Recent Applications of Space Weather Research to NASA Space Missions

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Abstract

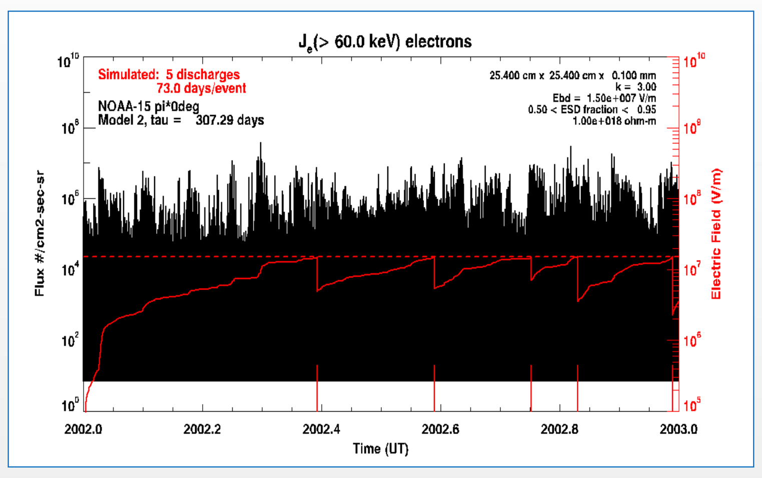
Marshall Space Flight Center's Space Environments Team is committed to applying the latest research in space weather to NASA programs. We analyze data from an extensive set of space weather satellites in order to define the space environments for some of NASA's highest profile programs. Our goal is to ensure that spacecraft are designed to be successful in all environments encountered during their missions. We also collaborate with universities, industry, and other federal agencies to provide analysis of anomalies and operational impacts to current missions. This presentation is a summary of some of our most recent applications of space weather data, including the definition of the space environments for the initial phases of the Space Launch System (SLS), acquisition of International Space Station (ISS) frame potential variations during geomagnetic storms, and Nascap-2k charging analyses.

The MSFC Space Environments Team performs spacecraft charging and radiation analysis for programs with a wide range of design complexity and mission scope. Some of the current and past projects we have supported include:

- ❖**James Webb Space Telescope (JWST)** – Low energy radiation and spacecraft charging section of environment definitions, Nascap-2k surface charging analysis, distant magnetotail plasma environments characterization and analysis, L2-Charged Particle Environment Model, and internal charging assessments
- ❖**Chandra X-Ray observatory** – Radiation transport model (design and construction), Chandra Radiation Model (operations planning), and radiation environment anomaly assessments
- ❖**Constellation** – Design Specification for Natural Environments (DSNE) document
- ❖**NASA Launch Services Program** – Radiation and spacecraft charging assessments
- ❖**Space Launch System (SLS) and Multi-Purpose Crew Vehicle(MPCV)/Orion**- DSNE
- ❖**International Space Station (ISS)** – Nascap-2k surface charging analysis, plasma environment and auroral charging characterization, FPMU operations, and plasma and radiation anomaly assessments
- ❖**Space Transportation System (Shuttle)** – Radiation environment characterization and effects analysis
- ❖**Crew Rescue Vehicle**-Environment specification for design
- ❖**Space Launch Initiative**-Environment specification for design
- ❖**Solar-B** – Radiation effects analysis
- ❖**Solar Sail-** Nascap-2k surface charging analysis, interplanetary radiation environment characterization and radiation dose evaluations
- ❖**Microwave Anisotropy Probe (MAP)** - Nascap-2k surface charging analysis
- ❖**Earth Observing System (EOS) – AURA**- Nascap-2k surface charging analysis
- ❖**Edison Demonstration for SmallSat Networks (EDSN)** - Nascap-2k surface charging and radiation transport analyses
- ❖**LDCM**- Nascap-2k surface charging analysis, auroral charging environment assessments
- ❖**Soumi NPP** – Surface and internal charging assessment

The tools we use to conduct our analysis include Nascap-2k, NUMIT (MSFC version), Trapped Proton Model 1 (TPM-1), AP8/AE8, AP9/AE9, SRIM, SHIELDOSE2, NOVICE, and CREME96 as well as in-house developed custom charging and radiation codes.

We use data from a variety of operational and research spacecraft as inputs to our models including Chandra, GOES, POES , DMSP, STEREO, ACE, SOHO, LANL, GPS, IMP8, POLAR, Wind, and COSMIC.



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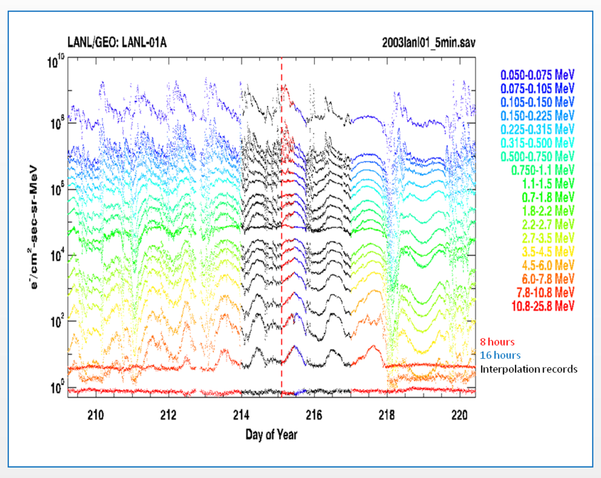

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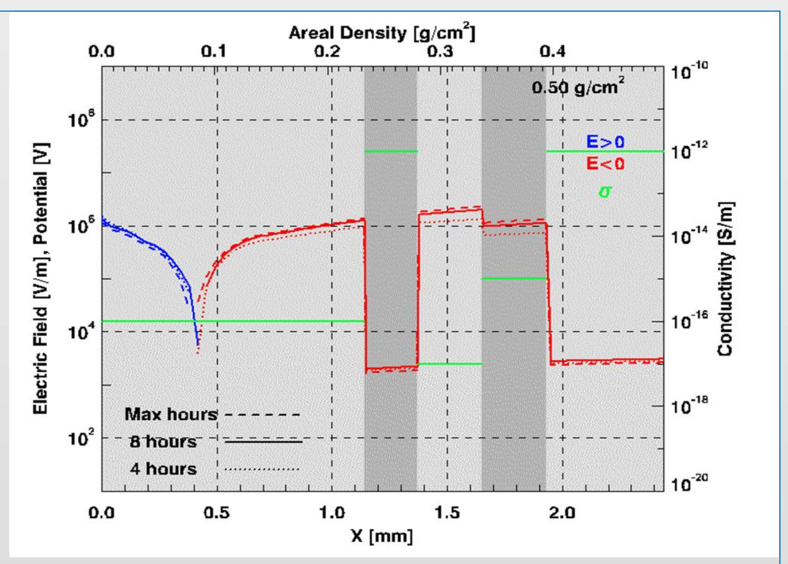
Material Layup

Layer	κ	σ (S/m)	Depth (mm)
1	2.0	10^{-16}	1.14
2	2.0	10^{-12}	1.37
3	2.0	10^{-17}	1.65
4	4.0	10^{-15}	1.93
5	2.0	10^{-12}	2.44

$Z_{eff} = 6$
$A_{eff} = 12$
$2.04\ g/cm^3$
$Kp = 10^{-14}$ S-sec/m-rad
$\Delta = 0.7$
$\Delta T = 1.0$ sec



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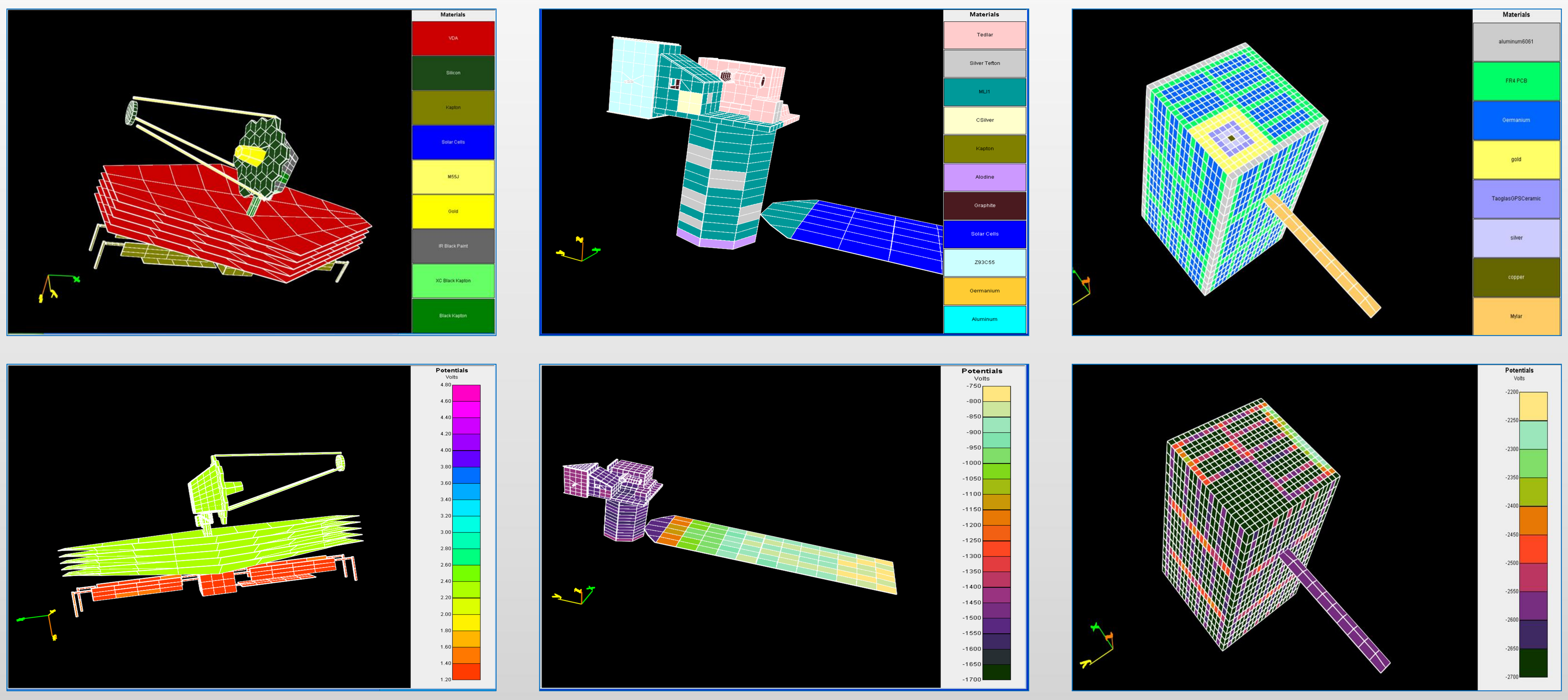
(1) Example of internal charging analysis using NOAA-15 data for the year 2002. Model assumes >60 keV electrons penetrate shielding to charge an insulator which arcs when the field reaches the dielectric breakdown strength. (2) Electron flux time series extracted from LANL geosynchronous orbit records for use as input to internal charging model. (3) Output from MSFC version of NUMIT internal charging code used to evaluate electric fields as a function of depth in multi-layer insulting materials.

The Space Environments Team uses Nascap-2k along with satellite environment data and material definitions to generate Nascap-2k charging analyses for spacecraft designs ranging from simple to very complex.

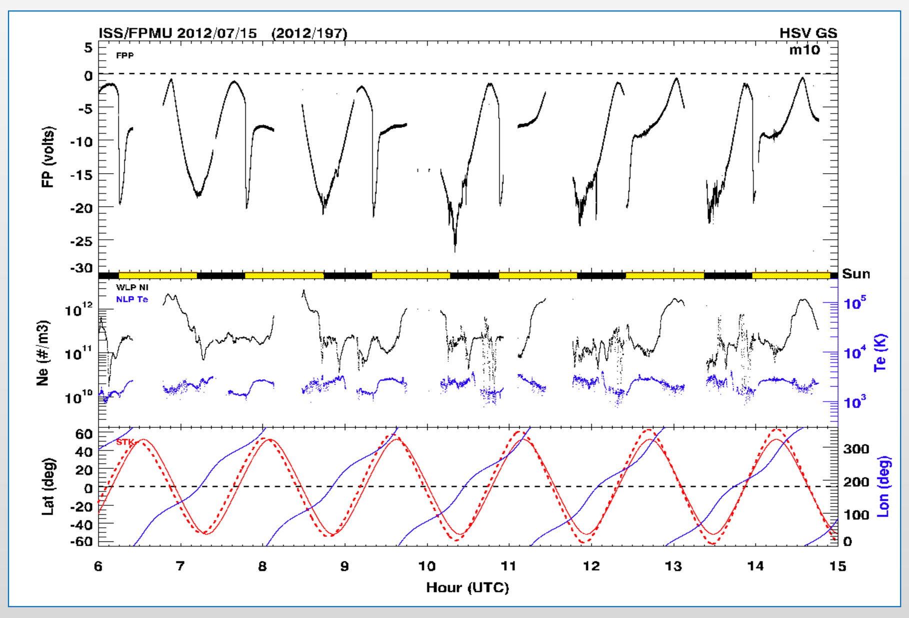


Charging analysis for James Webb Space Telescope (JWST) in an interplanetary environment

Charging analysis for LDCM in an auroral environment

Charging analysis for Edison Demonstration for SmallSat Networks (EDSN) in an auroral environment

The ISS space environments community monitors near real time space weather data from NASA, NOAA, and ESA sources to determine solar wind disturbance arrival times at Earth likely to be geoeffective (including coronal mass ejections and high speed streams associated with coronal holes). The Floating Potential Measurement Unit (FPMU) on board the ISS is activated in order to measure ISS frame charging as the vehicle passes through regions of precipitating auroral electrons.



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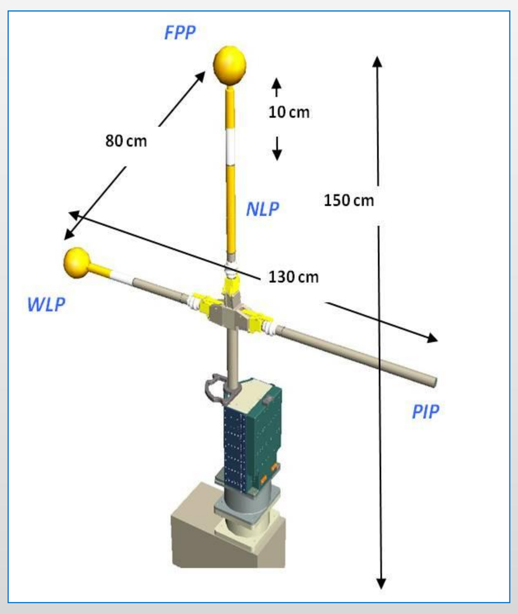

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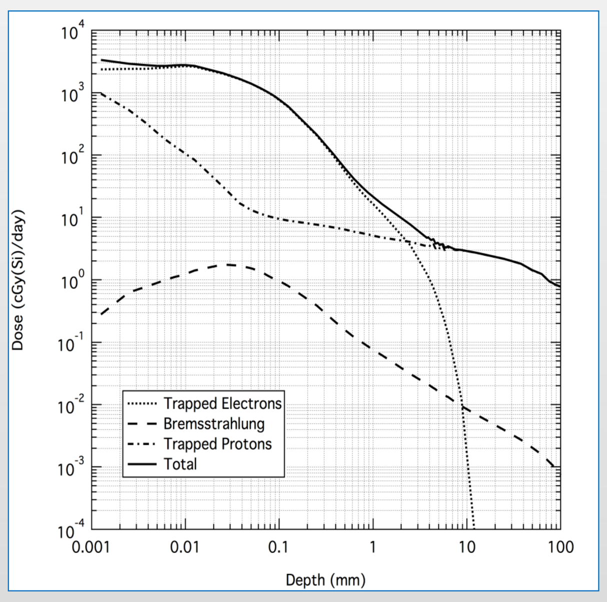
(1) FPMU records showing solar array charging at eclipse exit and auroral charging of ISS at high southern latitudes on 15 July 2012. (2) The FPMU is a collection of four probes: the Plasma Impedance Probe (PIP), Wide-sweep Langmuir Probe (WLP), Narrow-sweep Langmuir Probe (NLP), and the Floating Potential Probe (FPP).

The Space Launch System (SLS) Program is developing a heavy-lift launch vehicle to be capable of traveling to multiple destinations such as low Earth orbit, asteroids, the moon, Lagrange points, and ultimately for missions to Mars. The system will be flexible and include multiple launch vehicle configurations. The SLS will carry crew, cargo and science missions to deep space. The MSFC Space Environments team has defined the design environments required for the SLS missions. The environments that have been defined for SLS include LEO/ISS, GEO, Interplanetary, Lunar Orbit, Lunar Surface, NEA, Mars Orbit, and Mars Surface.



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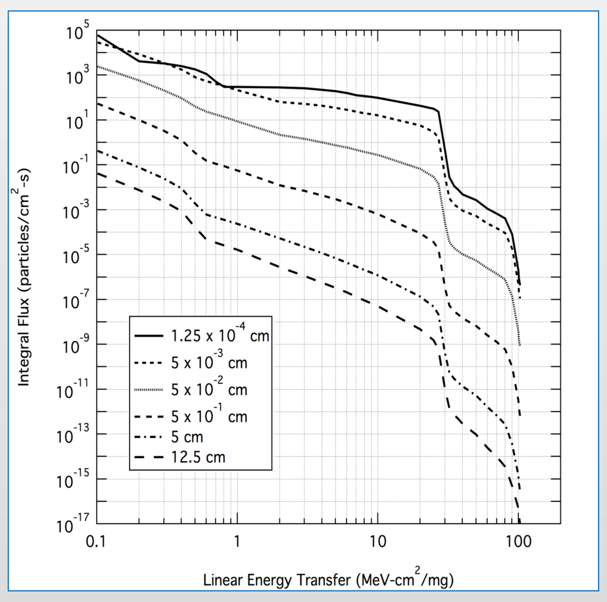

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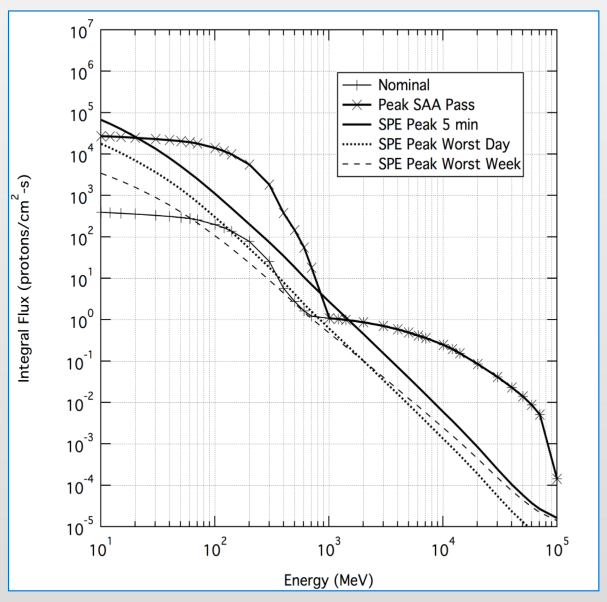

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Figures 1- 3 are examples of the data used to define the environments for the SLS program. All data shown is specific to an orbit of 500 km at 51.6° inclination. The full specification is documented in the Design Specification for Natural Environments (DSNE). (1) Daily TID inside shielding from trapped radiation belt protons and electrons. (2) SPE peak rate LET flux inside selected aluminum shield thicknesses as a function of LET. (3) Integral proton fluxes of an SPE and of the nominal and peak trapped protons.

Acknowledgements

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