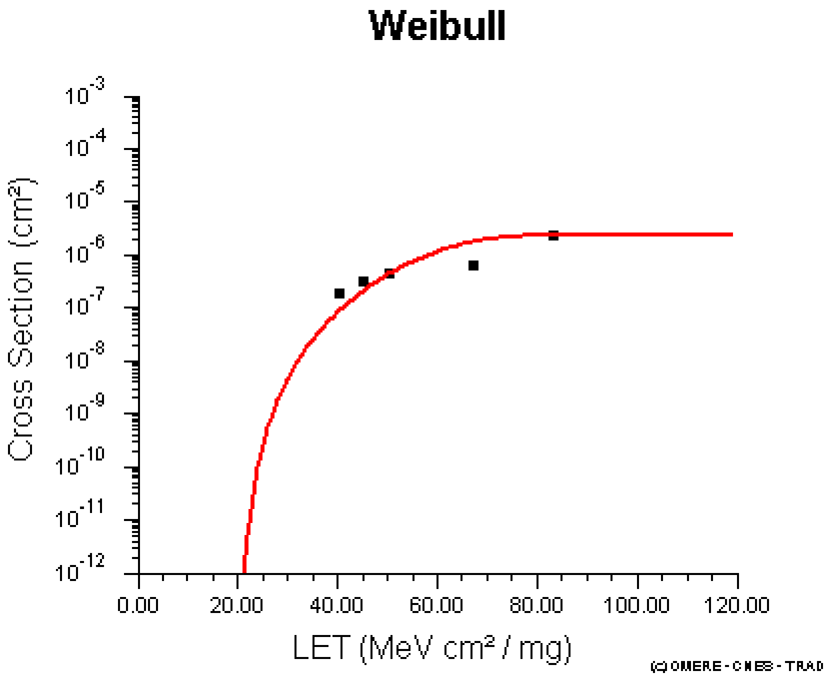
- **GANIL measurements**
- **Note the smooth appearance of the cross-section curve (no evident threshold, knee nor saturation)**
- **Note also SEU observation at 40 MeV/mg/cm²**
- **In its proton report Honeywell referred to SEUs "in the 15-40 MeV/mg/cm² range"**
- **Consistent with ESA / Hirex data on other date code**



Heavy ion sensitivity

- **Reference curve and Weibull fit used for rate calculations**

LETth	20 MeV/mg/cm²
Saturation X-section	2.6e-6 cm²/device
W	43.97 MeV/mg/cm²
s	4.22



LET (MeV/mg/cm²)	X-section (cm²/device)
40	2.00E-07
45	3.37E-07
50	5.00E-07
67	6.73E-07
83	2.61E-06

Flight rate estimation for IASI orbit
Galactic cosmic ions

- **CREME86, 1 mmAl, OMERE implementation**
- **Reference period 01 May 2007 to 01 January 2009 (611 days)**

- **The actual rate on the reference period (2 SEUs in South Pole Area) is <u>not</u> consistent with predictions even with conservative hypothesis in shielding and whatever statistic fog.**
- **Proton upsets are calculated to dominate the rate even outside SAA but estimated contribution factor of 10 under actual rate**
- **Infinitesimal calculated heavy ion rate, something's wrong here !**

	1 memory (SEU / day)	130 memories (SEU / year)	130 memories (SEU / reference period)
Honeywell GEO	1.00E-04	4.75E+00	7.94
LEO GCR M=1 solmin c=2 µm 1000000 volumes	1.44E-16	6.84E-12	1.14E-11
LEO GCR M=1 solmin c=2 µm 1 volume	2.58E-08	1.23E-03	2.05E-03
LEO GCR M=1solmin c=1 µm 1 volume	4.30E-08	2.04E-03	3.42E-03
LEO GCR M=3 c=1 µm 1 volume	4.34E-08	2.06E-03	3.45E-03
LEO GCR M=4 c=1 µm 1 volume	6.37E-08	3.02E-03	5.06E-03
Galactic protons M=1	1.84E-06	8.74E-02	0.15

Note : with 1 million volumes, individual volume has a surface area of 0.02 x 0.02 µm with one volume only it is 16 x 16 µm)

Conclusions

- There is a good chance that we face a problem of high-Z recoils
- CNES will now recommend in its RHA specifications
  - To get proton sensitivity data for rad-hard components
  - To make proton tests when those data are not available
  - To use the “1 e-10 upset/bit/day” as baseline for ion rate calculation (rates calculated with X-section curve and CREME are misleading)
  - To take into account GCR proton rate
  - To use safety margins when global estimated rate falls in the “few event” range for mission lifetime
- SAA rate is quite well reproduced using test data
- We did not succeed in properly estimating the flight rate outside SAA, estimation is lower than reality by a factor 10
- Protons (cosmic rays) seem to dominate rate also outside SAA
- Something’s wrong with ion predictions. Other phenomena involved ? (ion – ion interactions ? validity of sensitive volume theory for such devices ?)…