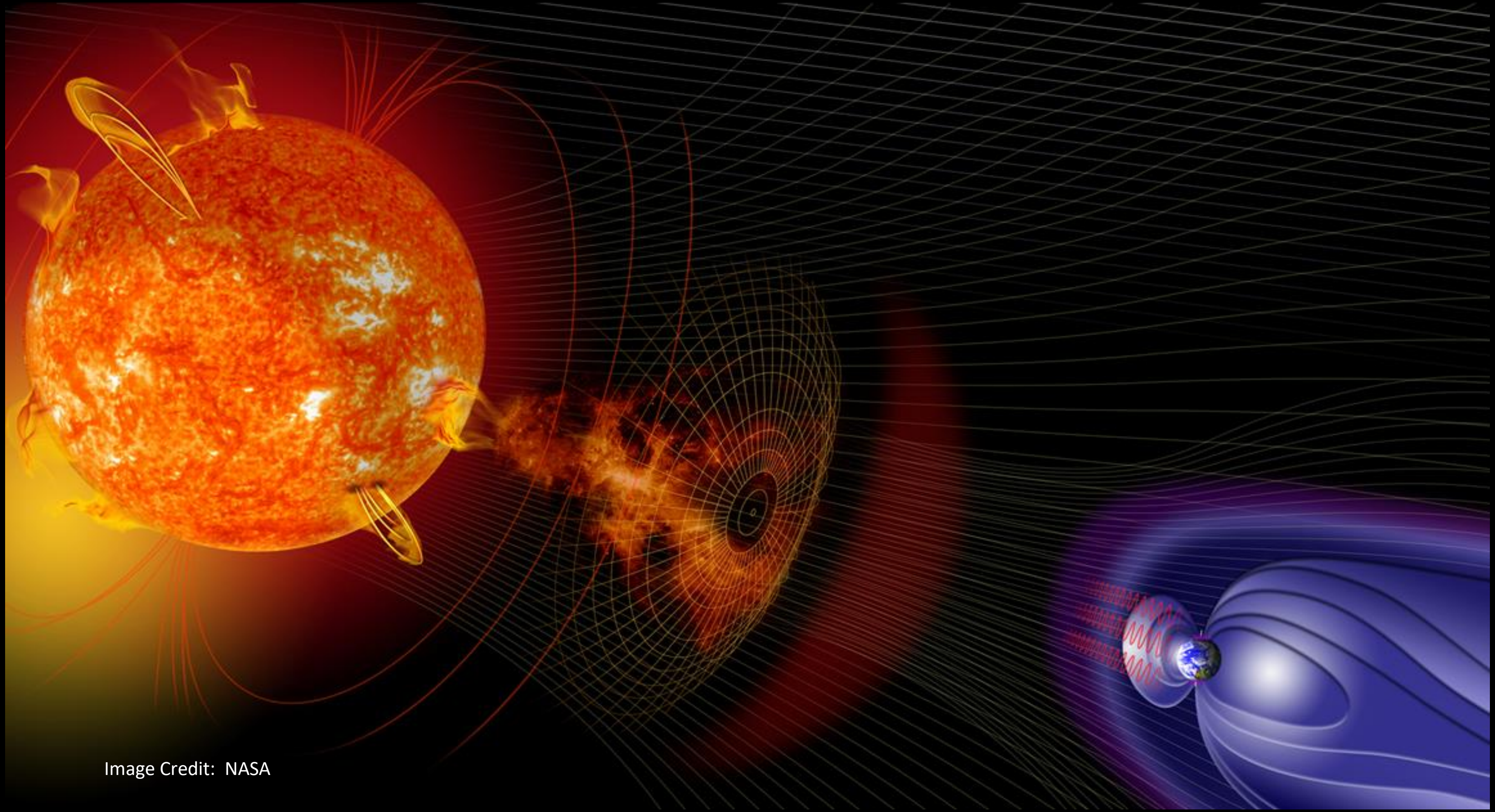
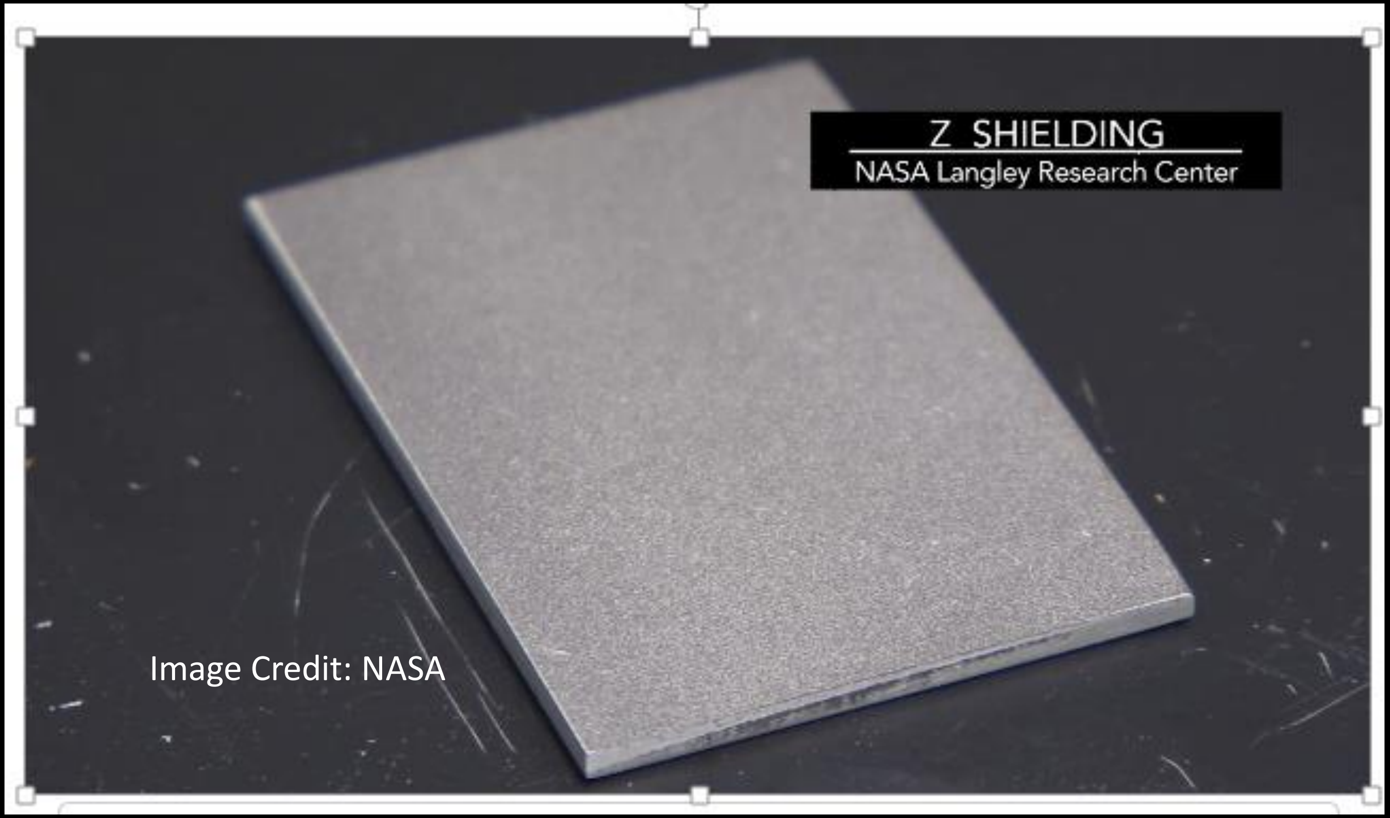
Shielding Collaborative Opportunities

Larry Thomsen
NASA Langley Research Center



16-17 October 2024

LaRC Z-Shielding Increases CubeSat Mission Lifetimes

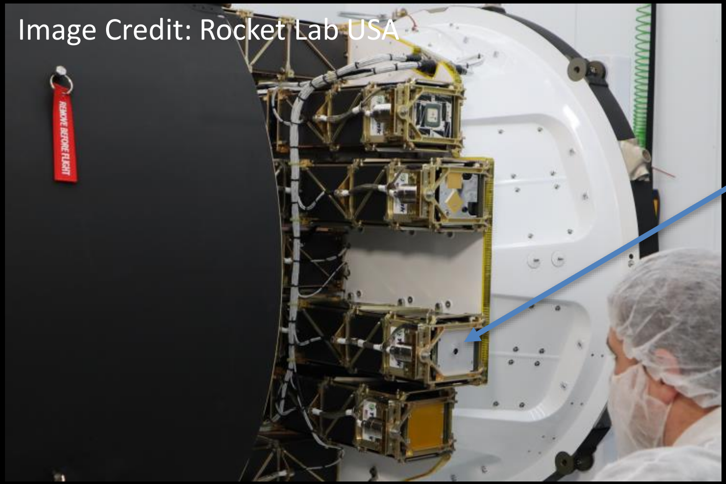


NASA Tech-Transfer web releases of LaRC Z-Shielding

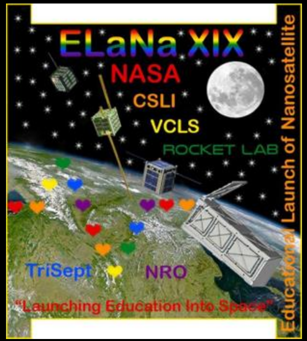
Z-shielding Technology pitch: https://www.youtube.com/watch?v=oHA8j5bpFcU&t=21s
Webinar: https://www.youtube.com/watch?v=RrqDocGqawQ
https://techgatewire.larc.nasa.gov/2017/01/26/radiation-protection-material-webinar/

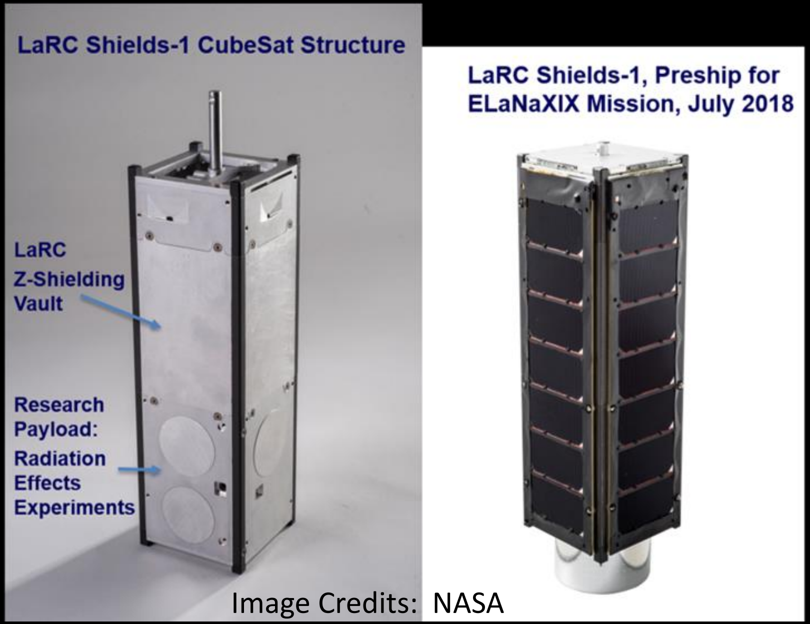
- Extends typical CubeSat missions from 3 months to years
- A 18-36x reduction of total ionizing dose and removal of internal charging effects.
- Increases return on investment

Shields-1 Electronics Enclosure Performing over 5 years in Polar Earth Orbit

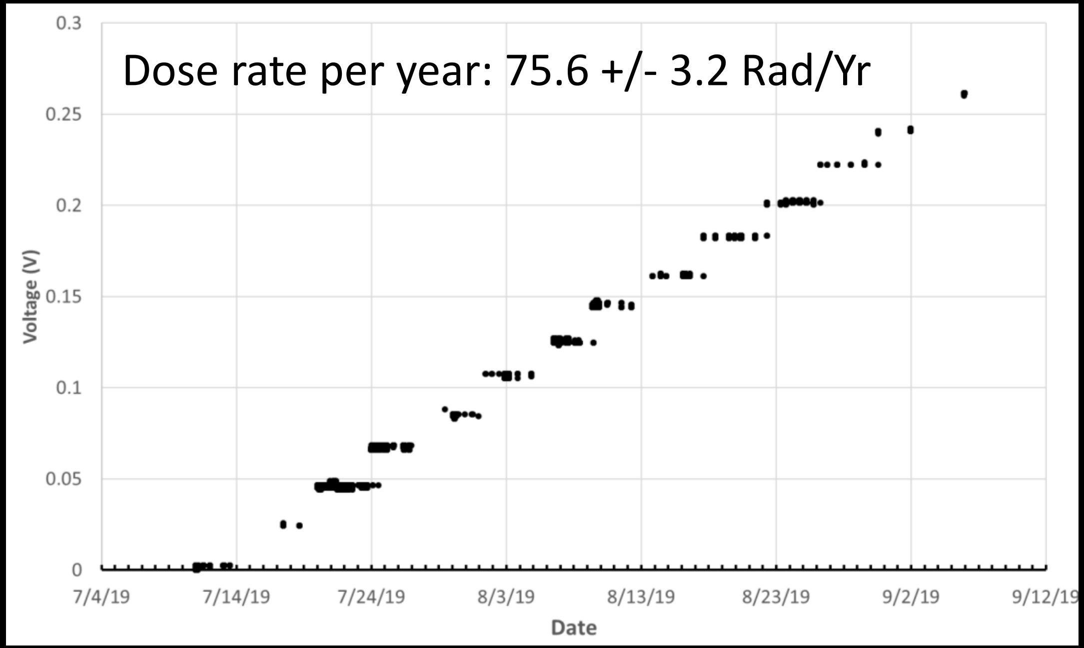


Shields-1 onboard Rocket Lab USA, Electron Rocket, NASA ELaNaXIX Mission, 16 December 2018 Launch

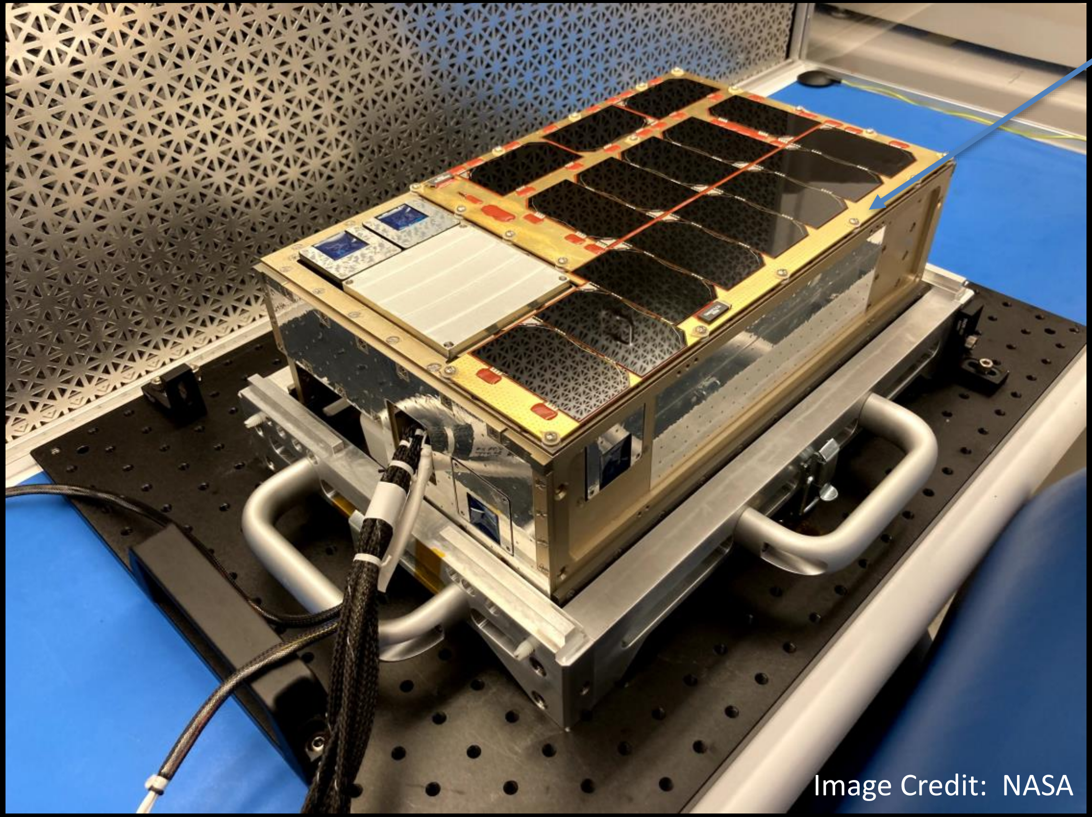




Electronics Enclosure Shielding Performance in Polar Low Earth Orbit



Thin Z-Shielding Innovation aboard GTOSAT

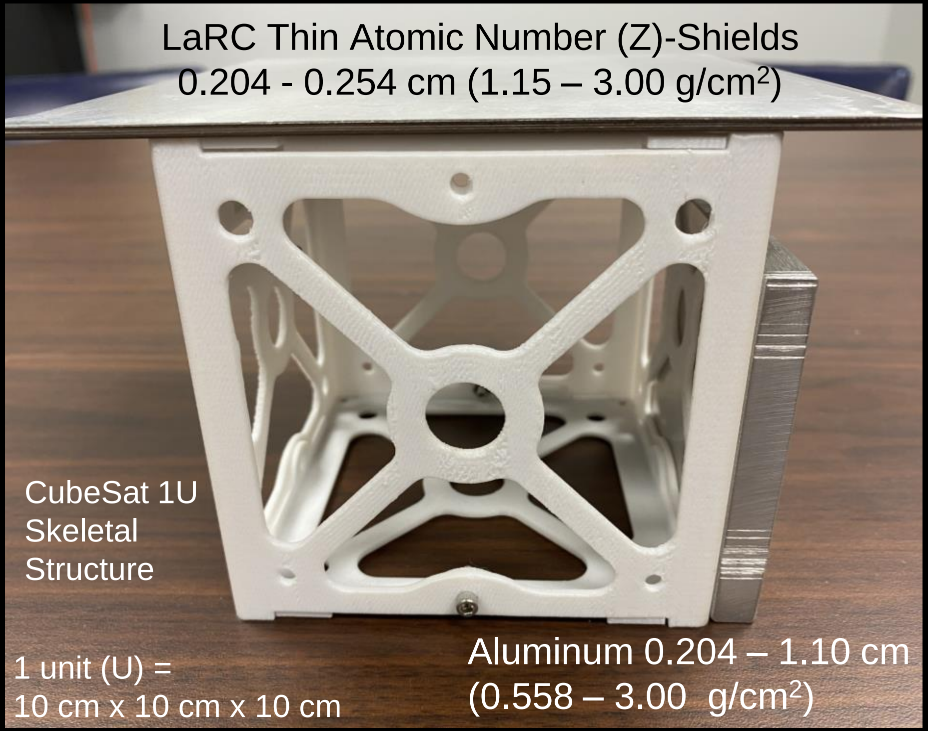


20 cm x 30 cm Thin Z-Shielding protecting NASA Heliophysics GTOSAT electronics:

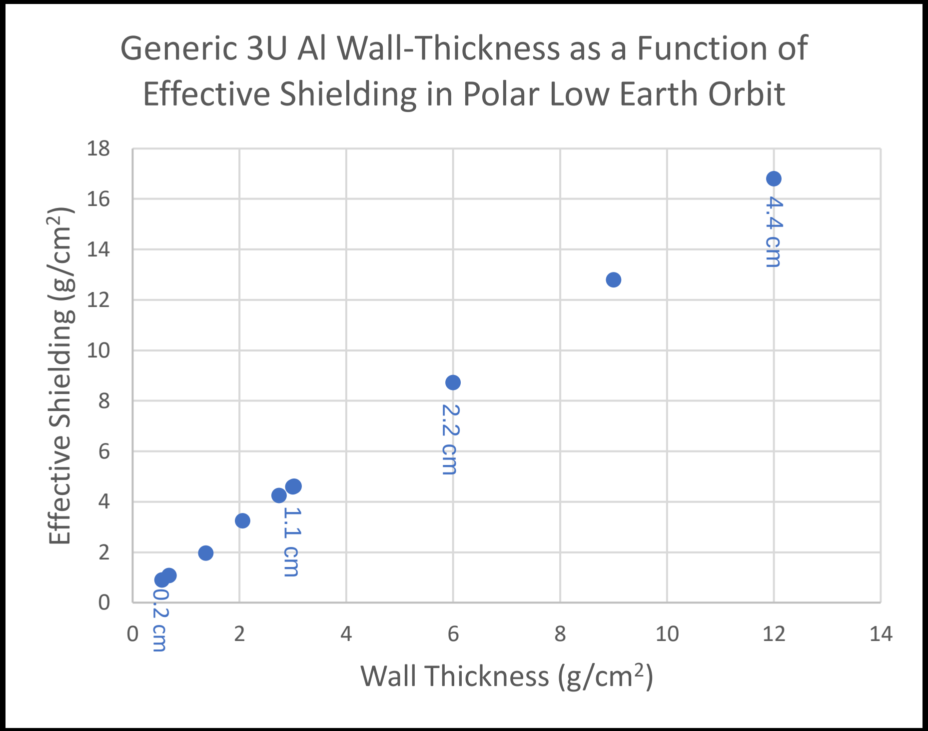
0.204 cm Z-shielding replaced aluminum for mission enabling TID reduction in geotransfer orbit. Z-Shielding successfully completed all preship requirements for the NASA mission: Vibration testing for heavy launch vehicle and all flight qualification requirements

<u>GTOSat: Radiation Belt Dynamics from the Inside, SmallSat Conference 2022:</u> "A specialty lid was made by NASA Langley Research Center using a custom developed Z-Shield material. This is a layering of tantalum, aluminum, and titanium to provide superior radiation protection while minimizing thickness. The Z-Shield lid enabled the clearance necessary to meet the PSC standard."

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.

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

National Oceanic and Atmospheric Administration = NOAA

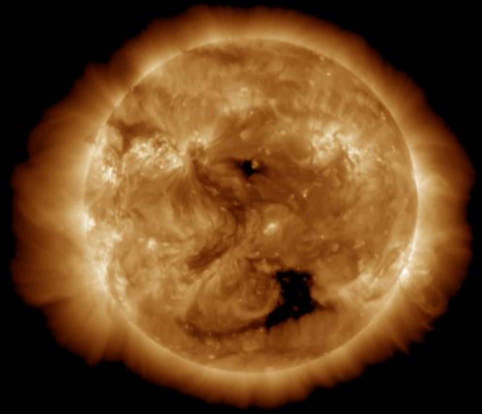
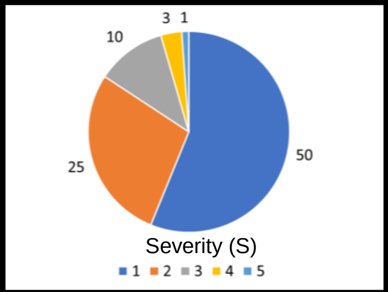


Image credit: NOAA

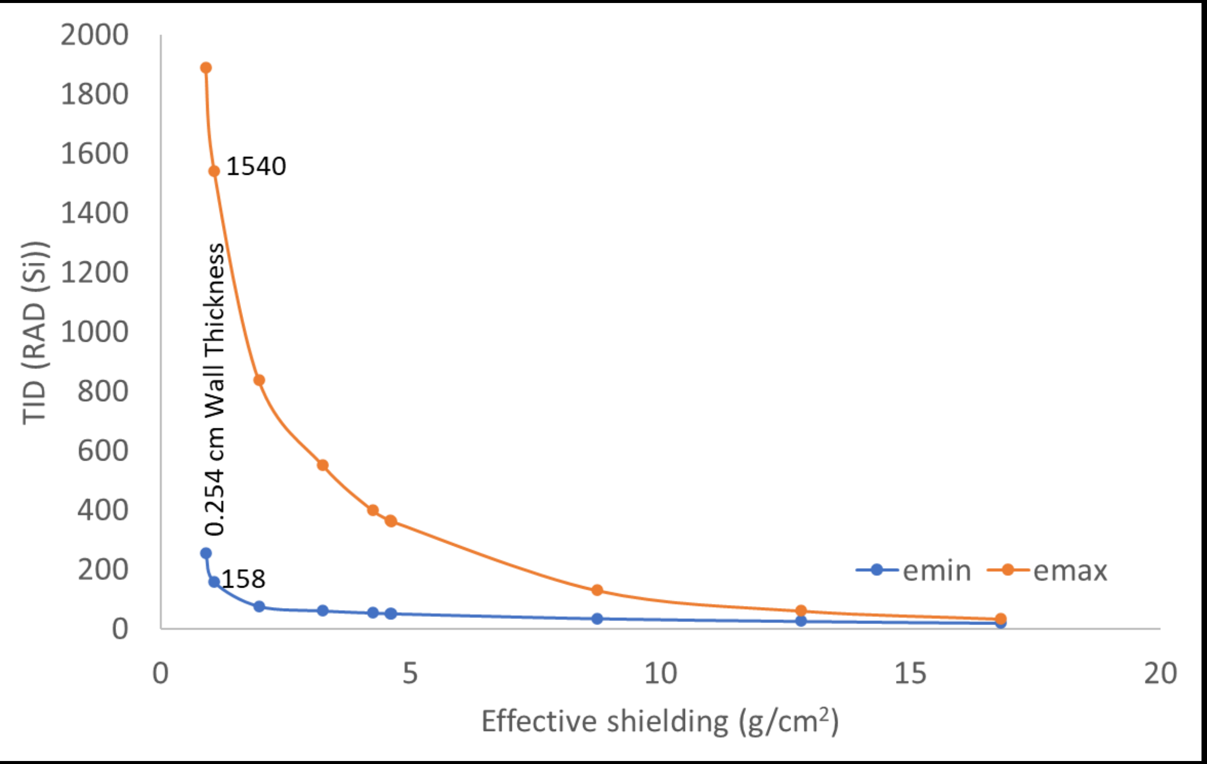
GOES-18 SUVI Composite 195 Angstroms 2023-05-04 13:20:07

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

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

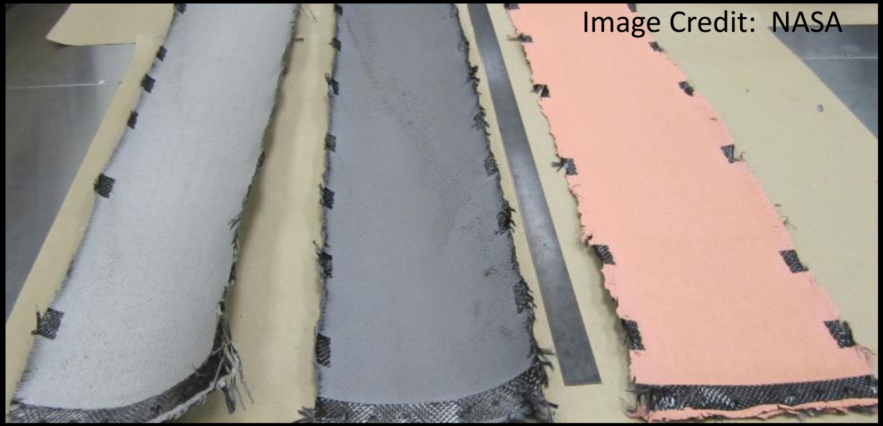
NASA Preferred Reliability Series, 1260, "Radiation Design Margin Requirement", May 1996.
NASA Preferred Reliability Series, 1258, “Space Radiation Effects on Electronic Components in Low Earth Orbit,” August 1996.

Thin Z-Shielding Commercial Processes

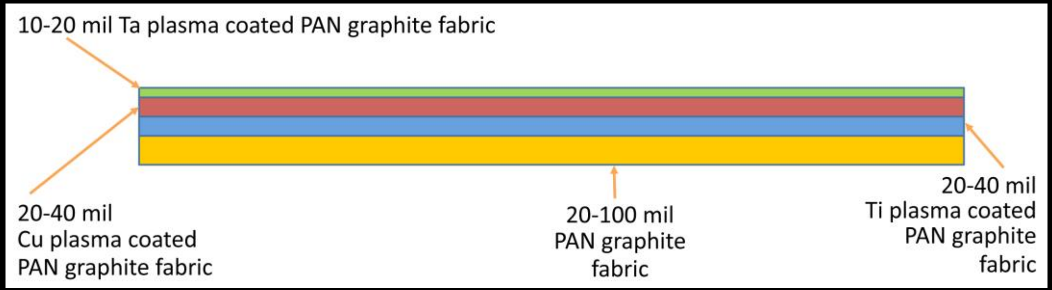
- **Diffusion Bonding by Commercial Hot Isostatic Press (HIP) or Thermal Vacuum Hot Press.**
- **Thin Z-Shield Lay-up Al / Ti / Ta / Ti:**
- **Standard Metals Cleaning.**
- **Standard Machining using CAD Design and standard tooling processes.**

Methods of Making Z-Shielding: US Patent 7,649,439 B2

Metal Coated IM-7 Carbon Fiber Fabrics



From left to right: Titanium 6-4, Tantalum, and Copper

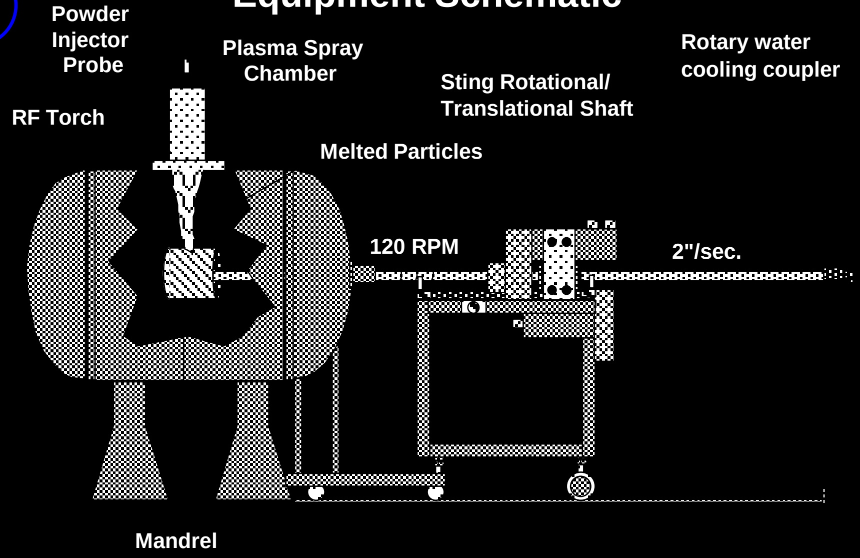


Schematic of Z-grade Lay-up with Fiber Metal Laminate

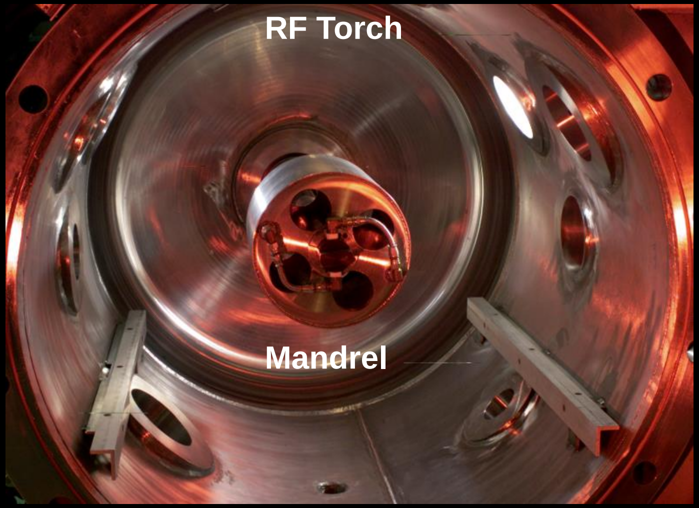
Metal Deposition via RF Plasma Spray

1 NASA-LaRC RF Plasma Spray Facility

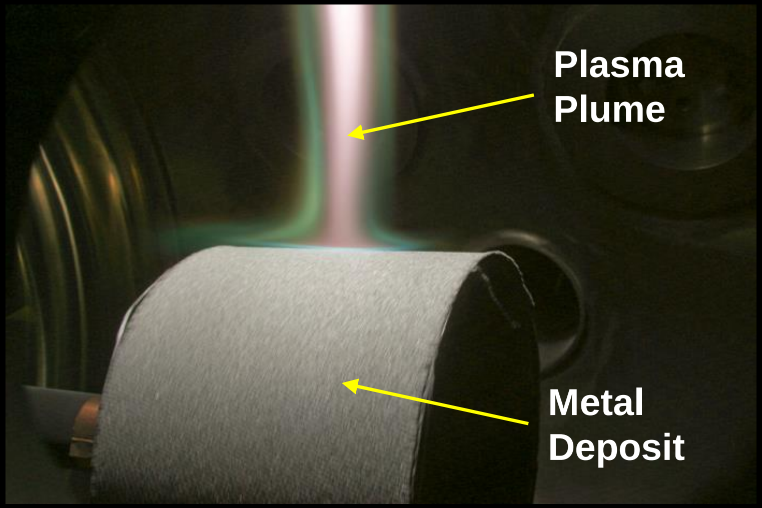
2 Equipment Schematic



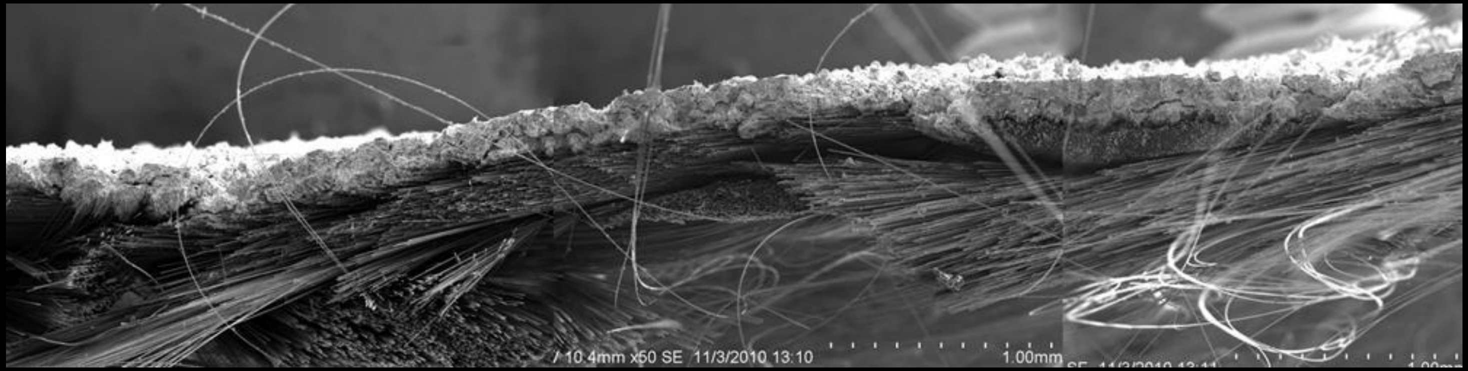
3 Chamber Interior

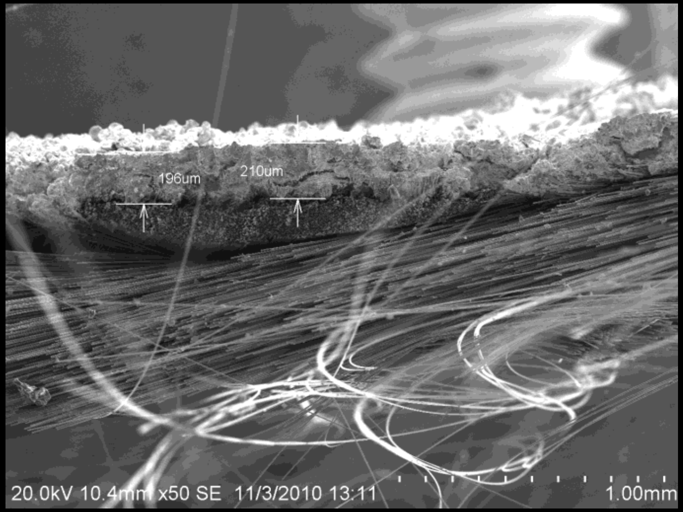


4 Metal Deposition on Rotating Substrate



Cross-section Ta on IM7 Carbon Fiber Fabric





- SEM cross-sectional image
- Thickness approximated between 196 - 210µm

Nuclear and Medical Commercial Applications

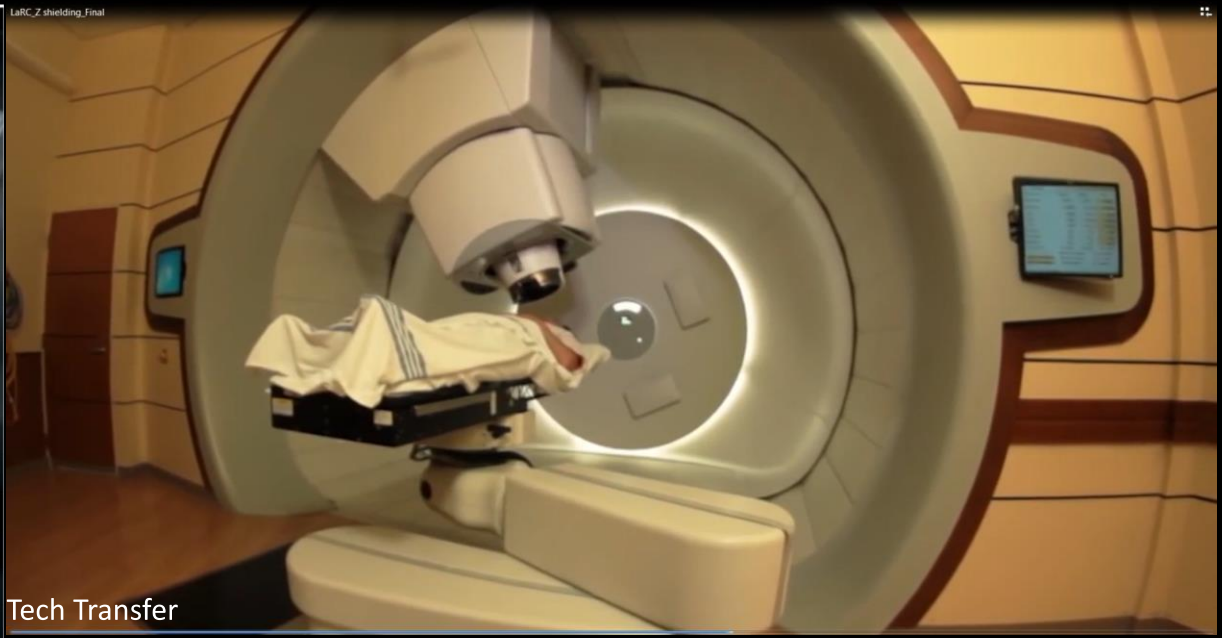


Image Credits: NASA Tech Transfer

Shielding for nuclear industry

Shielding for medical industry

Technology Transfer Opportunities

- Shielding offers reduction of total ionizing dose on sensitive electronics and reduced proton single event effects. Shielding also reduces dose on humans in medical environments

- 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

    - Flexible Lightweight Radiation Shielding (LAR-TOPS-354), https://technology.nasa.gov/patent/LAR-TOPS-354

  - Available for Government Use