Radiation material testing: Building up a dose profile using engineering tools

COMET : Modélisation et impact des radiations spatiales sur les matériaux et cellules solaires

NOOUS, Toulouse

Marine AUBRY

Outline

- TRAD presentation
- Space environment
- Our engineering tools
- Material dose curve calculation
- Test matrix build-up

TRAD - Tests & Radiations

A leading and innovative company providing high reliability support and products for radiation assurance services, for space, nuclear and other harsh environments.

Created in 1994

Toulouse
Montpellier

81
Employees

9 M€
Turnover

Our activities

PRODUCTS

Modeling and analysis software

OMERE

RayXpert

FASTRAD 3D Radiation simulation

R2 COTS

Class 3+ Space Ready COTS

Our activities

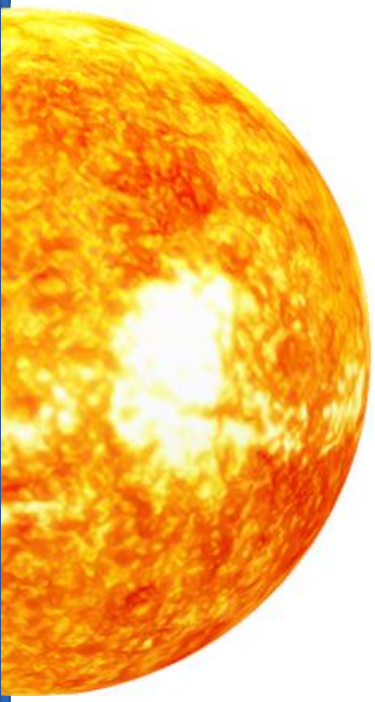
PRODUCTS

- Modeling and analysis software
- Class 3+ Space Ready COTS

SERVICES

- Radiation Engineering
- Material testing
- Radiation trainings
- Electronic Components Testing
- EEE Components services

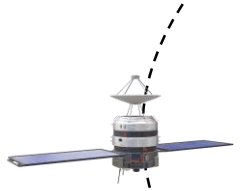
Space environment



hν

Solar energetic particles

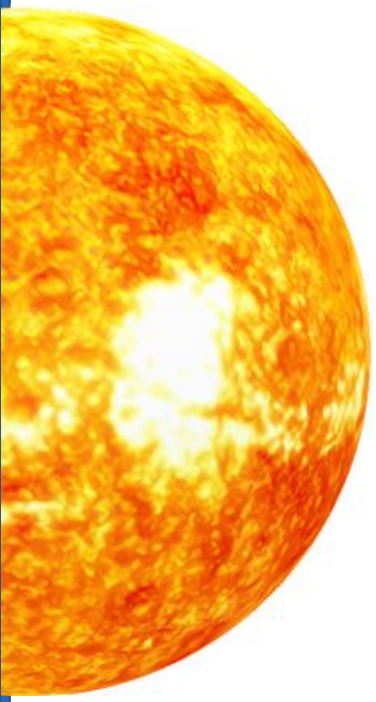
Galactic cosmic rays



hν

Radiations: Alphas, Protons, Electrons, Photons
Atomic Oxygen: Erosion of surfaces

Space environment



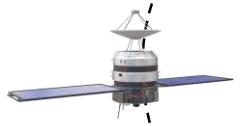
hν

Solar energetic particles

Galactic cosmic rays

+300°C

hν

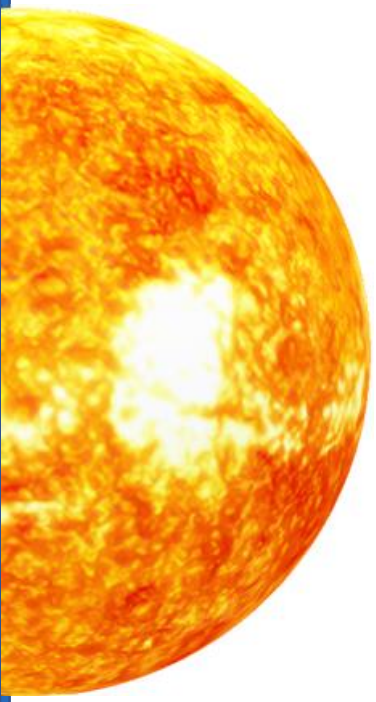


-200°C

Radiations: Alphas, Protons, Electrons, Photons
Atomic Oxygen: Erosion of surfaces

Temperatures:
Thermal cycling

Space environment



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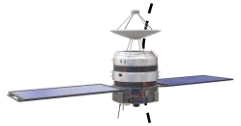


hν

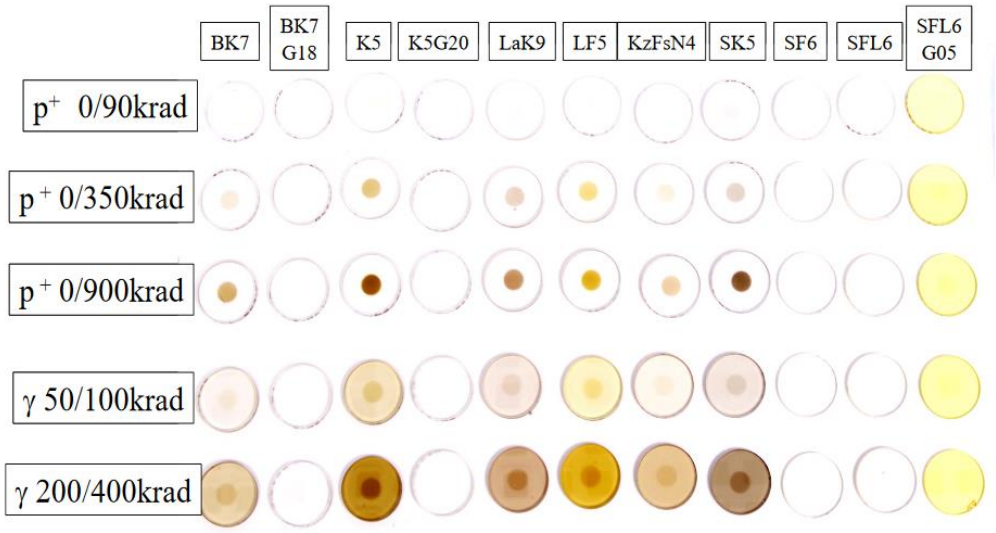
-200°C

Radiations: Alphas, Protons, Electrons, Photons
Atomic Oxygen: Erosion of surfaces

Temperatures:
Thermal cycling

Pieces Impacts:
Mechanical damages

Some examples of radiations effects



Source: CNES

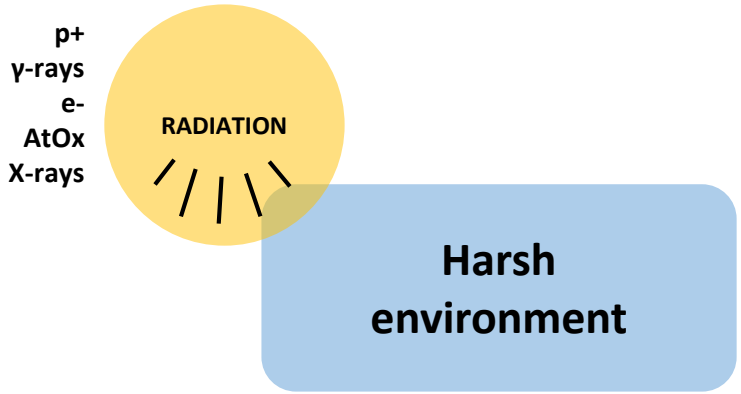
Dose increase

The primary functions of materials can be degraded or even annihilated when they do not resist radiation sufficiently

Our material acitivities

Harsh environment

Our material acitivities



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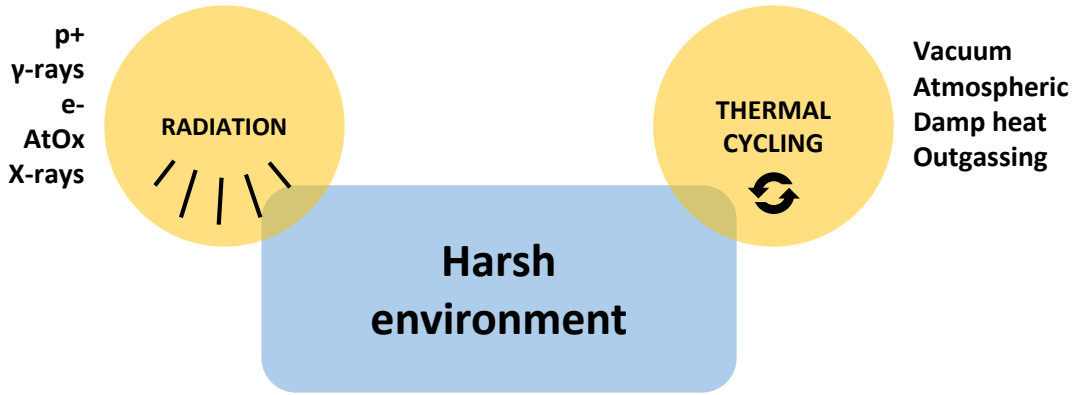

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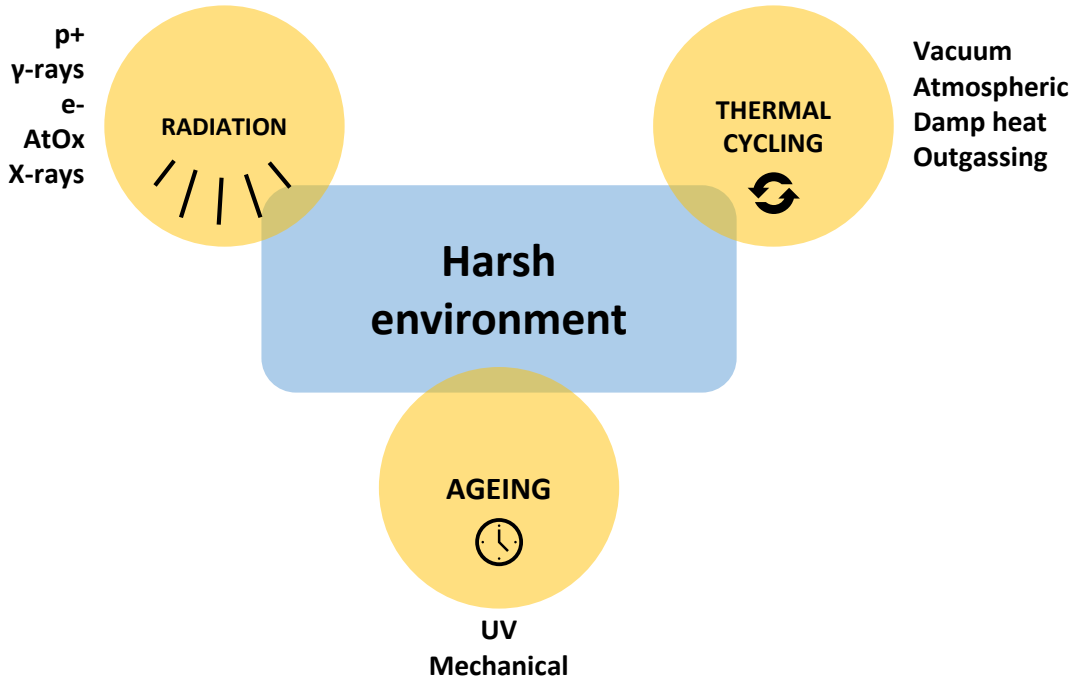

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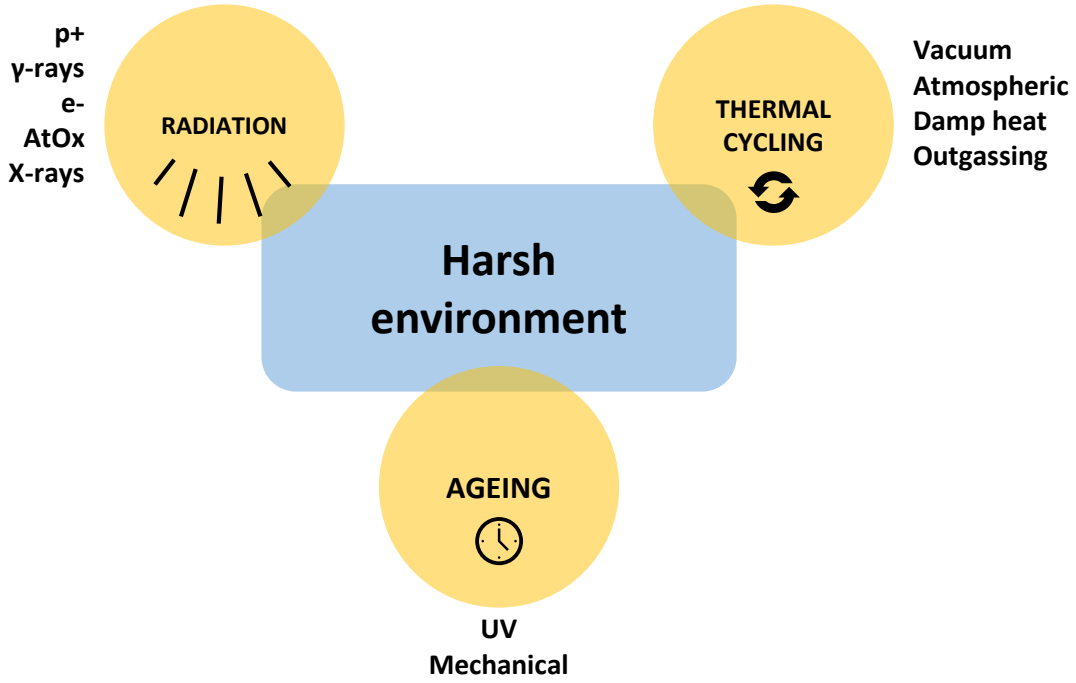
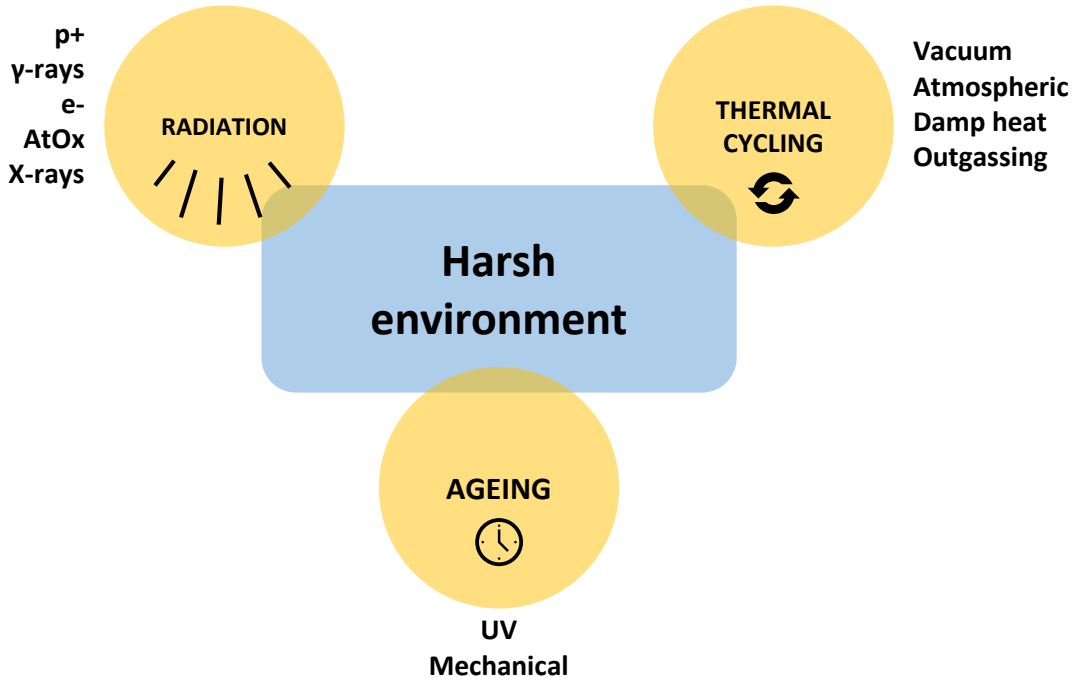


Measurements

Our material acitivities

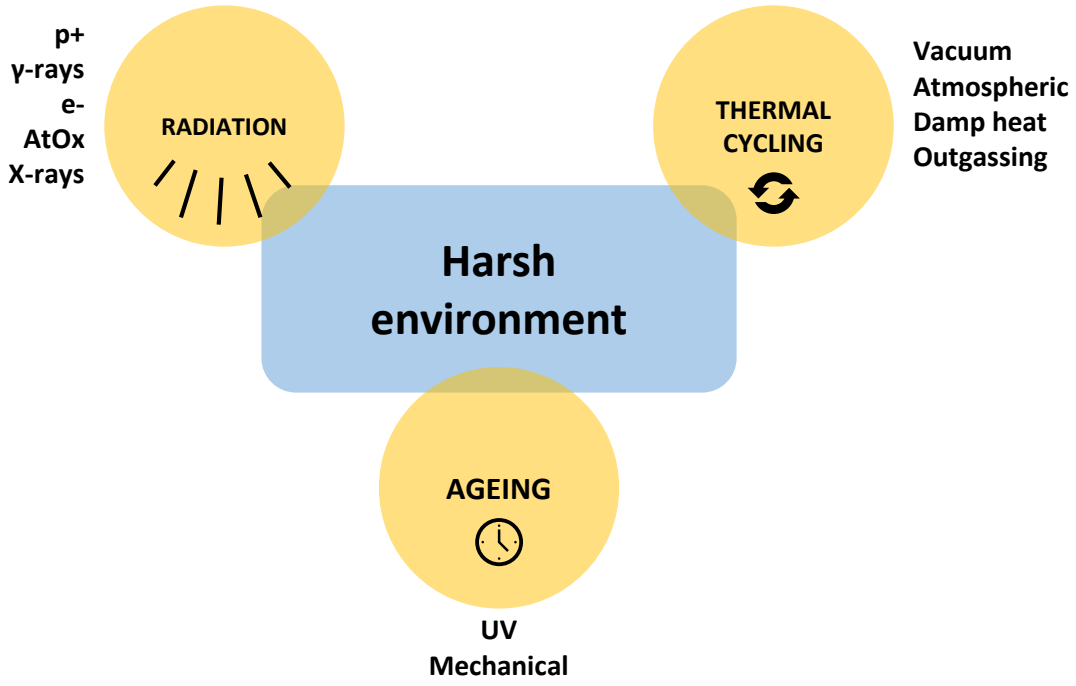


Electrical characterization:

- **Solar cells**
- **Isolation**
- **Resistance**

Measurements

Our material acitivities



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Optical characterizations:
- **Bulks**
- **Fibers**
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Measurements

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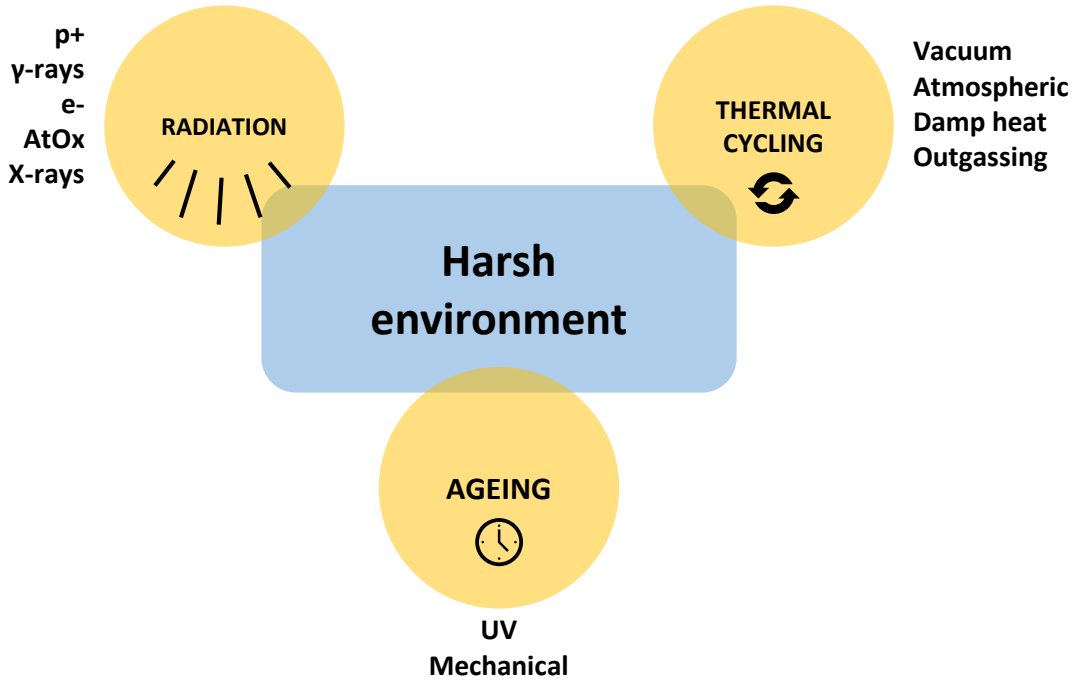

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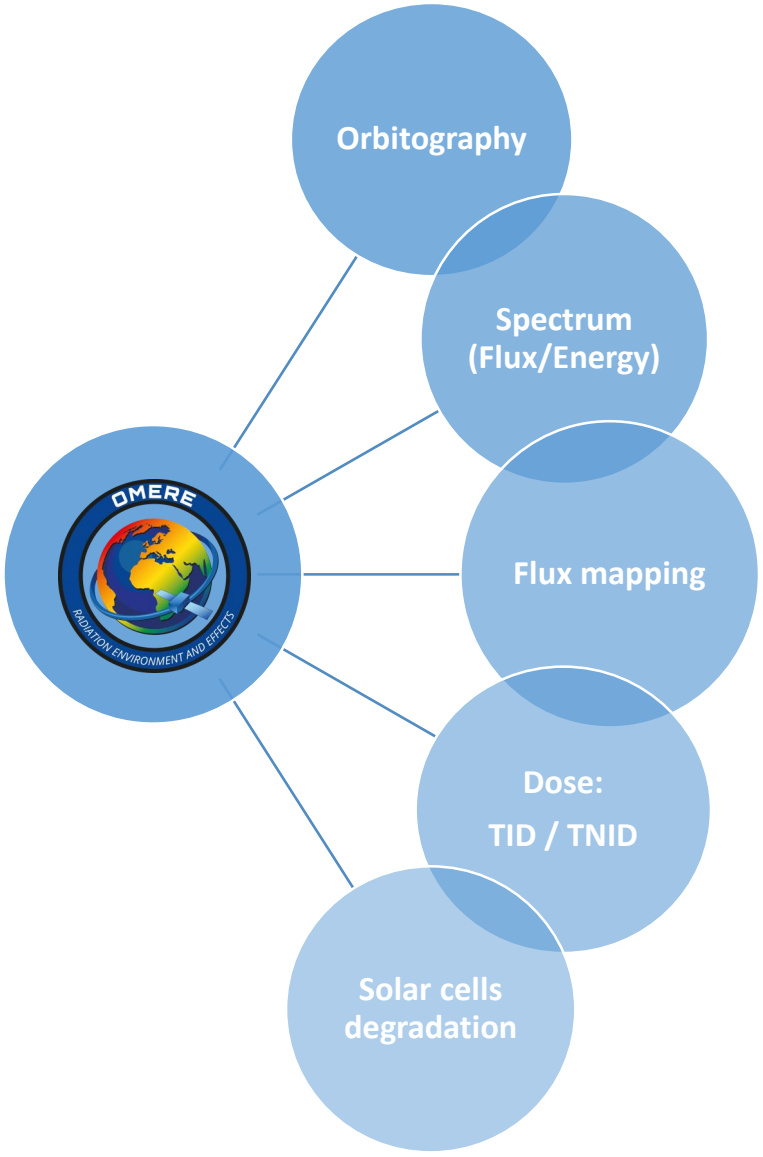
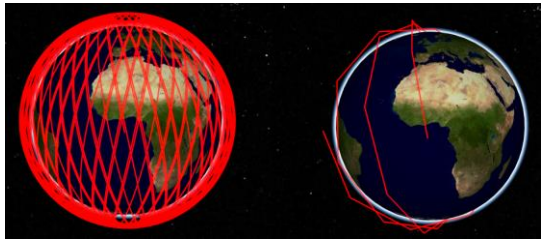
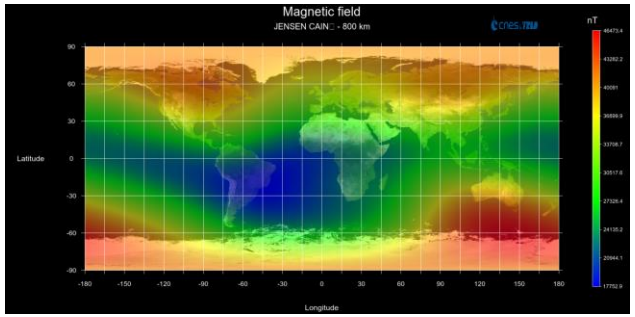
Measurements

Physical observation:
- **Microscope**
- **SEM & X-rays analysis**

Our engineering tools: OMERE - Fastrad







Our engineering tools: OMERE - Fastrad

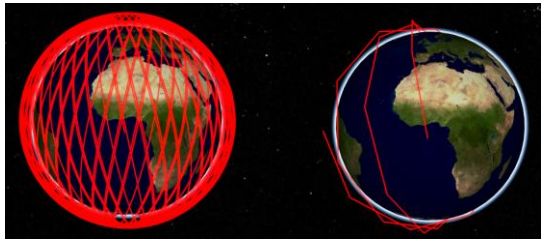
Orbitography

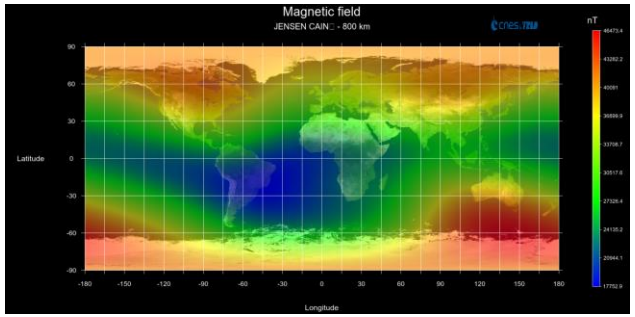
Spectrum (Flux/Energy)

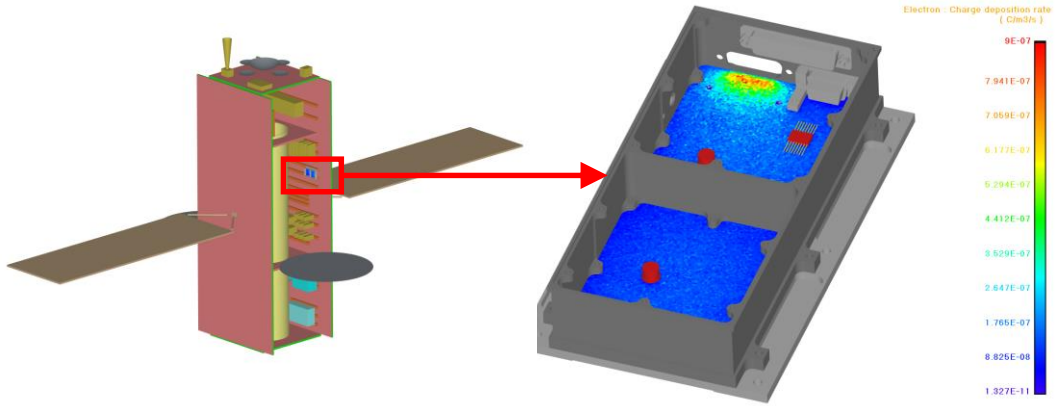
Flux mapping

Dose: TID / TNID

Solar cells degradation







CAD file / 3D model

Ray tracing

Flux mapping

Dose: TID / TNID

Shielding optimization

FASTRAD 3D Radiation simulation

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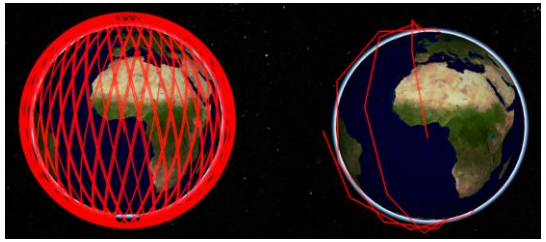
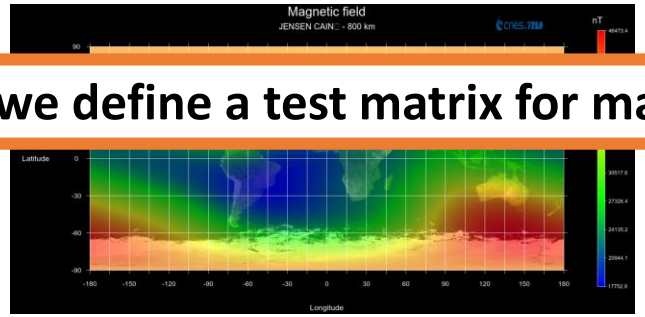
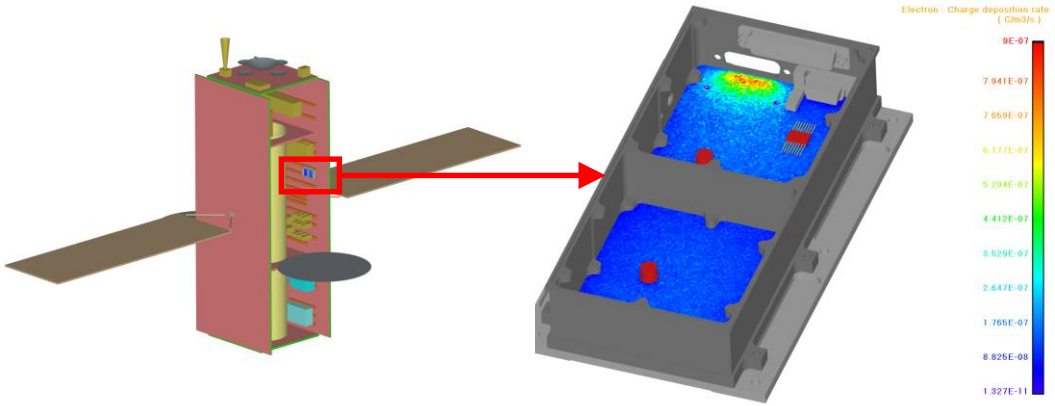




How do we define a test matrix for material testing?



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Shielding optimization

Philosophy of radiation testing of materials

- Qualification campaign
  - Mission environment definition
  - Geometry definition
  - Mission dose profile
  - Particles and energy selection for qualification campaign
  - Presentation of results – green/red flag from client for experimental tests
  - Experimental sequence (irradiation sequence, thermal cycling, characterization…)
  - Material qualification report: Fail / Pass?

Philosophy of radiation testing of materials

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Three ways to do so

Customer request

No idea about the orbit

Worst case environment proposition

Knows the orbit

Already has spectra

Environment definition

Input: Mission

- Generic orbit
- File import

Environment definition

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Environment

- Particle sources (radiation belts, solar particles, cosmic rays)
- Standard ECSS and US models.

Environment definition

Input: Mission

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Results:

- Trapped electrons
- Trapped protons
- Solar Mean Protons

Input for FASTRAD

Dose curve definition

Input : Radiation model

- Import STEP file from another CAD software
- Complex geometry of spacecraft/unit
- Realistic materials
- Component database

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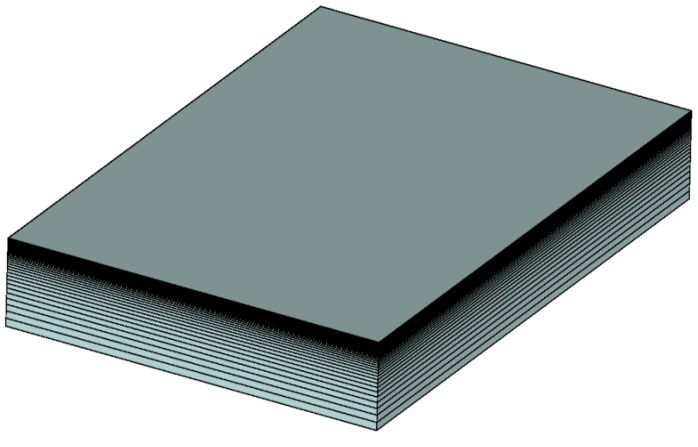
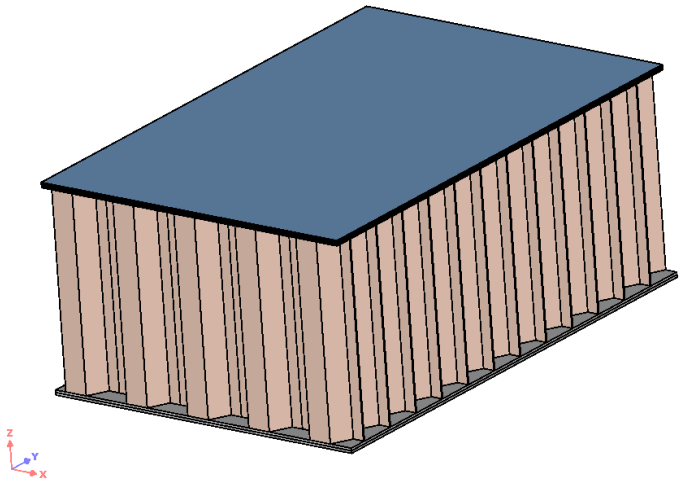
Modeling step

- Simplified or multi-layer model
- Chemical composition
- Density





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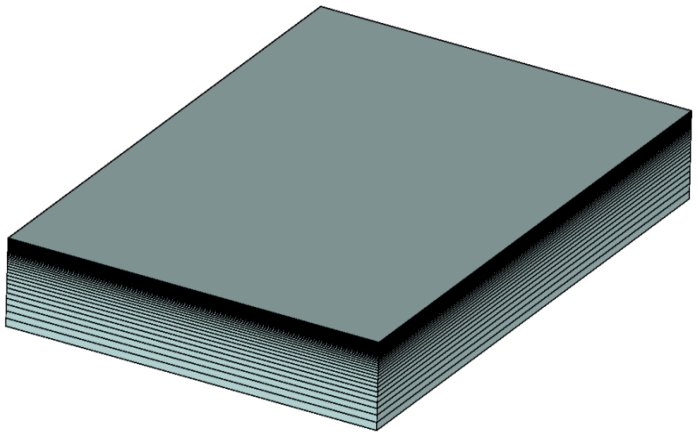
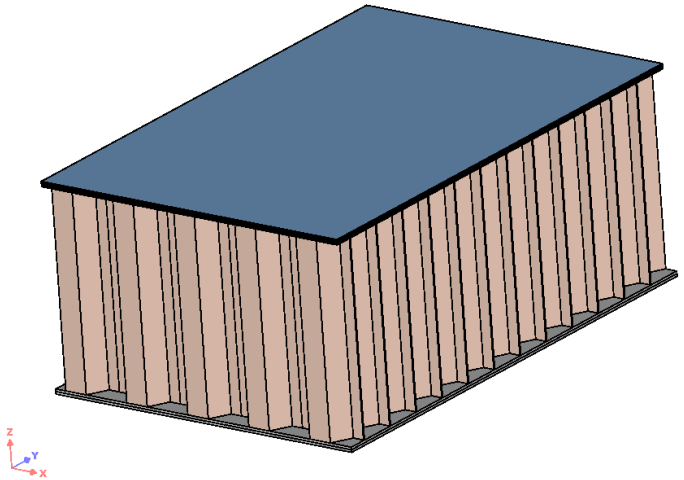
TID calculations

- Forward Monte-Carlo method
- Space environment as sources
- Layers as sensitive element





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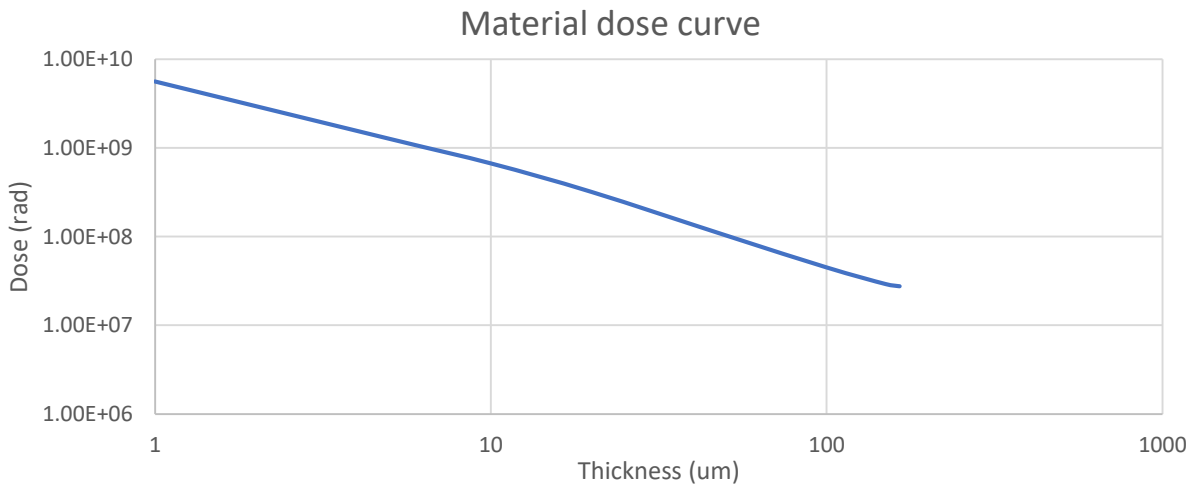

Test matrix definition

Input: Radiation model

- Same as previously

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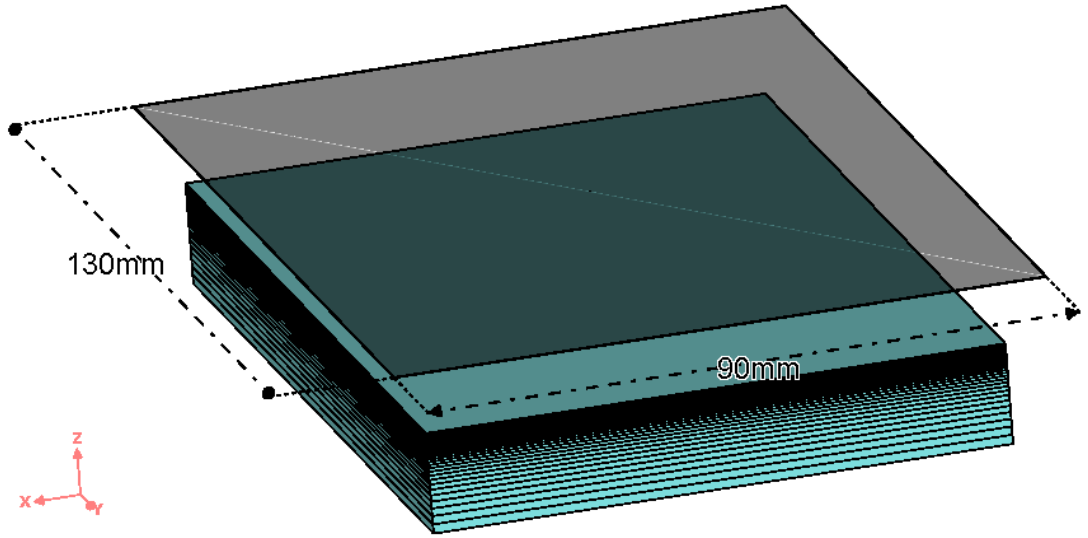
Modeling beams

- Rectangular beam
- Choose of beam energy / nature based on:
  - our beam portfolio
  - the samples characteristics



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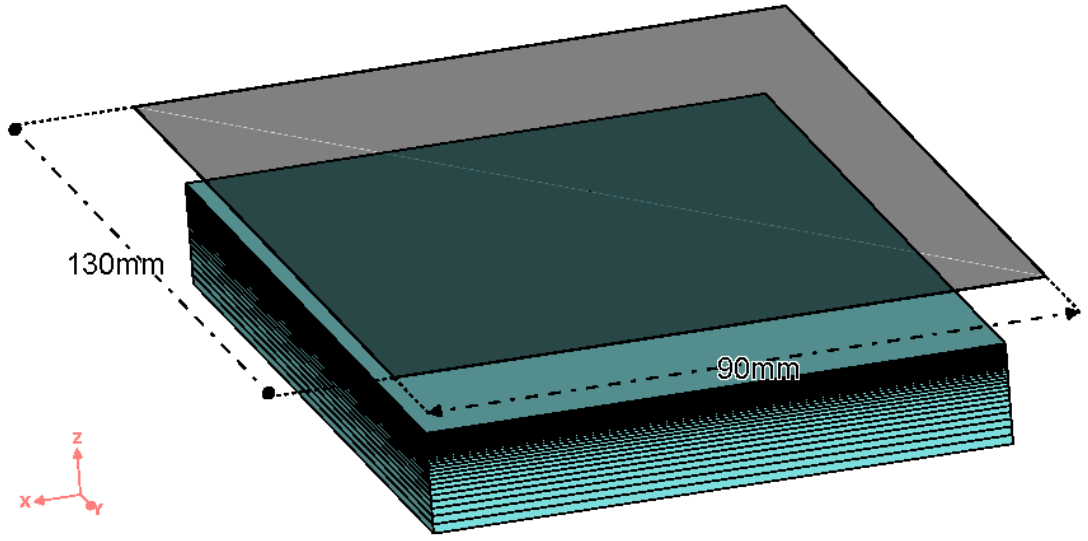

Test matrix definition

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Launch of several calculations

Results summary
Total deposited dose (rad):

	Name	electron	photon	proton	positron	Total
		Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]
1 -	1um :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97414e-09 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97414e-09 (0.1 %) [VVVVVVV]
2 -	1um_1 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97560e-09 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97560e-09 (0.1 %) [VVVVVVV]
3 -	1um_2 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97026e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97026e-09 (0.1 %) [VVVVVXV]
4 -	1um_3 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98546e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98546e-09 (0.1 %) [VVVVVXV]
5 -	1um_4 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98983e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98983e-09 (0.1 %) [VVVVVXV]
6 -	5um :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	7.99350e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	7.99350e-09 (0.1 %) [VVVVVXV]
7 -	5um_1 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00142e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00142e-08 (0.1 %) [VVVVVXV]
8 -	5um_2 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00481e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00481e-08 (0.1 %) [VVVVVXV]
9 -	5um_3 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00666e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00666e-08 (0.1 %) [VVVVVXV]
10 -	5um_4 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01012e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01012e-08 (0.1 %) [VVVVVXV]
11 -	5um_5 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01257e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01257e-08 (0.1 %) [VVVVVXV]
12 -	5um_6 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01649e-08 (0.1 %) [VXVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01649e-08 (0.1 %) [VXVVVXV]
13 -	5um_7 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01883e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01883e-08 (0.1 %) [VVVVVXV]
14 -	5um_8 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02115e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02115e-08 (0.1 %) [VVVVVXV]
15 -	5um_9 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02387e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02387e-08 (0.1 %) [VVVVVXV]
16 -	5um_10 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02709e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02709e-08 (0.1 %) [VVVVVXV]
17 -	5um_11 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02925e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02925e-08 (0.1 %) [VVVVVXV]
18 -	10um :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03241e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03241e-08 (0.1 %) [VVVVVXV]
19 -	10um_1 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03908e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03908e-08 (0.1 %) [VVVVVXV]
20 -	10um_2 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.04480e-08 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.04480e-08 (0.1 %) [VVVVVVV]
21 -	10um_3 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05146e-08 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05146e-08 (0.1 %) [VVVVVVV]
22 -	10um_4 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05721e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05721e-08 (0.1 %) [VVVVVXV]
23 -	10um_5 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.06429e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.06429e-08 (0.1 %) [VVVVVXV]
24 -	10um_6 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07109e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07109e-08 (0.1 %) [VVVVVXV]
25 -	10um_7 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07777e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07777e-08 (0.1 %) [VVVVVXV]
26 -	10um_8 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.08443e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.08443e-08 (0.1 %) [VVVVVXV]
27 -	10um_9 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.09166e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.09166e-08 (0.1 %) [VVVVVXV]

Test matrix definition

Input: Radiation model

- Same as previously

Modeling beams

- Rectangular beam
- Choose of beam energy / nature based on:
  - our beam portfolio
  - the samples characteristics

Launch of several calculations

Results summary
Total deposited dose (rad):

	Name	electron	photon	proton	positron	Total
		Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]	Value (Error) [Conver.] rad (%) [1234567]
1 -	1um :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97414e-09 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97414e-09 (0.1 %) [VVVVVVV]
2 -	1um_1 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97560e-09 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97560e-09 (0.1 %) [VVVVVVV]
3 -	1um_2 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97026e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.97026e-09 (0.1 %) [VVVVVXV]
4 -	1um_3 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98546e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98546e-09 (0.1 %) [VVVVVXV]
5 -	1um_4 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98983e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	9.98983e-09 (0.1 %) [VVVVVXV]
6 -	5um :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	7.99350e-09 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	7.99350e-09 (0.1 %) [VVVVVXV]
7 -	5um_1 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00142e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00142e-08 (0.1 %) [VVVVVXV]
8 -	5um_2 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00481e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00481e-08 (0.1 %) [VVVVVXV]
9 -	5um_3 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00666e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.00666e-08 (0.1 %) [VVVVVXV]
10 -	5um_4 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01012e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01012e-08 (0.1 %) [VVVVVXV]
11 -	5um_5 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01257e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01257e-08 (0.1 %) [VVVVVXV]
12 -	5um_6 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01649e-08 (0.1 %) [VXVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01649e-08 (0.1 %) [VXVVVXV]
13 -	5um_7 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01883e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.01883e-08 (0.1 %) [VVVVVXV]
14 -	5um_8 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02115e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02115e-08 (0.1 %) [VVVVVXV]
15 -	5um_9 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02387e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02387e-08 (0.1 %) [VVVVVXV]
16 -	5um_10 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02709e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02709e-08 (0.1 %) [VVVVVXV]
17 -	5um_11 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02925e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.02925e-08 (0.1 %) [VVVVVXV]
18 -	10um :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03241e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03241e-08 (0.1 %) [VVVVVXV]
19 -	10um_1 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03908e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.03908e-08 (0.1 %) [VVVVVXV]
20 -	10um_2 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.04480e-08 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.04480e-08 (0.1 %) [VVVVVVV]
21 -	10um_3 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05146e-08 (0.1 %) [VVVVVVV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05146e-08 (0.1 %) [VVVVVVV]
22 -	10um_4 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05721e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.05721e-08 (0.1 %) [VVVVVXV]
23 -	10um_5 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.06429e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.06429e-08 (0.1 %) [VVVVVXV]
24 -	10um_6 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07109e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07109e-08 (0.1 %) [VVVVVXV]
25 -	10um_7 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07777e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.07777e-08 (0.1 %) [VVVVVXV]
26 -	10um_8 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.08443e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.08443e-08 (0.1 %) [VVVVVXV]
27 -	10um_9 :	0.00000e+00 (100.0 %) [XXXXXXX]	0.00000e+00 (100.0 %) [XXXXXXX]	1.09166e-08 (0.1 %) [VVVVVXV]	0.00000e+00 (100.0 %) [XXXXXXX]	1.09166e-08 (0.1 %) [VVVVVXV]

Test matrix definition

Input: Radiation model

- Same as previously

Modeling beams

- Rectangular beam
- Choose of beam energy / nature based on:
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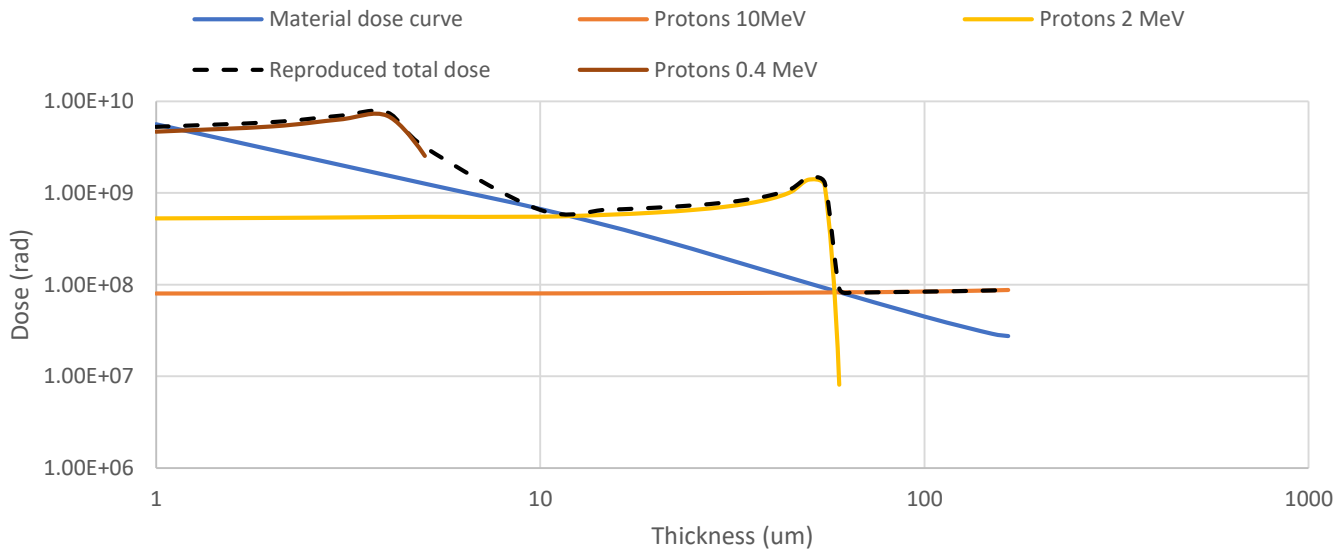
Launch of several calculations



Conclusion

- Test matrix must be elaborated to reproduce space environment
- TRAD uses its own softwares to do so
  - OMERE for mission environment
  - FASTRAD for dose profile and test matrix

Thank you for your attention

For further information on:

www.trad.fr – www.fastrad.net
www.rayxpert.com – www.r2cots.com

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