CubeSat compatible instrumentation for monitoring the radiation environment

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RADMON

Radiation Monitor for a CubeSat
RADMON: Energetic particles @ LEO

RADMON
Mass: 0.4 kg
Power: 1 W
Volume: 0.4 U

Analog Board
Digital Board
PSU Board

Detector Unit
RADMON measurement principle: \( \Delta E \) vs \( E_{\text{res}} \) method

\( \Delta E \) @ constant \( E_{\text{res}} \) gives the species

\( \Delta E + E_{\text{res}} \) gives the energy

RADMON Mass: 0.4 kg
RADMON Power: 1 W
RADMON Volume: 0.4 U
Energetic (>10 MeV) protons

Inner-belt protons observed in SAA at a stable rate [not much orbit-to-orbit variations]
Inner-belt electrons observed in SAA at a stable rate
Outer-belt electrons observed at higher latitudes more variable
Quasi-trapped electron flux increases with longitude from trapped region

Fig. A. Punkkinen
RADMON electron detection efficiency in channel e1-5

Geometric factor [cm² sr]

Incident electron energy, MeV
RADMON proton contamination in channel e2-e5

Geometric factor [cm$^2$ sr]

Incident proton energy, MeV
Comparison of RADMON and PROBA-V/EPT electrons

Gieseler et al. (submitted)
Electron spectra from 9 to 20 November 2017 for 3.75 < L < 5.25

- **PROBA-V/EPT differential flux**
  - $\frac{dj}{dE} = A \cdot E^{-\gamma}$ from RADMON e2 and e3
  - $\frac{dj}{dE} = A' \cdot E^{-\gamma'}$ from RADMON e3 and e4

- **RADMON integral flux**
  - $J( > E^i ) = A/(\gamma - 1) \cdot E^{1-\gamma}$ from RADMON e2 and e3
  - $J( > E^i ) = A'/(\gamma' - 1) \cdot E^{1-\gamma'}$ from RADMON e3 and e4
Summary / RADMON

- Despite its low-cost, low-power and low-mass, RADMON is a very capable instrument concept
- FPGA-based signal processing allows several improvements for future models without changes in hardware
  - Better electron/proton separation
  - Extension of proton energy range to 250 MeV
- Sensitivity can also be improved ten-fold by increasing the size of the sensors with marginal mass increase
- Dynamic range of counting can be further improved by changing the scintillator material (to, e.g., LYSO)
  - Power consumption will increase, though
- Mass and size can be somewhat reduced by redesigning electronics
- Next version developed for constellation mission (see Huovelin et al. on Thursday)
Particle Telescope (PATE)

Particle Telescope aboard FORESAIL-1 mission
- Mass 1.2 kg
- Power 2.5 W
- Size 1.4 U
- Telemetry 1.3 kbit/s

Measures electrons and protons
- Electron energy range: 80–800 keV
- Proton energy range: 0.3–10 MeV

Prototype tested with radioactive sources (alpha and beta)

EQM will be assembled and functionally tested by the end of November

Qualifications: Dec-Jan —> TRL 6

Launch: 2020
Proton response

Geometric factor [cm² sr]

Incident proton energy, MeV
More compact design

Size: 0.7 U
Mass: 0.9 kg
Power: 2.5 W
Electrons: 0.1–1 MeV, >1 MeV
Protons: 0.4–10 MeV, >10 MeV

Developed in collaboration with Aboa Space Research Oy for a small constellation mission concept (SCOPI).
Summary / PATE

• A high-fidelity particle telescope designed for medium-energy electrons and ions
  – Qualification campaign about to start for the 1.4U device
    —> TRL 6 to be reached within 3 months
  – Launch on-board a 3-U CubeSat (FORESAIL-1) to polar LEO in 2020 —> TRL 9 within 15 months

• Compact variant for monitoring applications with somewhat higher energy range in preliminary definition phase
  – Representative prototype to be built and tested during 2020 —> TRL 5
  – Lots of heritage from PATE —> swift development cycle
Conclusions

• University of Turku develops CubeSat compatible instrumentation for high and medium energy particles
  – Protons: 0.3 – 10 MeV and >10 MeV
  – Electrons: 0.08 – 1 MeV and >1 MeV

• High-energy instrumentation is already flying hardware and the first medium energy instrument will fly in 2020

• We collaborate with several Finnish SMEs and can adapt our design quite flexibly to accommodate needs for various space weather missions.

Thank you for your attention!
Instrument for LEO constellation

- Based on Aalto-1/RADMON (TRL 9), but with significant improvements to cover
  - Protons: 10–250 MeV, ten differential channels
  - Electrons: >1 MeV, five integral channels
- Foreseen specs:
  - Mass <500 g
  - Volume <0.5 U
  - Power <1.5 W
  - Dynamic range up to 1 MHz in counting
  - Nominal GF ≥ 0.2 cm² sr (increasing with energy)
  - Data rate: configurable