Monitoring capabilities of the Earth charged particle environment

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ONERA-DESP, Toulouse, France
CNES-CST, Toulouse, France

First European Space Weather Week
ESTEC, Noordwijk, 30th November 2004
HIGH ENERGY PARTICLES

XMM - EPIC Radiation Monitor

SAC-C Icare

DEMETER IDP
ESA X-ray Multi Mirror Mission (XMM)

Launch: December 10, 1999

Orbit: 7000×114,000 km, i = 70°

European Photon Imaging Camera, EPIC

EPIC radiation Monitor, ERM

EPIC Particle Sensors

87 mm
EPIC Low Energy Sensors

Electron energy range: 0.16 – 1.55 MeV
Proton energy range: 1.05 – 2.85 MeV
EPIC Low Energy Sensors

Incident Energy (MeV)

Deposited Energy (MeV)

$e^-$

GEANT4
<table>
<thead>
<tr>
<th>Reduced channel name</th>
<th>Original channels</th>
<th>Electrons</th>
<th>Protons</th>
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EPIC HIGH ENERGY SENSORS

Electron energy range: 0.95 – 2.54 MeV

Proton energy range: 8.7 – 76 MeV
EPIC HIGH ENERGY SENSORS

Incident Energy (MeV)

Deposited Energy (MeV)

GEANT4
## HIGH ENERGY TABLES

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GOES versus XMM proton fluxes at 44.6 MeV

Solar proton event

$y = 1.4981x$
SAC-C (CONAE, Argentina)

• Orbit:
  - 715 x 715km, inclination: 98.2°

• Launch:
  - 21 Nov 2000 Delta-2 from VAFB

• Instrument: **ICARE-CNES**
  - Detector heads derived from the CESR ERM/XMM instrument
  - Development, operations: CNES
  - Calibration, science: ONERA
  - Investigators: R. Ecoffet (CNES), D. Boscher (ONERA)

• Purpose of the instrument:
  - Space environment
  - Radiation effects on components (SEE, dose)
ICARE

Component test bed
Acquisition chains
Detectors

DC/DC converter board

CPU, data processing (multi-channel analysers) and TM/TC

Mass: 2.4 kg
Mean power: 2.5 W
281 x 155 x 71 mm

Sampling rate: 64s
ICARE detectors

"E" detection head
- 500 µm Al casing
- 50 µm Si window
- 500 µm Si diode

"P" detection head
- 500 µm Al casing
- 150 µm Si diode
- 6 mm Si/Li diode

"I" detection head
- 500 µm Al casing
- 500 µm Si diode
GEANT-4 simulations

DETECTOR SPICA/PC MATRIX TRANSFERT (Deposited E vs. Incident E)
e- ] 0 MeV, 4 MeV, 'Total' irradiation, 'coincidence' mode (if V1&V2 then V2)
isotropic incidence, 100000 particles
matrix 100 x 100
Bin of deposited E : 0.040404 MeV

p ] 0 MeV, 100 MeV, 'Total' irradiation, 'coincidence' mode (if V1&V2 then V2)
isotropic incidence, 100000 particles
matrix 100 x 100
Bin of deposited E : 1.0101 MeV
Cross calibration with GOES

Protons, 10.5 MeV

\[ y = 0.9303x \]
# Energy channels

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<td>electrons 320 keV</td>
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<td>E3</td>
<td>electrons 360 keV</td>
<td>PE1 electrons 1.5 MeV*</td>
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<td>electrons 420 keV</td>
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<tr>
<td>E11</td>
<td>electrons 1400 keV*</td>
<td>P4 protons 33.5 MeV</td>
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* contaminated
Mirror point in South hemisphere in loss cone

Drift shell inside the Earth in SAA

Ele. 300-2500 keV NOAA-15 (825 km 98°)

L* @ 825 km

Ele. 0.4 MeV SAC-C (700 km 98°)

Jan-Feb 2003

Ele. 0.5 MeV PROBA (553x677 km 98°)

Jan-Feb 2003
Influence of Solar energetic particles on the proton radiation belt

Example of SAC-C measurements $E = 10.5$ MeV, 31 March 2001 event

before

after

4 months
Influence of Solar Energetic Particles on the Proton RB

Example of SAC-C measurements $E = 10.5$ MeV (715km)

![Graph showing flux over time with L = 1.9 and L = 2.9, March 31 and Nov. 24, and a time lag $\tau \sim 6$ months.](image-url)
Effect of the 29-31 October 2003 event seen by ICARE / SAC-C

Effect of rotating coronal hole on outer belt

CME and inner belt injection
“SPACECRAFT ANOMALIES”
ICARE SAC-C ELECTRONS 560 keV

L-value

TIME (Days)

ADEOS-II failure
For ~2 years, enhanced fluxes in the proton belt, whose fluxes build up in Oct/Nov. 2003, magnetic storms « sweep out » excess fluxes.

A possible explanation for the decrease of SPOT5 mass memory SEU rates after the solar event of the 29/09/04

Solar events Nov. 2001 (flares = magnetic storms) create conditions for an injection in the proton belt.
DEMETER: A FRENCH MICRO-SATELLITE ON A LOW POLAR ORBIT

Goals: Study of human electromagnetic emissions, of ionospheric effects of volcanism and earthquakes...
Electrons:
256 channels from 70 keV to 2.5 MeV

Protons:
An integral channel E > 2.5 MeV
OUTER BELT – SLOT - INNER BELT
INNER BELT WAVES EFFECT

DEMETER

31/Aug/2004

L (Re)

1
2
3
4

1x10^6
2x10^5
4x10^5
6x10^5
8x10^5

E (MeV)

GCLAT 50.97
GCLONFG 255.46

17:55 18:00 18:05 18:10 18:15 18:20 18:25

22.30 -6.48 -35.12 -63.26
246.56 240.20 233.28 220.39

Log flux

σ: 2.4
σ: 1.7
σ: 1.0
σ: 0.2
σ: -0.5
σ: -1.2
σ: -1.9
INNER BELT ENERGY SPECTRA

FLUX

ENERTGY (MeV)

100 keV
INNER BELT - WAVE

Variation of the resonant energy with L

(Abel and Thorne, JGR, 1998)
SOUTH OF THE ATLANTIC ANOMALY

NON HARMONIQUES

Fréquemment observés au sud de l’Afrique
DEMETER - 2004

22:30, Sept. 13

> 2.4 MeV

0.7-1.0

0.3-0.7

H⁺

e⁻

e⁻
LOW ENERGY PARTICLES

Satellite charging
Earth orbiting spacecraft can encounter plasma of vastly diverse characteristics in the energy range: \(~\text{eV} - 60\ \text{keV}\)

Versatile and reliable particle experiment are needed. To meet the objectives, the instrumentation has to satisfy the following criteria:

- Be immune to UV flux
- Be immune to high energy particle background
- Provide uniform coverage over a large pitch-angle range with a good angular resolution
- Have high sensitivity and large dynamic range (\(~\text{10}^7\)
LOW ENERGY PARTICLES

Rely as much as possible on well-proven designs by basing sensor designs on those successfully flown:

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LOW ENERGY PARTICLES

UV: Three reflections, scalloping, coating

High energy particle background: Coincidence or multiplier sample

Uniform coverage: top-hat (Carlson, Paschmann et al., 1982)
LOW ENERGY PARTICLES
SUMMARY

1) We have the necessary tools to measure/model the Earth’s radiation belts

   New improvements are needed to measure pitch-angle distributions

2) We need a framework to build common experiments

3) Past and ongoing missions will be used to define simple low energy sensors