PSI ESA QCA/CNES 2009

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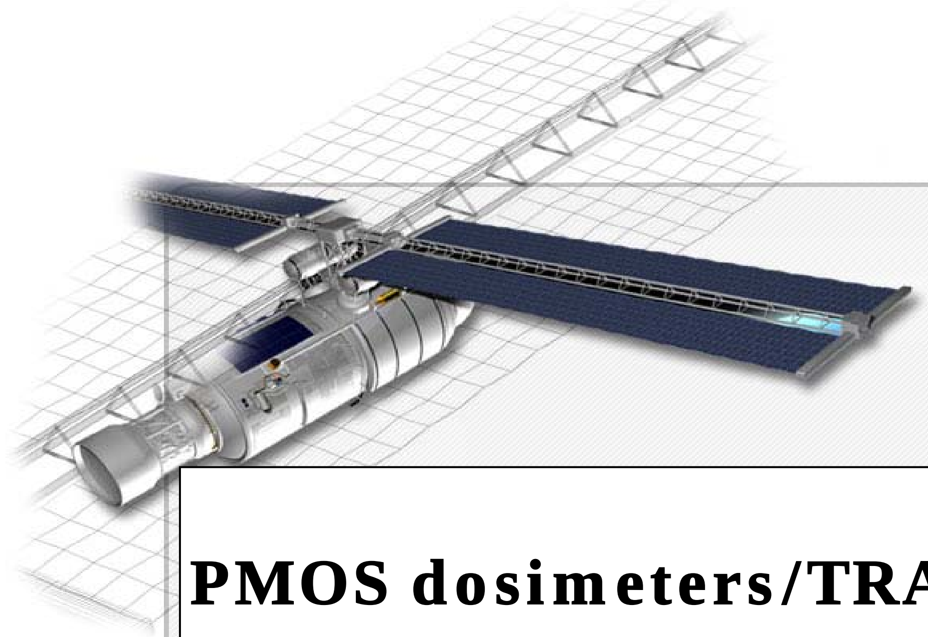

PMOS dosimeters/TRAD DOSIMETER (TSD) & Methods for Dose Calculations*.

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Anna CANALS, Olivier RONY, Pierre-François PEYRARD, Christian CHATRY — TRAD

* under CNES contract

Content of the presentation

The PMOS sensors on CARMEN2/MEX experiment

Test results for total dose and protons

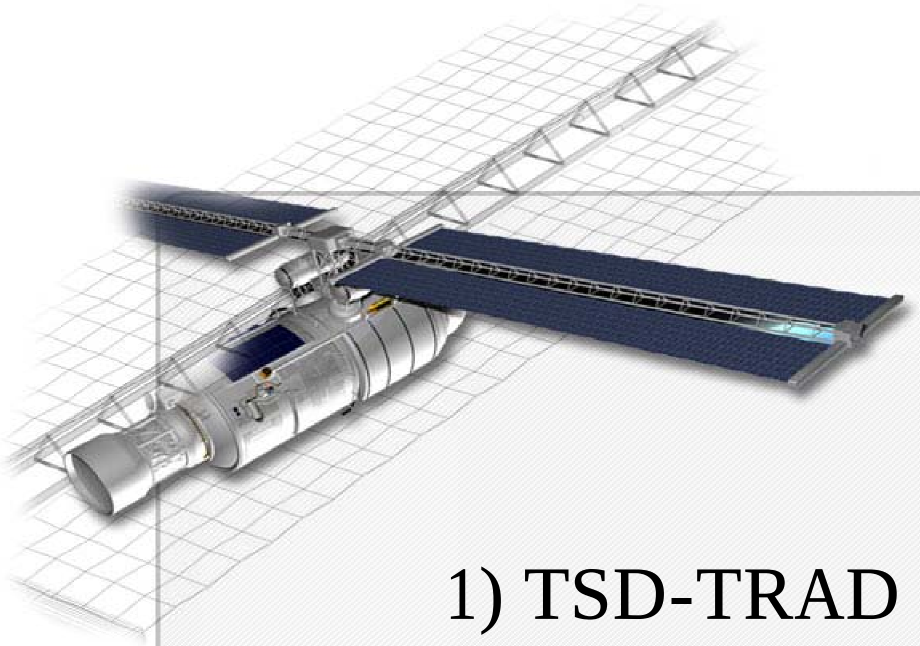
Application to CARMEN2 embedded sensors

Evaluation of dose calculation methods for 2 different environments

JASON2

GALILEO

Comparisons Calculation/ in flight data



1) TSD-TRAD Space Dosimeter

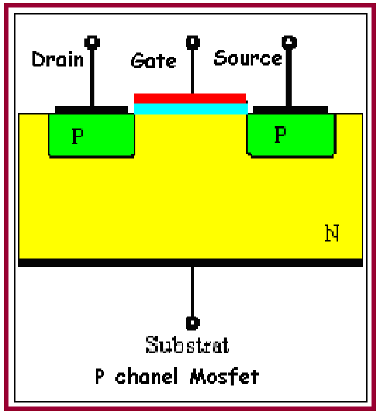
Radiation evaluation results & application to CARMEN2/MEX embedded dosimeter

TRAD SPACE DOSIMETER: TSD

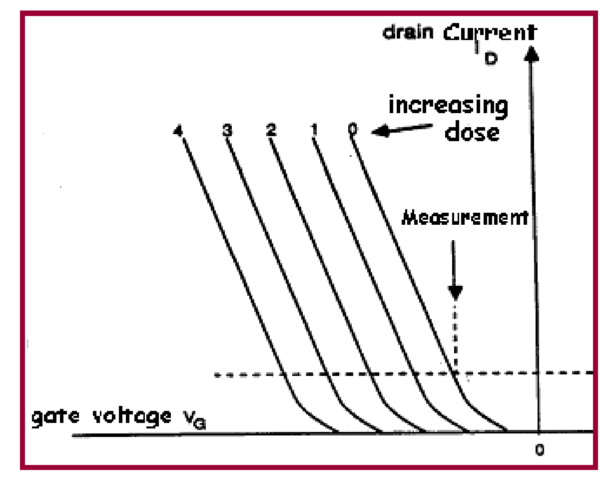
- **TSD overview**
- A MOSFET DOSIMETER from LAAS/CNRS laboratory
  - Low threshold Voltage : 2.5 V for 1.6 µm oxide
  - Large range of oxide thickness (increasing the dose range)
  - Zero temperature coefficient at Iztc
  - Reproductibility better than 5 %
  - Active or passive dosimeter
  - Easy to read with simple voltmeter
- Dose response for Co^{60}
- Protons response (60 MeV)
  - For CARMEN conditions.
    - Actif mode (HS)
    - Passive mode (LS)
- In-flight measurements

TRAD
Tests & radiations

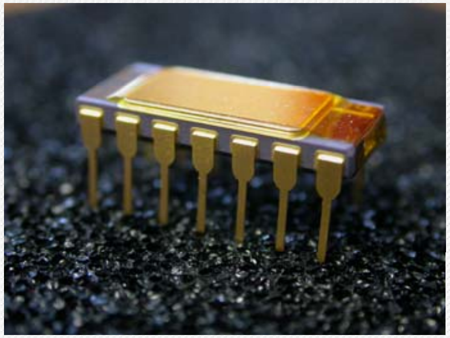
TRAD SPACE DOSIMETER: A MOSFET DOSIMETER

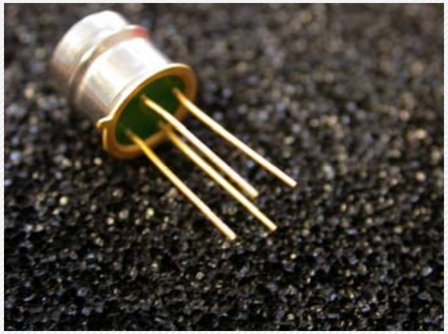


Dose response

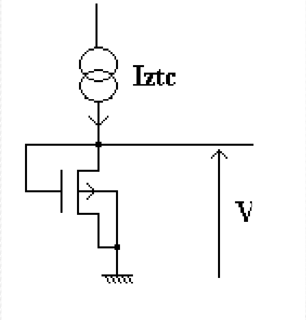


Different packages possible





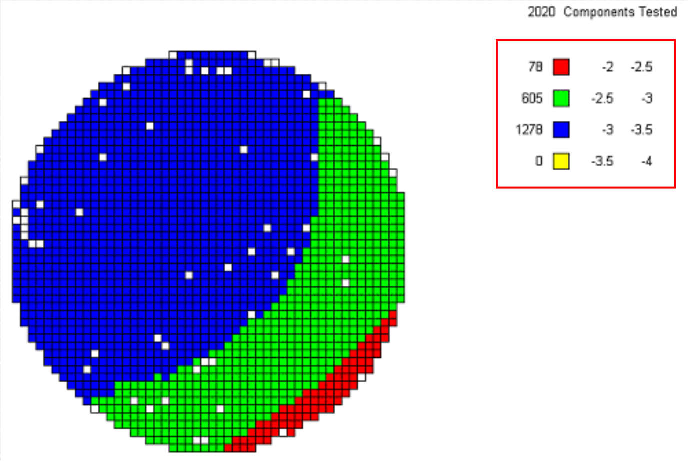
Pmos Measurement



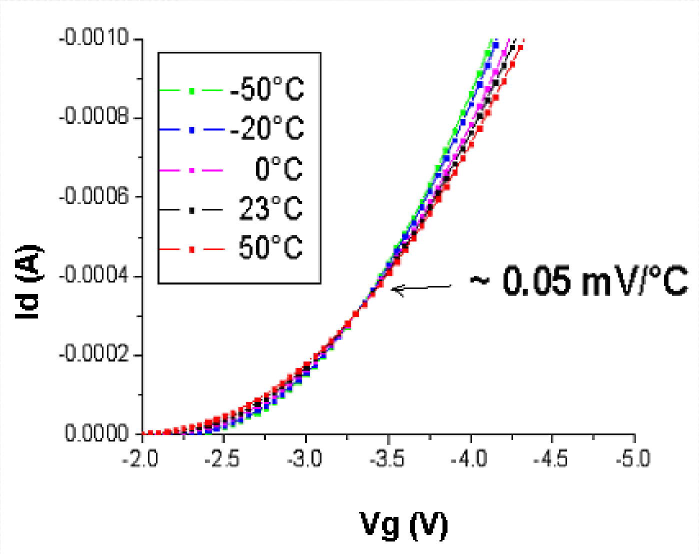
Under LAAS courtesy

TRAD SPACE DOSIMETER: A MOSFET DOSIMETER

Low threshold Voltage distribution & Zero temp coefficient : IZTC



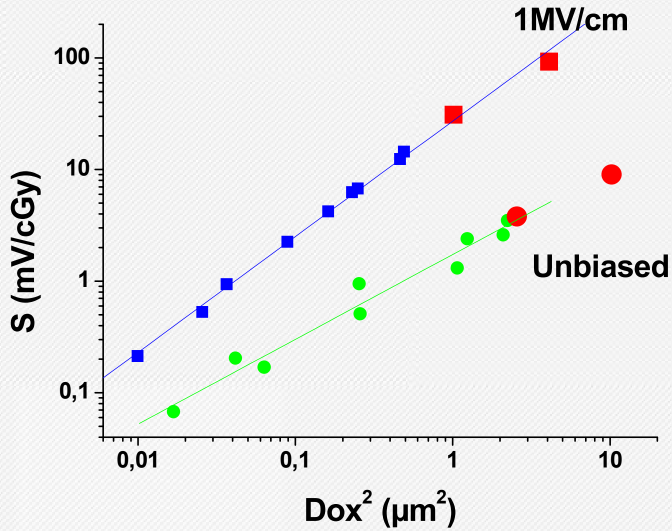
Wafer cartography

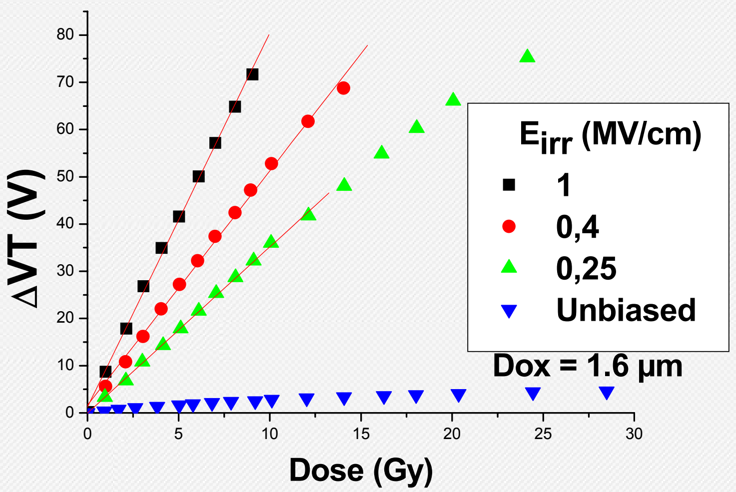


Iztc determination

TRAD SPACE DOSIMETER: A MOSFET DOSIMETER

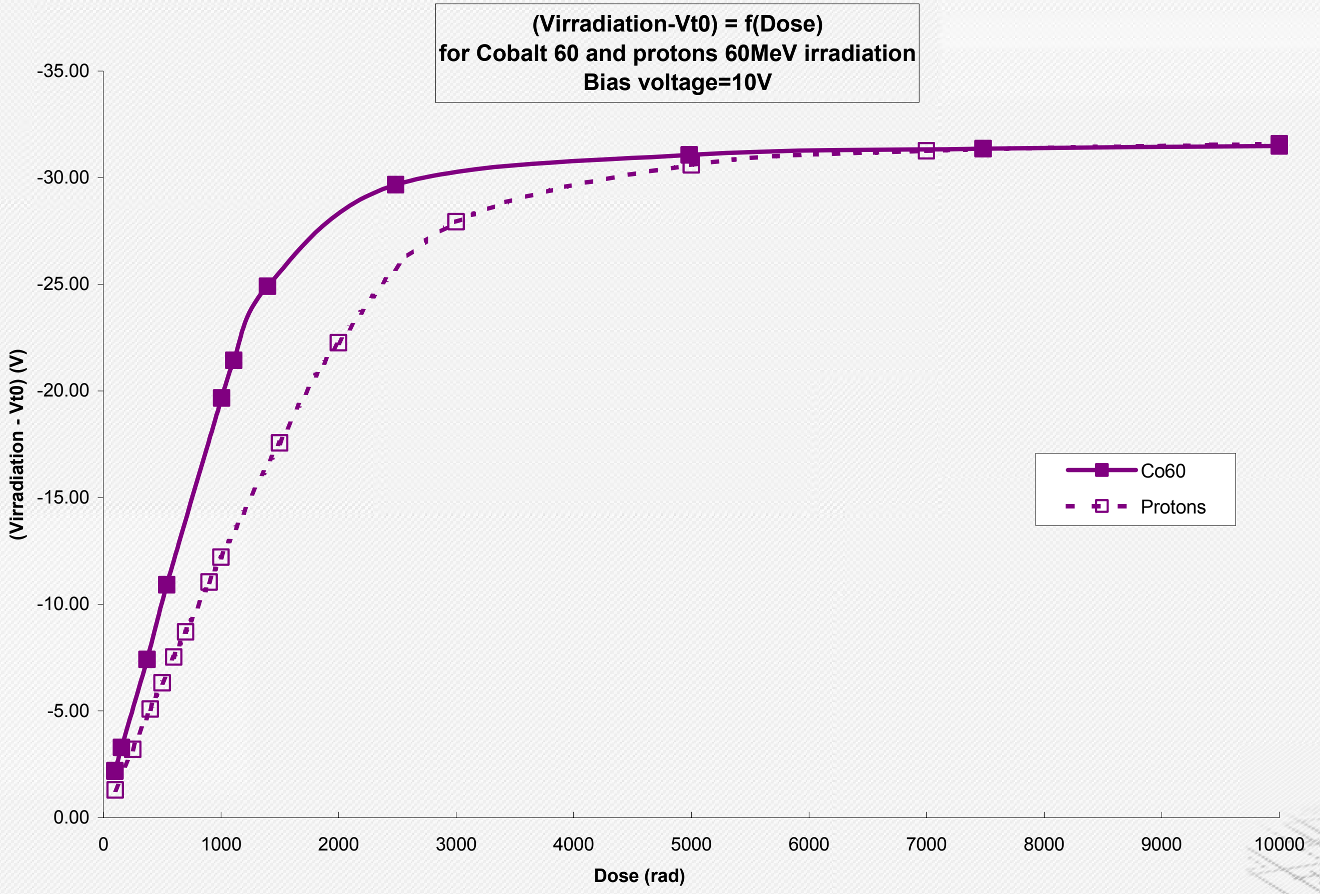
Different oxide thickness available to increase the dose range





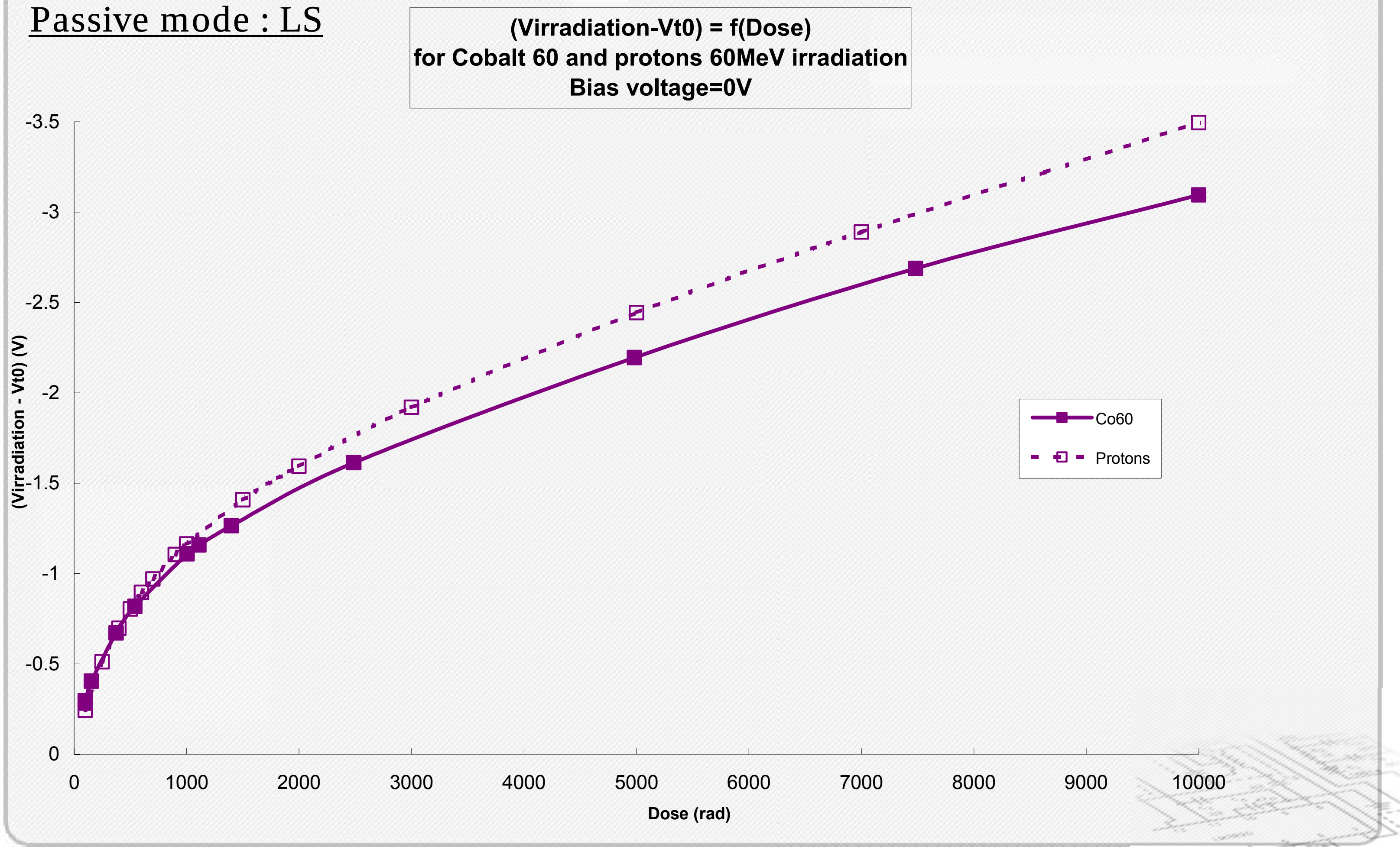
TSD: DOSE RESPONSE Co60 AND PROTON (60MeV)

Active mode : HS



DOSE RESPONSE Co60 AND PROTON (60MeV)

Passive mode : LS



Comparison with in flight data Experimental data

Difference between Proton & Cobalt sensitivity at 1 krad:

HS Configuration:	SCo60 = 20mV/rad	
	Sproton = 12mV/rad	40%
LS Configuration:	SCo60 = 1.06mV/rad	
	Sproton = 1.19mV/rad	10%

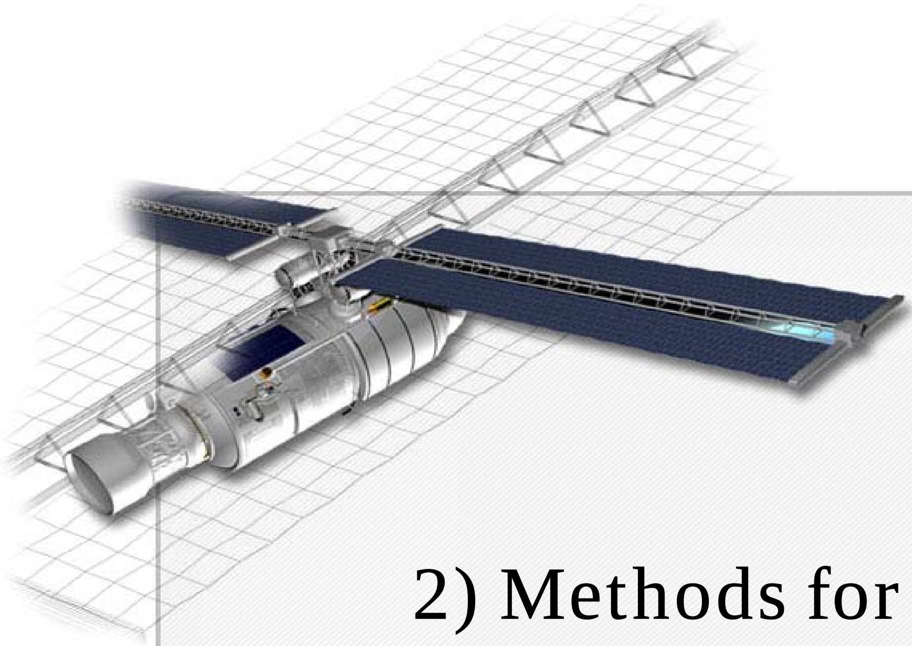
Carmen 2 profile : dose contribution > 90 % Protons

Using the calibration curves to determine the mission dose rate.

HS Configuration: 1st month = 208 rad

LS Configuration: 1st month = 192 rad → 7% between the 2 configurations

TRAD Tests & radiations



2) Methods for Dose Calculations

for JASON 2 & GALILEO environment

RADIATION ANALYSIS OF CARMEN

Presentation content :

- **Analysis objectives**
- **3D radiation model**
- **Dose calculation results in a JASON 2 environment**
  - Environment description
  - Calculation results
  - Comments
  - Conclusion
- **Dose calculation results in a GALILEO environment**
  - Environment description
  - Calculation results
  - Comments
  - Conclusion

TRAD Tests & radiations

Analysis objectives

First objective : **compare the measured dose received by the CARMEN module of JASON 2 satellite with the dose calculated by simulation.**

Second objective : **compare the results of dose calculation in different configurations (different type of 3D radiation models, environments and calculation algorithms)**

Concerning environments, we will present you :

1. **Results in JASON 2 environment (protons)**
2. **And then results in an electronic environment : GALILEO**

TRAD Tests & radiations

3D radiation model

- **JASON 2 model :**

Modelling of CARMEN neighbouring equipments with equivalent boxes (in term of dimensions and weight) :

- GPSP

- PCU

- LPTE

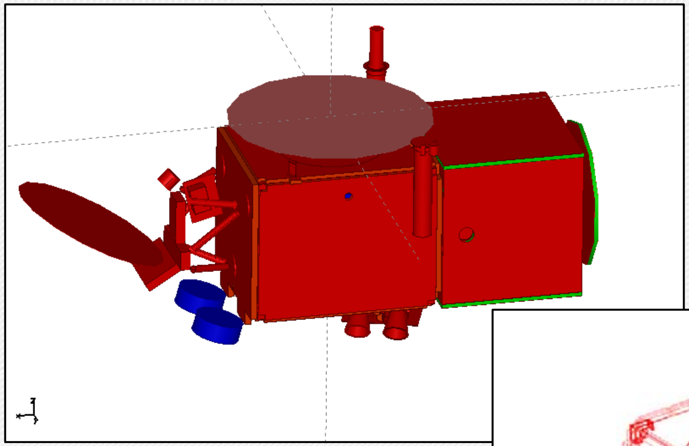
- LPTS

- GPSP ANT

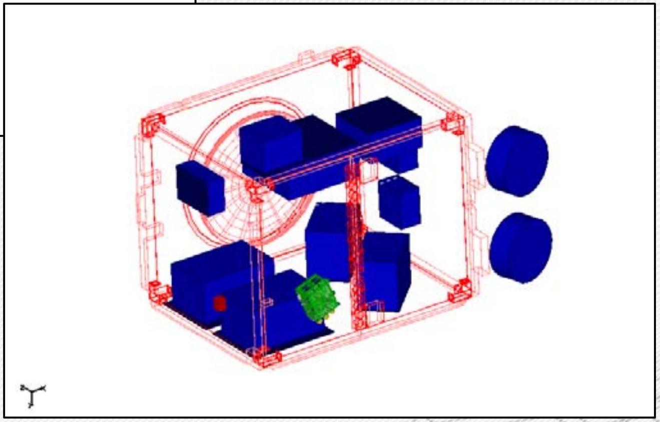
- DORIS_BDR

- T2L2

- RFU



Radiation model of JASON 2



View of the « equivalent boxes » (blue) modeled in order to take into account shielding provided by CARMEN (green) neighbouring equipments

3D radiation model

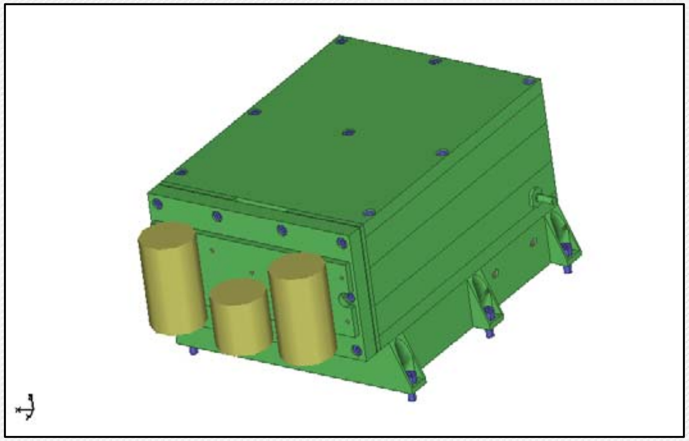
- **CARMEN radiation model :**

It has been made with :

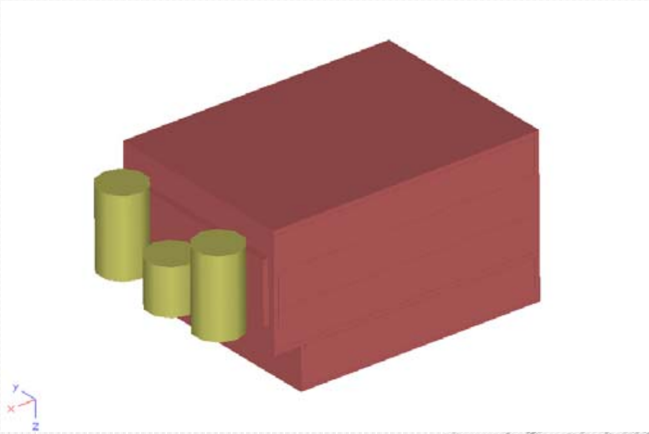
- IGES file provided by EREMS (including structure and boards)

- Board descriptions (plans and list of components)

A simplified radiation model (conform to NOVICE) using simple geometrical forms has also been built according to IGES model



IGES model of CARMEN



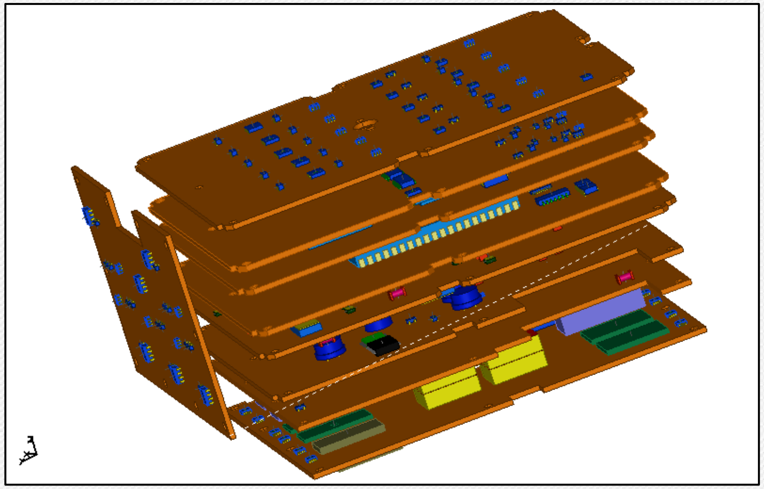
Re-constructed model of CARMEN

Tests & radiations

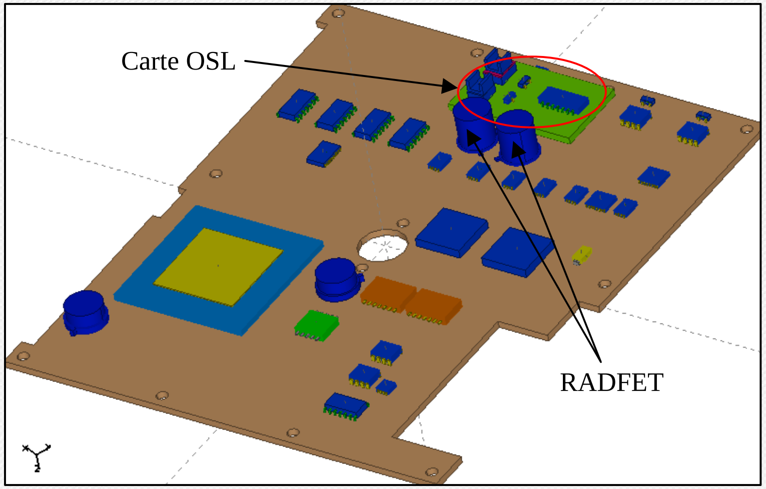
3D radiation model

- **CARMEN radiation model :**

Here are some views of modeled boards :



General view of modeled boards



View of 1210-2 board

Each component package has been modeled precisely, with respect to dimensions and materials. In all, 377 components have been placed in the model.

3D radiation model

- **CARMEN radiation model**

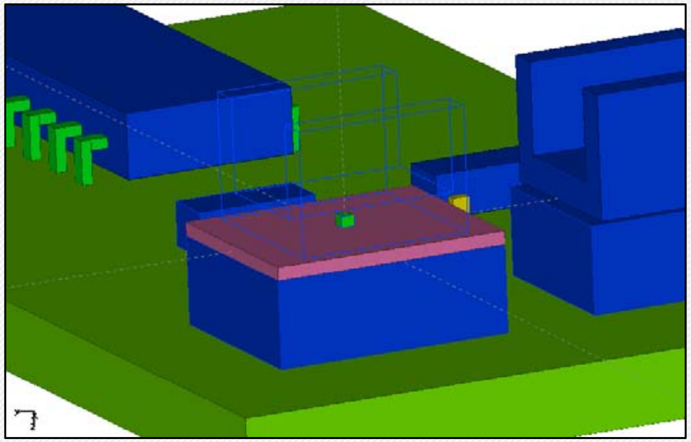
Doses have been calculated for 4 different components :

- RADFET2 T1

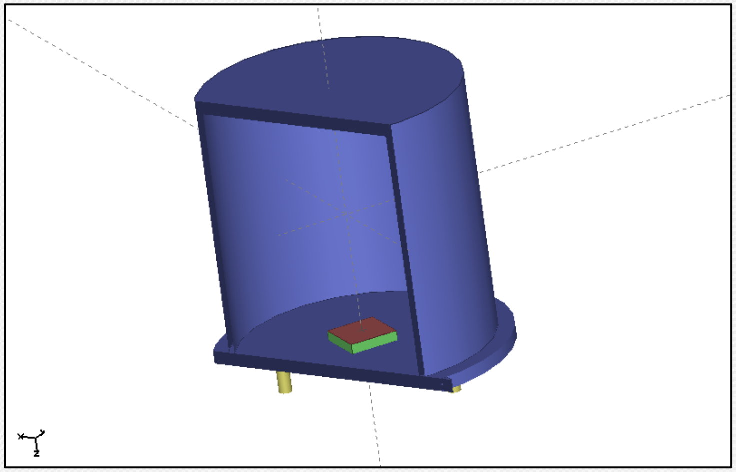
- RADFET2 T2

- SFH425 – D5

- OSL



View of the OSL part : the « SFH425-D5 » detector is placed at the center of a Gallium-Arsenide die (in green) and the « OSL » detector at the center of the Strontium-Sulfide layer (in pink)



Sectional view of RADFETs
(the detector has been placed at the center of the oxyde layer in red)

TRAD Tests & radiations

Dose Calculation results in a JASON 2 environment

- **Environment description (according to specifications)**

  1. Orbit :

  - altitude : 1336 km

  - inclination angle : 66°

  2. Mission duration : 5 years

  3. Trapped particle model used for calculations : AE8max et AP8min

=> A proton environment

(Solid and shell dose depth curve have been calculated with NOVICE software)

Tests & radiations

Dose Calculation results in a JASON 2 environment

- **Calculation results**

Dose calculations have been performed for different configurations :

1. Two types of equipment model : IGES or re-constructed (for radiation)

2. Two types of satellite model

- a realistic satellite model

- a satellite cube, whose the 6-direction thicknesses have been determined with the 6 faces technique.

3. Different calculation methods :

- sector analysis (RT : Ray-Tracing)

- Reverse Monte Carlo (RMC)

4. For sector analysis, different methods :

- « slant » calculation with solid dose depth curve

- « minimum path » calculation with shell dose depth curve

5. Two « minimum path » calculation algorithms have been tested :

- weighting : averaging of « normal » calculated thicknesses

- overlapping detection.

TRAD Tests & radiations

Dose Calculation results in a JASON 2 environment

- **Calculation results :**

Summary of calculation methods /Abbreviations :

- **RTS** : Ray-Tracing, « slant » method, solid sphere

- **RTN** : Ray-Tracing, « minimum path » method, shell sphere

- **RTNW** : Ray-Tracing, weighted « minimum path » method, shell sphere

- **RTNW + overlapping** : Ray-Tracing, weighted « minimum path » method, shell sphere, with overlapping detection

- **RMC** : Reverse Monte Carlo

TRAD Tests & radiations

Dose Calculation results in a JASON 2 environment

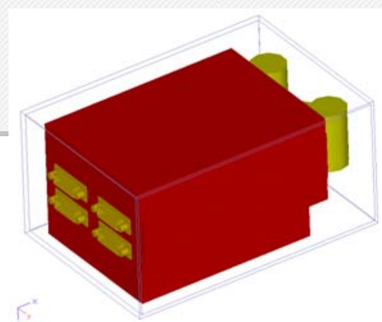
•Calculation results :

		Realistic satellite model				Satellite cube			
		Simplified equipment		IGES equipment		Simplified equipment		IGES equipment	
		Results krad(Si)	Calculation duration	Results krad(Si)	Calculation duration	Results krad(Si)	Calculation duration	Results krad(Si)	Calculation duration
NOVICE	RTS	10.04 10.02 10.41 10.31	1 min 45 sec	-	-	12.22 12.09 12.35 12.23	1 min 30 sec	-	-
	RTN	13.46 13.35 13.69 13.68	1 min 40 sec	-	-	15.30 15.20 15.54 15.42	1 min 25 sec	-	-
	RMC Reference	**10.11** **10.09** **10.35** **10.33**	**6 h 20 min**	-	-	**12.36** **12.14** **12.48** **12.45**	**4 h 10 min**	-	-
FASTRAD	RTS	10 10 10.4 10.3	14 sec	9.7 9.7 10 10	35 sec	12.2 12.1 12.3 12.3	9 sec	11.6 11.5 11.9 11.7	40 sec
	RTN	13.4 13.4 13.8 13.7	1 min 10 sec	12.9 12.9 13.2 13.2	2 min 45 sec	15.3 15.2 15.5 15.4	1 min 40 sec	14.6 14.5 14.5 14.6	5 min 10
	RTNW	13.4 13.4 13.8 13.7	1 min 5 sec	12.9 12.9 13.2 13.2	3 min	15.3 15.2 15.6 15.5	36 sec	14.5 14.5 14.6 14.7	1 min 45
	RTNW + overlapping	13.5 13.4 13.8 13.7	1 min 15 sec	12.9 12.9 13.2 13.2	3 min 20 sec	15.3 15.2 15.6 15.5	39 sec	14.5 14.5 14.6 14.7	1 min 30

Deposited dose calculation results are given for the 4 detectors : RADFET2-T1, RADFET2-T2, SFH425-D5 and OSL.

Here is the satellite cube determined with a 6 face analysis :

Axis equipment	Shielding Thickness (Aluminum mm)
+Xe	1,3
-Xe	3,8
+Ye	1,4
-Ye	1,5
+Ze	2
-Ze	5,3



TRAD Tests & radiations

Dose Calculation results in a JASON 2 environment

- **Comments :**

1. RTS method provides almost the same results than RMC method. The main reason is that more than 95% of deposited dose is due to protons that propagate in a straight line (approximation).

2. RTN method overestimates deposited dose for this environment.

3. The simplification of the satellite structure and of CARMEN model leads to an increase of the calculated deposited dose (respectively about 20% and 3%).

4. Performing calculations with IGES model increases calculation duration by a factor 2 or 3 (but only 5 minutes max !). But, using IGES model is still time-saving because make radiation model from CAD model can take several days.

TRAD
Tests & radiations

Dose Calculation results in a JASON 2 environment

- **Conclusion :**

1. Comparison between measured datas and calculated datas :

- Measured dose received by CARMEN : ~ 200 rad/month
=> ~ 12 krad during the total JASON 2 mission (5 years)

- Calculated dose by simulation ~ 10 krad (RTS and RMC results)
in a AE8max and AP8min trapped particle model

Datas measured by ICARE on JASON 2 seem to show a proton spectrum which is 20% higher than AP8min.

<u>Conclusion</u> : measured dose and calculated dose by simulation are corresponding : 12 krad = 10 krad + 20%

As a reminder : in the JASON 2 environment used for calculations (AE8max and AP8min trapped particle model), more than 95 % of the calculated dose was due to protons.

2. FASTRAD sector analysis algorithms for deposited dose calculation give similar results than NOVICE algorithms.

Dose Calculation results in a GALILEO environment

- **Environment description (according to specifications)**

1. Orbit :

- altitude : 23222 km

- inclination angle : 56°

2. Mission duration : 12 years

3. Trapped particle model used for calculations : AE8min and AP8min

=> An electronic environment

(Solid and shell dose depth curve have been calculated with NOVICE software)

Dose Calculation results in a GALILEO environment

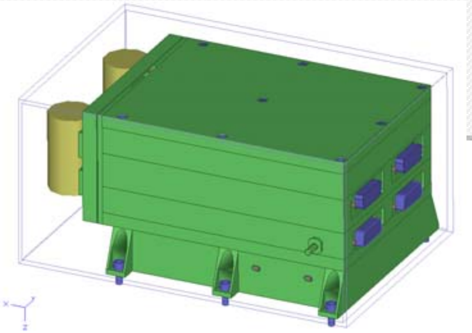
•Calculation results :

		Realistic satellite model				Satellite cube			
		Simplified equipment		IGES equipment		Simplified equipment		IGES equipment	
		Results krad(Si)	Calculation duration	Results krad(Si)	Calculation duration	Results krad(Si)	Calculation duration	Results krad(Si)	Calculation duration
NOVICE	RTS	6.56 6.81 7.96 6.26	1 min 45 sec	-	-	14 12 12.6 8.16	1 min 30 sec	-	-
	RTN	9.24 8.88 9.64 10.7	1 min 45 sec	-	-	12.4 11.9 12.1 13.7	1 min 30 sec	-	-
	RMC Reference	**7.04** **7.07** **10.55** **8.14**	**6 hours 30 min**	-	-	**9.66** **8.77** **13.53** **10.29**	**6 hours**	-	-
FASTRAD	RTS	6.5 6.7 7.9 6.2	15 sec	6.3 6.4 7.6 6.1	50 sec	13.9 11.9 12.5 8.1	25 sec	11.9 10.2 11.5 7.7	35 sec
	RTN	9.5 9.1 8.9 10.5	3 min 20 sec	8.7 8.5 8.1 9.6	6 min	12.3 11.7 10.8 12.5	2 min 40 sec	11.2 10.7 9.4 10.6	4 min 45 sec
	RTNW	9.2 8.8 9.5 10.6	1 min 10 sec	8.4 8.3 8.7 9.5	1 min 50 sec	12.3 11.8 11.9 13.6	1 min 10 sec	10.7 10.2 10.2 11.2	1 min 45 sec
	RTNW + overlapping	9.2 8.8 9.5 10.6	1 min 15 sec	8.4 8.3 8.7 9.5	2 min 15 sec	12.3 11.8 11.9 13.6	1 min 10 sec	10.7 10.2 10.3 11.2	2 min 45 sec

Deposited dose calculation results are given for the 4 detectors : RADFET2-T1, RADFET2-T2, SFH425-D5 and OSL.

Here is the satellite cube determined with a 6 face analysis :

Axis equipment	Shielding Thickness (Aluminum mm)
+Xe	1,2
-Xe	3
+Ye	1,6
-Ye	1,6
+Ze	1,9
-Ze	3,1



Tests & radiations

Dose Calculation results in a GALILEO environment

- **Comments**

1. **For calculations in a realistic satellite model, calculated doses tend to be :**
   - **underestimated by the the « slant » method**
   - **overestimated by the « normal » method**

2. **The simplification of the satellite structure leads to an increase of calculated dose :**
   - **about +30% using Reverse Monte Carlo and « normal » methods**
   - **+30 to +110% using « slant » method**

3. **The simplification of CARMEN equipment leads to an increase of calculated dose of 2 to 15% according to the selected detector.**

4. **Performing calculations with IGES model still increases calculation duration by a factor 2 or 3.**

Tests & radiations

Dose Calculation results in a GALILEO environment

- **Conclusion :**

1. The reference calculated dose (Reverse Monte Carlo) is more difficult to approach (by sector analysis) in an electronic environment than in a proton environment.

Cause : **the type of propagation of protons (straight lines) is closer from the sector analysis principle than the type of propagation of electrons (more irregular).**

2. FASTRAD sector analysis algorithms for deposited dose calculation give similar results than NOVICE algorithms in electronic environment.

Conclusion

- **Radiation evaluation of TSD :**

1. **Completed on various lots including CARMEN2/MEX flight lot**
2. **Depending on the biasing mode, there is a difference between electron and proton dose response.**
3. **Still working on a model to predict combined e- & p+ degradation.**

- **FASTRAD tool evaluation :**

FASTRAD sector analysis algorithms for deposited dose calculation give similar results than NOVICE algorithms in electronic environment.

- **Comparison In flight data & prediction :**

Very good agreement.

TRAD Tests & radiations