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Radiation shielding experiment for CubeSat on highly elliptical orbit

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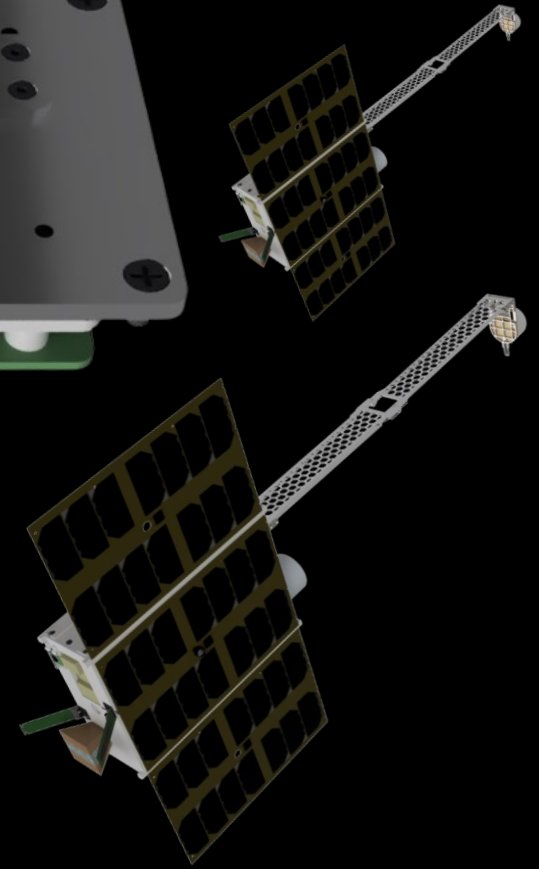
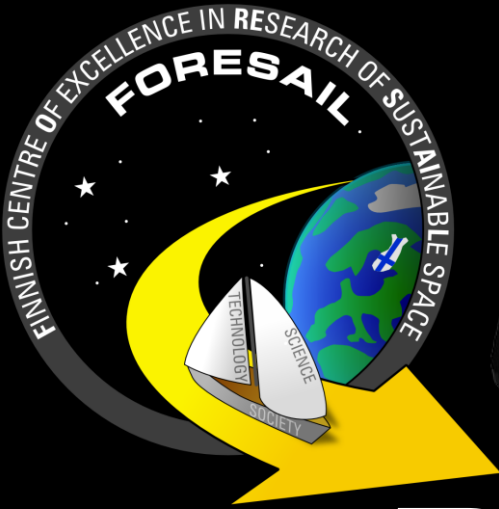
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RadEx

RADIation EXperiment onboard Foresail-2/3

*Anton Fetzer, Marius Anger, Tomi Kärkkäinen,
Antoni Eritja Olivella and Jaan Praks*





SUOMEN AKATEMIA
FINLANDS AKADEMI
ACADEMY OF FINLAND



FORESAIL

FINNISH CENTRE OF EXCELLENCE IN RESEARCH OF SUSTAINABLE SPACE



HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

A!

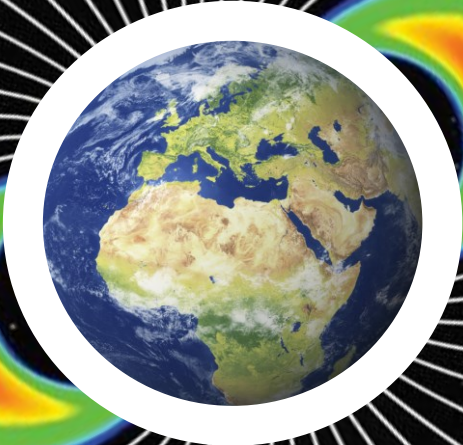
Aalto University



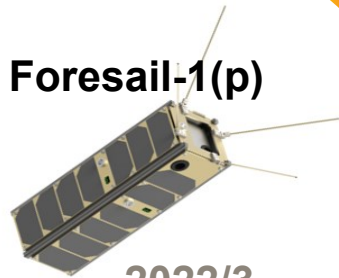
UNIVERSITY
OF TURKU



FINNISH METEOROLOGICAL
INSTITUTE



Foresail-1(p)



2022/3
Mission to
LEO

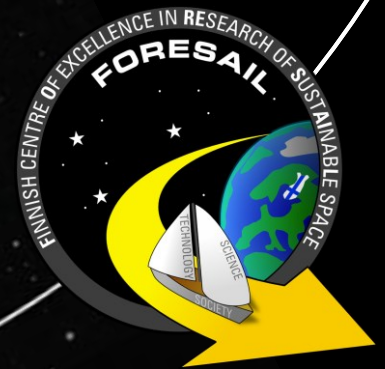
Foresail-3



Foresail-2



2025
Mission to
high elliptical orbit



From Hudson [2013]

Magnetopause

EMIC

High-energy electrons

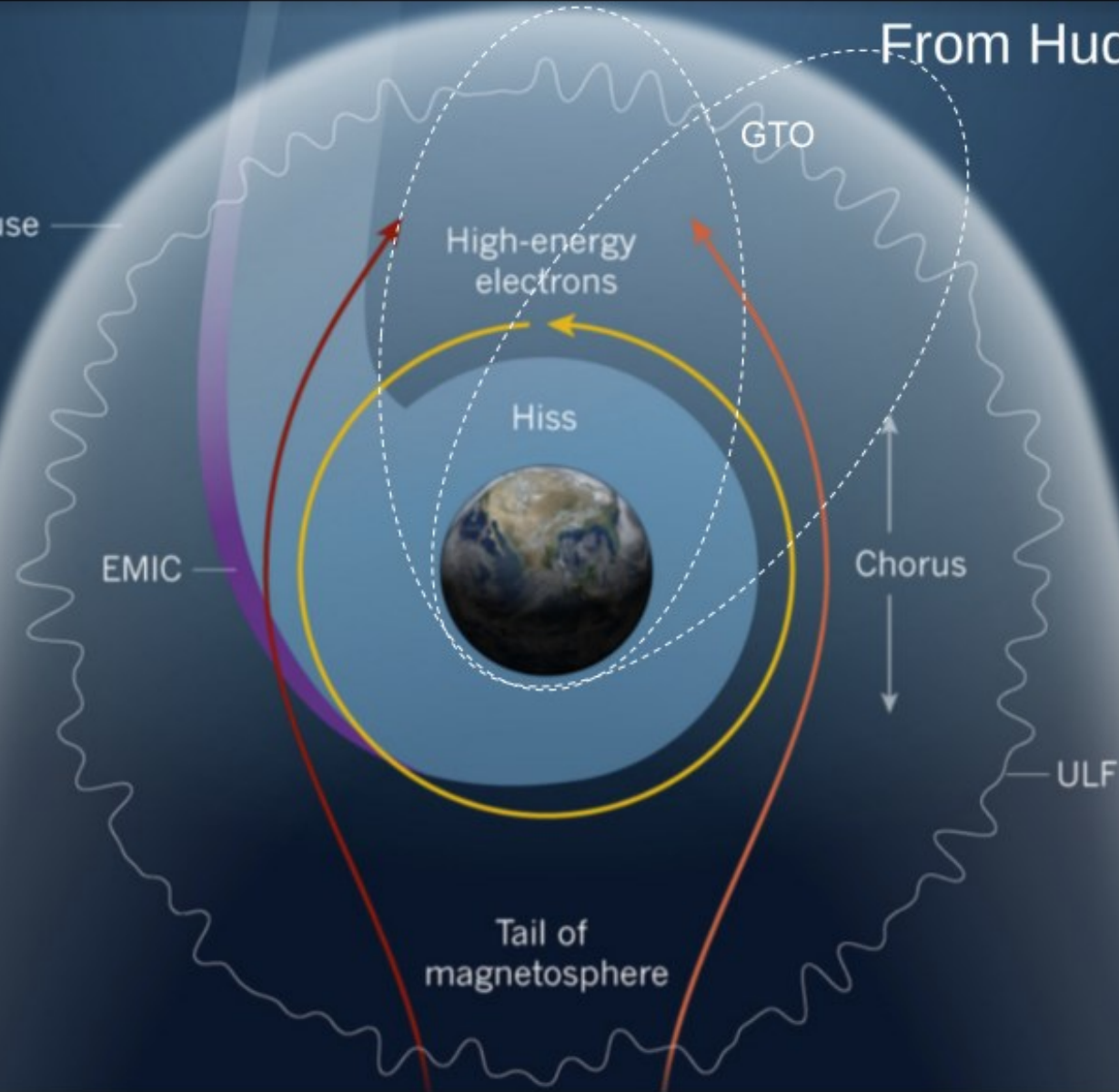
Hiss

GTO

Chorus

ULF

Tail of magnetosphere



Foresail-2/3

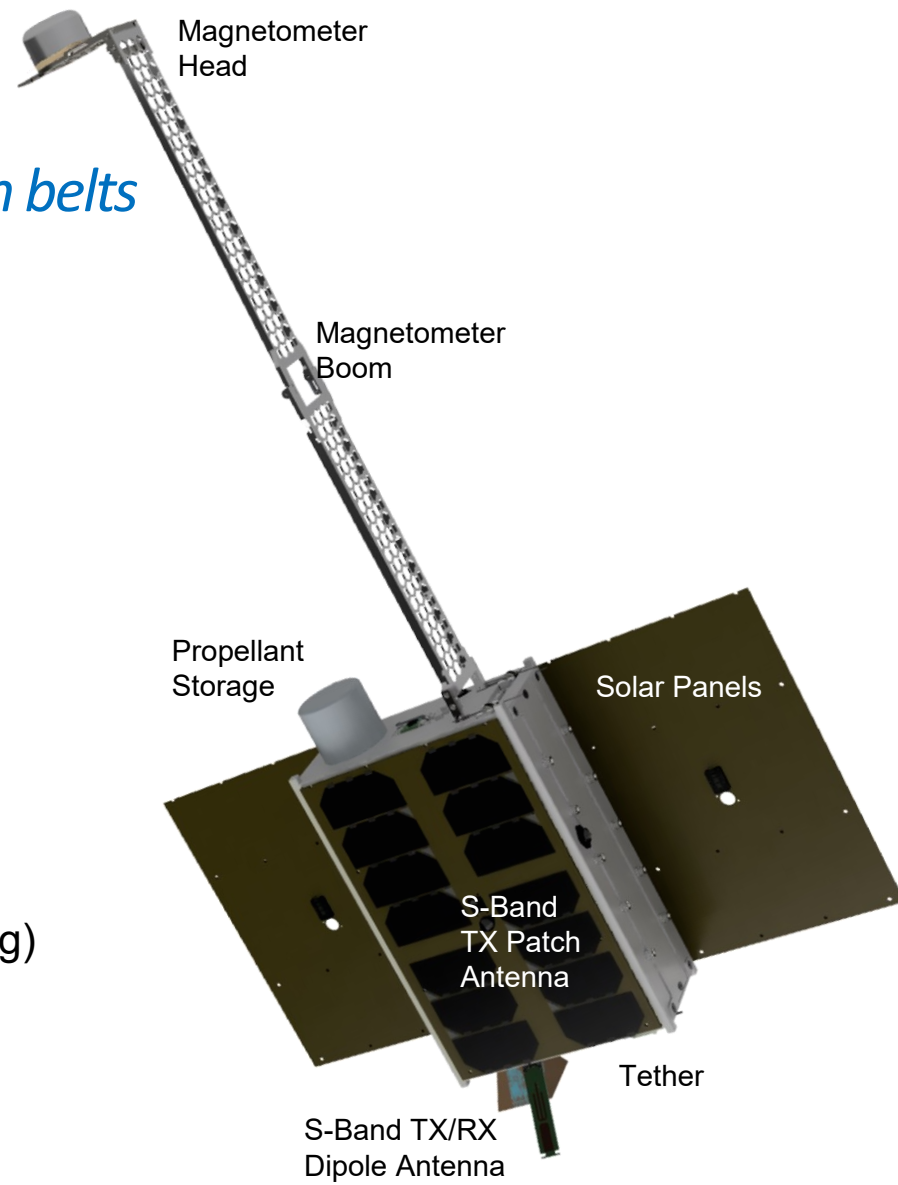
Measure ULF waves in Earth's radiation belts

1. **Measuring full 3D magnetic field (ULF waves)**
2. Measuring electron and proton spectra (belt dynamics)
3. Deploying a long charged tether; measuring ambient plasma density (Plasma and drag characteristics)
4. Based on COTS components and developed in-house

Mission duration: min 6 months

Launch date: 2025-2026

Target orbit: High elliptical orbit
(apogee > 15000 km, incl. < 30 deg)

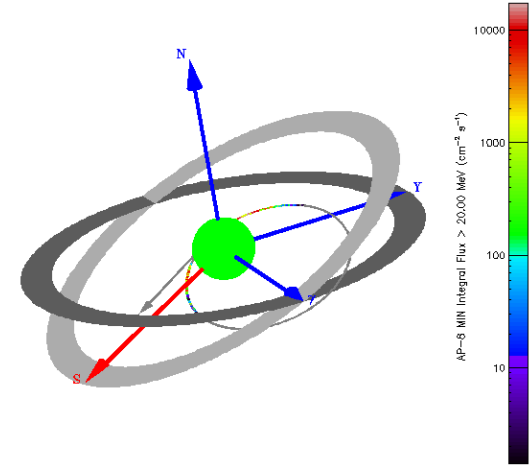
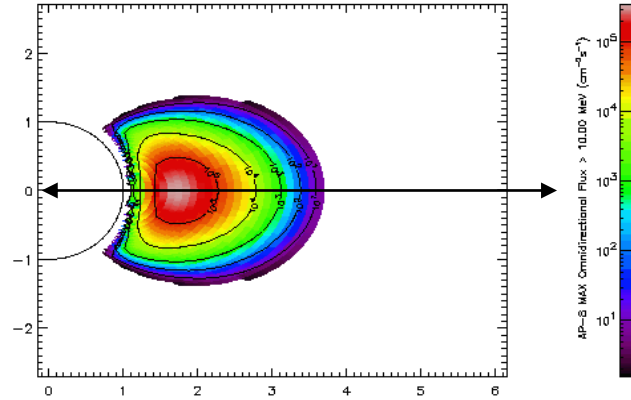


Foresail-2/3

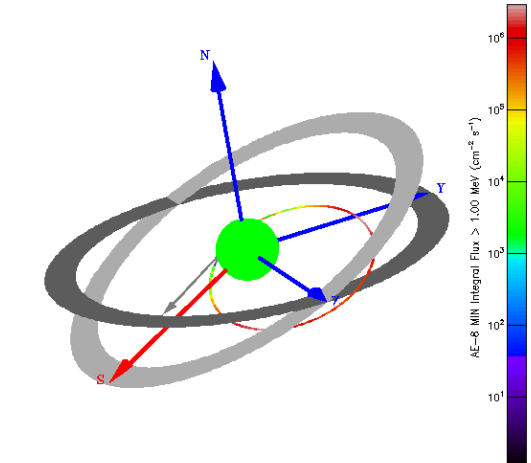
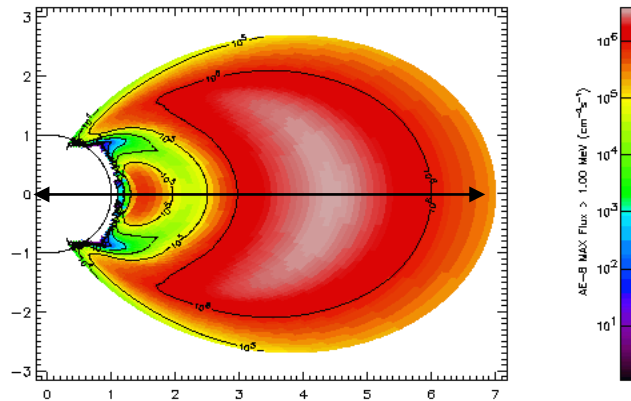
Source: SPENVIS

Mission constraints: Radiation environment

Proton flux > 10 MeV



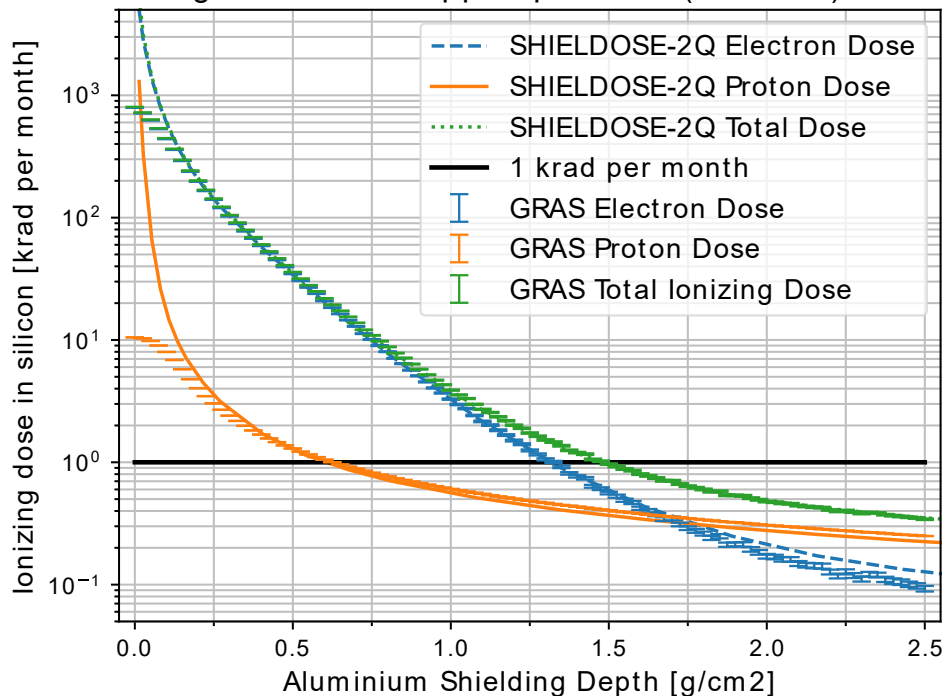
Electron flux > 1 MeV



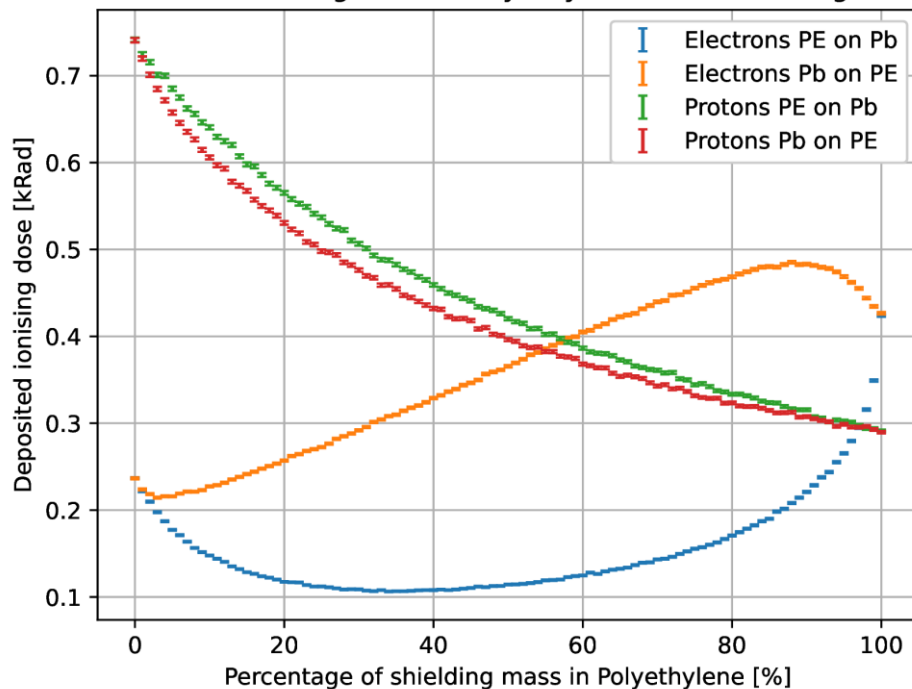
Foresail-2/3

Radiation Shielding

Ionising dose from trapped particles (AE9/AP9) on GTO



Dose deposited by trapped particles in 0.5 mm Si behind 1.5 g/cm² of Polyethylene-Lead shielding

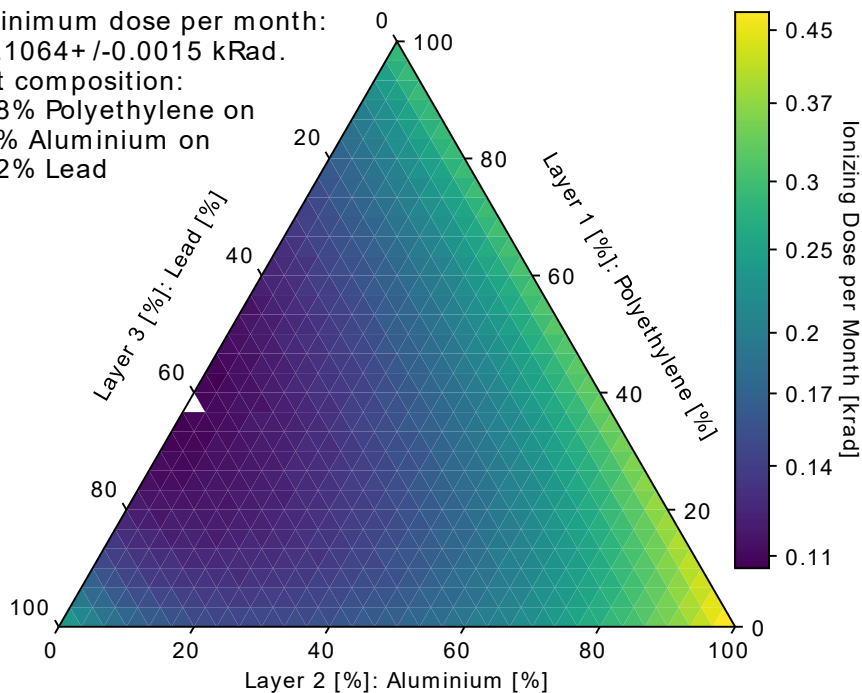


Foresail-2/3

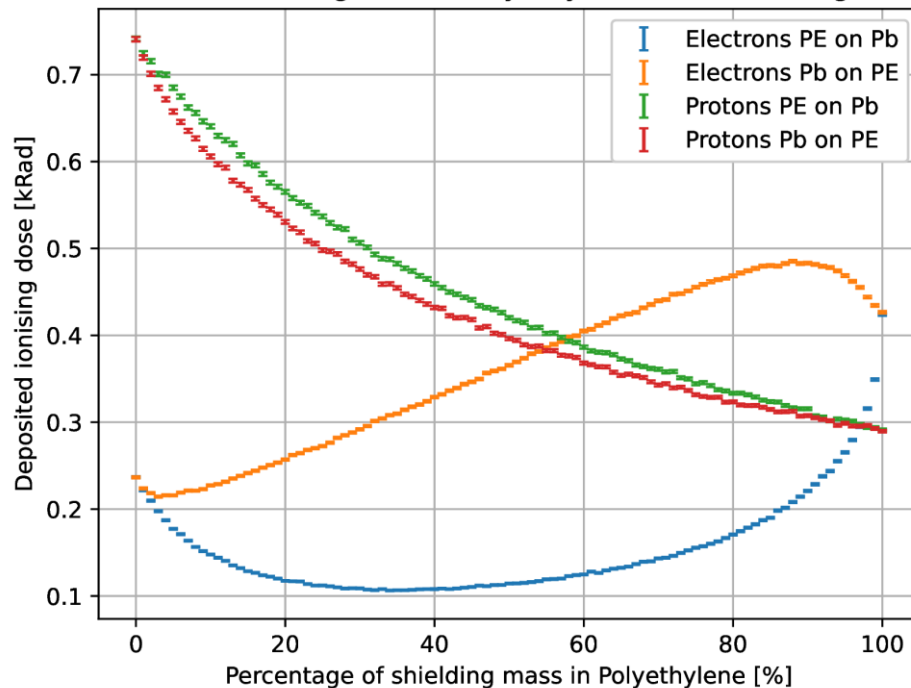
Multilayer Radiation Shielding Optimisation

Electron Dose behind 3-layer shielding

Minimum dose per month:
0.1064+/-0.0015 kRad.
At composition:
38% Polyethylene on
0% Aluminium on
62% Lead

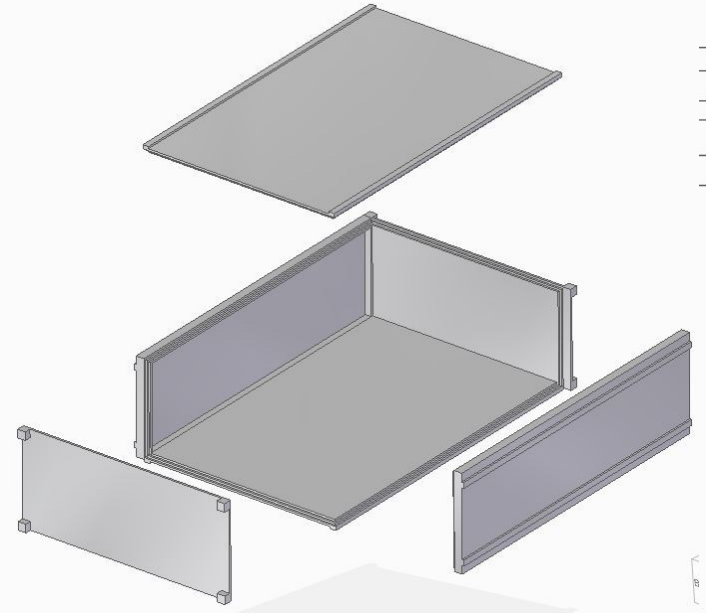


Dose deposited by trapped particles in 0.5 mm Si behind 1.5 g/cm² of Polyethylene-Lead shielding

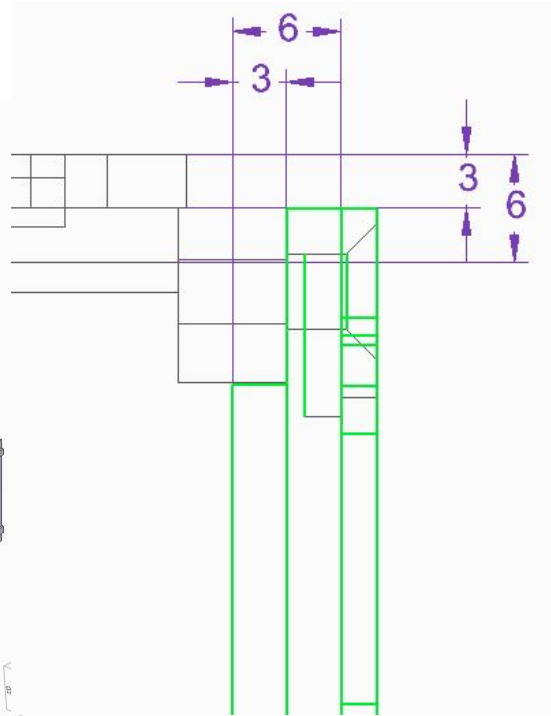


Foresail-2/3

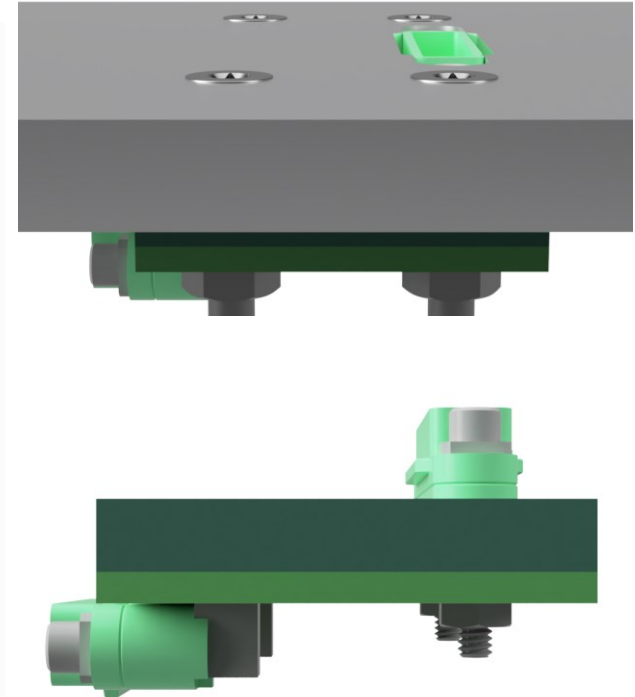
Shielding



6mm of Aluminium surrounding the whole 6U CubeSat Body



Overlapping panels to prevent radiation leakage through gaps

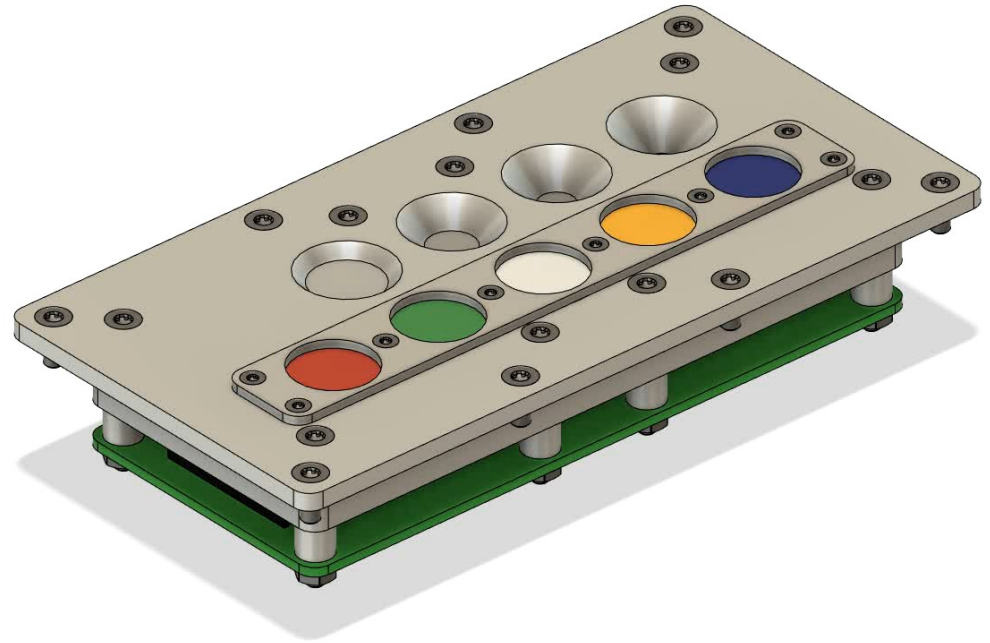


Covered pass-through connectors to prevent radiation leakages through gaps

Foresail-2/3

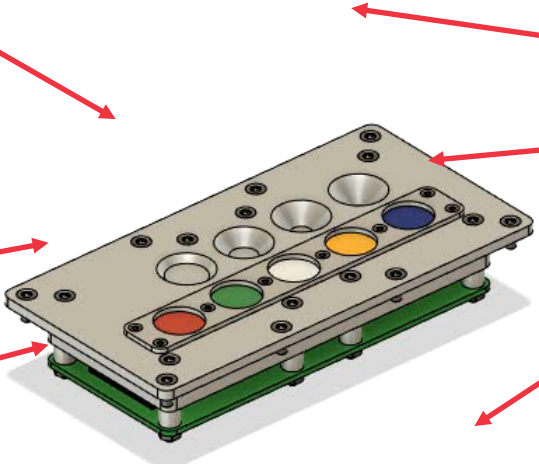
RadEx Radiation Experiment

- RADFET TID sensors
- Different thicknesses of aluminium shielding
- Alternative shielding materials
 - FR4 + Solder
 - Polyethylene +
 - Lead ?
 - Tungsten ?
 - Tantalum ?



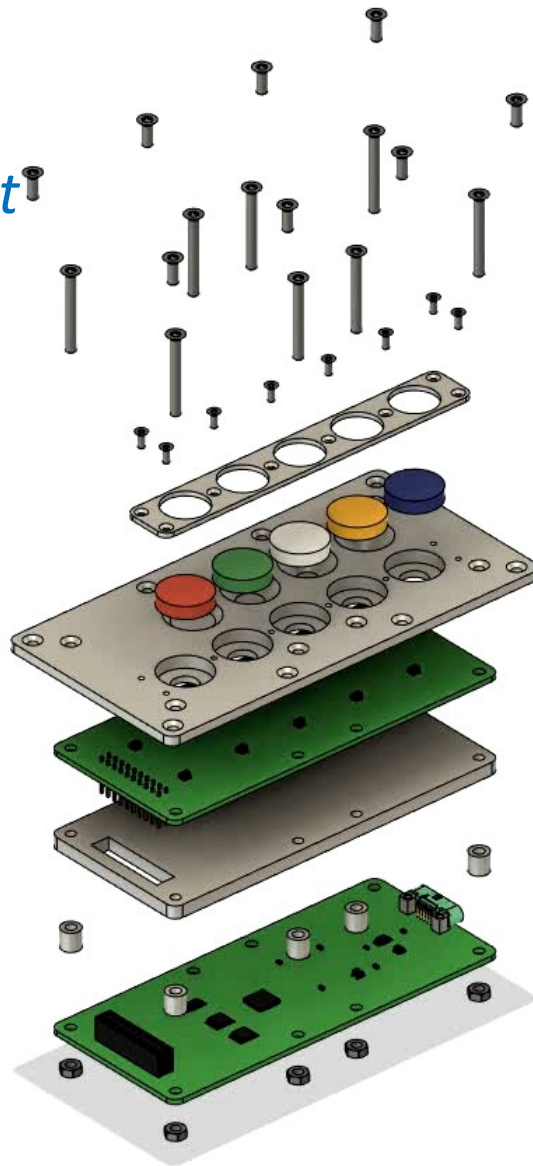
Foresail-2/3

RadEx Radiation Experiment

- 6mm aluminium top plate
 - Cut-outs for 0, 1, 2, 4 and 6mm of aluminium
 - Sensor PCB
 - 4mm aluminium backplate
 - 5 alternative materials
 - 10 RADFET TID sensors
 - PCB for readout and processing
 - ATmegaS64M1 microcontroller
- 

Foresail-2/3

RadEx Radiation Experiment



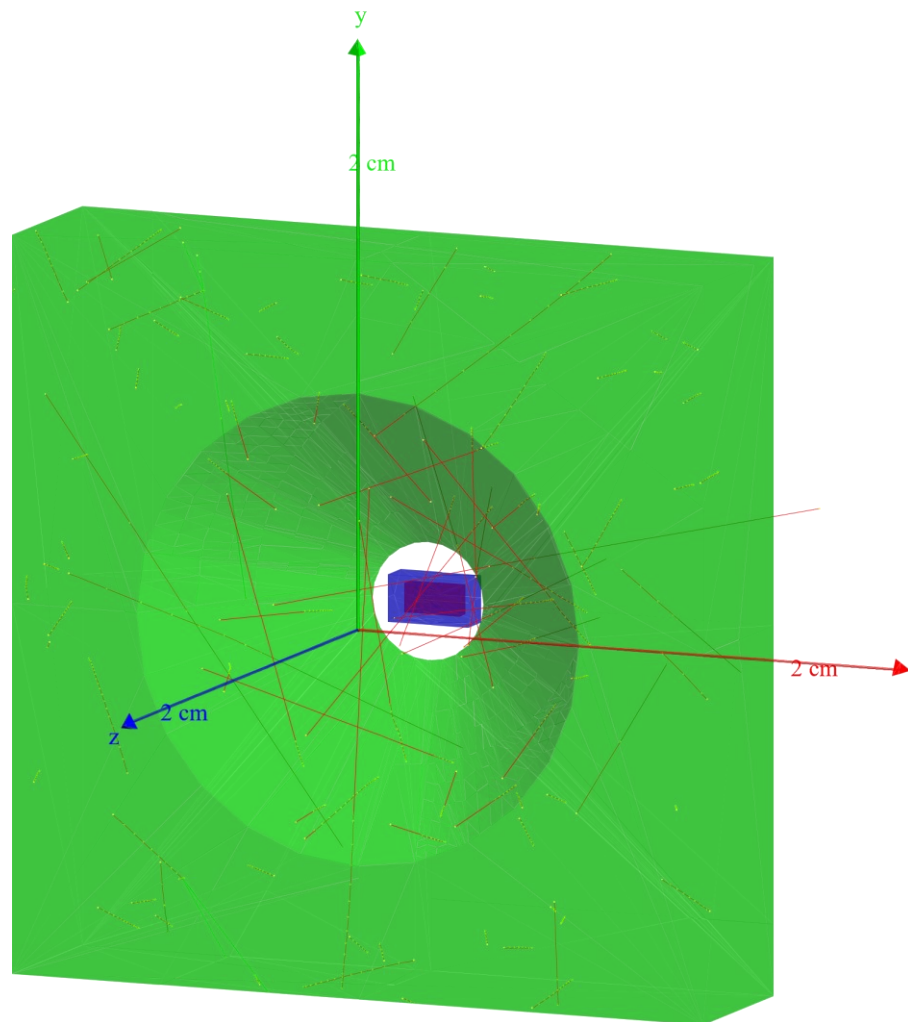
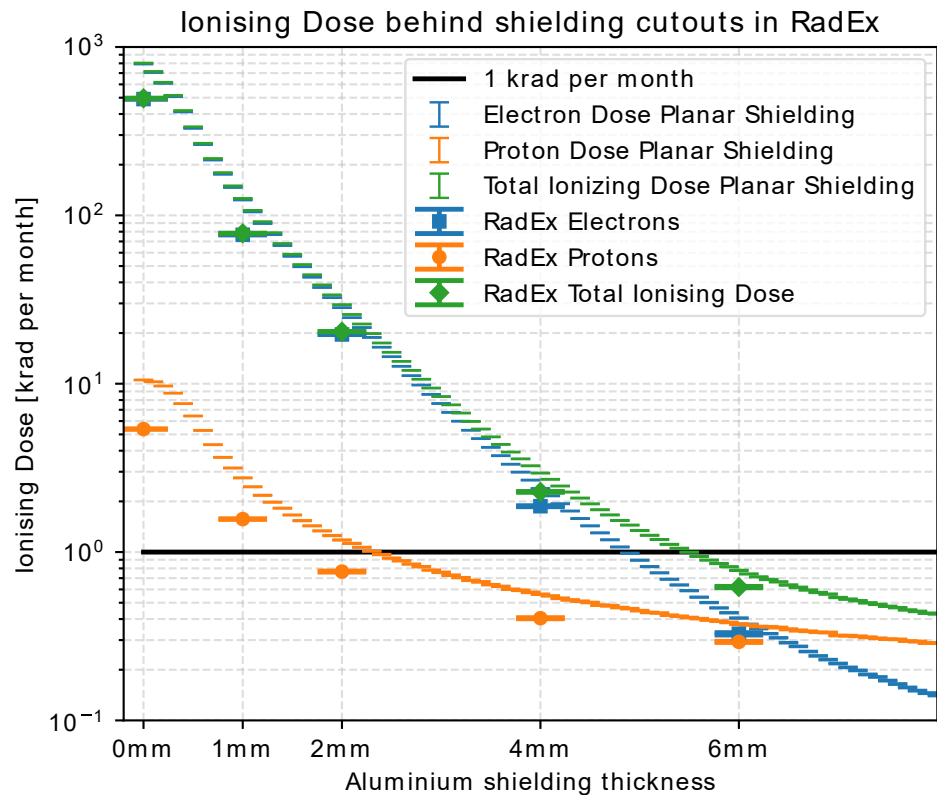
RadEx Radiation Experiment

Varadis RADFET TID Sensors

- Radiation sensitive
p-channel MOSFET
- optimized for
radiation sensitivity
- Extremely compact
SOT-23 six lead package
- No power or bias needed
during irradiation
- 10 μ A current for readout
- Very low duty cycle
- VT01
 - 1 cGy (1 rad) - 1 kGy (100 krad)
- VT05
 - 10 Gy (1 krad) - 10 kGy (1 Mrad)

Aluminium Shield Cut-outs

Geant4 Simulations



Foresail-2/3

RadEx Radiation Experiment: Additional Features

Single Event Effects (SEE)

- CPU with memory (e.g. Hercules)
- Run test loop to monitor registers
- Count bit flips to estimate SEE rate

Displacement Damage (DD)

- GaAs-LED
- Effectively immune to ionising dose
- Non-ionizing-energy-loss (NIEL)
reduces light output

Foresail-2/3

RadEx Radiation Experiment: Testing

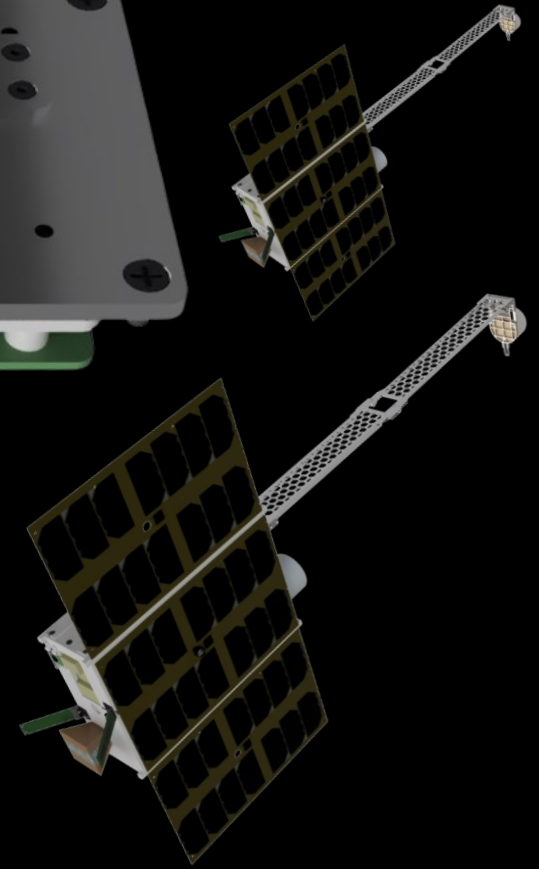
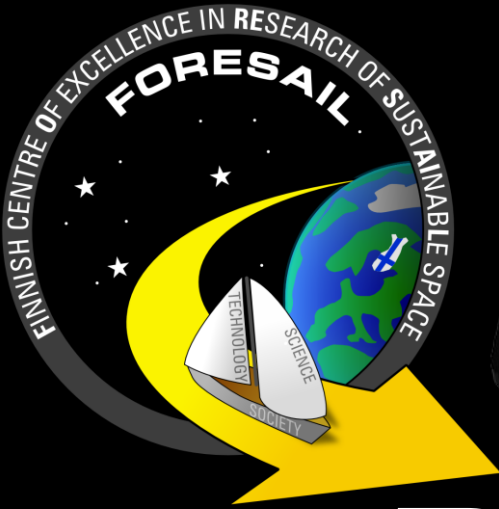
Total Ionizing Dose

- Co-60 gamma source by VTT in Otaniemi Finland

Displacement Damage

+ Single Event Effects:

- Proton and heavy ion beams at RADEF in Jyväskylä Finland.



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