Shielding SmallSats: Collaborative Opportunities

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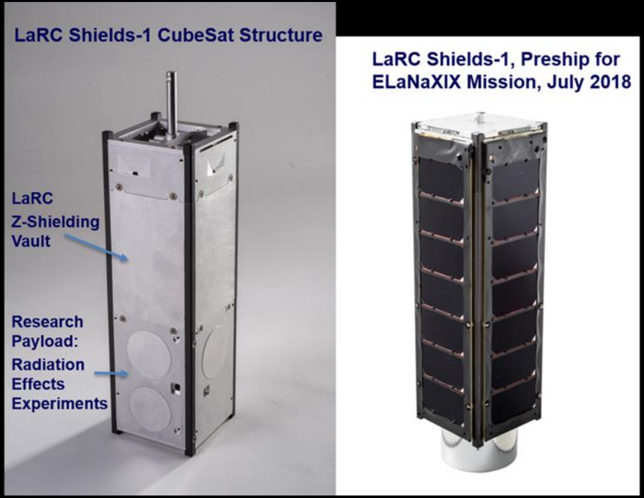
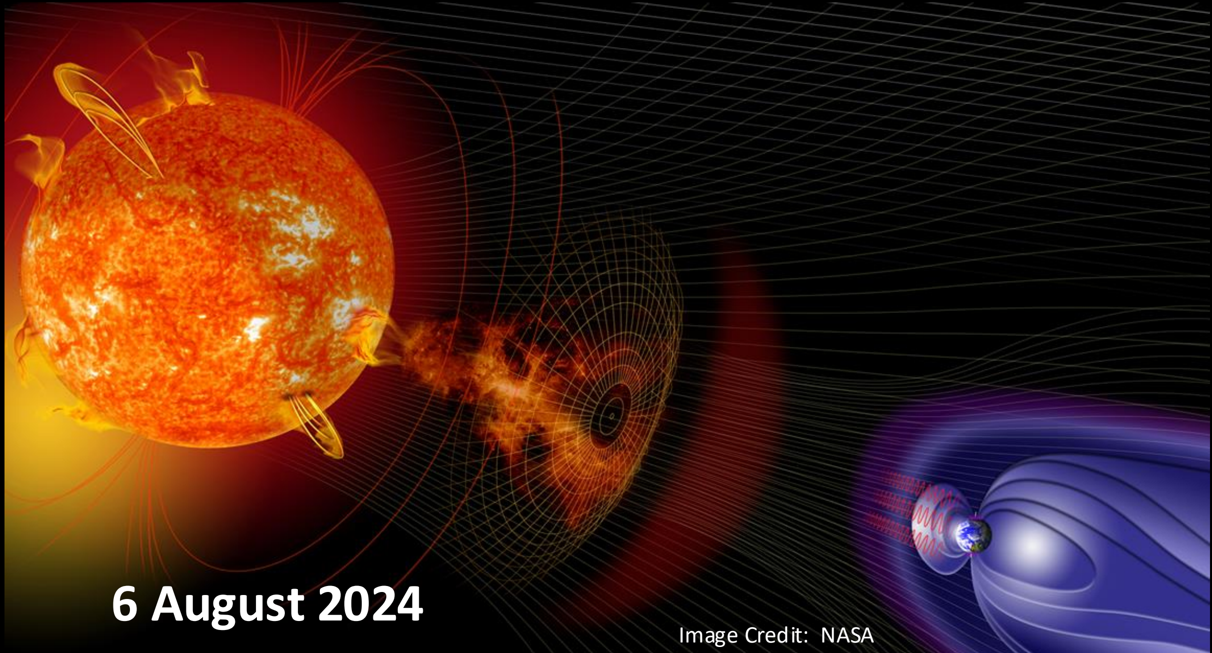




6 August 2024

Image Credit: NASA

Solar Activity Influences Dose Rate in Spacecraft:

Solar active radiation effects have predictability

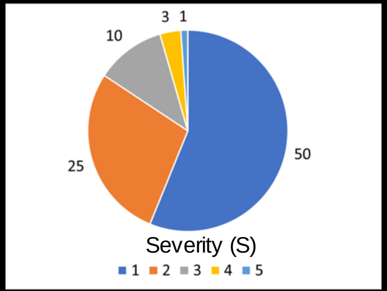
- **NOAA Space Weather Prediction Center (SWPC) Solar Radiation Storm Severity (S) Scales**
  - **magnitude flux levels above 10-MeV proton energies from 1-5, and correspond to historical occurrence rates for a 11-year solar cycle.**
  - **Typically 50 minor (S1), 25 moderate (S2), 10 strong (S3), 3 severe (S4), and less than 1 extreme (S5) solar particle event (SPE). SEE events have increased probability of occurrence from moderate to extreme severity.**
  - **S Scale numbers corresponds to magnitude flux increases from 10 particle flux units (pfu)s (S1) to 100,000 pfu (S5) for the GOES-16 10 MeV proton threshold sensor.**
  - **Many SPEs last several days and longer with increased flux over a short amount of time.**

https://www.swpc.noaa.gov/noaa-scales-explanation

Image credit: NOAA

GOES-18 SUVI Composite 195 Angstroms 2023-05-04 13:20:07

89 Estimated Solar Particle Events during a 11-year Solar Cycle

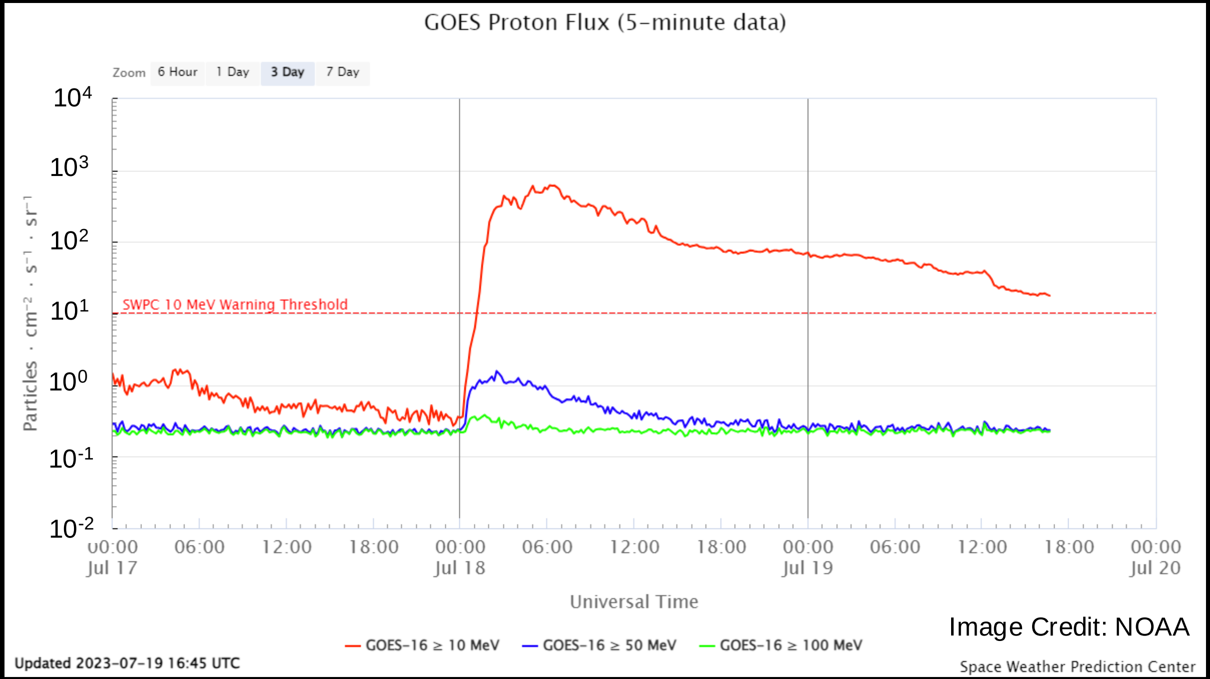


S Scale	Number	Percent
1	50	56.2
2	25	28.1
3	10	11.2
4	3	3.4
5	1	1.1

National Oceanic and Atmospheric Administration = NOAA

Solar Particle Event Level 2: 18-20 July 2023

Associated Solar Flare M5.7



https://www.swpc.noaa.gov/products/goes-proton-flux

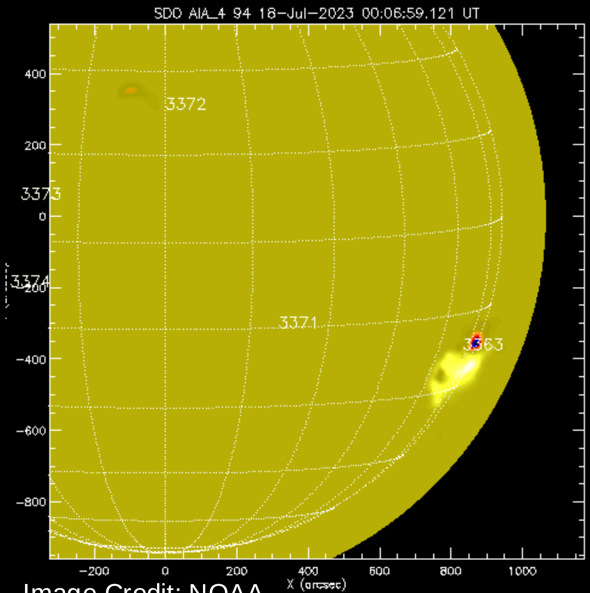
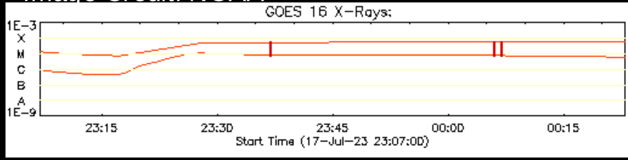
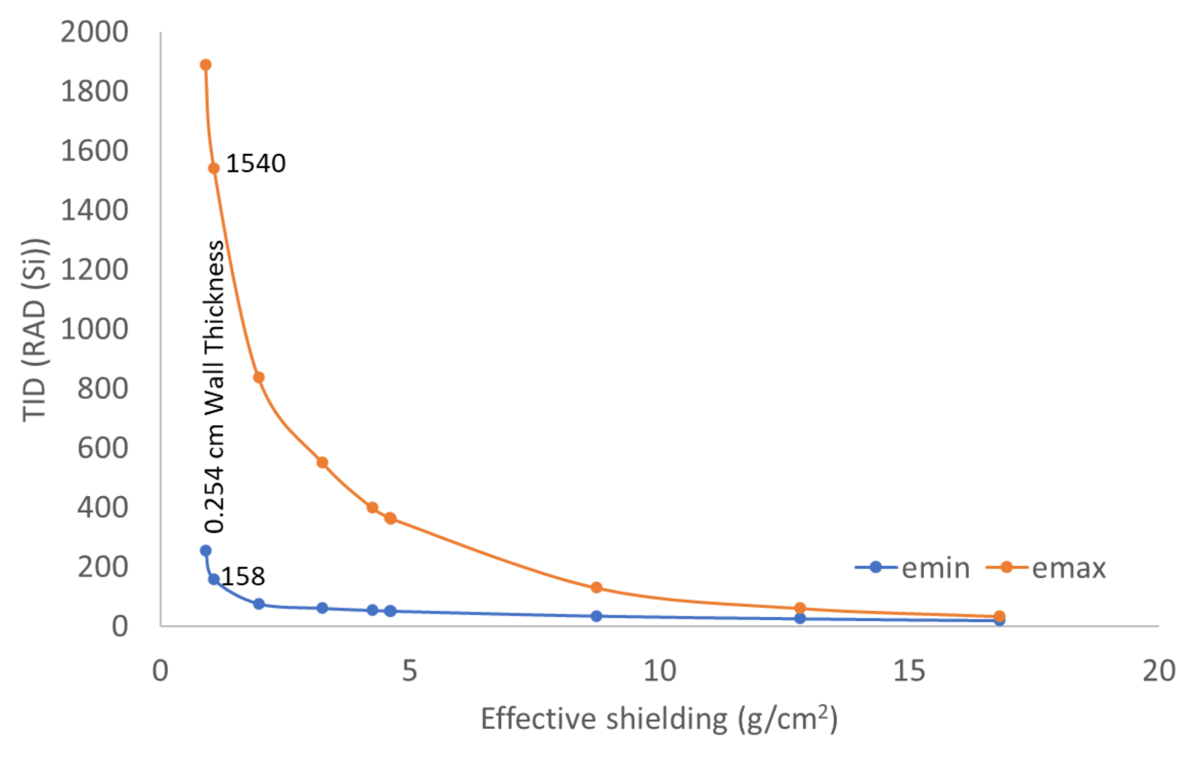


Image Credit: NOAA



https://www.ngdc.noaa.gov/stp/space-weather/interplanetary-data/solar-proton-events/SEP%20page%20code.html

TID Increases during Solar Maximum for Thin-Walled Shielding



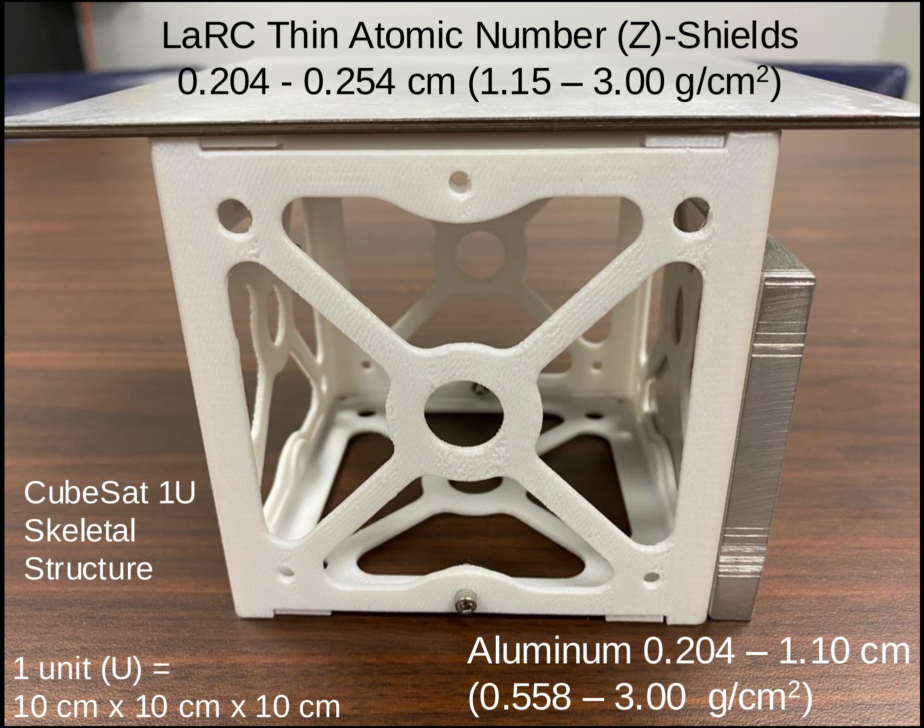
- For thin-walled shielding, TID 10x difference solar minimum to solar maximum
- With a Radiation Design Margin (RDM) of 2 or 3, (3 kRAD or 4.5 kRAD), at limits of commercial part hardness range of 2 to 10 kRAD.

solar minimum = emin, solar maximum = emax, total ionizing dose = TID

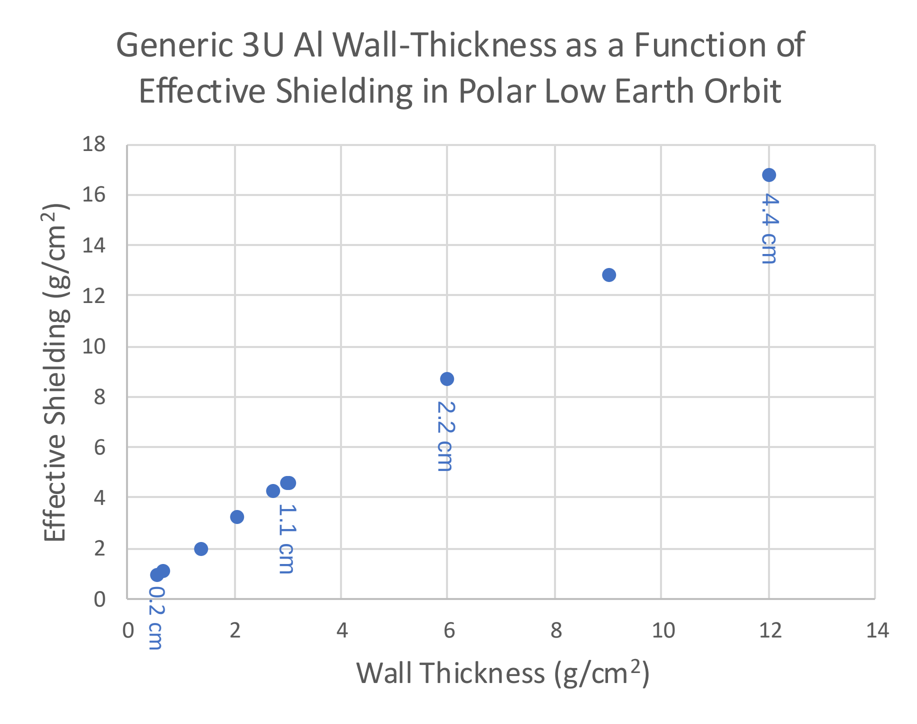
NASA Preferred Reliability Series, 1260, "Radiation Design Margin Requirement", May 1996.

NASA Preferred Reliability Series, 1258, “Space Radiation Effects on Electronic Components in Low Earth Orbit,” August 1996.

The Problem of Radiation Shielding of CubeSats is Putting Mass into the Walls of Thin Structures



Thomsen, D.L., et al., Shielding Considerations for CubeSat Structures During Solar Maximum, in 37th Annual Small Satellite Conference. 2023: Logan, UT. p. 9.



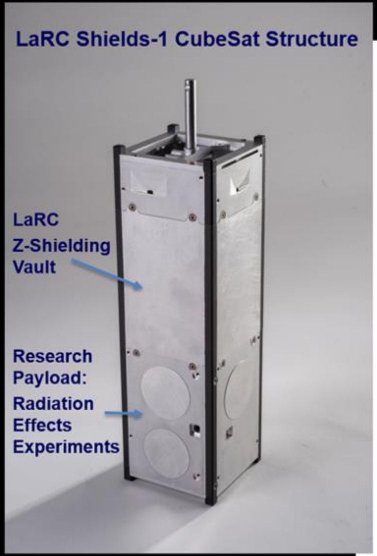
Effective Shielding determined using NOVICE SIGMA, 3-D Ray Tracing Sector Analysis, Estimates with Aerospace Corporation Proton (AP)8 Solar Minimum Model for a 500-km altitude and 85º inclination orbit.

Shields-1 (Z-Shield Vault): Dose Rate during Solar Minimum

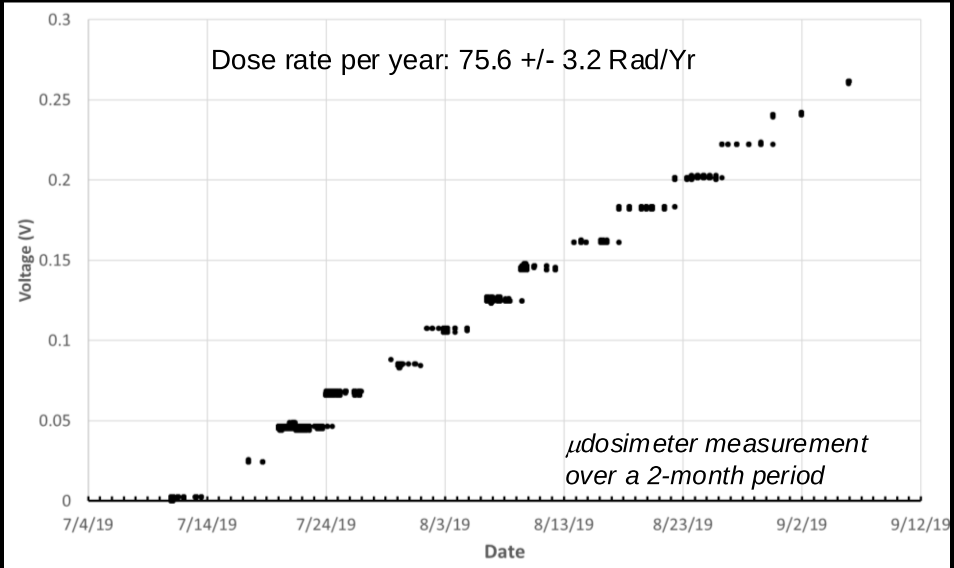
Minimum Proton Threshold is 151 MeV, high energy proton sensor

Well defined from NOVICE Ray Tracing Estimate

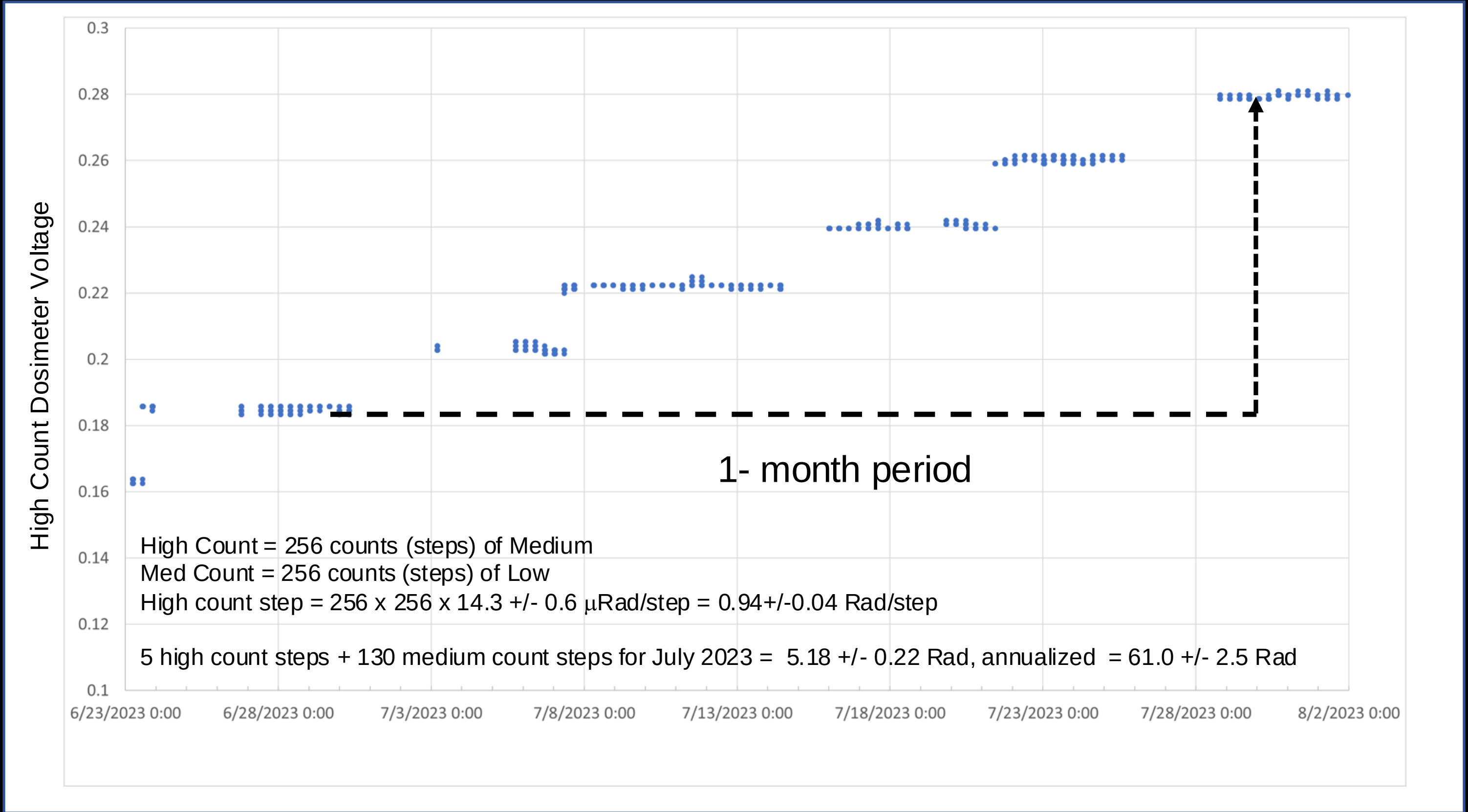
The Z-shielding enabled the development of adding mass to volume constrained environements



Z-Shield Vault Performance in Polar Low-Earth Orbit



Shields-1 Dose during Solar Active July 2023
Lower than 2019 Solar Minimum



Collaborative Opportunities

- Shielding offers reduction of total ionizing dose on sensitive electronics and reduced proton single event effects

- NASA Technology Transfer Portal: https://technology.nasa.gov/

  - Commercial and Research Licensing Available

    - Novel Radiation Shielding Material for Dramatically Extending the Orbit Life of Cubesats (LAR-TOPS-250), https://technology.nasa.gov/patent/LAR-TOPS-250

    - Atomic Number (Z)-Grade Radiation Shields from Fiber Metal Laminates (LAR-TOPS-201), https://technology.nasa.gov/patent/LAR-TOPS-201

  - Available for Government Use

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- NASA Wallops Flight Facility CubeSat Ground Operations