FP Days March 2017
Introduction to CNES part

space environment and radiation transport

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Space environment and new components office
DSO/AQ/EC

07-03-2017

« My God, space is radioactive ! »
Ernie Ray, 1958

Thanks

Many thanks to ESA's

Space Environments and Effects (TEC-EPS) section

Component Space Evaluation and Radiation Effects (TEC-QEC) section

For their invitation to a joint event

“FP Days” have been organized with TEC-QEC since 2009

First time we do the same with TEC-EPS

Particular thanks to Ali Zadeh, Véronique Ferlet-Cavrois, Alessandra Costantino, Marco Vuolo (ESA) and Françoise Bezerra (CNES)

Space environment R&D at CNES

Mostly done through the “R&T” (research and technology) program

- Bulk of it in the “MT” objective (micro-technologies and environment)
- Technical axis “MT3” “space environment”
  - Space radiation and plasma knowledge and modelling (DSO/AQ/EC)
  - Radiation hardness assurance incl. radiation transport codes (DSO/AQ/EC)
  - Radiation effects on electronic components (DSO/AQ/EC ++)
  - Space environment effects on materials (DSO/TB/TH, DSO/AQ/MP)
  - Contamination (DSO/AQ/LE)
  - Spacecraft charging (DSO/TB/EL)
  - Space debris (DSO/DV/ISL, DSO/TB/SM)
- Complimentary actions on other lines of the R&T program
  - May be on “platforms”, “telecom”, “Earth observation” and other lines
- Associates many CNES departments and offices
- Close partnership with ONERA

Links with ECI (at CNES : “RCS”)

Main orientations : space data

High level goal : direct access to space environment data

Be able to have first-hand knowledge of space environment

→ Develop and fly radiation "monitors" and technology modules

- → ICARE on SAC-C (ICARE), MIR (SPICA), ISS (SPICA-S)
- → ICARE-NG on SAC-D, JASON-2, JASON-3 (CARMEN-1, -2, -3)

Gather other data through bilateral agreements

→ UCL/CSR (EPT)

→ NASA, NOAA (mostly open but need support of the PIs)

→ LANL, USAF, JAXA, MSU

→ ONERA IPODE data base

- → ~ 50 series, LEO/MEO/HEO/GEO/IP, > 3 solar cycles

Develop data processing procedures and routines

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ICARE-NG

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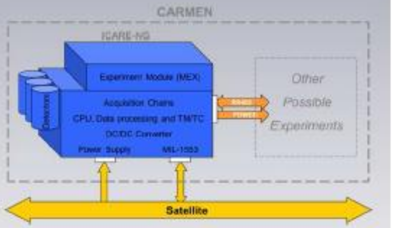
Space for Earth

CARMEN *is multi-sensors mission based on a main instrument (ICARE-NG) dedicated to study the influence of space radiation on advanced components and able to interface and manage some others external sensors.*

Carmen

- **Evaluation of radiation ageing in operation**
- **In orbit monitoring / Help to anomaly investigation**
- **Improvement of radiation environment modelling**
- **Improvement of RHA methods and requirements**
- **Solar activity index**

- **SPECTROMETER** Measurement ranges : electrons → 0.250 -6MeV / protons → 8 - 300MeV, 3 detectors, 5 analog acquisition chains with programmable levels, gain and accumulation time.
- **Experiment MODULE** Devices under test for SEE monitoring, on board dosimeters.
- **Electrical I/F** ~20-42V up to 70V regulated power supply bus, MIL-1553B or serial interfaces for TM/TCs.
- **Implantation** Internal or External (with possible window), FoV → 3 x conical 26°half angle + homogenous wall in front of the baseplate.
- **Data rate** From 420 to less than 20bits/s (with a possible on board memory capability).
- **Budget** (*)



Size (mm^3)	~205 x 118-138 x 96
Mass (kg)	2.0 – 2.8
Power (W)	6 to 10

(*) *With Experiment Module (MEX) and without any other experiment*

MISSION HERITAGE

- **ICARE** on SAC-C Argentinean satellite (launch 11/2000, 11 years operational)

+

- **CARMEN-1** → **ICARE-NG** + **3xSODAD (μ-debris sensors)** on SAC-D Argentinean satellite (launch in 06/2011).
- **CARMEN-2** → **ICARE-NG** aboard JASON-2 satellite (launched in 06/2008)
- **CARMEN-3** → **ICARE-NG** + **AMBER (Electrostatic Charging Sensor)** aboard JASON-3 satellite (launch in 2015-16)
- **CARMEN-4** → **ICARE-NG** aboard a GEO Indian satellite (in development).

→ more than 22 years on various orbits

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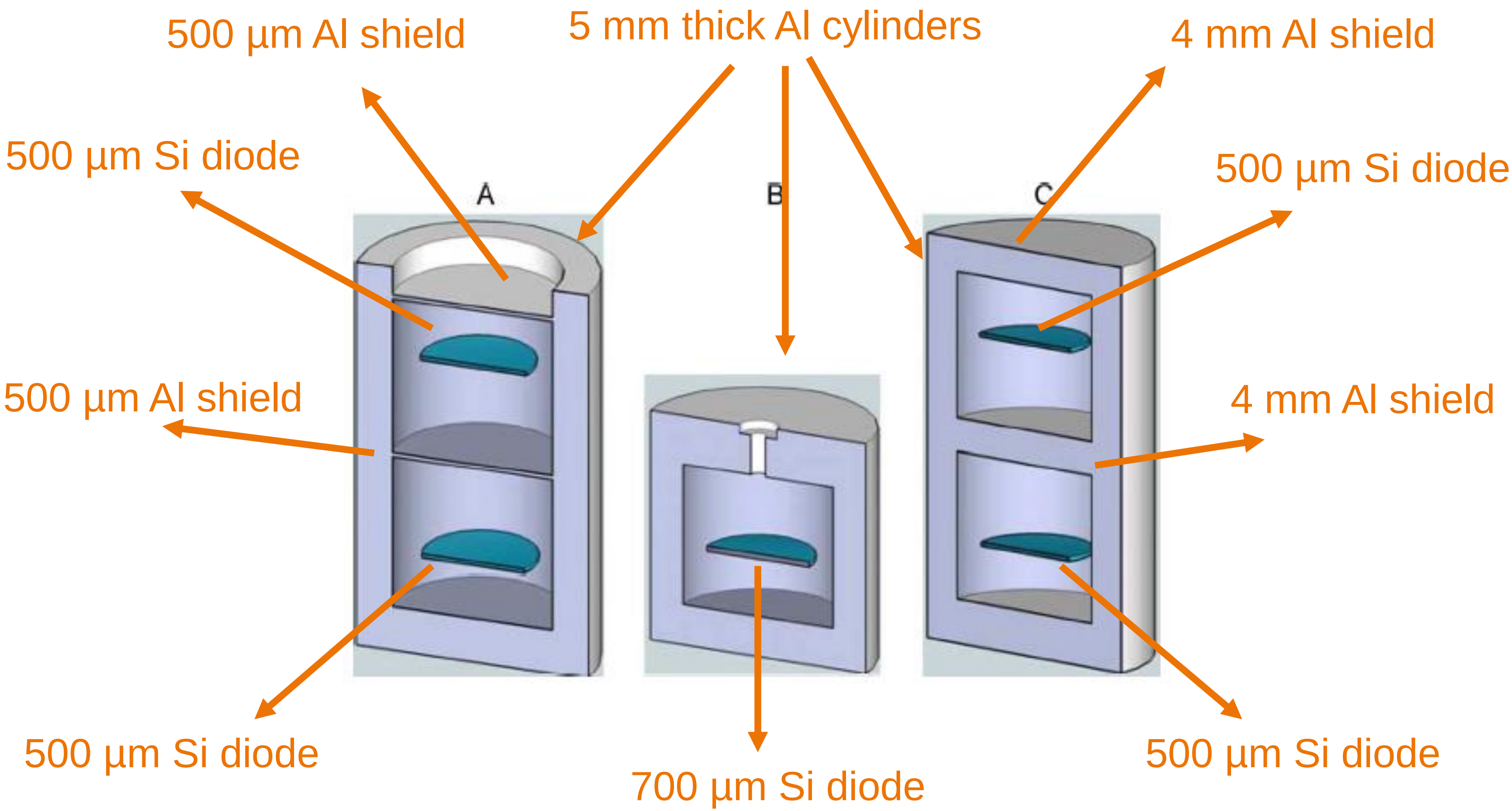
ICARE-NG detectors



In Flight Measurements of Radiation Environment on Board the French Satellite JASON-2

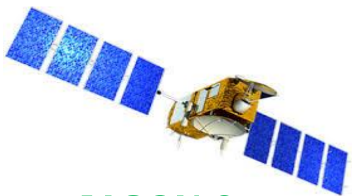
Daniel Boscher, Sebastien A. Bourdarie, Didier Falguère, Didier Lazaro, Philippe Bourdoux, Thomas Baldran, Guy Rolland, Eric Lorfèvre, and Robert Ecoffet

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 58, NO. 3, JUNE 2011

ICARE-NG spectrometer energy channels

- On JASON, ICARE-NG looks through the satellite wall
- On SAC-D, ICARE-NG looked through a window in the satellite wall

Electrons		Protons	
Integral (MeV)	Differential (MeV)	Integral (MeV)	Differential (MeV)
>1.6	3.6	>64	27.5
>1.67		>69	86
>1.74		>76	89
>1.81		>80	91
>1.88		>83	93
>1.95		>87	95
>2.02		>93	98
>2.09		>94	104
>2.6		>97	105
		>104	112
		>108	114
		>113	120
		>115	126
		>119	132
		>127	142
		>138	155
		>163	
		>186	
		>222	
		>292	

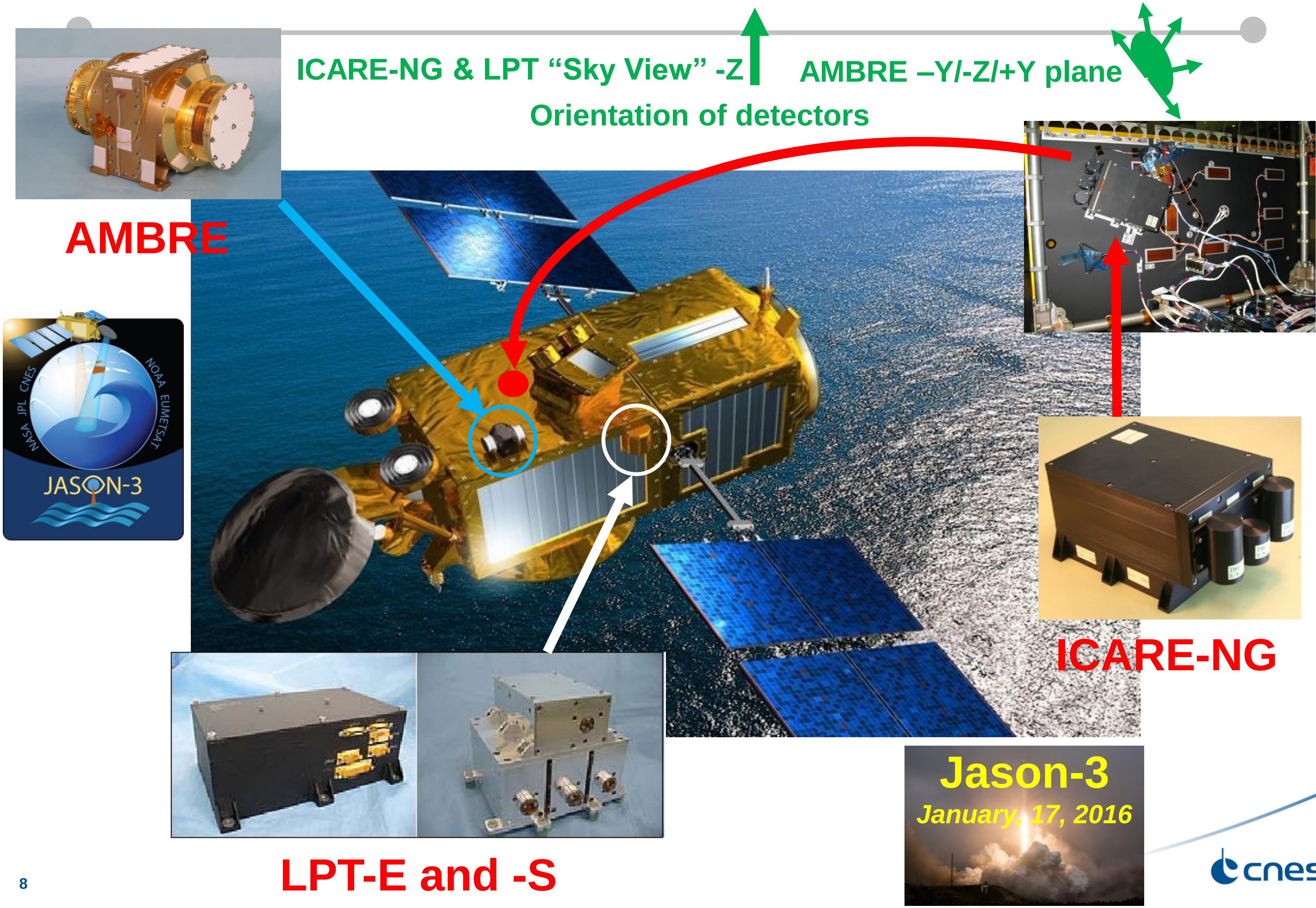


JASON-2
1336 km, 66°

Electrons		Protons	
Integral (MeV)	Integral (MeV)	Integral (MeV)	Differential (MeV)
> 0.249	> 1.093	> 54	12.9
> 0.270	> 1.135	> 56	18.6
> 0.299	> 1.192	> 60	31
> 0.320	> 1.226	> 65	47.3
> 0.342	> 1.300	> 66	61
> 0.363	> 1.359	> 70	63
> 0.384	> 1.508	> 73	64
> 0.413	> 1.657	> 75	65
> 0.455	> 1.823	> 80	67
> 0.505	> 1.974	> 81	69
> 0.554	> 2.106	> 85	74
> 0.604	> 2.254	> 90	75
> 0.653	> 2.404	> 100	80
> 0.703	> 2.567	> 105	81
> 0.752	> 2.680	> 115	85
> 0.802	> 2.770	> 130	90
> 0.870	> 2.850	> 160	100
> 0.895	> 2.930	> 190	115
> 0.930	> 3.010		
> 0.986	> 3.090		
> 0.994	> 3.170		
> 1.078	> 3.250		

SAC-D
657 km, 98°

Example : Jason-3 mission



Main orientations : modelling & user tools

High level goal : optimize radiation belt specifications

Improve radiation belt science and modelling (CRATERRE)

→ **Improve science, techniques & "expert tools" (*not* for the engineer)**

- → **Physics-based dynamic model (Salammbô)**
- → **Data assimilation techniques**

Develop user-oriented products and services

→ **Develop radiation belt engineering models**

- → **Make the models available to final users → OMERE (TRAD)**

→ **Develop space environment tools & services**

- → **Space data visualization → IPSAT**
- → **Radiation belts activity indices (EUMETSAT, CNES)**

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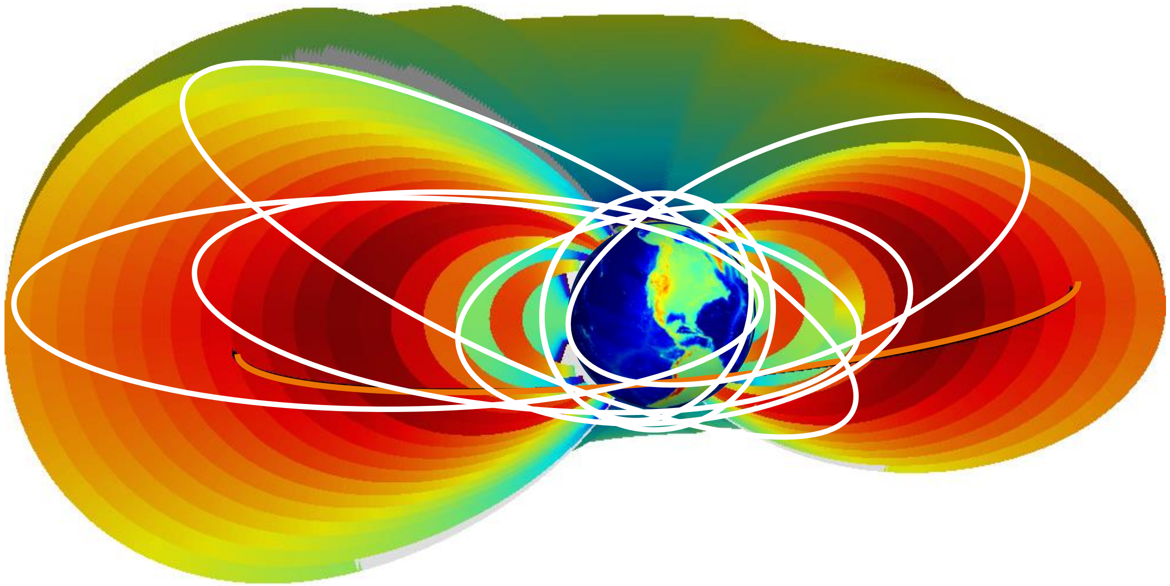
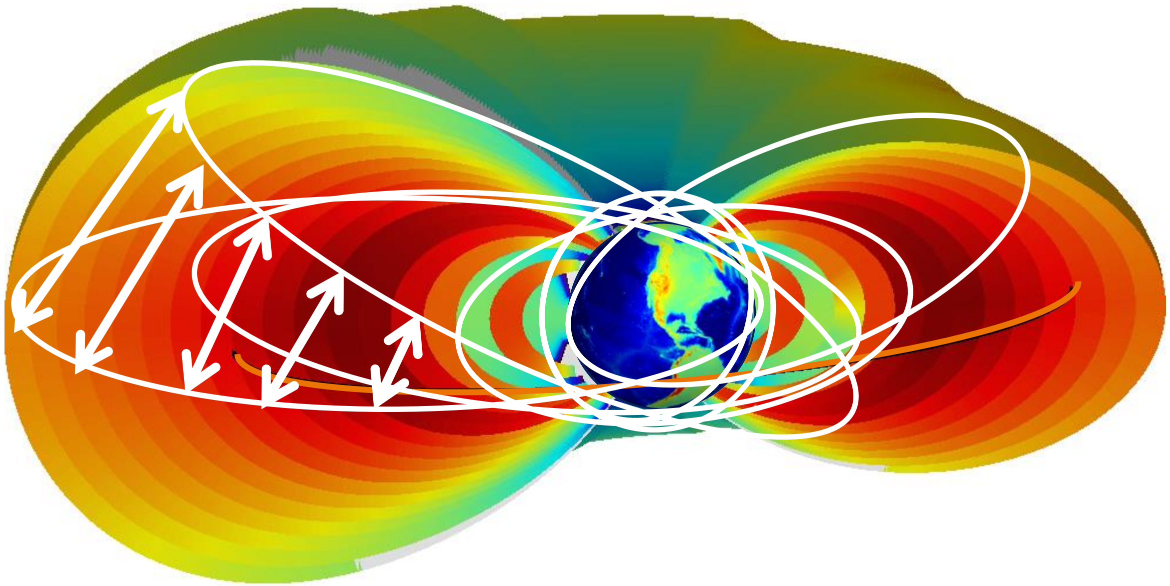
All along the watchtower



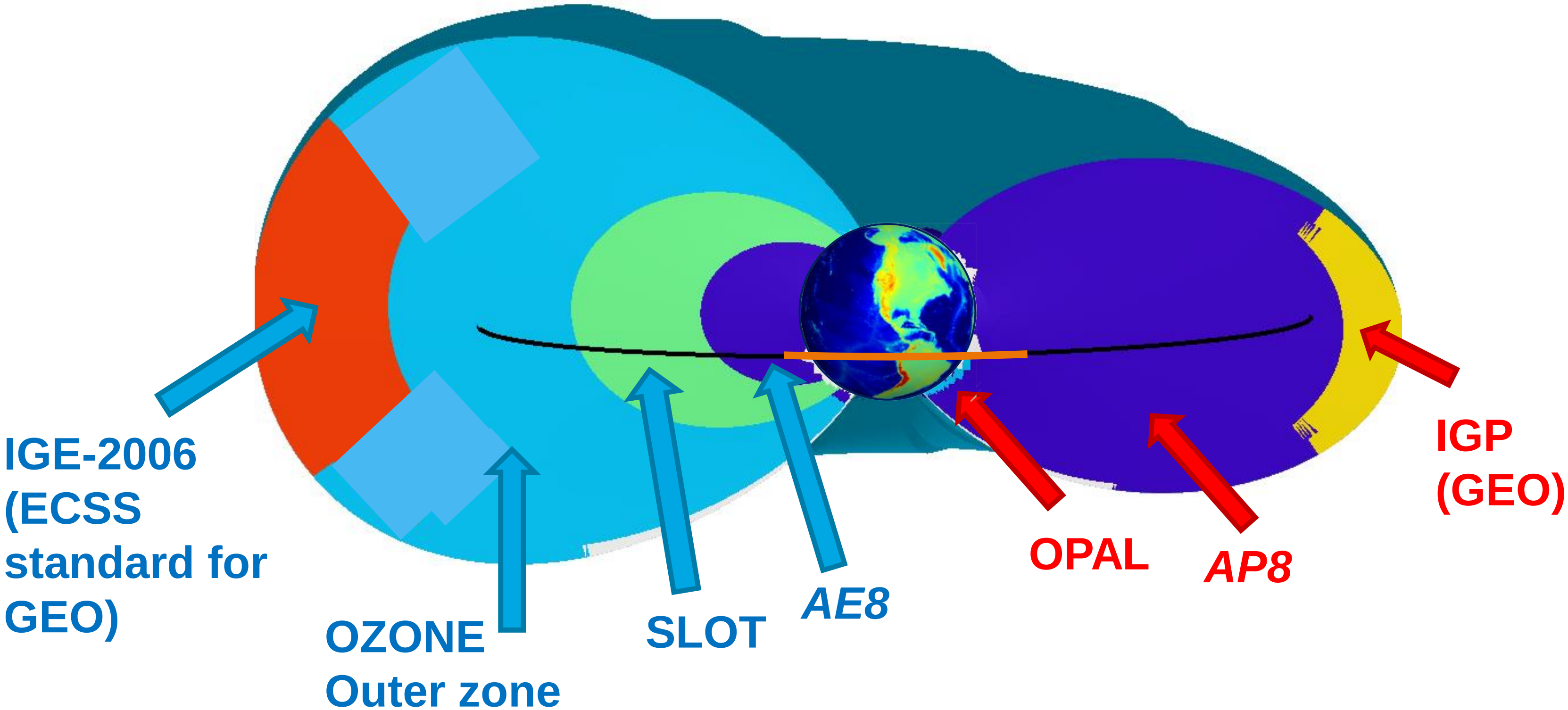
Data from ~50 couples instrument / satellite over more than 3 solar cycles
In-house data + international co-operations, Europe, USA, Russia, Japan
LEO/MEO/HEO/GEO/IP

Combination of the 2



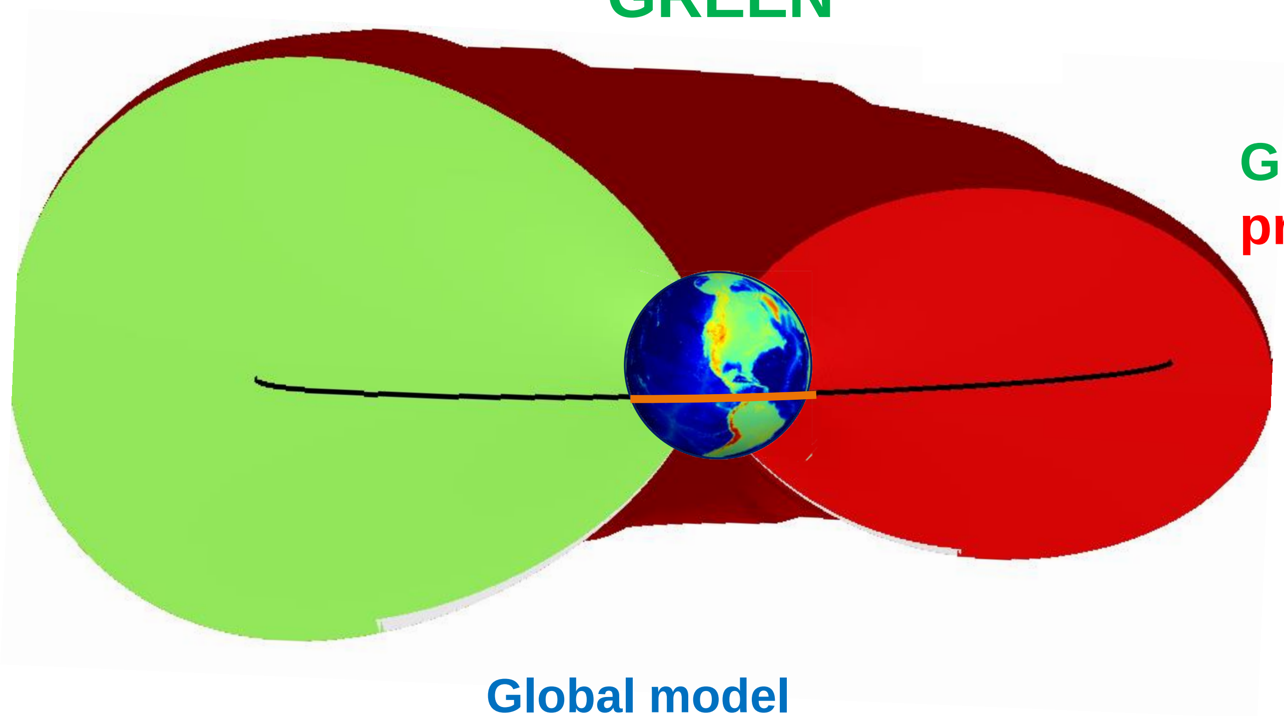
Space and time propagation using dynamic modelling (Salammbô) and data assimilation

She’s like a rainbow



Development of local models

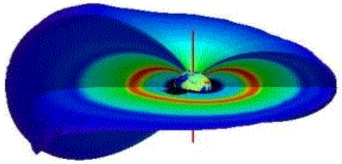
Voodoo child

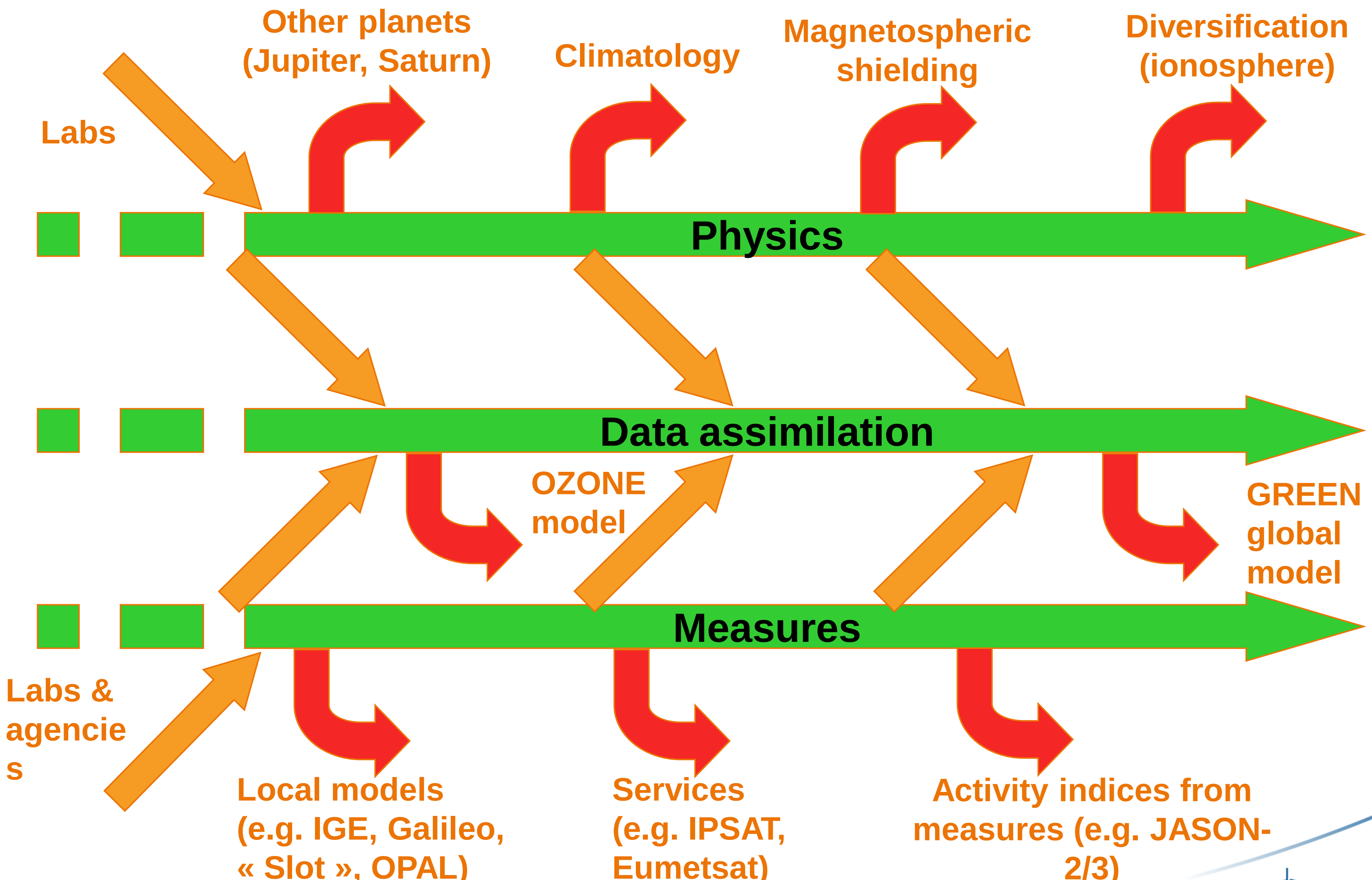


Global model
V0 (2016) pasting, V1 (2017) smoothing, V2+ extension

Global Radiation Earth ENvironment

CRATERRE Project





Courtesy Daniel Boscher, ONERA

Example : IGE 2006

Developed by ONERA in the early 2000's with CNES support (R&T) and through collaborations with LANL and JAXA

Introduced in ECSS E-ST-10-04C in 2008 as a standard for GEO orbit

Effectively used in specifications ~2015 (NEOSAT)

Research → Publications, reviews (1st round of discussions)

→ Acknowledgement by scientific community

→ Uplift to standards (2nd round of discussions)

→ Adoption by industry – may need a trigger

→ ~15 years from early research to application

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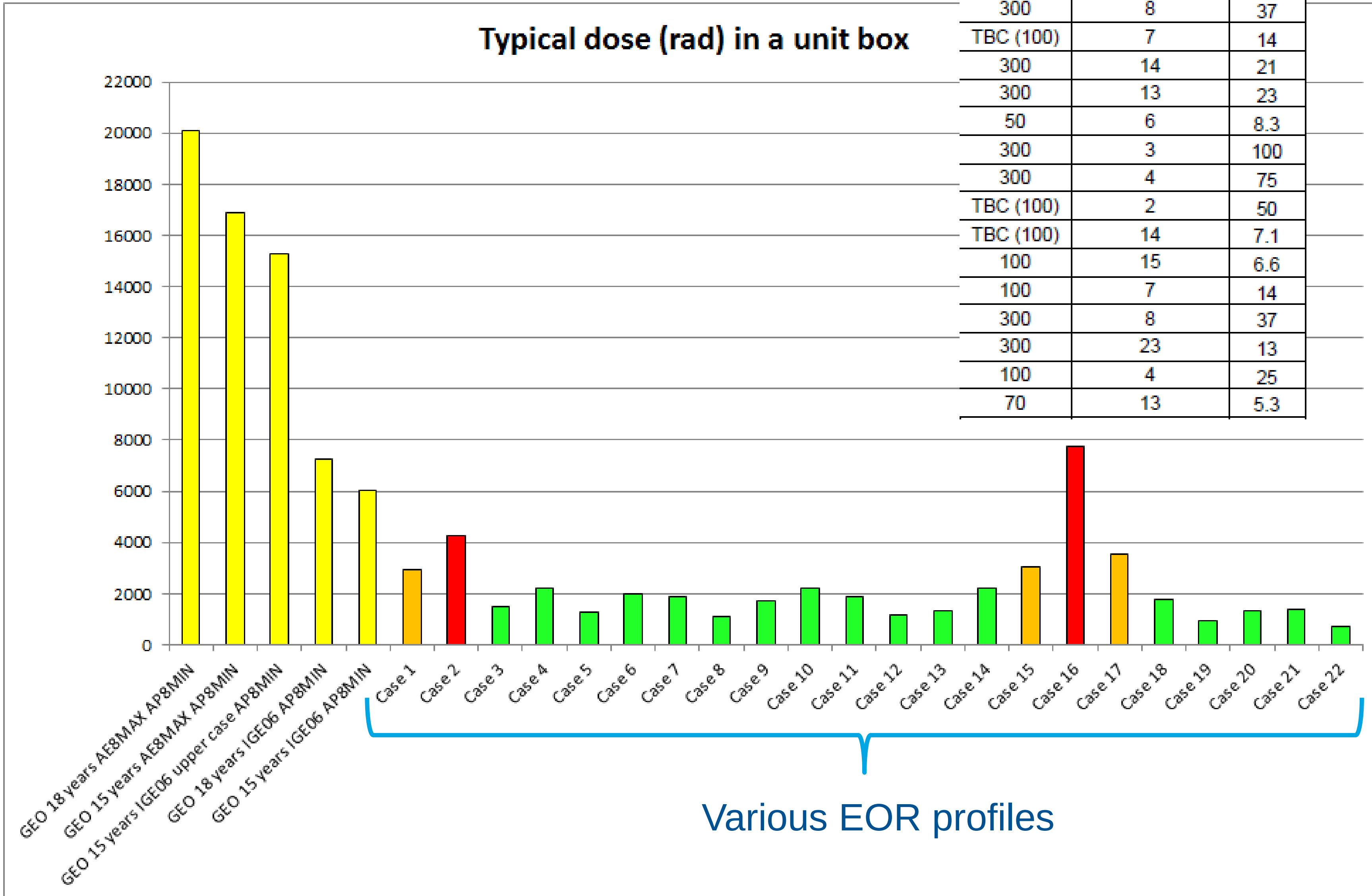
Example : IGE 2006

TIDS (krad)	TIDL 15 Years GEO (krad)	Margin
300	6	50
300	8	37
TBC (100)	7	14
300	14	21
300	13	23
50	6	8.3
300	3	100
300	4	75
TBC (100)	2	50
TBC (100)	14	7.1
100	15	6.6
100	7	14
300	8	37
300	23	13
100	4	25
70	13	5.3



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Space data visualization : IPSAT

https://craterre.onecert.fr/ipsat/index.php

PLOT | ADVANCED PLOTS | INTER-CALIBRATION | DATA/MODELS | SOS SPACE | DATABASE | ?

ONERA
THE FRENCH AEROSPACE LAB

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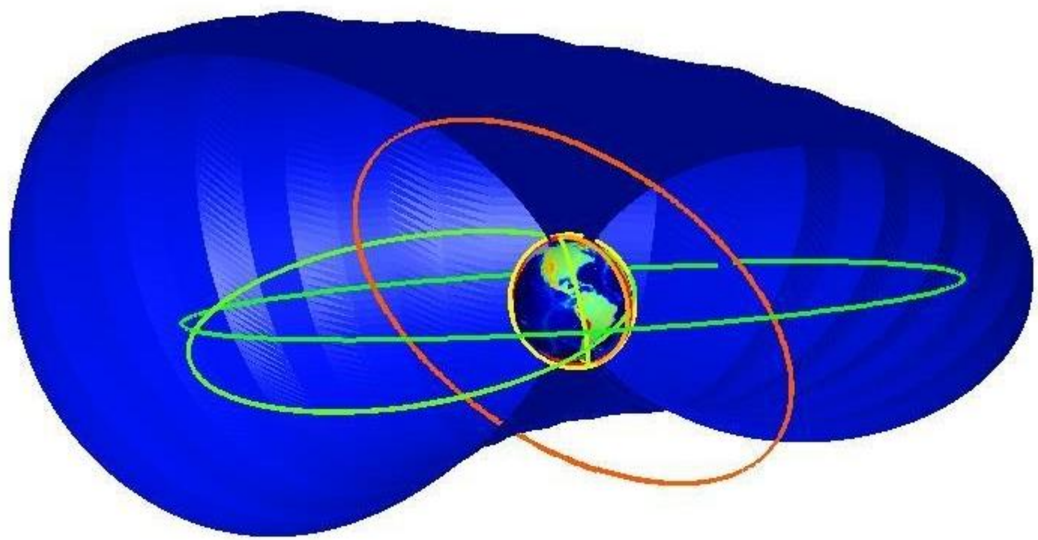
CENTRE NATIONAL D'ÉTUDES SPATIALES



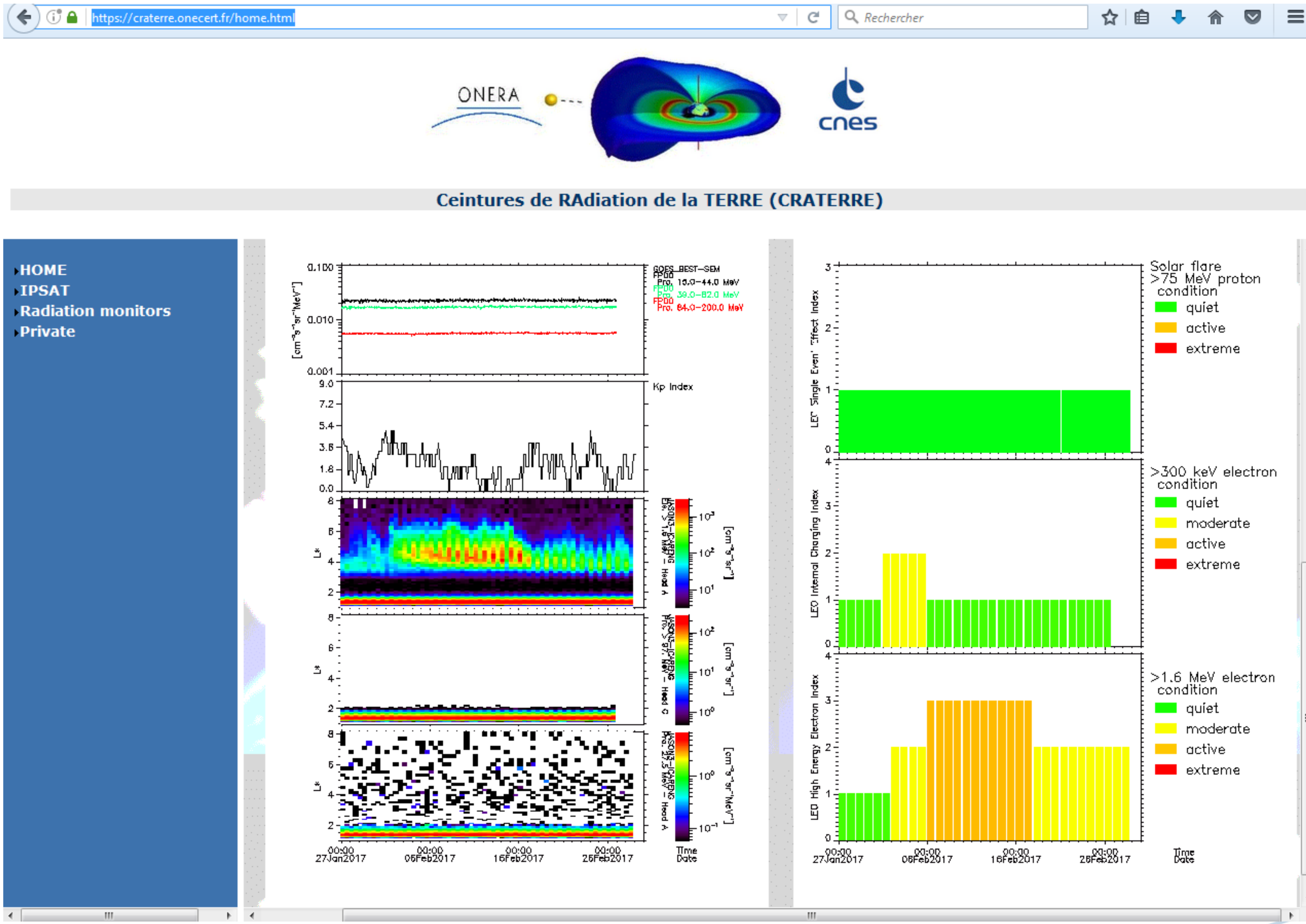
Ionising Particle in Space Analysis Tool - IPSAT V4.0

Web site designed for:

Email to web site manager (Bourdarie Sebastien)

https://craterre.onecert.fr/ipsat/index.php

Space weather : radiation belt indices



https://craterre.onecert.fr/home.html

Main orientations : OMERE

High level goal : space environment and effects tool <u>on a desktop</u>

Engineering – oriented

→ Each year, orientations defined within a core user group

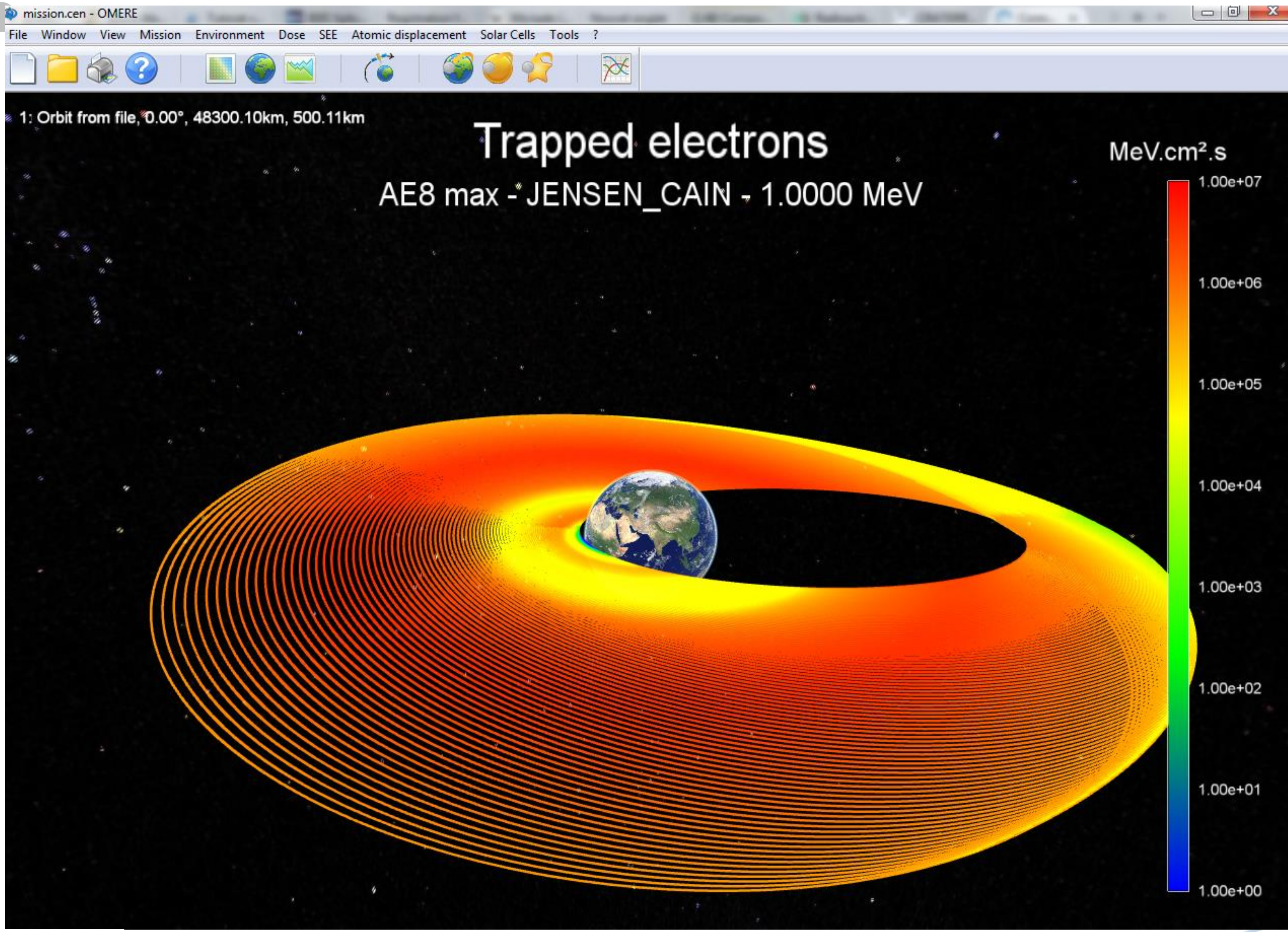
→ CNES, TRAD, ONERA, AIRBUS-DS, TAS, CEA, ESA

Standard models, new models (ONERA, Ax9,…)

Idem for radiation effects

→ Diffusion vector for our R&D outputs & those of our partners

Engineering tools : OMERE



http://www.trad.fr/OMERE-Software.html?lang=en

Main orientations : radiation engineering

High level goal : <u>optimize</u> radiation design margins

Evaluate the impact of parameters on environment specifications

→ e.g. anisotropy Y/N, orbit description,…

Evaluate the impact of new models on environment specifications

→ e.g. A9/AP9 but also new ONERA models

Assess and improve radiation transport techniques

Assess and improve margin evaluation at each step of RHA process

Improve the definition of interface specifications

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