An overview of PROBA-II and PROBA-V SEE analysis flow and comparison to in-flight data

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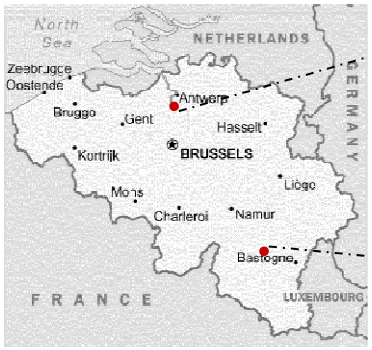
QinetiQ

QinetiQ Space nv

1 Company Introduction

Key Data

- Former Verhaert Space (name change April 2010 to QinetiQ Space)
- Founded in 1969 as product developer
- Space activities started in 1983
- Delivered 100+ systems and sub-systems for manned space stations, satellites and interplanetary missions
- Belgians leading space company and innovative product developer
- Acquired by the QinetiQ group (UK) in 2005
- 110 highly educated specialists employed in Belgium + 60 in Farnborough (UK space activ.)
- Turnover over 24 MEURO (2011 – Belgian activities only)



QinetiQ Space nv Headquarters

- Located in Kruibeke - Belgium
- Offices: 3.742 m², Warehouses: 1.200 m²
- 2 Class 100.000 cleanrooms

QinetiQ Space nv Ground Station Operations

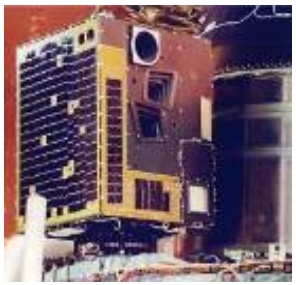
- Located in Redu - Belgium
- ESA satellite ground station
- Jointly operated with SES Astra Techcom

QinetiQ Space UK

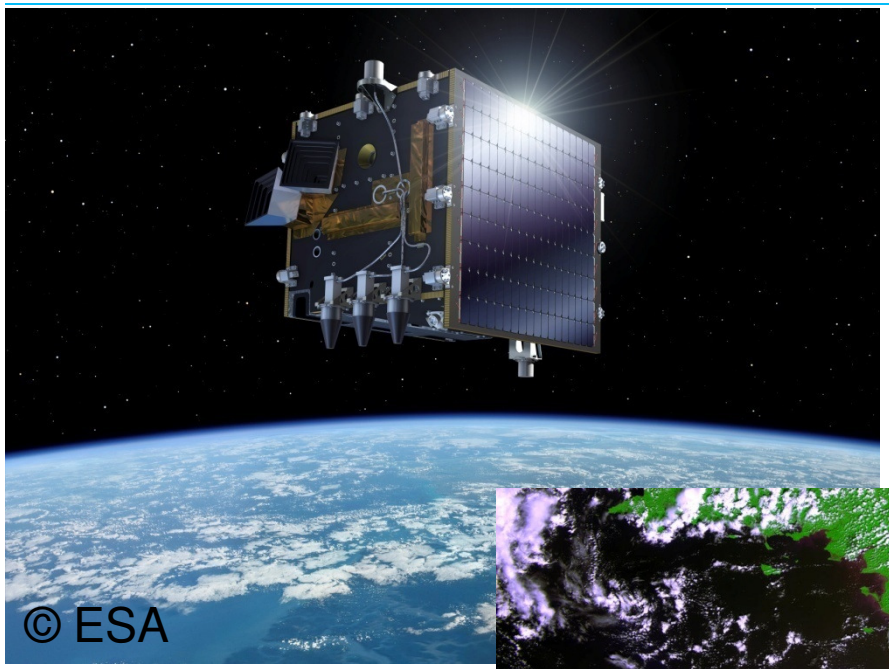
- Located in Farnborough - UK
- Integration Facilities
- Test Facilities

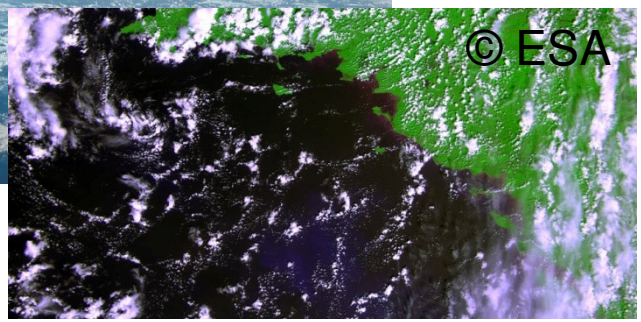
QinetiQ Space

The leading provider of Small Space Systems

Satellites & Platforms	Scientific Payloads	Subsystems	Downstream services
			
▪Small satellite bus ▪End-to-end mission solutions	▪Microgravity research ▪Planetary exploration ▪Earth observation	▪On-board computers ▪Docking & Berthing Systems ▪Space Mechanisms	▪Satellite Operations ▪Integrated Applications ▪Technical consultancy
	▪Frequency Monitoring ▪Metrology	▪Electrical Propulsion ▪UHF transponders	▪GIS applic & serv ▪Space tourist training

2 Proba V Science Mission – Global Vegetation Growth





3 SEE Analysis setup

For all SEE components a radiation hardness analysis report is made. Critical components and circuits are analyzed and simulated in more detail. This includes SET pspice analysis, TID calculation, SEU/SET rate predictions and latchup protection simulation.

Spenvis and Omere were used for PROBA-2 and PROBA-V to perform SEE rate and TID calculations.

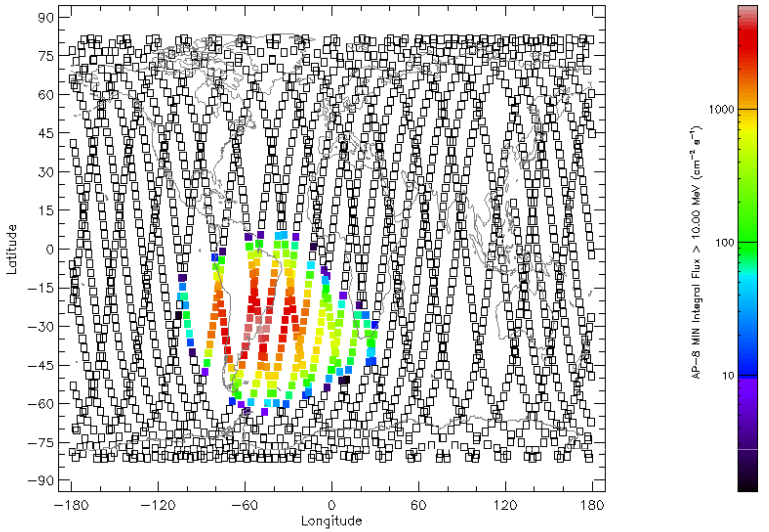
Radiation analysis inputs

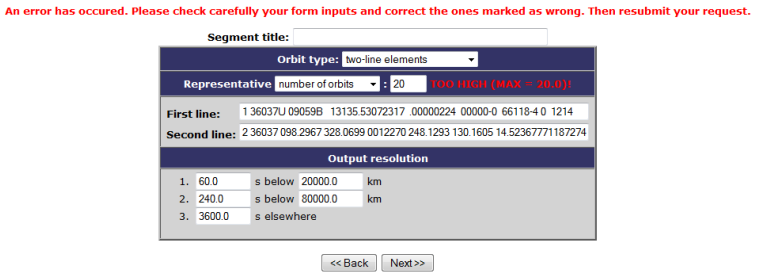
- Mission requirements (examples)
  - Orbit definition (polar, appr. 800km)
  - Latchup threshold >37MeV.cm²/mg
  - Total dose 20Krad with standard shielding
- Models selection according to ECSS specs and ESA experts recommendations
  - Trapped particles: AE-8-MAX, AP-8-MIN
  - solar particles : ESP 95% confidence level
  - Cosmic Rays : GCR ISO or CREME96
- Component data availability
  - Hi-Rel parts with full characterization
  - Company characterization of commercial upscreened parts
  - Historic data with sufficient level of detail

4 Orbit Definition

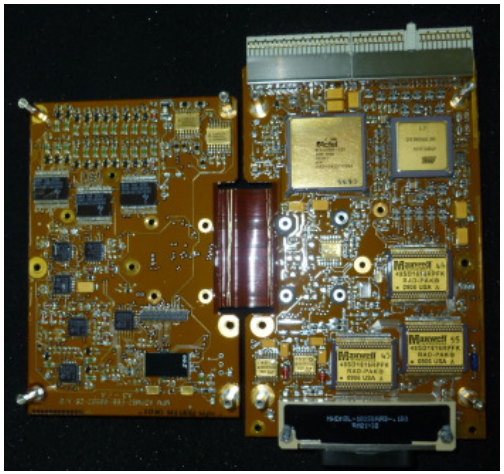
Basic parameters are straightforward and fixed but others are open to the user.

- Lots of different input possibilities!
- Use as many orbits as possible to have a good earth coverage. Maximum 20 in Spenvis, 100 used in Omere.
- Default output resolution is kept (60sec)
- Visualisation to ensure critical regions are passed in the correct ratio (poles, SAA crossings)
- For short duration calculations (e.g. SAA pass), TLE input with begin and end-time would be nice to have.





5 ADPMS SEU analysis examples



K6R4016V1C SRAM (Samsung)

- Commercial upscreened part
- Radiation test reports publicly available
  - ESA_QCA103S_C (heavy-ions and protons)
  - ESA_QCA103T_C (total dose)

48SD1616RPFK SDRAM (Maxwell)

- Class K, Hi-Rel screened device
  - RAD-PAK, total dose >100krad (Si)
  - No latchup : SEL_{TH}>85 MeV.cm²/mg @25°C
  - SEE characterized by manufacturer
- Radhard does NOT mean insensitive to SEU, SEFI, stuck bits…

M29F032D70N6 FLASH (ST Microelectronics)

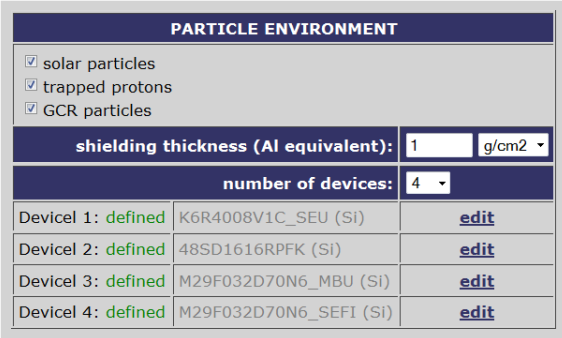
- Commercial upscreened part
- Limited public data with lack of details for analysis
- Flight lot was radiation characterised by QinetiQ Space
  - Total dose testing
  - Heavy Ion and Proton SEU, SEFI an SEL testing

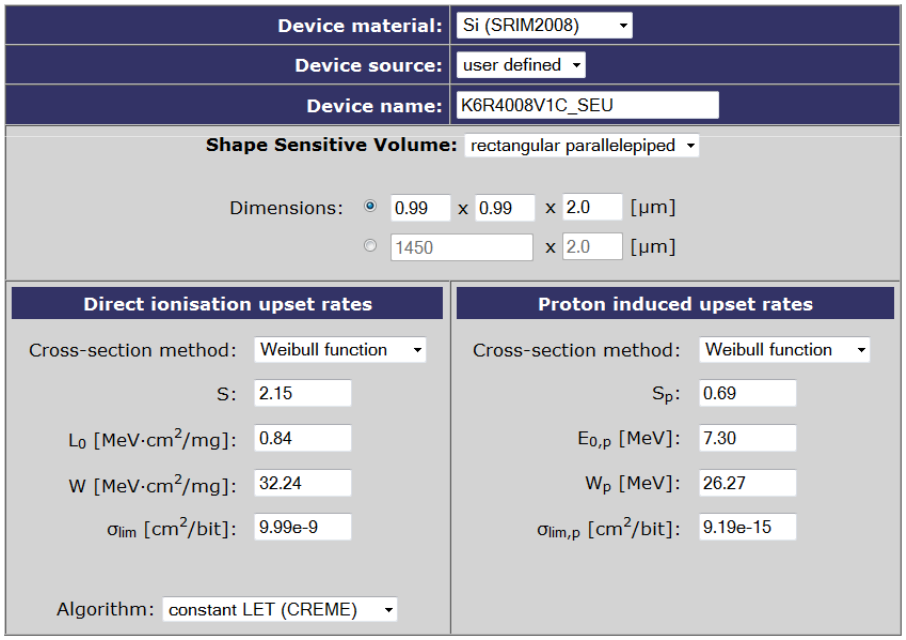
6 Component data input

Initial analysis goal is to get a worst case behaviour to configure scrubber rates, implement SEFI recovery procedures and latchup protections.

But test reports don't give all the data!

- Sensitive volume
  - Area deduced from saturated cross-section
  - Sensitive depth in most cases unknown
- Error margins can be huge
  - Only few parts tested
  - Variations between test houses, reports
- Weibull fit or experimental data for both heavy-ions and protons are preferred
- SIMPA and PROFIT to be used with caution





7 Proba-II in flight data

Prior to the PROBA-V launch, comparison between Proba-II in flight date and Spenvis/Omere calulcations was possible.

- SRAM upsets are overestimated
  - 250 SEUs expected, only 4 seen per device
  - Scrubber / EDAC clears single bit errors
  - Simulated shielding is very conservative (3.7mm Al)
- Flash does not show any upsets
  - as expected, not sensitive to protons
  - Results are per device!
- SDRAM seems more sensitive
  - Expected rate is only 2 events during the mission
  - 2457 single bit errors since launch
  - Mainly on a few addresses, not random

Total mission single event upsets

Device	Effect	(bit^{-1})
K6R4008V1C	Direct ionization	5.0858E-07
	Proton induced ionization	2.9351E-05
	Total	2.9860E-05
48SD1616RPFK	Direct ionization	5.7033E-12
	Proton induced ionization	7.0378E-09
	Total	7.0435E-09
M29F032D70N6_MBU	Direct ionization	3.0455E-02
	Total	3.0455E-02
M29F032D70N6_SEFI	Direct ionization	1.2381E-01
	Total	1.2381E-01

8 Future analysis

- During analysis, GEANT4 tools were not yet used
  - Not yet a good overview of possibilities
  - Explore sectorial analysis
  - Effect of graded shielding
- Omere / Spenvis
  - Differences in results, mostly very minor (TID, heavy ion upsets)
  - Proton upset rates mismatch, under investigation (parameter settings?)
- Component input
  - Gathering and extracting relevant data from more radiation reports
  - Expected error/safety margins for simulation results
  - More component details (DIE structure, sensitive depth, areas) are needed

QinetiQ Space nv

www.QinetiQ.be