Update on PROBA-2 TDM and ALPHASAT TDP8 Flight Data

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ESA ESTEC

OUTLINE

1. PROBA-2 TDM
2. Summary of PROBA-2 TDM SEE flight data on memories
3. ALPHASAT TDP8
4. Summary of ALPHASAT TDP8 SEE flight data on memories

PROBA-2

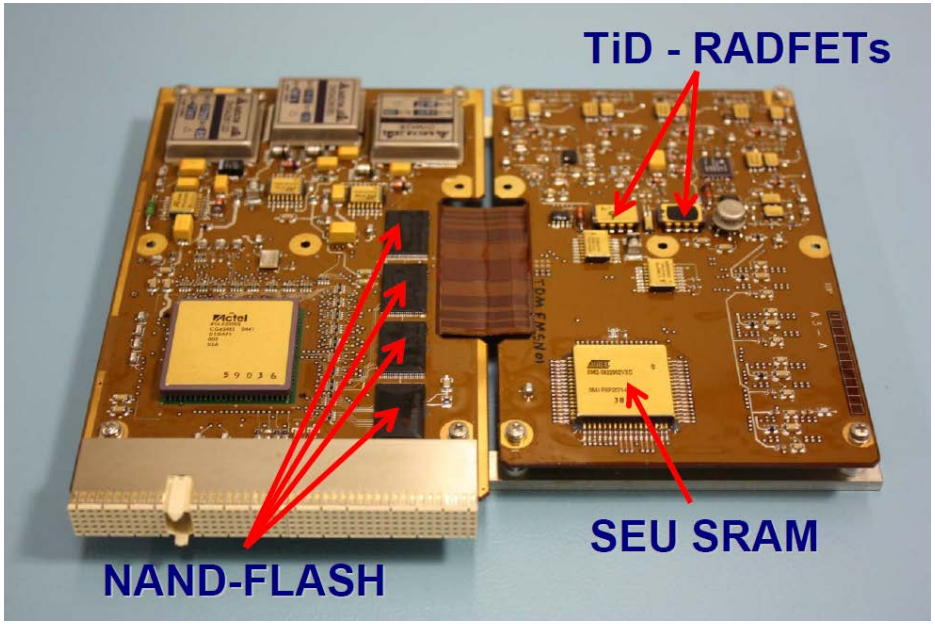
Launched on November 2, 2009
LEO orbit: 713-733 km, 98 degrees inclination

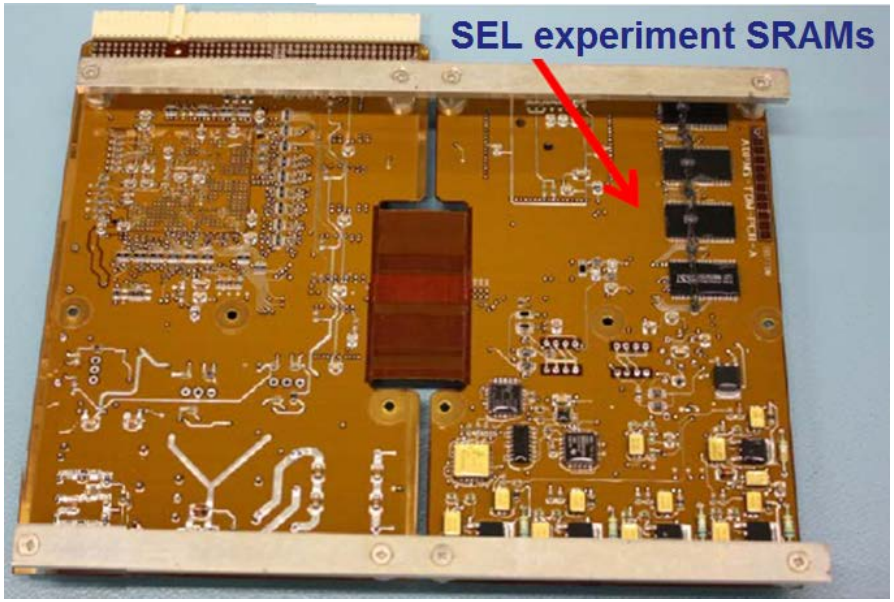
PROBA-2 - TDM

1. TDM :
    a. *TID (RADFETs)*
    b. ***Reference SEU monitor***
    c. ***SEL experiment***
        – ***SEL***
        – ***SEU***
    d. ***Flash memory experiment.***
2. Period analyzed
    a. ***March 2010-January 2015***
        – ***(1769 days)***

Memories on board TDM/Proba II		
Atmel	AT68166 (4*AT60142)	2M x 8
Alliance Semi.	AS7C34096A-12TI	512K x 8
Samsung	K6R4008V1D	512K x 8
ISSI	IS61LV5128AL-12	512K x 8
ISSI	IS62WV20488BLL	2M x8
Samsung	K9FG08U0M	1G x 8

PROBA-2 TDM

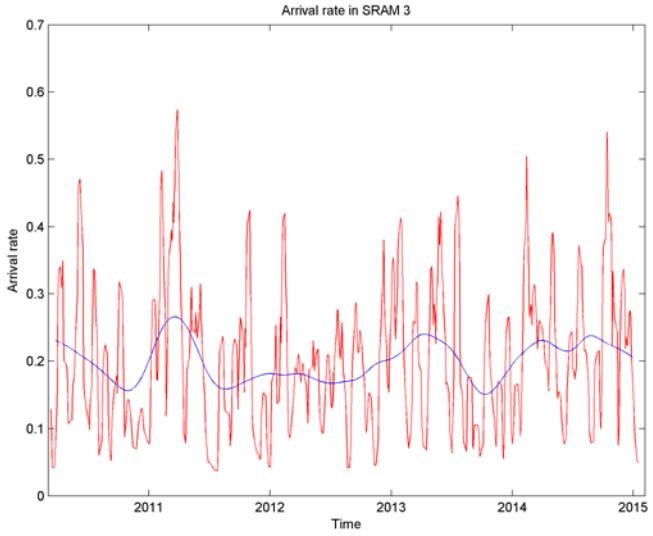




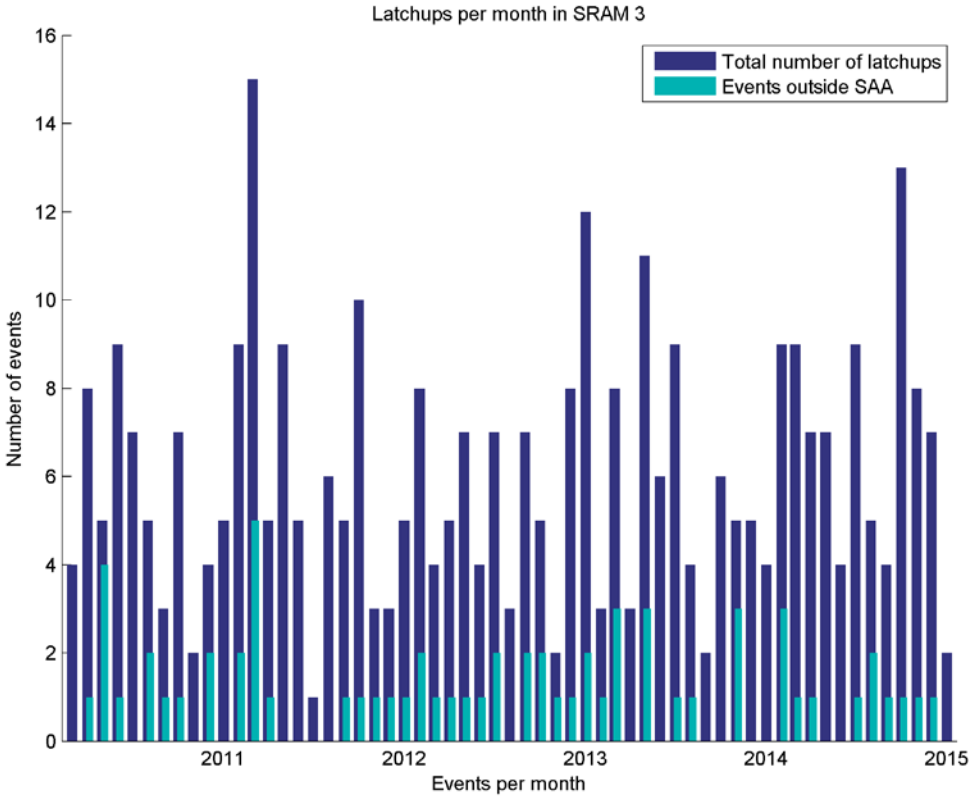
SEL experiment, SEL Data

SEL experiment in TDM/Proba-2			Tot	SAA
Alliance Semi.	AS7C34096A-12TI	512K x 8	3	2
Samsung	K6R4008V1D-TI10	512K x 8	8	4
ISSI	IS61LV5128AL-12	512K x 8	357	293
ISSI	IS62WV20488BLL	2M x8	12	5

SEL experiment, SEL Data
IS61LV5128AL



Differential latchup rate (smoothed in blue)



SEL experiment, SEL Data Comparison with Calculated Rates

SEL rate prediction was performed for the 4 SRAMs using OMERE under solar maximum conditions, a sensitive volume thickness of 1 micron and 10 mm of Aluminum shielding.

Ground test data was taken at 60°C (average board temperature in-flight ~ 50°C)

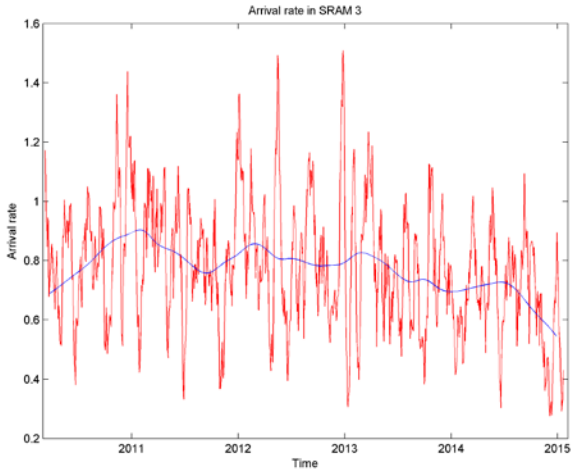
Memory	Total (SEL/day)	Trapped Protons (SEL/day)	GCRs (SEL/day)	Observed (SEL/day)
AS7C34096A-12TI	**1.36E-03**	1.28E-03	7.30E-05	**1.70E-03**
K6R4008V1D-TI10	**2.57E-03**	2.40E-03	1.67E-04	**4.52E-03**
IS61LV5128AL-12	**1.81E-01**	1.54E-01	2.68E-02	**2.02E-01**
IS62WV20488BLL	**1.10E-02**	1.02E-02	8.82E-04	**6.8E-3**

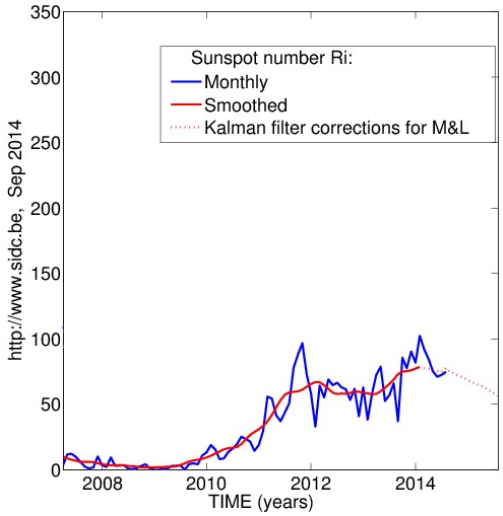
SEL experiment, SEU Data

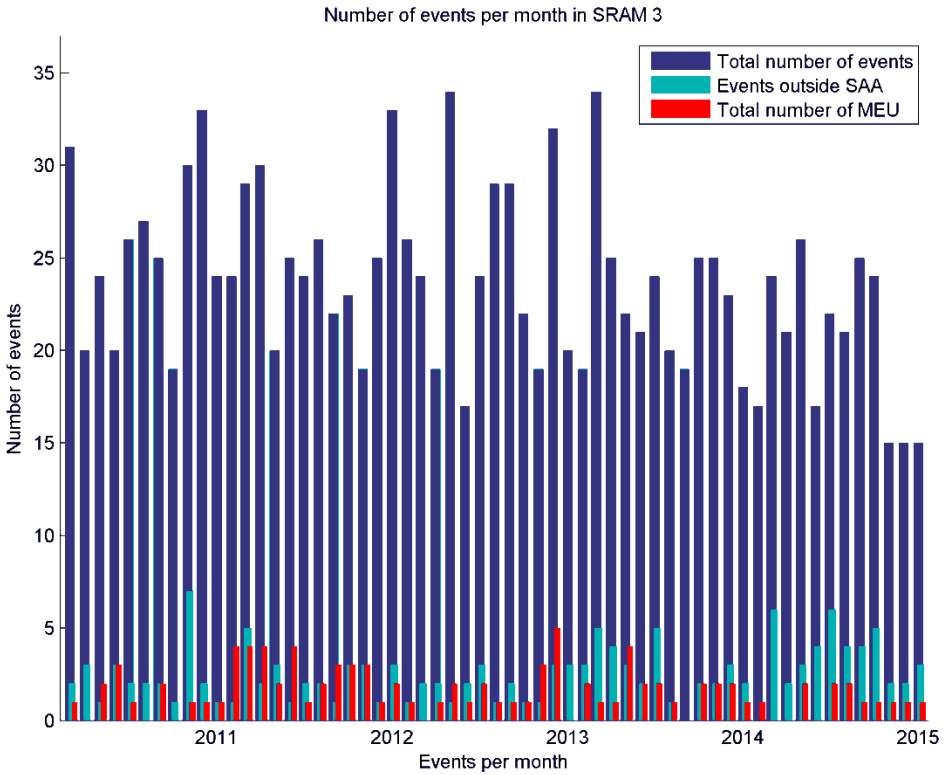
Memory	N ° event	Inside SAA	SEU	MEU
AS7C34096A-12TI	1078	88%	1039	39
K6R4008V1D-TI10	966	88%	834	132
IS61LV5128AL-12	1391	90%	1296	95
IS62LWV20488BL	4756	86%	3908	848*

** IS62WV20488BL prone to big MEU (50 MEU of more than 300 bit upsets)*

SEL experiment, SEU Data
IS62LWV20488BL







SEL experiment, SEL Data Comparison with Calculated Rates

SEU rate prediction was performed using OMERE under solar maximum conditions, a sensitive volume thickness of 1 µm, 10 mm of Aluminum shielding.

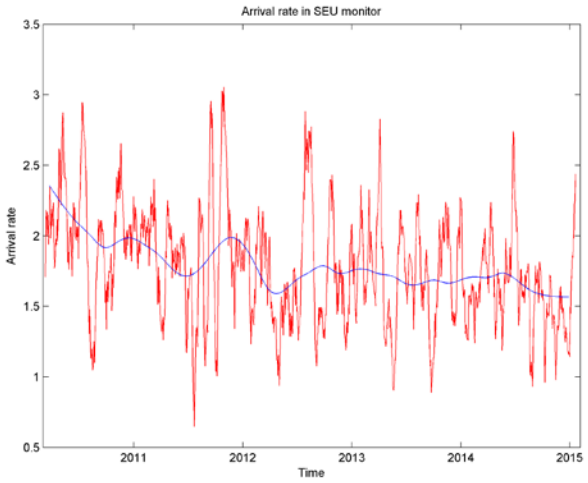
Ground test data was taken at 40°C (average board temperature in-flight ~ 50°C)

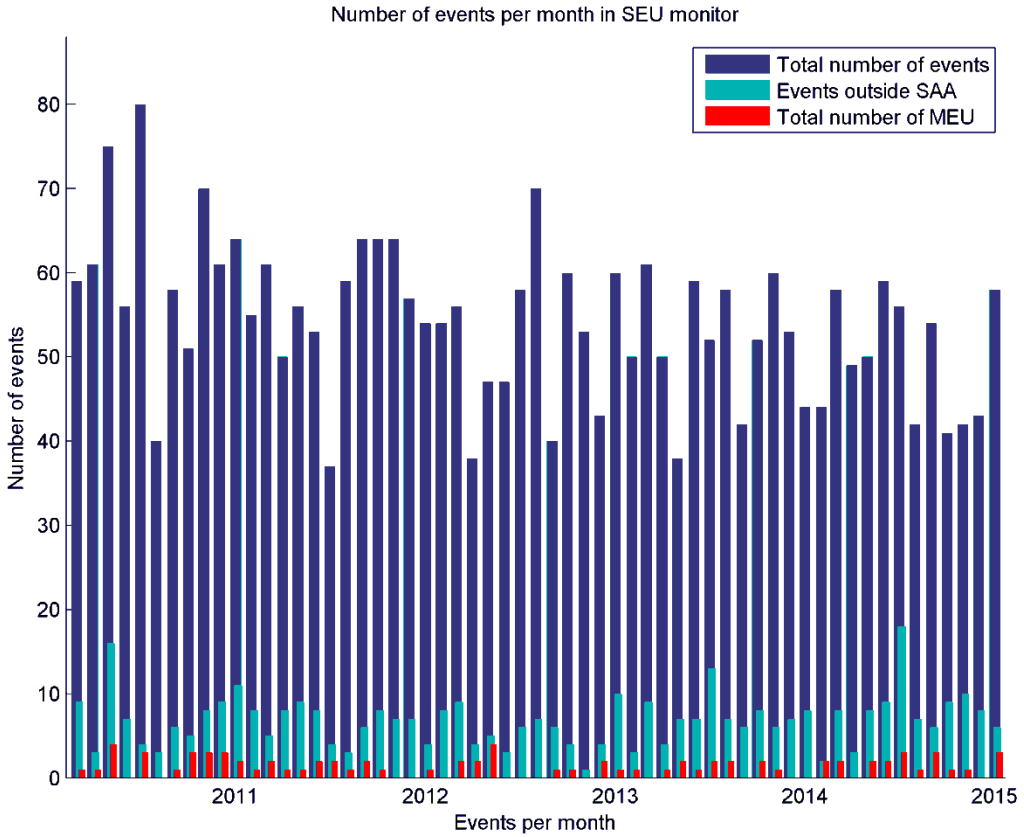
Memory	Total (SEU/day)	Trapped Protons (SEU/day)	GCRs (SEU/day)	Observed (Event/day)
AS7C34096A-12TI	0.977	0.913	6.40E-02	**0.6**
K6R4008V1D-TI10	0.790	0.755	3.56E-02	**0.55**
IS61LV5128AL-12	1.22	1.15	7.54E-02	**0.79**
IS62WV20488BLL	4.45	4.13	0.319	**2.7**

Reference SEU monitor Data

3190 events, 87% in SAA

3110 SEU, 80 MEU





Reference SEU Monitor Data Comparison with Calculated Rates

SEU rate prediction was performed for the AT68166 using OMERE under solar maximum conditions, a sensitive volume thickness of 1 micron and 10 mm of Aluminum shielding

Total (SEU/day)	Trapped Protons (SEU/day)	GCRs (SEU/day)	Observed (Event/day)
2.80	2.75	0.049	1.8

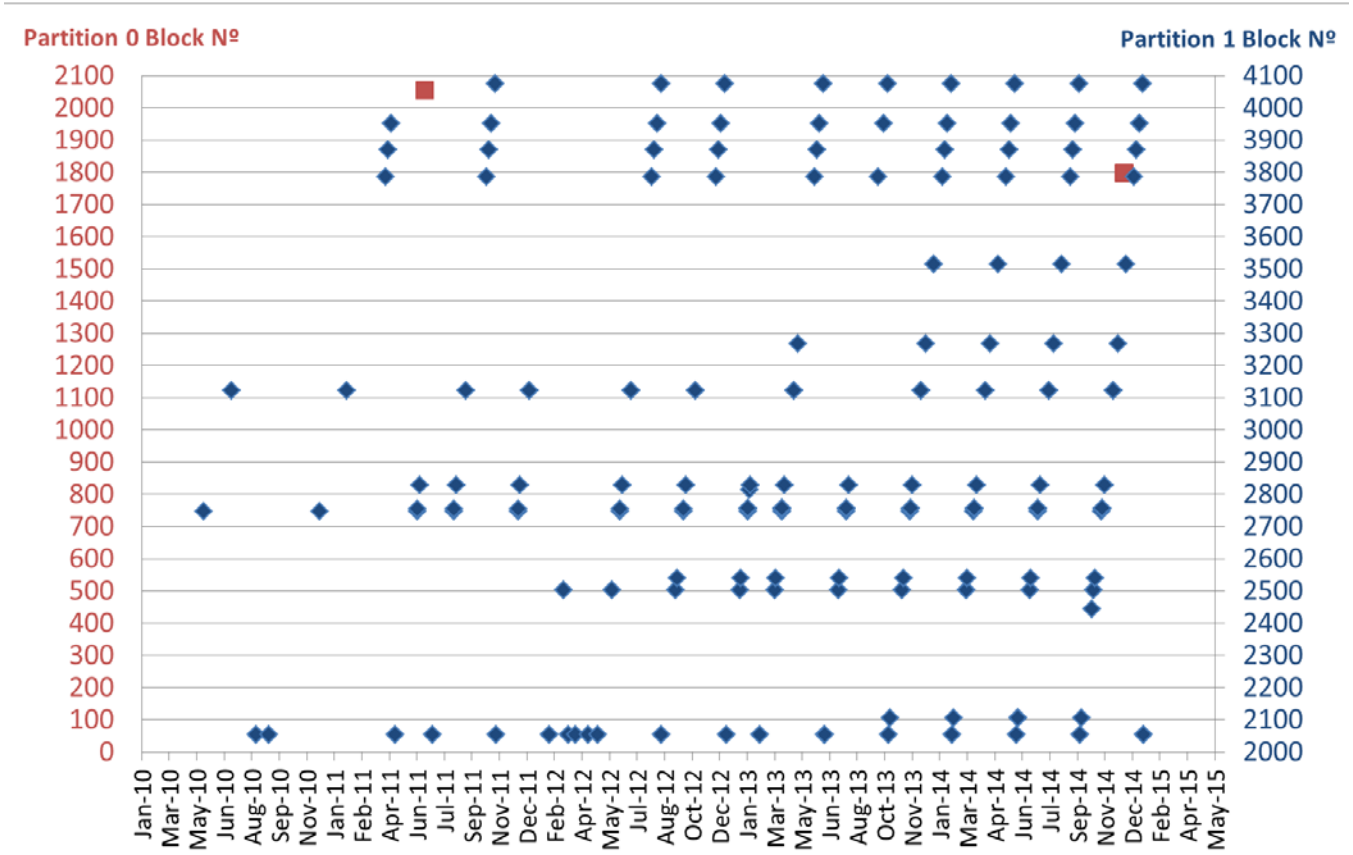
Flash Memory Experiment Description

1. Flash memory array is composed of 4 Samsung K9F8G08U0M 8 Gbit NAND flash memories
    a. double (4,2,3) Reed-Solomon Codes

2. Flash memory array is split in 2 partitions
    a. Partition 0: Short term error collection, 10 segments of 200 blocks
        – continuous erase, write and read operations
        – One segment per test cycle tested
    b. Partition 1: Long Term Storage Mode, 2048 blocks
        – Read only operations, SEU are not corrected
        – one page tested per test cycle

Flash memory experiment, Data

- 3 events in partition 0 (1 event affects 2 bytes in the same page)
- 20 events in partition 1 (2 events affect 2 byte in the same page)
- No SEL
- No SEFI



Flash Memory Experiment
Comparison with Calculated Rates

SEU rate prediction was performed for the K9F8G08U0M using OMERE under solar maximum conditions, a sensitive volume thickness of 0.2 micron and 10 mm of Aluminum shielding, only for the long time storage partition

Total (Errors/day)	Trapped Protons (Errors/day)	GCRs (Errors/day)	Observed (Error/day)
0.010	0.0092	0.0012	**0.011**

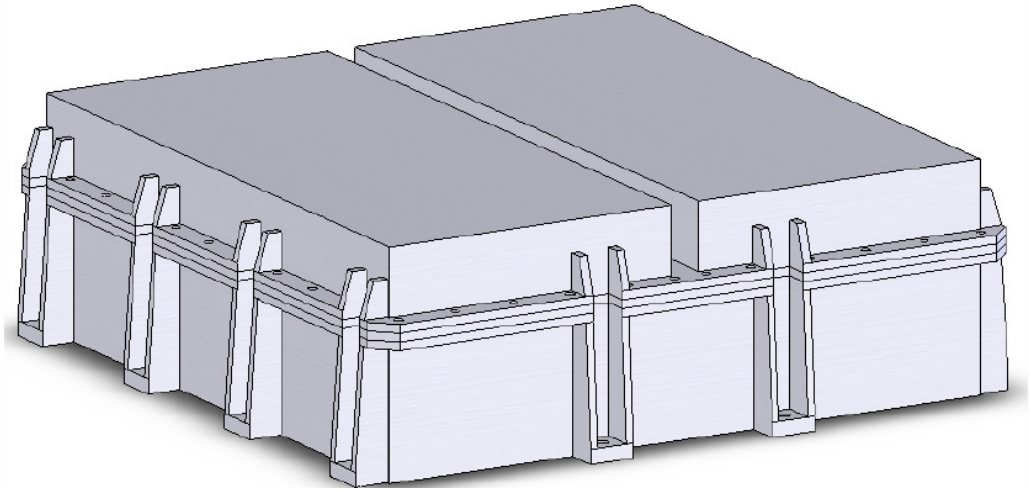
Launched on July 25, 2013

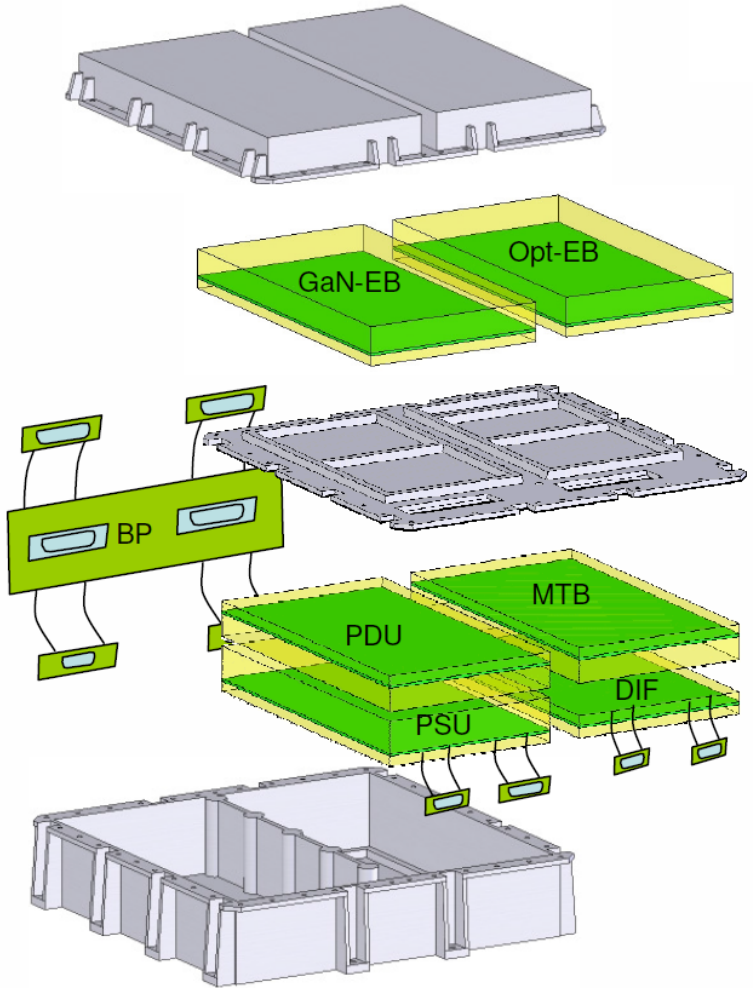
Alphasat – TDP8 MTB

1. MTB
    a. TID (RADFETs)
    b. SEL experiment
        – SEL
        – SEU
    c. Reference SEU monitor
    d. Flash memory experiment
2. Period Analyzed
    a. SEL: 28/08/2013- 16/12/2014*
    b. SEU: 02/10/2013- 07/5/2014*
        – * MTB was off 24/10/2013 – 8/11/2013 and 7/5/2014 – 3/7/2014

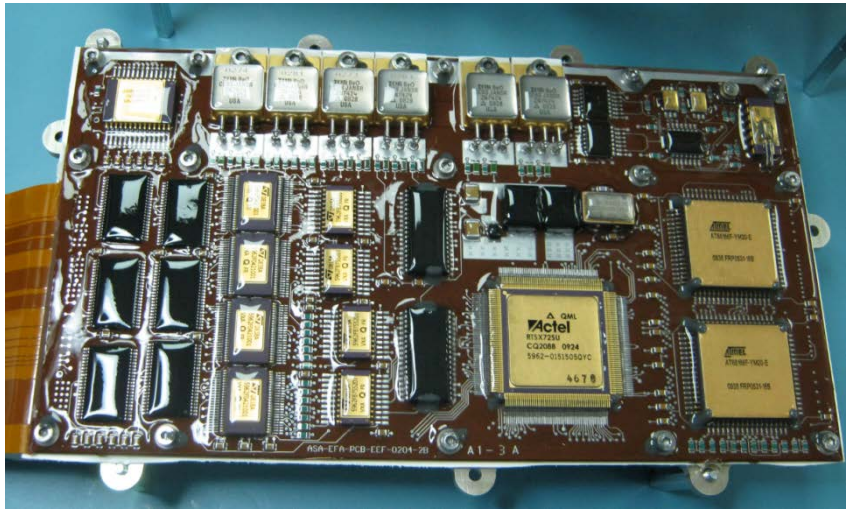
Memories on board MTB/ TDP8 Alphasat			
ISSI	IS62WV20488BLL	SRAM 16Mb	1-3
BSI	BS62LV8001EIP55	SRAM 8Mb	5-7
ISSI	IS61LV5128AL-12	SRAM 4Mb	9-11
Samsung	K6R4008V1D	SRAM 4Mb	13-15
Atmel	AT68166F-YS18CC	SRAM 16Mb	17-18
Samsung	K9FG08U0M	Flash 8Gb	19-22

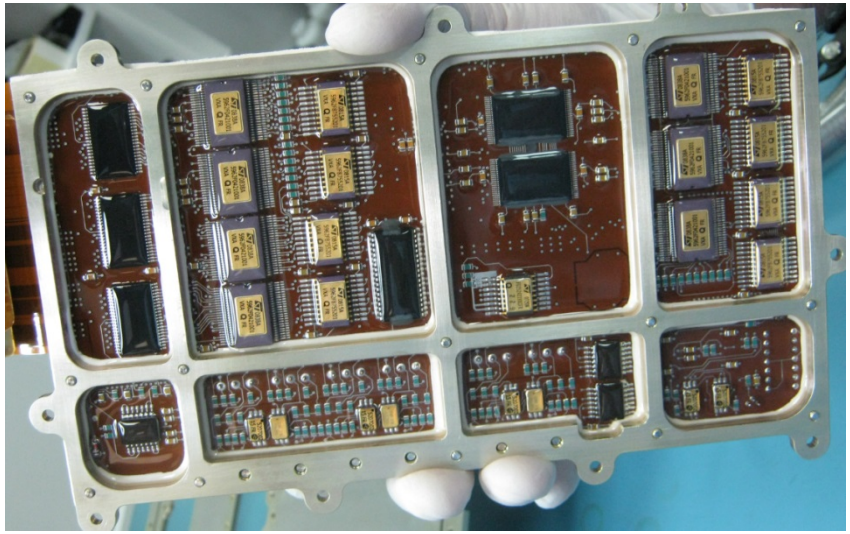
ALPHASAT TDP8 CTTB



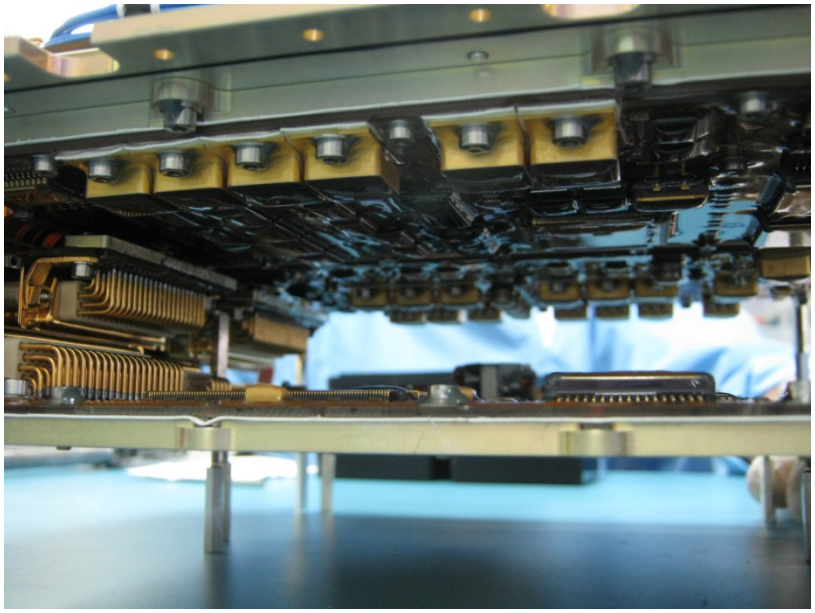


ALPHASAT TDP8
Memory Test Board (MTB)



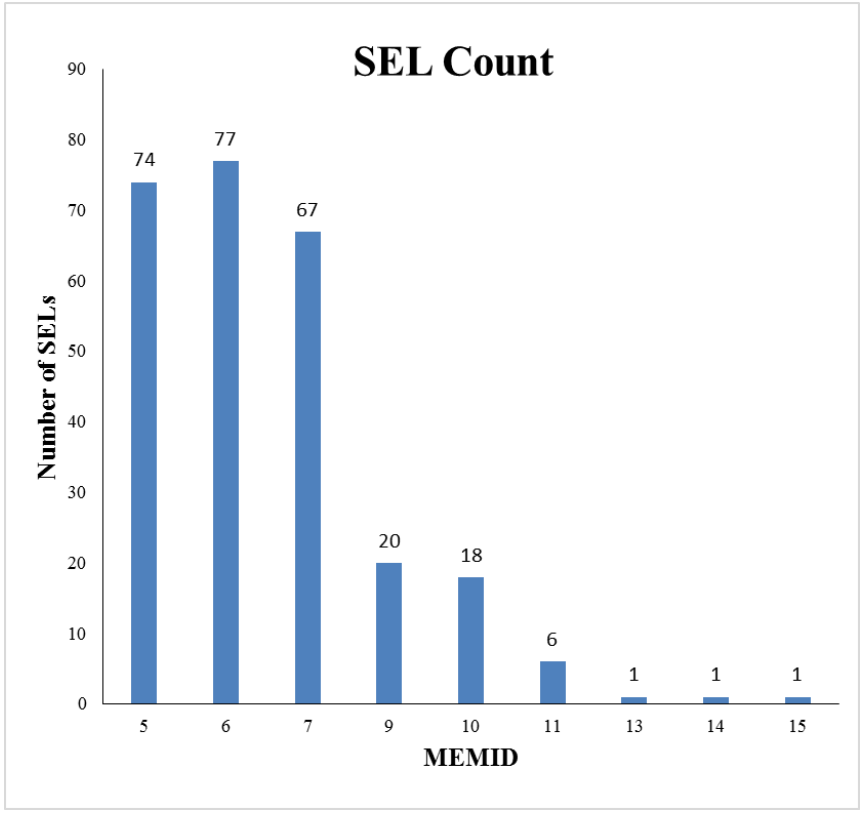


MTB

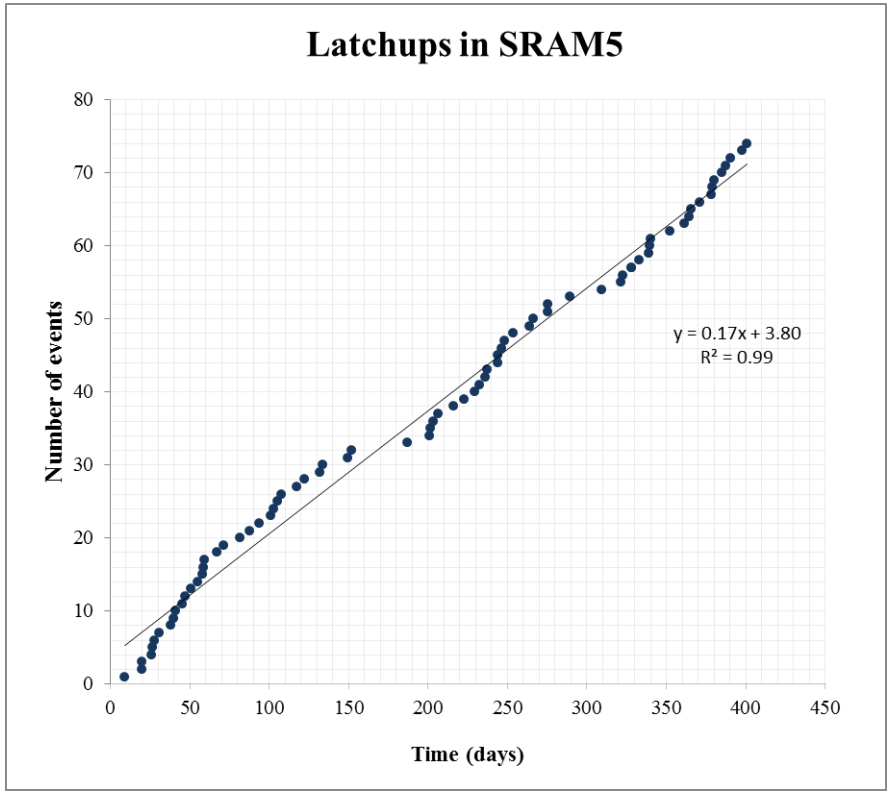


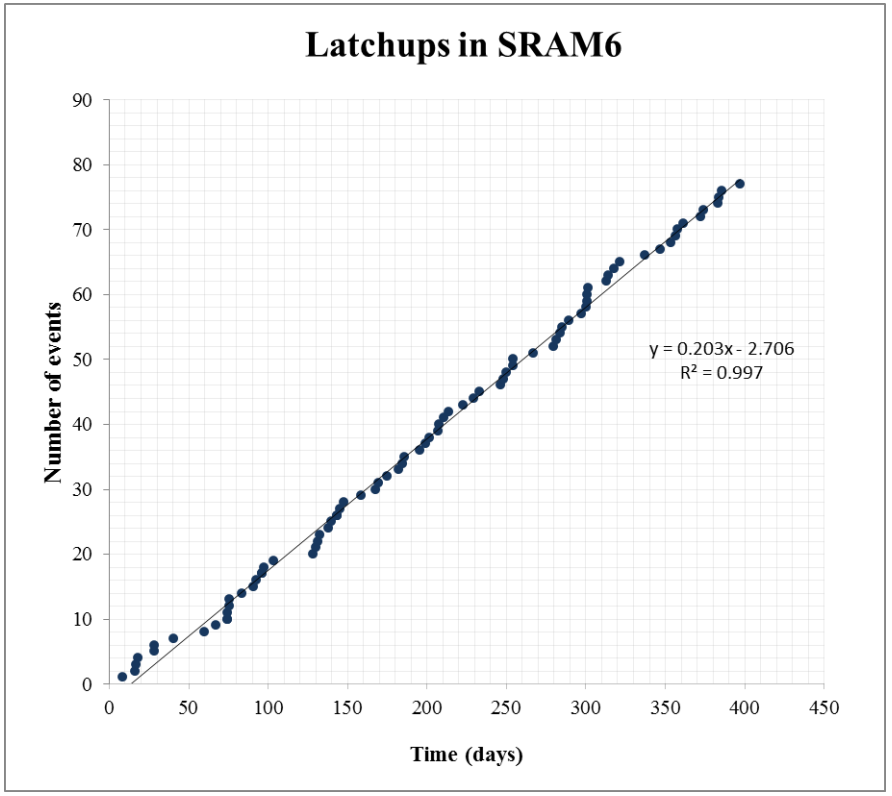
ALPHASAT TDP8 MTB
SRAM, SEL

Memories on board MTB/Alphasat			
ISSI	IS62WV20488BLL	16Mb	1-3
BSI	BS62LV8001EIP55	8Mb	5-7
ISSI	IS61LV5128AL-12	4Mb	9-11
Samsung	K6R4008V1D	4Mb	13-15
Atmel	AT68166F-YS18CC	16Mb	17-18



ALPHASAT TDP8 MTB
SRAM, SEL





Time is in days since start of the experiment, suppressing time gaps

ALPHASAT TDP8 MTB, SRAM, SEL Comparison with Rate Calculations

SEL rate calculation was performed for the SRAMs using OMERE under solar maximum conditions, a sensitive volume thickness of 2 µm and 6 mm of Aluminum shielding.

The data used for the Weibull fit was taken from ground test data at 45 °C (min temperature for which data is available), whereas the temperature of the satellite in its geostationary orbit is of 24 °C approximately.

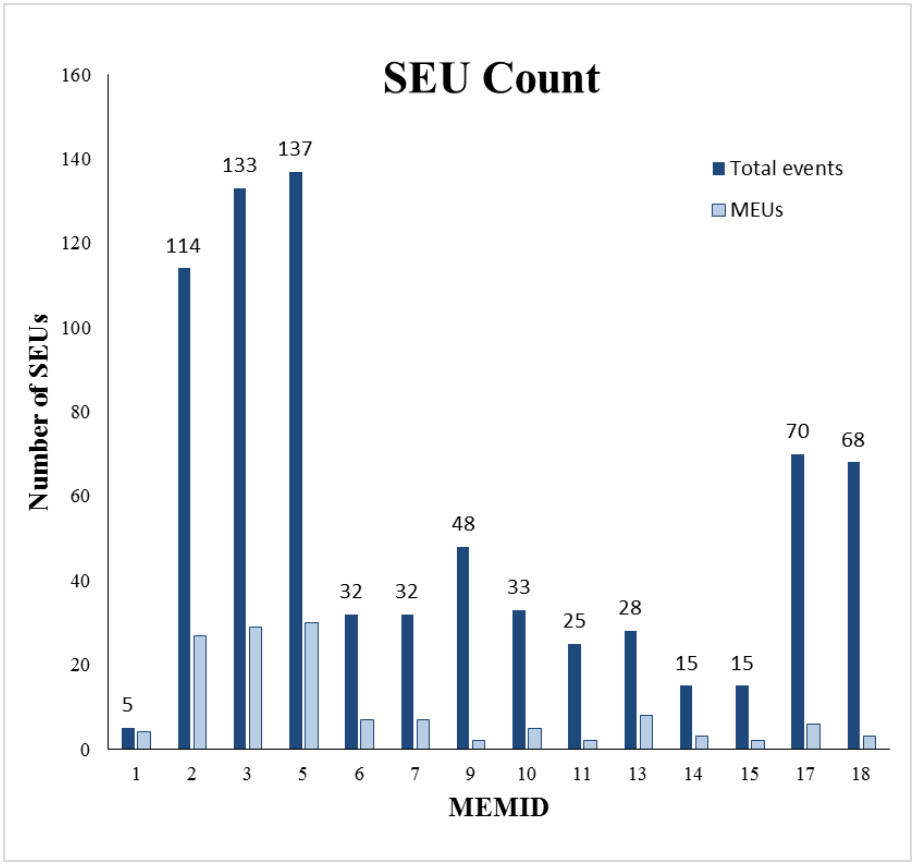
ALPHASAT TDP8 MTB, SRAM, SEL
Comparison with Rate Calculations

			OMERE (solar max) (latchups/day)		In-flight data (latchups/day)	Ratio between results
IS61LV5128AL-12	**4Mb**	(memories 9 - 11 alphasat)		Mem. Num		
				9	5.03E-02	
				10	4.53E-02	
				11	4.53E-02	
				Average		
			6.42E-02		**4.70E-02**	**1.37**
IS62WV20488BLL	**16Mb**	(memories 1-3 alphasat)		Mem. Num		
				1	0	
				2	0	
				3	0	
				Average		
			1.25E-03		**0**	
BS62LV8001EIP55	**8Mb**	(memories 5-7 alphasat)		Mem. Num		
				5	1.86E-01	
				6	1.94E-01	
				7	1.69E-01	
				Average		
			4.89E-01		**1.83E-01**	**2.67**
K6R4008V1D	**4Mb**	(memories 13-15 alphasat)		Mem. Num		
				13	2.52E-03	
				14	2.52E-03	
				15	2.52E-03	
				Average		
			5.63E-04		**2.52E-03**	**0.22**
AT68166F	**16Mb**	(mem 17-18 aphasat)		Mem. Num		
				17	0	
				18	0	
				Average		
					0	

ALPHASAT TDP8 MTB
SRAM, SEU

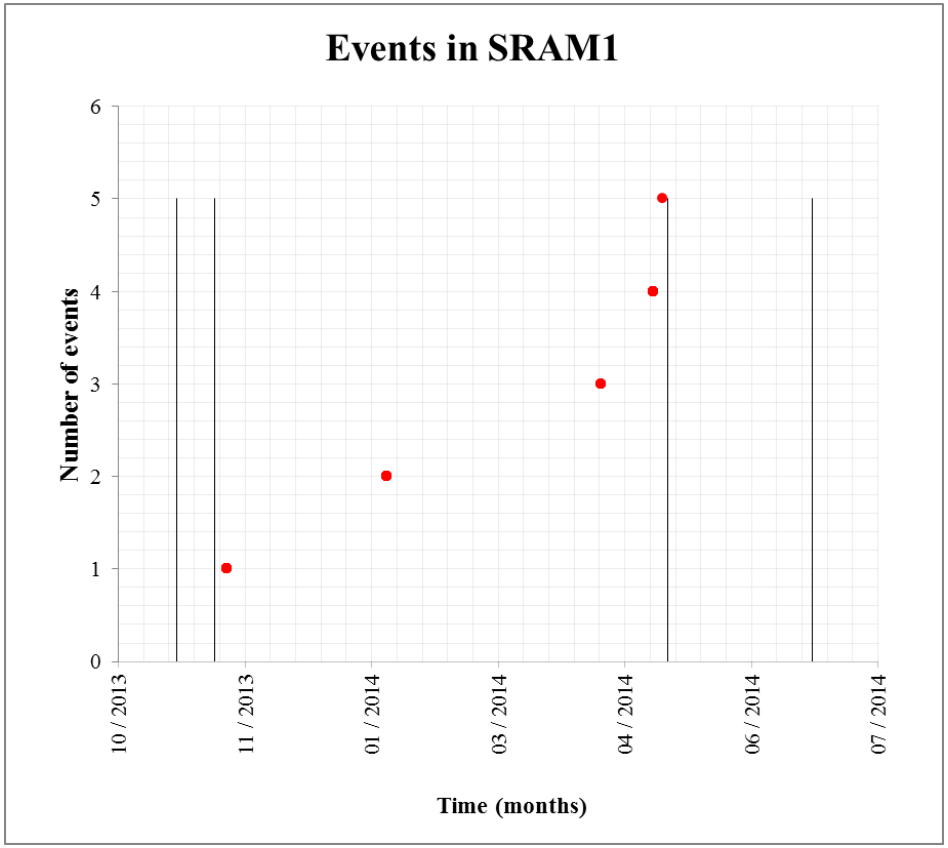
High part to part variability is observed

Memories on board MTB/Alphasat			
ISSI	IS62WV20488BLL	16Mb	1-3
BSI	BS62LV8001EIP55	8Mb	5-7
ISSI	IS61LV5128AL-12	4Mb	9-11
Samsung	K6R4008V1D	4Mb	13-15
Atmel	AT68166F-YS18CC	16Mb	17-18

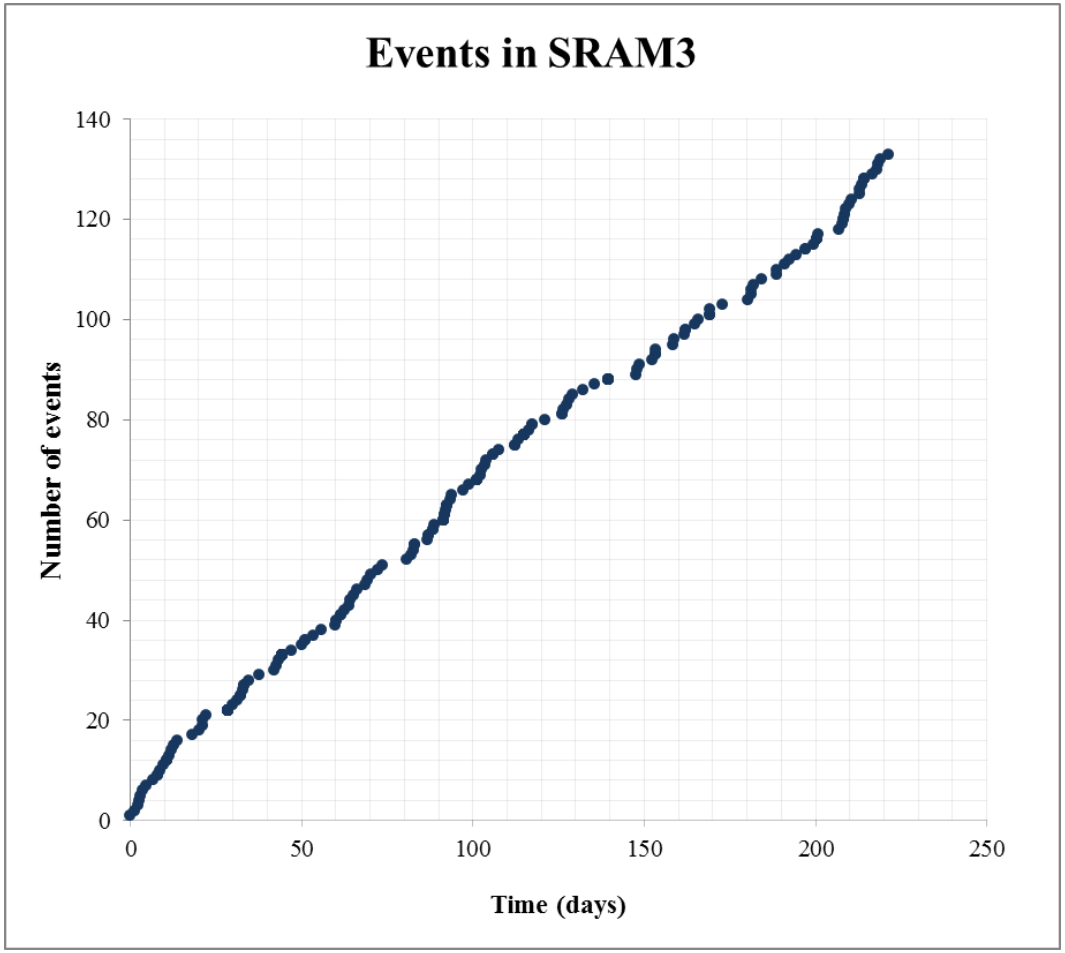


ALPHASAT TDP8 MTB
SEL experiment, SEU

The IS62WV20488BLL (SRAMs 1-3) is prone to big events with multiple bit upsets. The memories have received 0.02 big events per day, with approximately 400 bit upsets each. In SRAM1, much less sensitive than the other two, just 5 SEUs have been recorded, and 3 of them where events with over 410 bit upsets.



ALPHASAT TDP8 MTB
SEL experiment, SEU

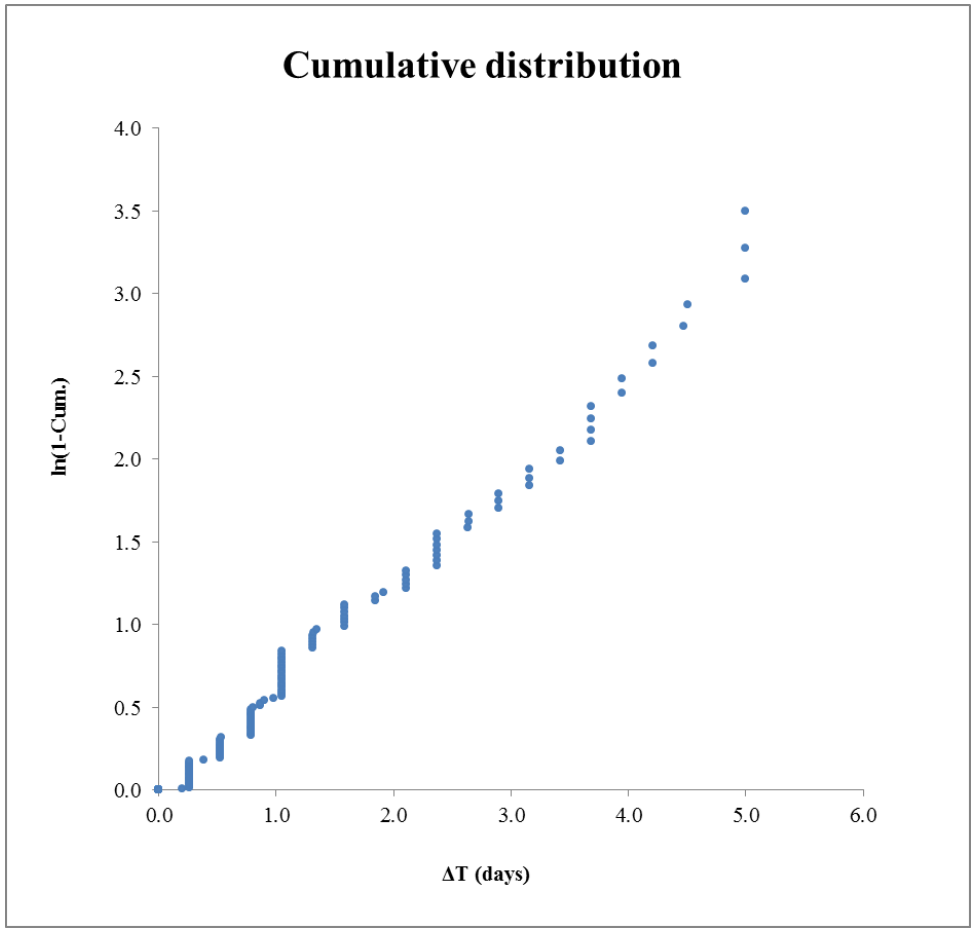


Time is in days since start of the experiment, suppressing time gaps

ALPHASAT TDP8 MTB
SEL experiment, SEU

The random nature of the events for the SEU can be seen (the stairs are due to the read cycle).

Event numbers are still low to make a proper distribution



$$-\ln(1-F(t)) = -\ln(1-1+e^{-\Lambda(t)}) = \Lambda(t)$$

ALPHASAT TDP8 MTB, SEL experiment, SEU Comparison with Rate Calculations

SEU rate prediction was performed for the SRAMs using OMERE under solar maximum conditions, a sensitive volume thickness of 2 µm and 6 mm of Aluminum shielding.

The data used for the Weibull fit was taken from ground test data at 45 °C, whereas the temperature of the satellite in its geostationary orbit is of 24 °C approximately.

ALPHASAT TDP8 MTB, SEL experiment, SEU Comparison with Rate Calculations

			OMERE (solar max) (upsets/day)		In-flight data (upsets/day)	Ratio between results
IS61LV5128AL-12	4Mb	(memories 9 - 11 alphasat)		Mem. Num		
				9	0.217	
				10	0.149	
				11	0.113	
				Average		
			0.39		**0.160**	**2.44**
IS62WV20488BLL	16Mb	(memories 1-3 alphasat)		Mem. Num		
				1.00	0.023	
				2.00	0.515	
				3.00	0.600	
				Average		
			1.81		**0.379**	**4.78**
BS62LV8001EIP55	8Mb	(memories 5-7 alphasat)		Mem. Num		
				5.00	0.619	
				6.00	0.144	
				7.00	0.144	
				Average		
			0.71		**0.302**	**2.34**
K6R4008V1D	4Mb	(memories 13-15 alphasat)		Mem. Num		
				13.00	0.126	
				14.00	0.068	
				15.00	0.068	
				Average		
			0.27		**0.087**	**3.12**
AT68166F	16Mb	(mem 17-18 aphasat)		Mem. Num		
				17.00	0.316	
				18.00	0.307	
				Average		
			1.35		**0.312**	**4.35**

ALPHASAT TDP8 MTB
Flash Memories

No SEL, SEFI or SEU have been recorded for the flash memories. The absence of SEL and SEFI was expected for the short period of observation. But for SEU, the expected rates using predictions from OMERE are 0.03 ev/day in static mode. Therefore, the absence of SEU is surprising.