Radiation Effects Study by SEE Experiment on CubeSat - MTCube

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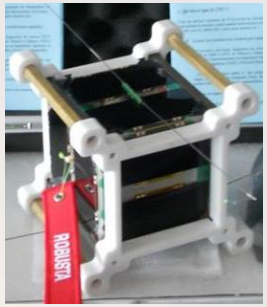
Overview

1. Activities at CSU
2. Background and motivations for MTCube
3. Presentation of the CubeSat project
4. Candidate memories for the payload
5. Radiation Effects Study Experiment
6. Test results:
   - Impact of test mode
   - Impact of stacked layers
7. Conclusion

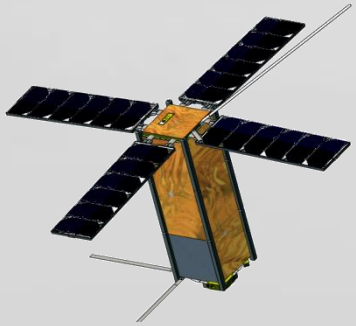
Activities at CSU (Montpellier – Nîmes)

ROBUSTA-1B (1U CubeSat)
Status: Under testing, launch end 2015 on Falcon 9
Mission : Measure IC bipolar degradation in flight, comparison with accelerated test methods (« débits commutés » – IES/Radiac)
Financed by CNES



MTCUBE – Robusta 1C (1U CubeSat)
Status: Phase B
Mission : SEE events on advanced memory technologies
Financed by ESA

CELESTA – ROBUSTA 1D (1U CubeSat)
Status: Project to be started
Mission : Fly the RadMon V.7 (CERN)
Financed by CERN



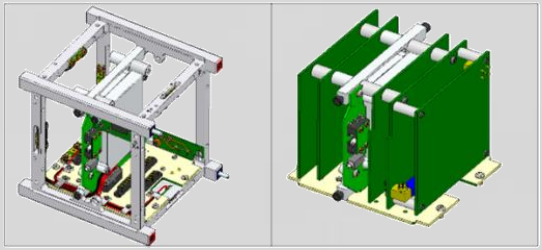
Robusta-3A (3U CubeSat _ 3 axis stabilisation)
Status: Phase A review in the coming months
Mission-1: Meteorological data collection in Mediterranean area
Mission-2: Low data rate communication with schools in Africa and Madagascar
Mission-3: Technology demonstration of a star tracker
Financed (in the near future) by CNES and LABEX NUMEV

Motivations for MTCube

- **Motivations:**
  1. Need to qualify more integrated COTS memories in real environment and compare with ground tests
  2. Emerging memories, possible use on satellites ?
  3. Availability of a complex and cheap system for qualifying components in space radiation environment (CubeSat + payload)

- **Goal of the mission:**

  Characterise the behaviour of **COTS memories** (SRAMs 90nm and 65nm, FLASH, MRAM and FRAM in 3D configuration) in the real space environment against **SEEs** and compare with **radiation tests on ground** AND **mapping** the SEE response of these memories along the orbit.



Presentation of the project 1/2

- **MTCube : M**emory **T**est **Cube**Sat

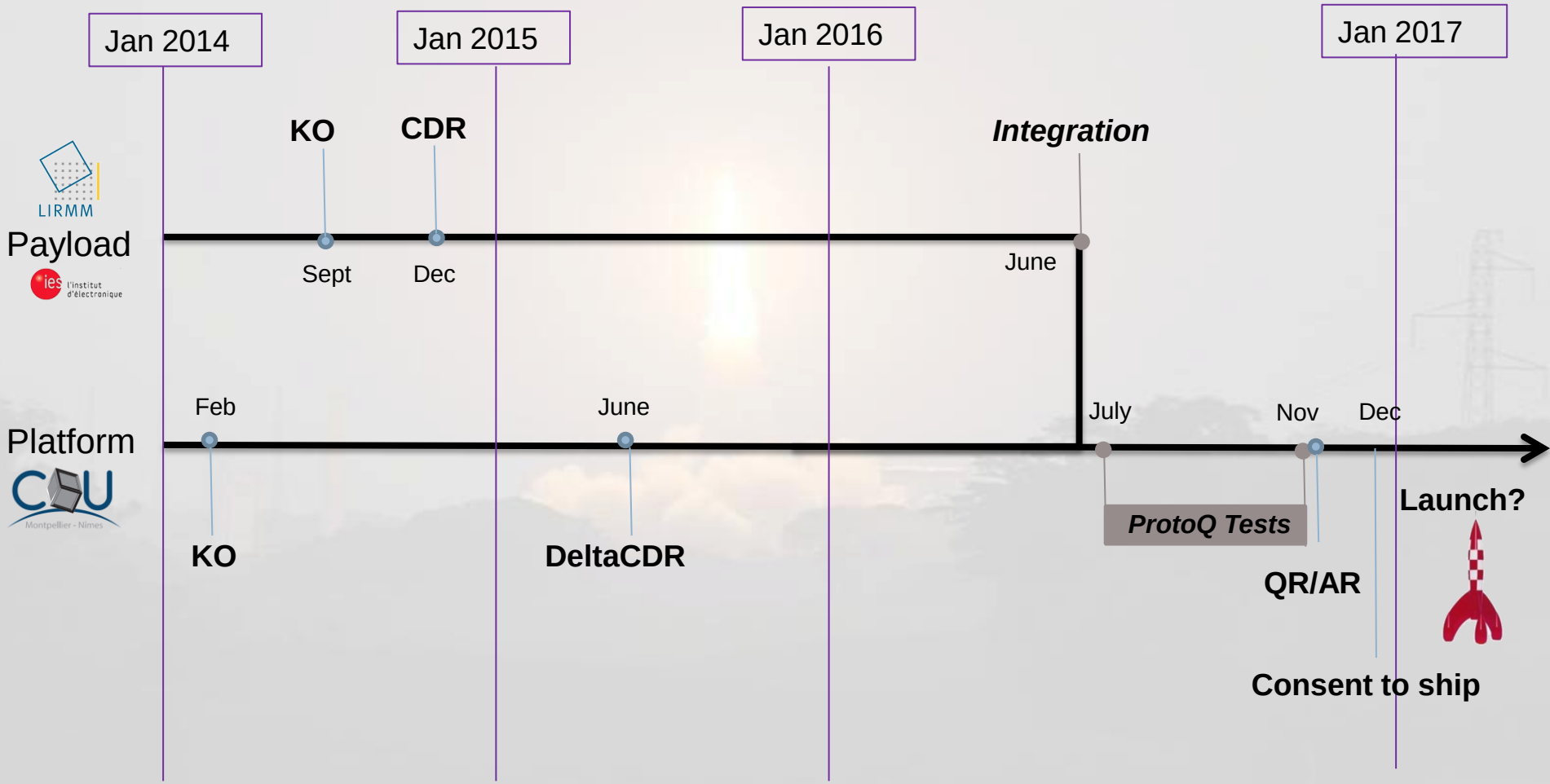
- MTCube is a 1 Unit CubeSat (10*10*10 cm^3) which will carry the RES Experiment : **R**adiation **E**ffects **S**tudy by SEE Experiment

- **2 year nominal mission** with consent-to-ship planned by end 2016

- Scientific experiment:
  - Single Event Effects on memories
  - Correlation using dose measurements (**RadFET** and **OSL)**

- MTCube will be developed, built and tested by **students from University of Montpellier** hence implying a strong educational aspect.

Presentation of the project 2/2



MTCube Memories

SRAMs:

- Volatile memory
- Fast access time, low power consumption
- Cell based on 6 Transistors
- Currently used on satellites
- Interest: Compare the response of 2 technology nodes, compare dynamic/static tests

FLASH:

- Non-volatile memory
- high storage capacity, low cost
- Interest: control circuitry, buffer sensitivity, charge pump, data rentention (TID effects)

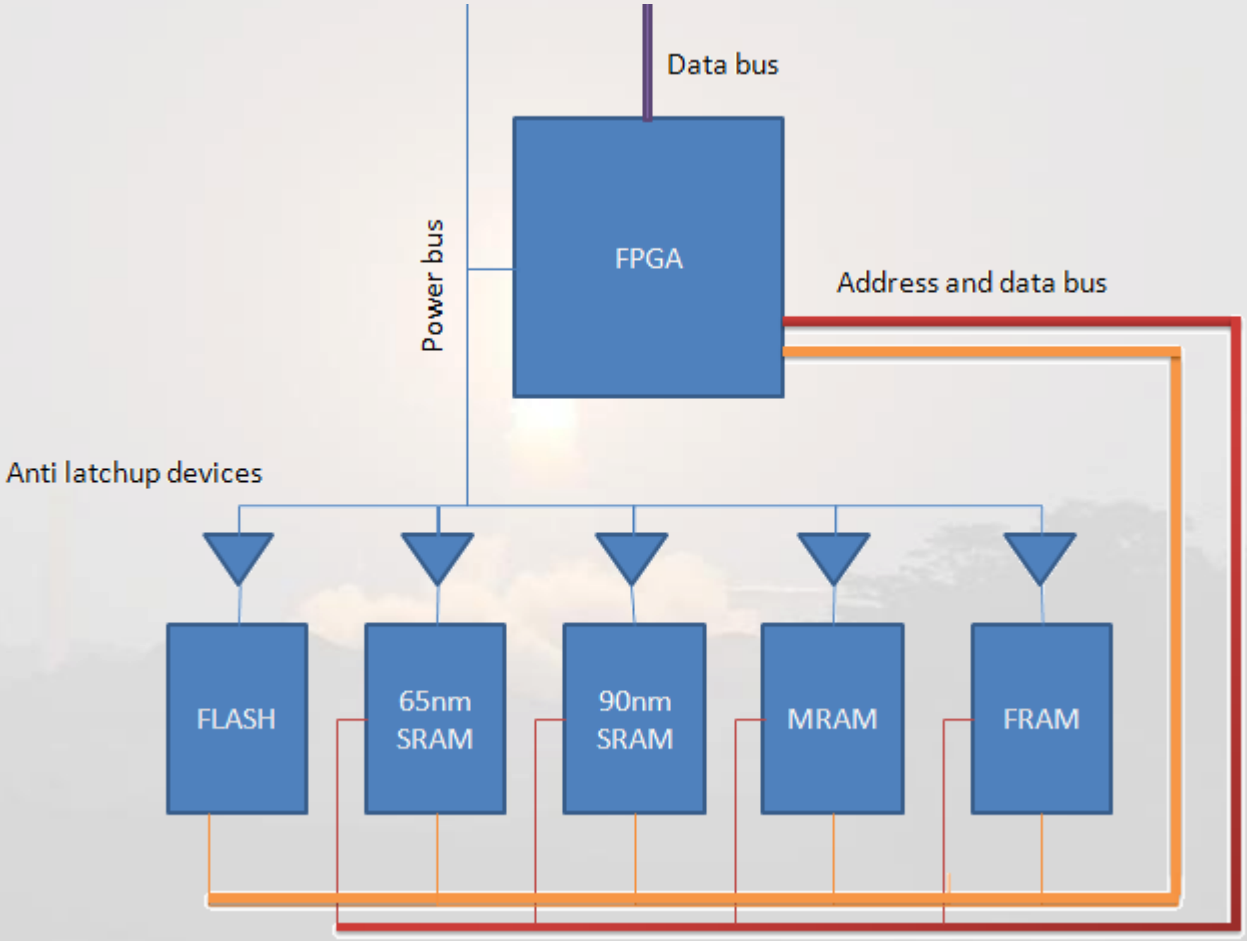
MRAM 3D plus:

- Non-volatile memory
- High endurance, speed access similar to SRAM, random access, high density (similar to DRAM)
- Interest: use for space applications to be assessed, main focus on SEL

FRAM 3D plus:

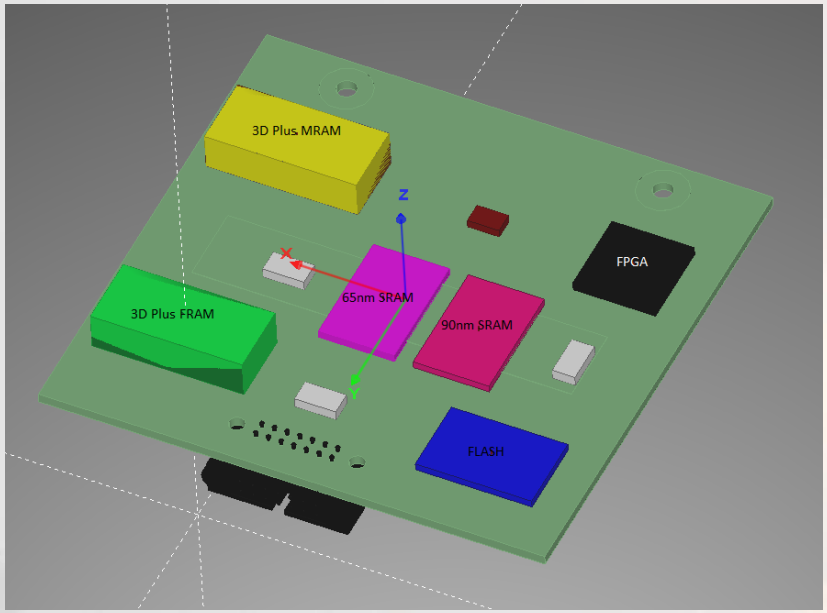
- Non-volatile memory
- Fast and low power consumption, high endurance
- Interest: use for space applications to be assessed, main focus on SEL

MTCube – RES Experiment 1/2



RES Experiment simplified electrical schematic

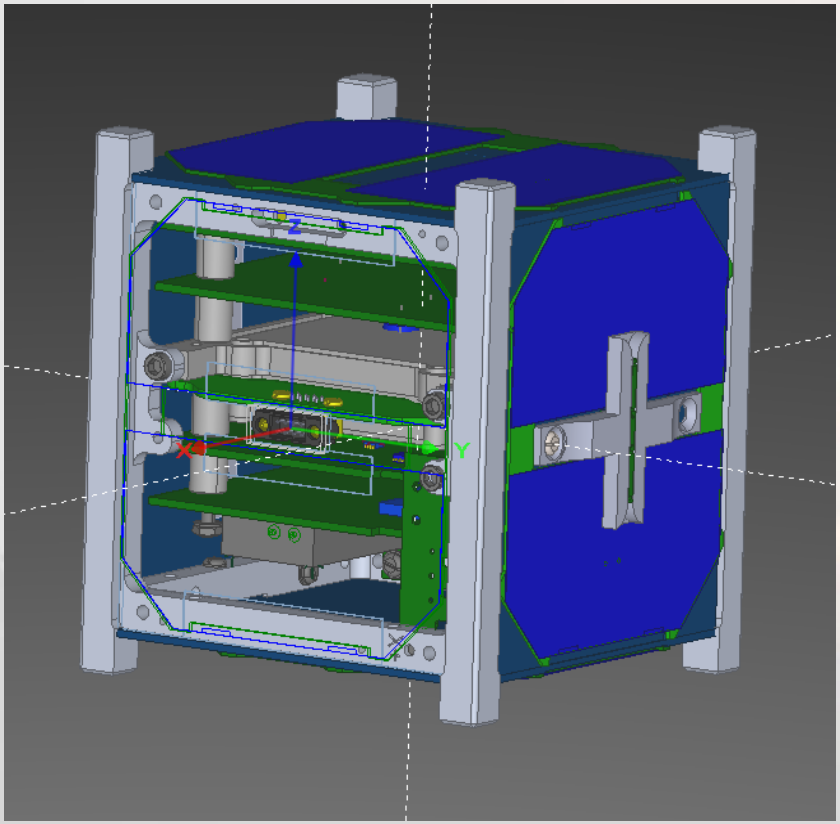
MTCube – RES Experiment 2/2



FASTRAD model of the payload

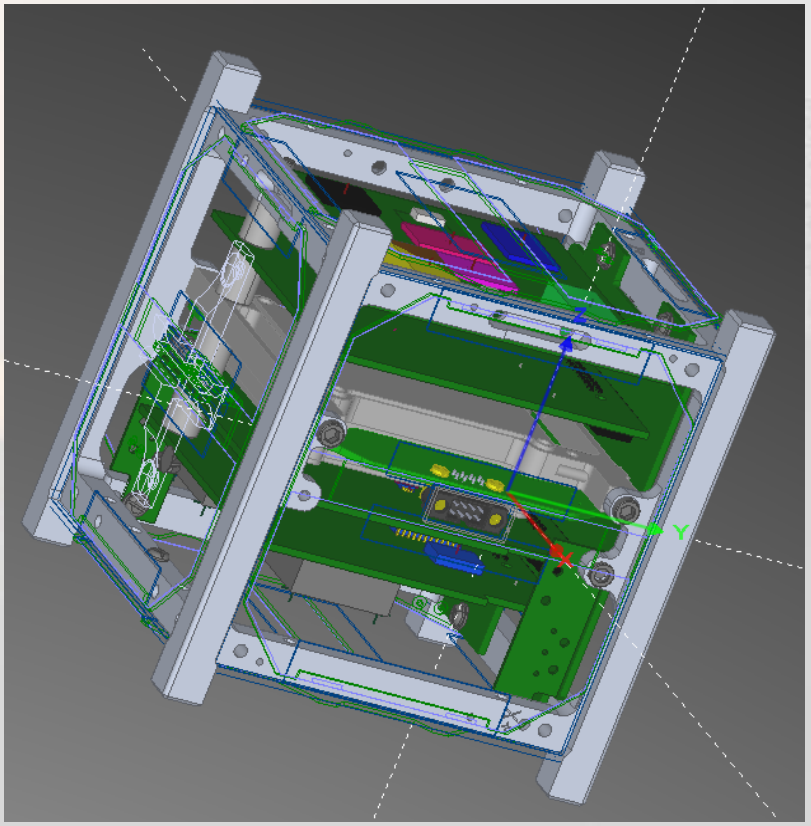
First prototype of the payload

MTCube nanosatellite



Global view (with solar panels)

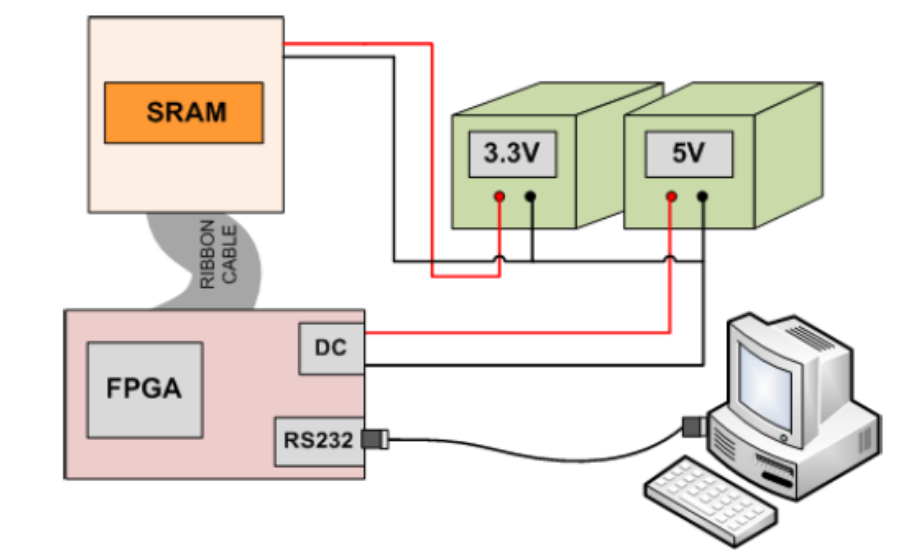
Global view (w/o side panels)



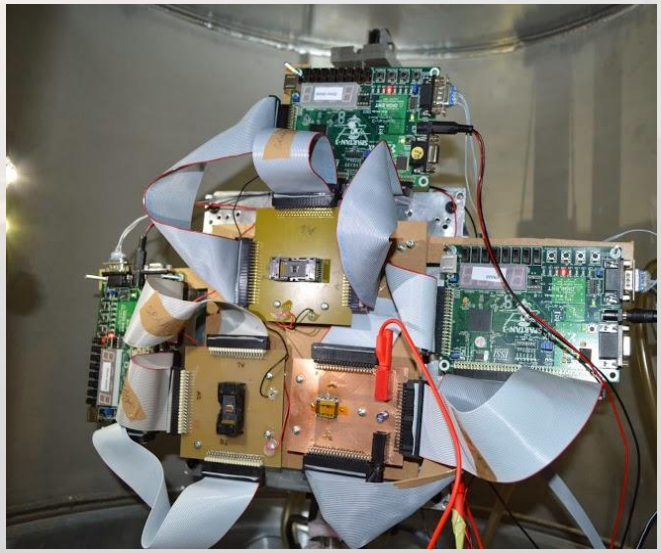
MTCube – Memory characterisation

Some tests performed so far:

Heavy Ion testing, RADEF (Dec. 2013): SRAM (90 and 65 nm), FRAM
Low energy proton testing, RADEF (Feb/Mars 2014): SRAM (90 and 65 nm)
Heavy Ion testing, RADEF (Apr 2014/Jan 2015): SRAMs (90 and 65 nm), FRAM
Heavy Ions testing (@ high penetration), UCL (Nov 2014): SRAM 90 nm



Radiation test set-up



Picture of the set-up in RADEF

Radiation testing principles

Static Tests

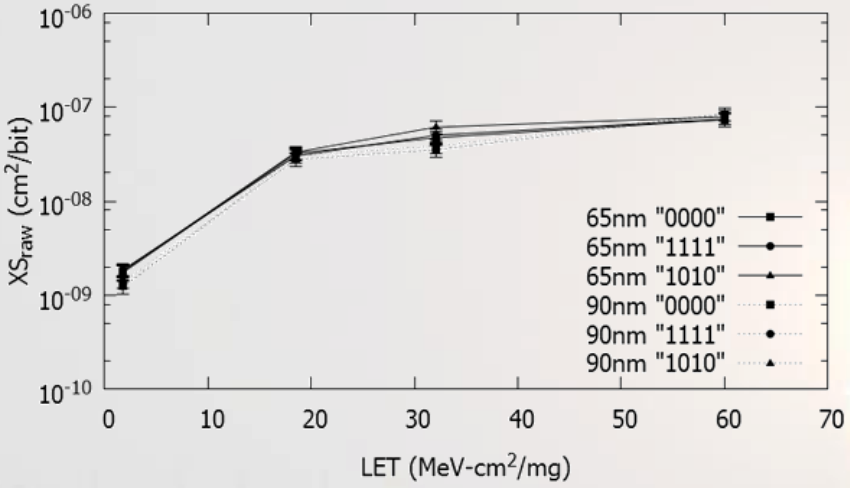
1. Data pattern written on the entire memory
2. Irradiation of the memory
3. Stored data is read and compared to the initially written pattern

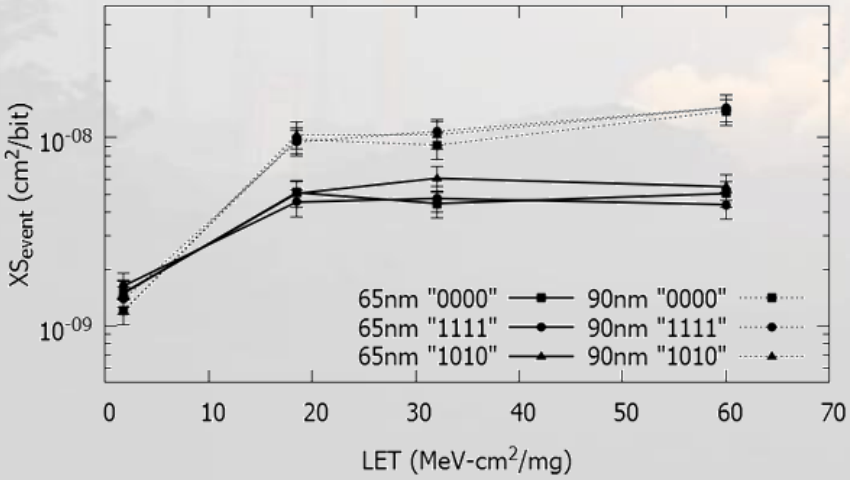
Dynamic Tests

1. During irradiation: data pattern is recursively written and read according to a specific sequence in the entire memory
2. During read operations, the stored data is compared with the previously data written

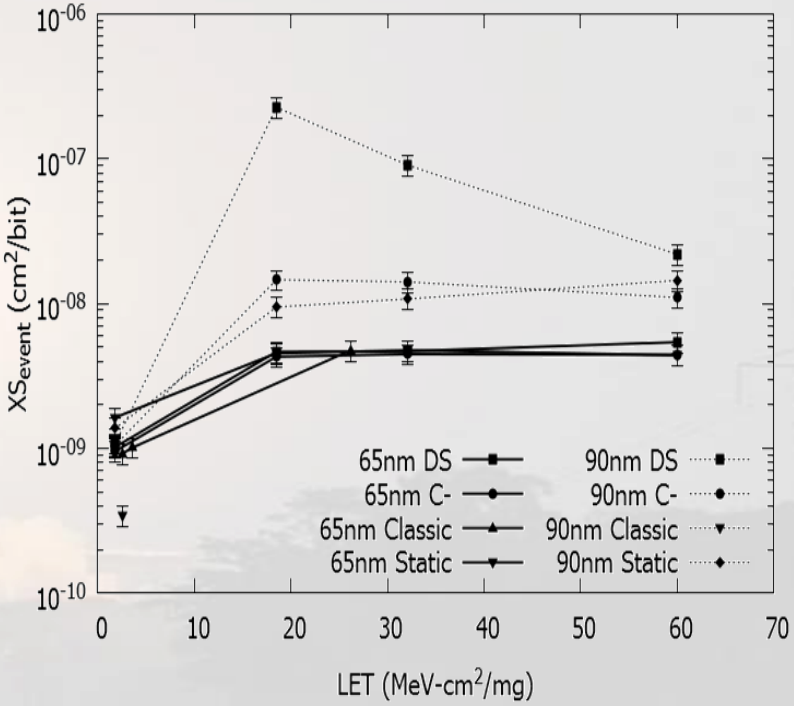
Example of test results (SRAMs)

Static Tests





Dynamic Tests

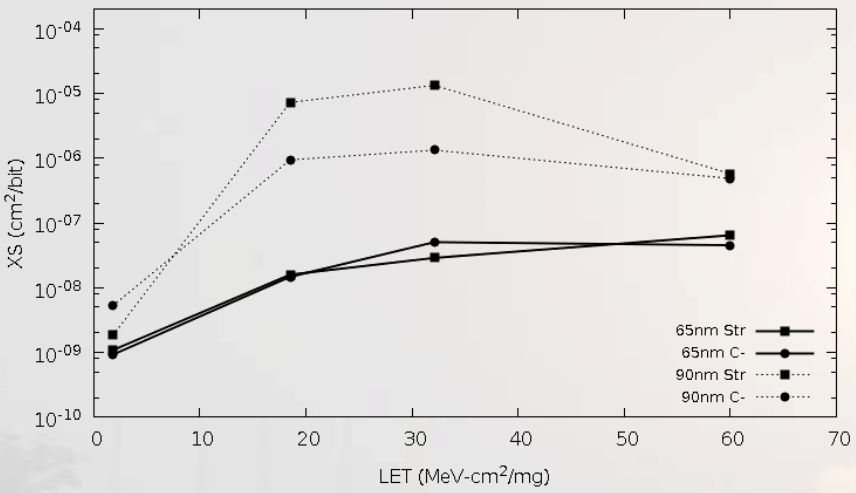


Comments:

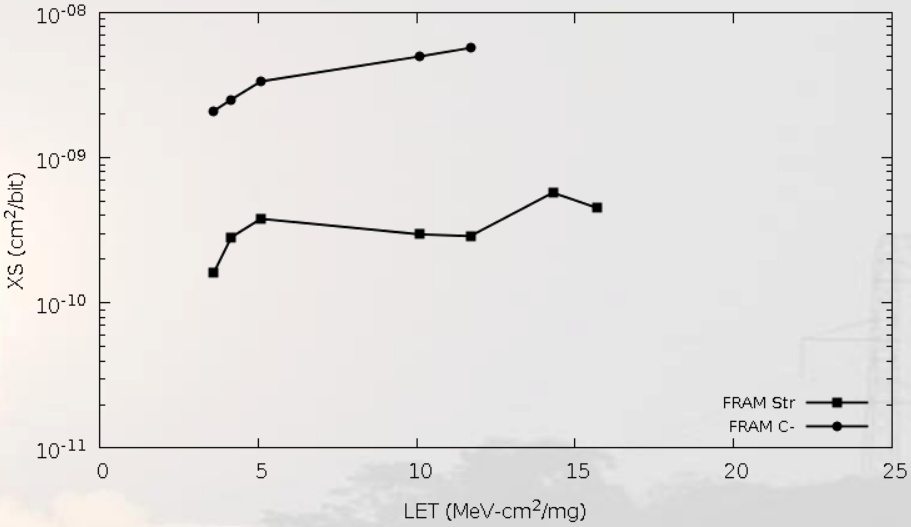
- Clustering flipped bits provides better in-sight on particle induced events
- Dynamic tests may sensitise more the memory depending on the type of dynamic test applied

Difference in response to dynamic tests

SRAM Dynamic Test



FRAM Dynamic Test

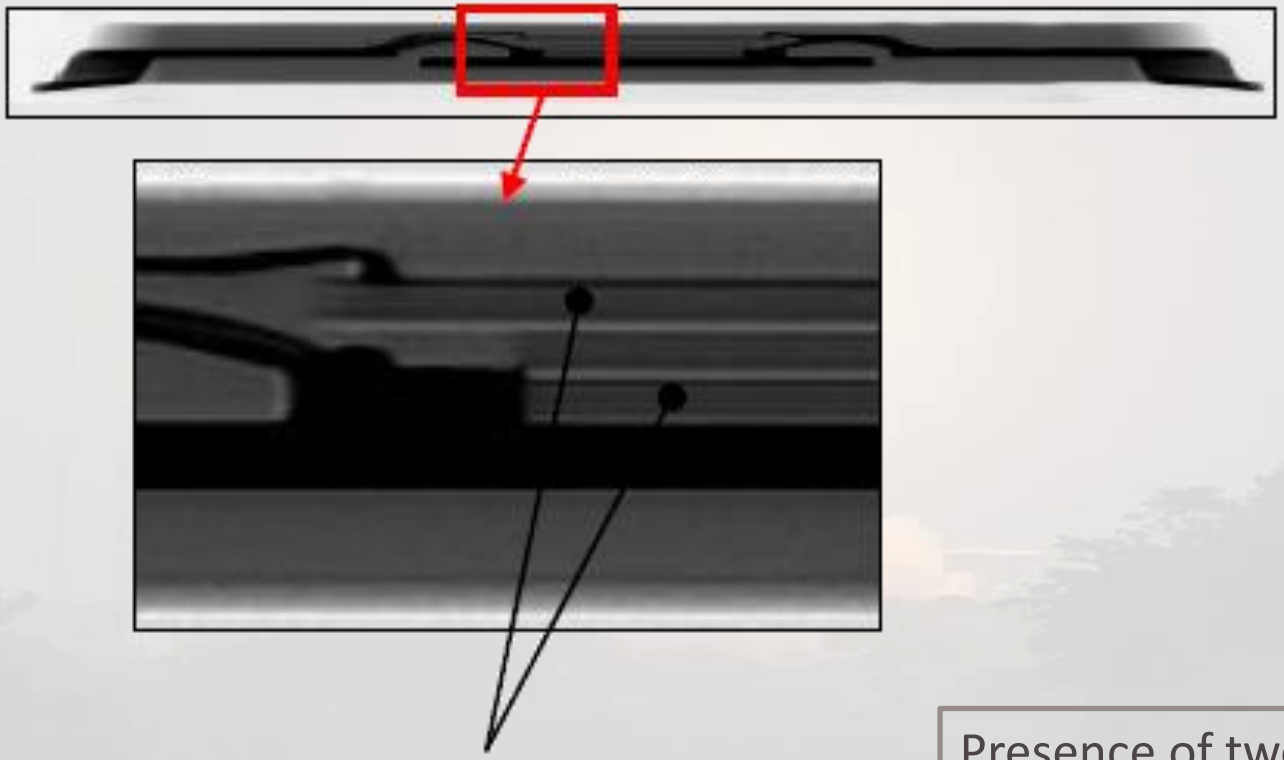


Comments:

- Different memory technologies are stressed differently depending on the type of dynamic algorithm

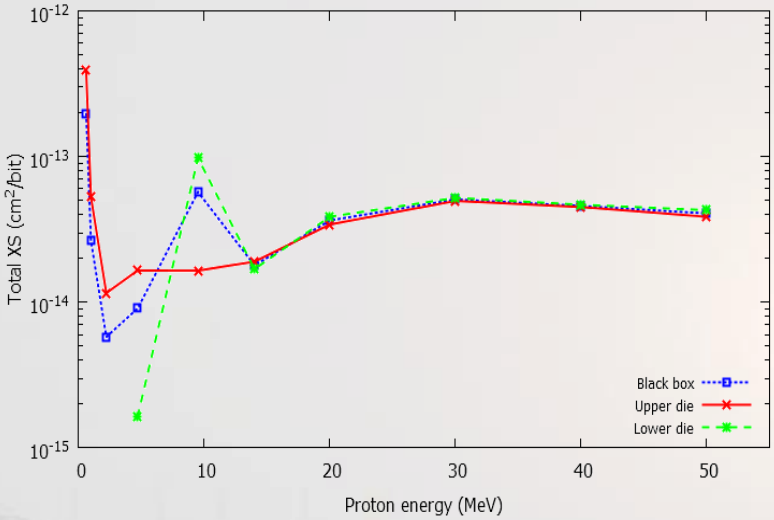
- Test results allow to selected the most suitable dynamic algorithm for the RES experiment

SRAM with double layer 1/2

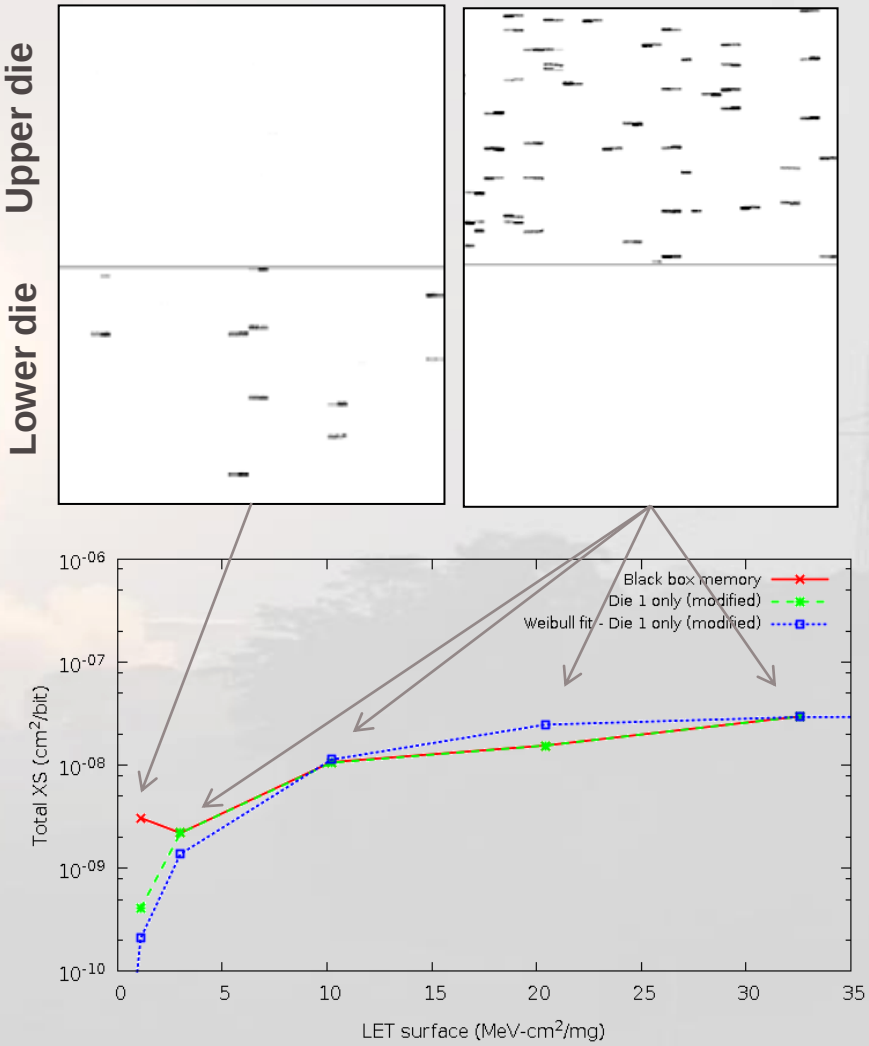


Presence of two stacked dice within the package of the 90 nm SRAM

SRAM with double layer 2/2

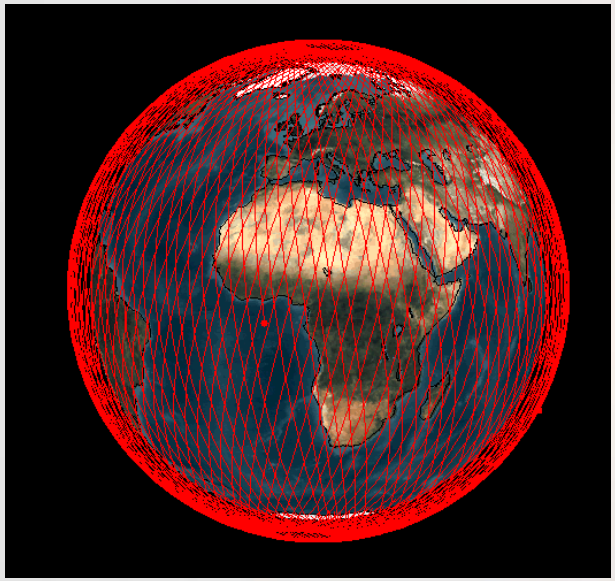


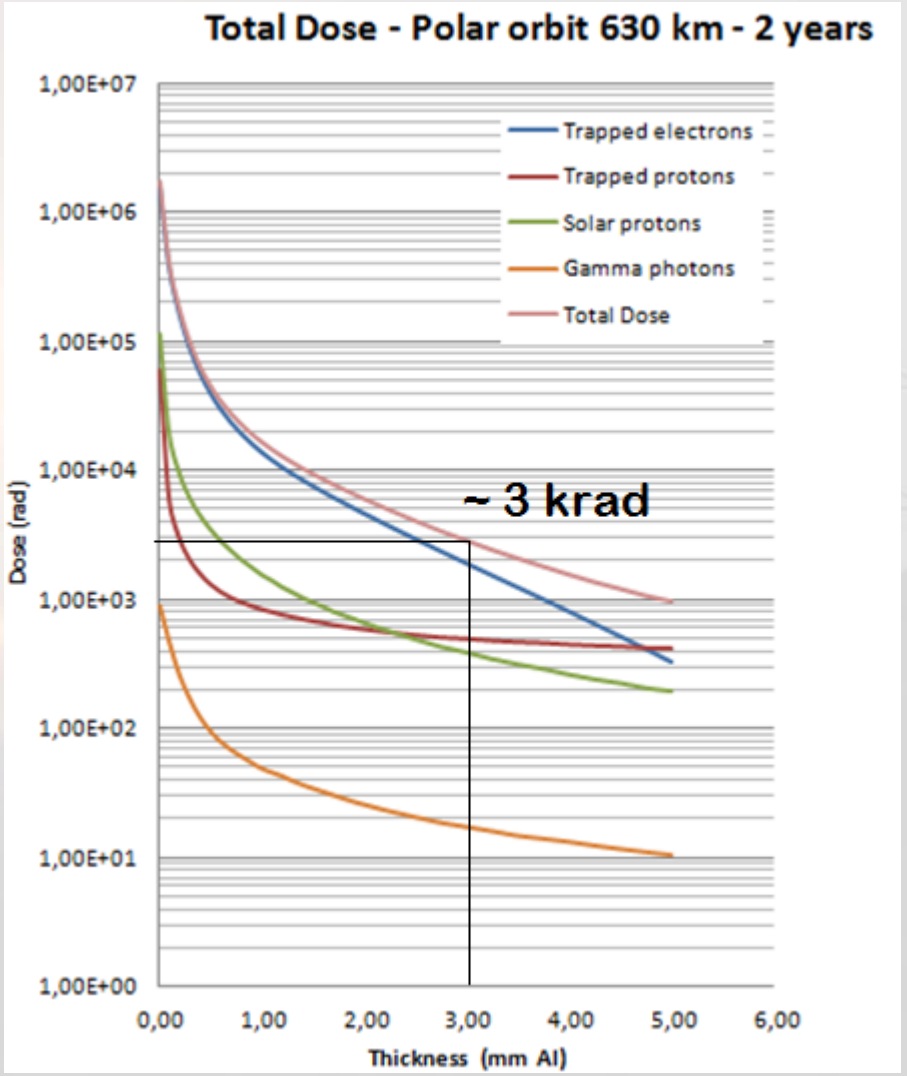
Low energy proton test results



Heavy ion test results

MTCube – Radiation environment (OMERE)





SEU events for SRAM 65 nm 16Mbit:

- Heavy ions: ~ 3 SEU/device/day
- Protons: ~3 SEU/device/day

(Rough estimation with SIMPA extrapolation from HI results)

Future Steps

Payload:

- Further testing of other memory candidates
- Software finalization and implementation
- Payload design refinement
- Tests

Platform:

- Finalize the design of the improved Robusta 1C platform
- Integrated and environmental tests

Launch:

- Initiation of negotiations to find a suitable launch opportunity for end 2016

Conclusion

- **MTCube** is a 1U CubeSat built at the **University of Montpellier** in the frame of a **student** project.
- The payload of MTCube is being developped under an **ESA contract**
- The payload will consist of different types of **memories** that will be tested in-orbit focusing on **SEEs**.
- The total ionizing **dose** will also be measured using **RadFET** and house built **OSL**
- **Extensive radiation tests** are being carried to test the memories to be flown (as well as other critical parts of the satellite)
- MTCube is foreseen to be ready-for-launch by **end 2016** and its nominal **mission** will be of **2 years**.

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