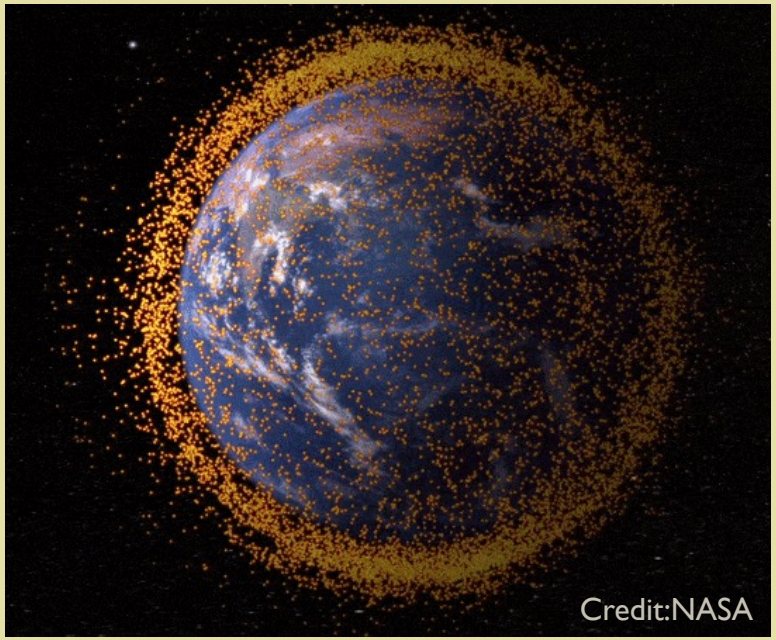
SHA
Space Hazards Applications, LLC

Building Commercial Applications To Safeguard Satellites From Space Weather Hazards

J.C. Green, T.P. O'Brien, A. Kellerman, A. Boyd, J. Likar, Y. Shprits

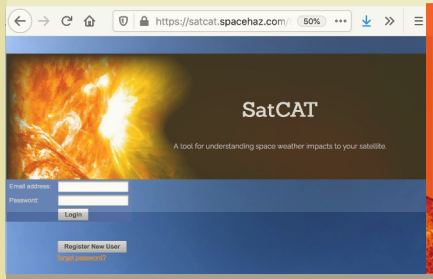
Space Hazards Applications, LLC

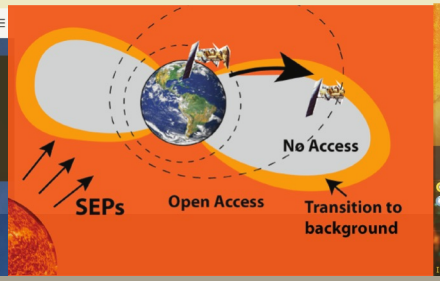


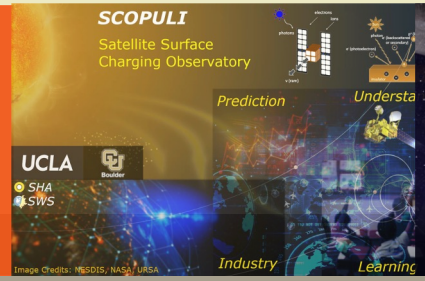
Our goal is to create a suite of easy to access applications that give the unique real time and retrospective space weather hazard to specific satellite systems along any satellite orbit.

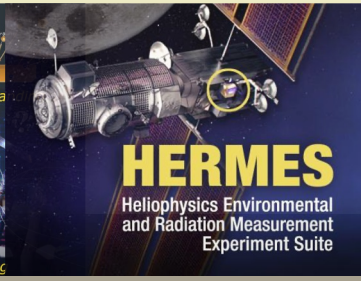
Assess and mitigate on orbit space weather hazards to satellites from the Earth to moon

- Real-time Models
- Web Applications
- Consulting Services

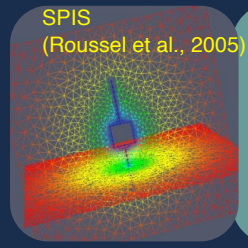






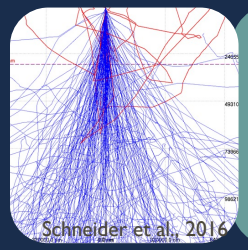


Particle Radiation Hazards



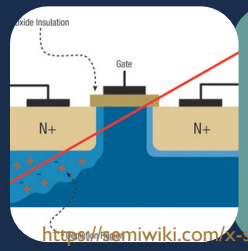
Surface Charging:
Charged particles collect on satellite surfaces producing high differential voltages, electrostatic discharges, and electromagnetic interference.

Low energy protons /electrons



Internal Charging:
Energetic electrons accumulate in dielectrics (circuit boards, cable insulators) and on ungrounded metal (spot shields, connector contacts) leading to damaging discharges.

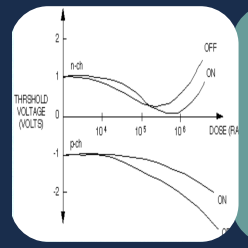
High energy electrons



Single Event Upsets:
Energetic ion passage through microelectronic device node causes catastrophic device failure, latent damage, or uncommanded mode/state changes.

https://semiwiki.com/x-subscriber/silvaco/3604-single-event-upsets/

High energy protons/ions

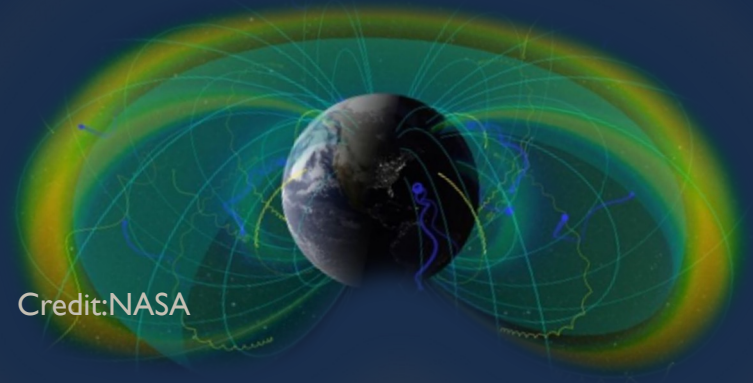


NASA ASIC Guide

Total Dose:
Energy loss when proton/electrons pass through microelectronic devices causing degradation and reduced performance that accumulates over mission (or step-wise during high dose rate events).

High energy protons electrons

Regions

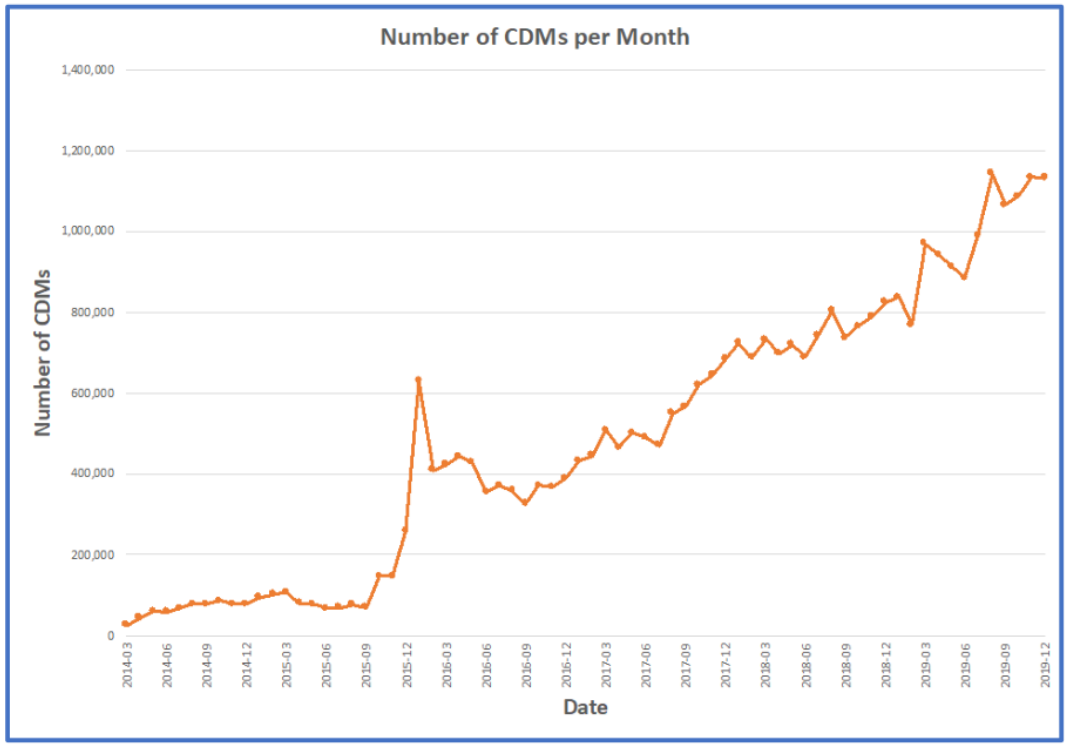


Magnetosphere

Moon

LEO Space Traffic Coordination

- ~6700 satellites in orbit, 5938 in Low Earth Orbit
- Number of Conjunction Data Messages (CDMs) sent to warn operators of possible collisions is increasing
- 27 “emergency” conjunction messages were sent daily in 2019
- Space weather is an overlooked aspect of Space Traffic Coordination
- An issue for one satellite can escalate to an issue for many (i.e Galaxy 15 zombiesat)

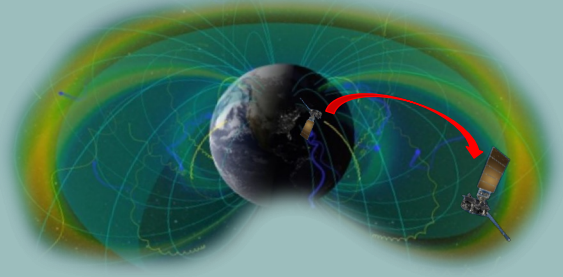


Source: 18th Space Control Squadron (DoD)

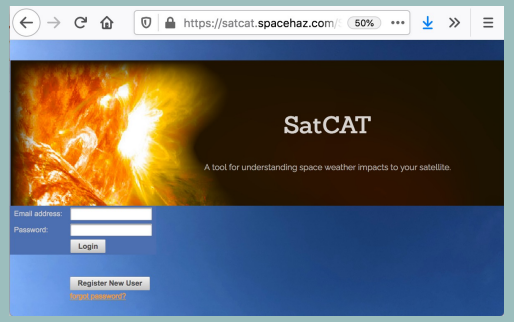
Models And Applications

Internal Charging

SHELLS-hires Electron Radiation Belt Model

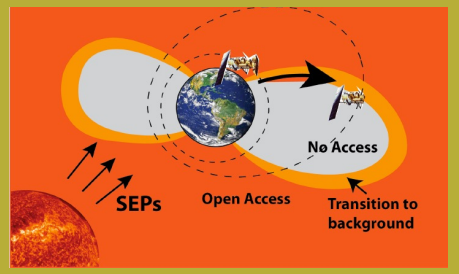


Satellite Charging Assessment Tool

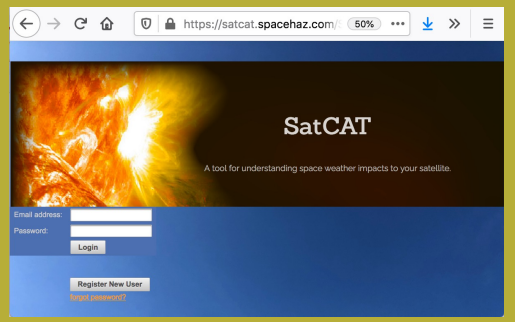


Single Event Effects

Solar Particle Access Model (SPAM)



Satellite Hazard Assessment Tool

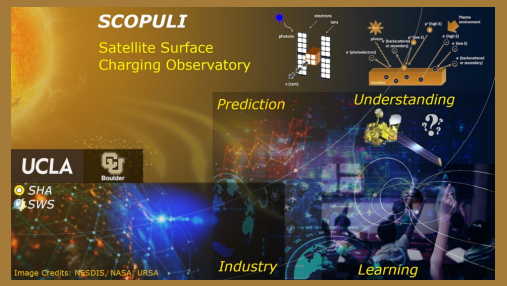


Surface Charging

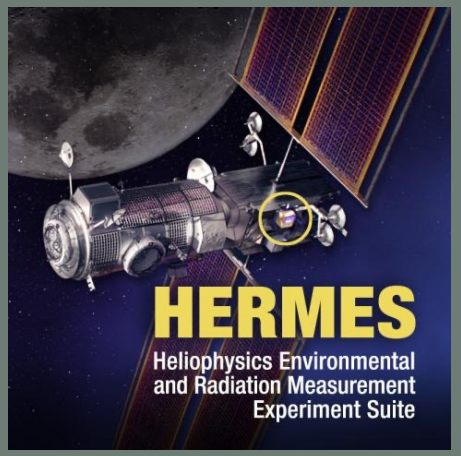
Lunar Impacts

Under Development

SCOPULI

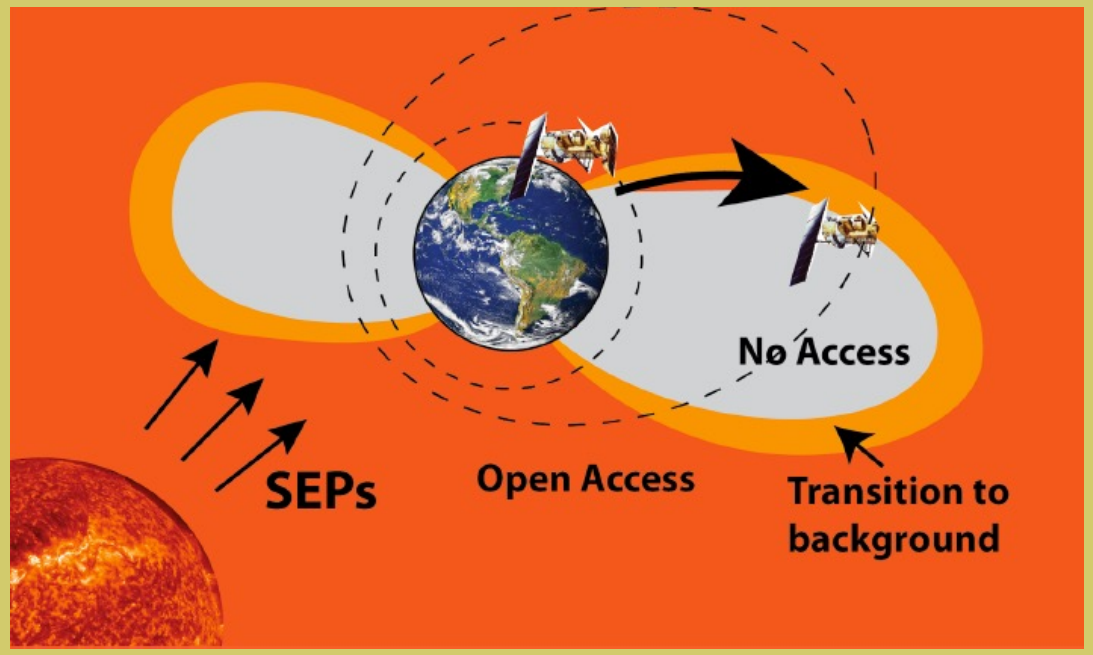


NASA HERMES Interdisciplinary Science Team



Single Event Effects: SPAM Model

Solar Particle
Access Model (SPAM)



An empirically derived data driven model for mapping solar particle flux throughout the magnetosphere for satellite anomaly monitoring and attribution

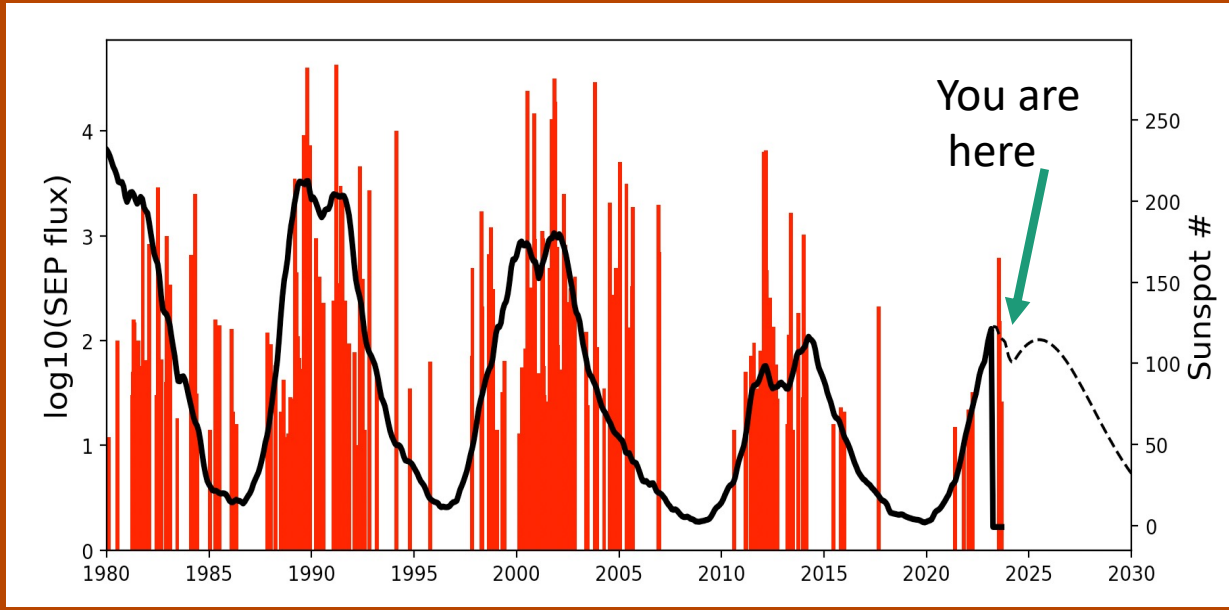
Solar Energetic Particles

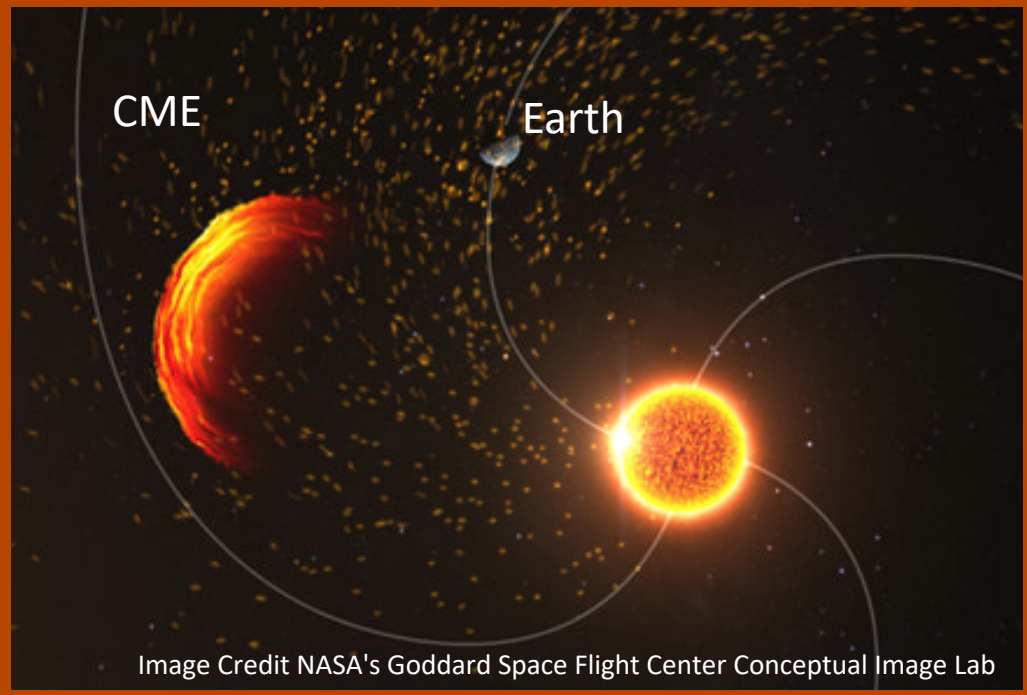
Solar energetic particle (SEP) events occur when the sun launches a fast moving coronal mass ejection (CME).

Ions are accelerated in the shock front preceding the CME. They stream ahead and flood near Earth space for days to weeks.

SEP stats

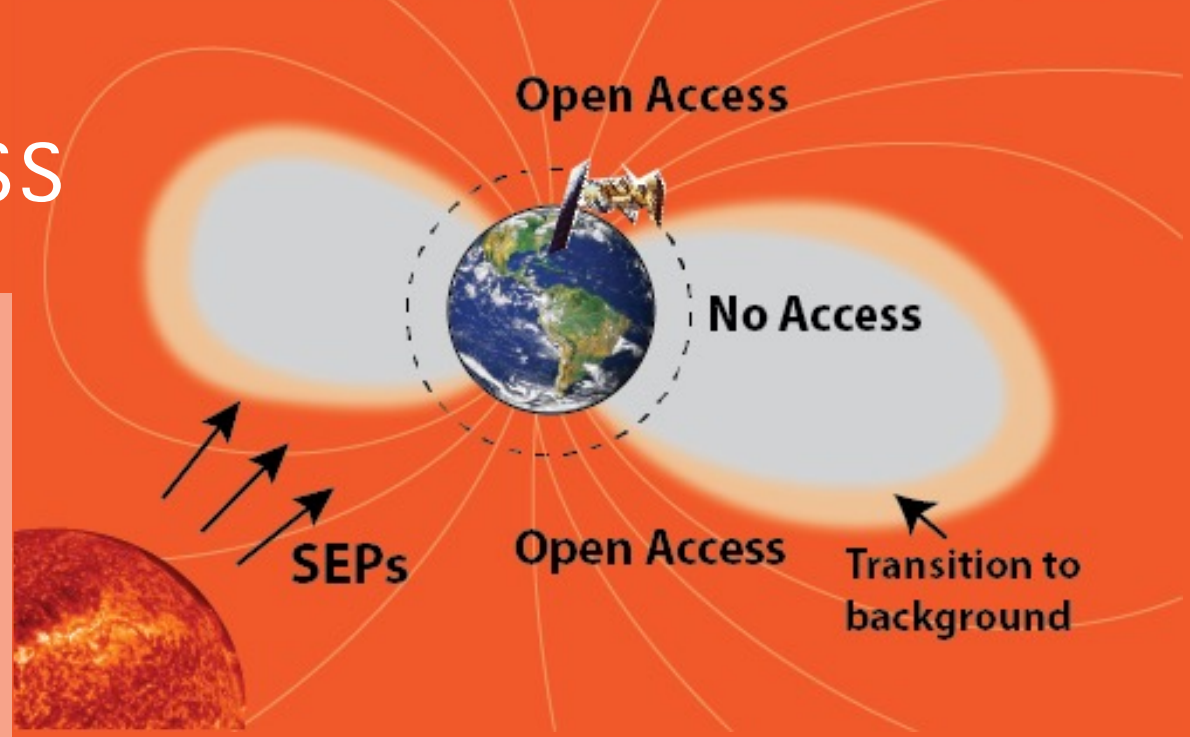
- 270 events impacted Earth since 1976 (based on GOES 10 MeV protons >10 /cm2-s-str)
- 0-23 per year, average ~ 6
- Occurrence rate follows the solar cycle but large events can happen any time
- 3 in 2023



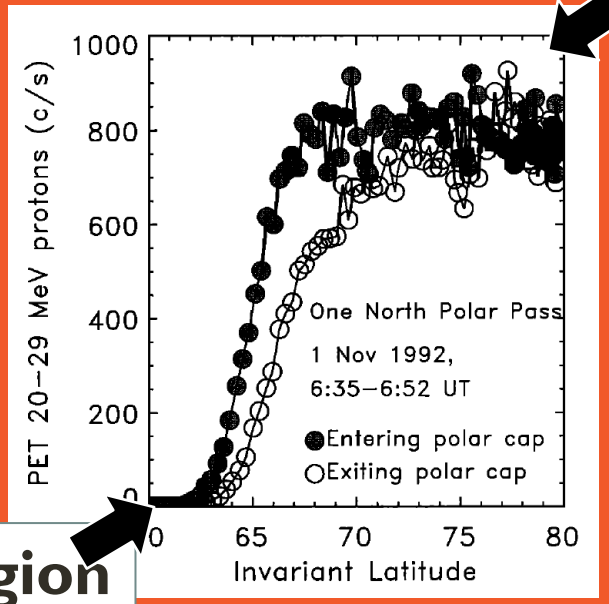


SOLAR PARTICLE ACCESS

- Some regions are shielded as ions are deflected by Earth's magnetic field.
- Polar orbiting MEO/LEO satellites will pass in and out of high flux regions.
- Monitoring the threat from these ions requires knowledge of where they have access or are deflected.
- Access regions change as the magnetic field is distorted by the oncoming solar wind.



Particle Flux



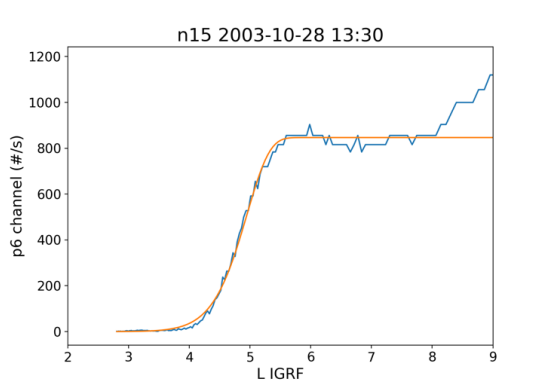
Polar Cap

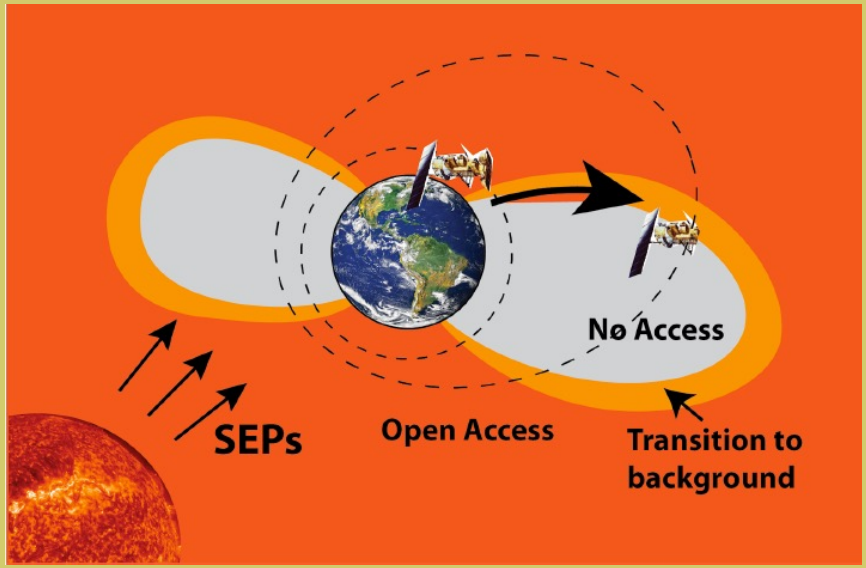
Shielded region

Leske et al., 2001

Single Event Effects: SPAM Model

POES proton flux





SPAM defines SEP access using real time observations of ions in Low Earth Orbit (POES/MetOP)

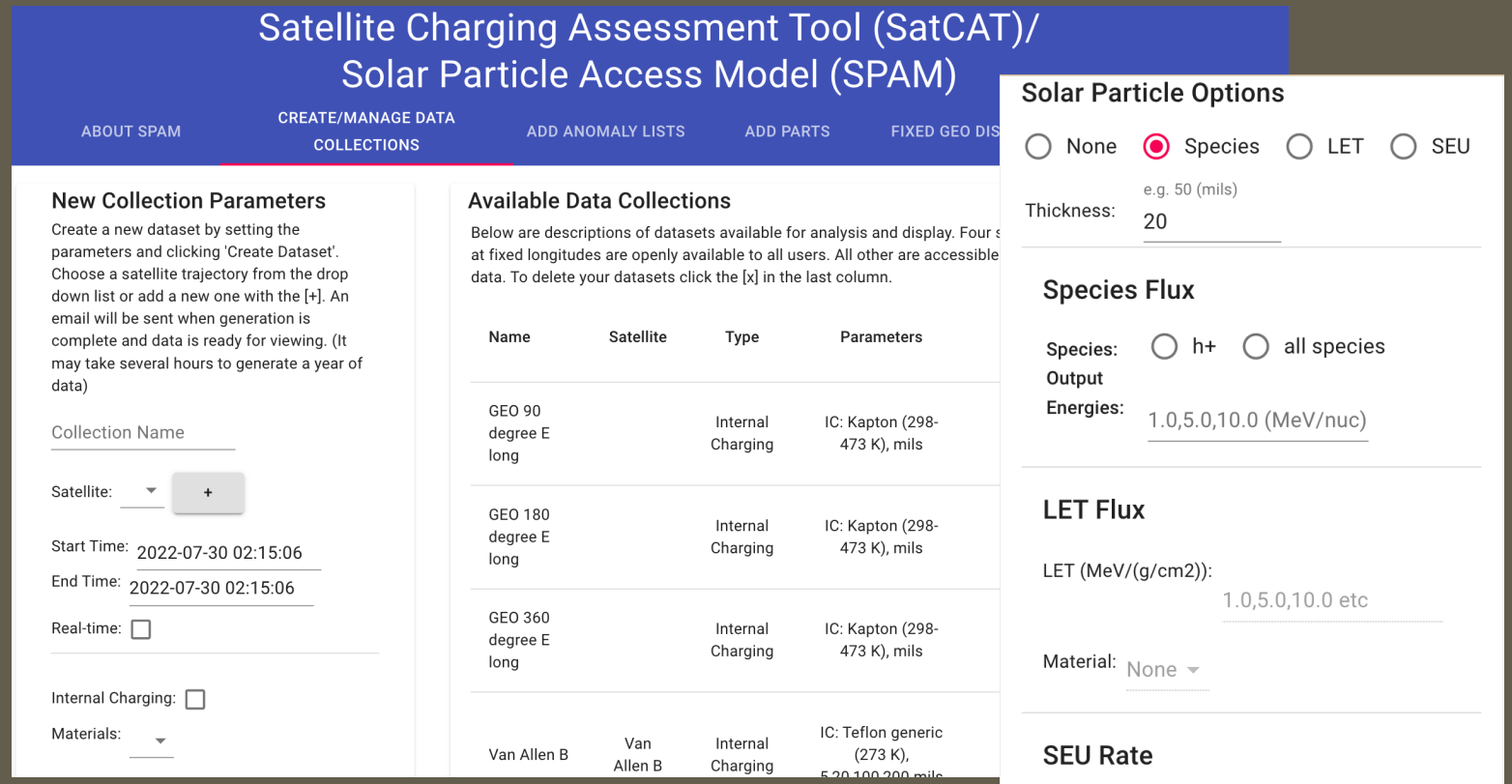
Empirically maps each POES/MetOp pass through the cutoff regions to:

- All Magnetic Local times
- All altitudes
- All ion species

Translates to LET spectrum and SEU rate

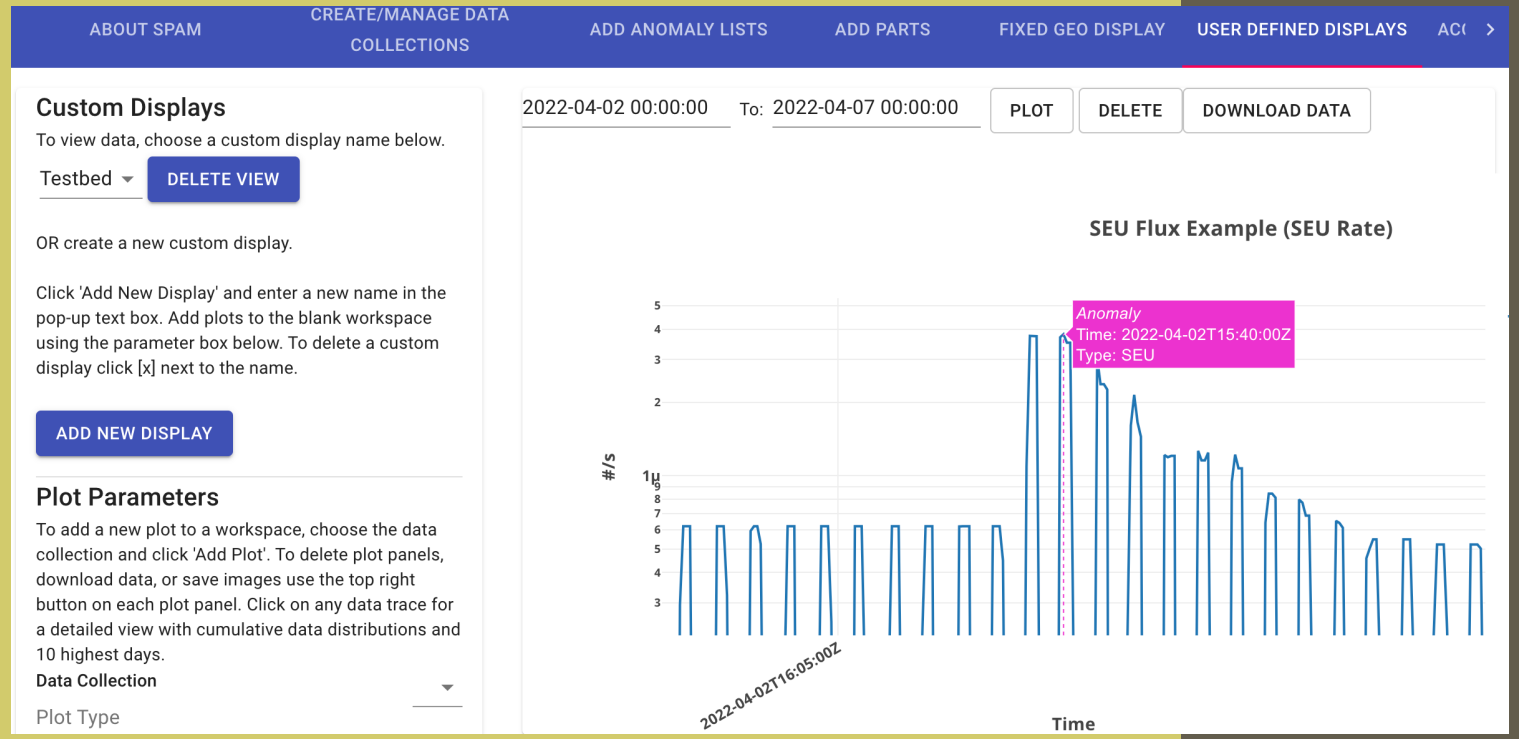
SatCAT/SPAM

Easy to use online interface



- Create a dataset by filling in selections
- Choose a satellite
- Add start and stop time (or real time updates)
- Add shielding layers
- Choose to view particle flux, LET flux, or SEU rate (select from a list of common parts or add your own)
- The tool collects TLE's, creates the trajectory, gets the ion flux from SPAM, translates to LET and SEU for specific component and and stores in a database for display and download

SATCAT/SPAM



Visualization

GUI allows you to plot data (such as SEU rate) along with anomalies to identify correlations

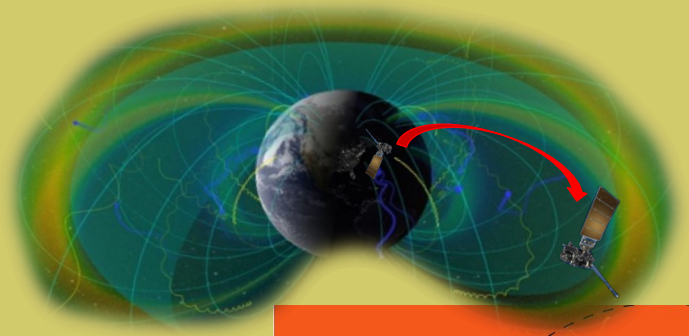
Analysis

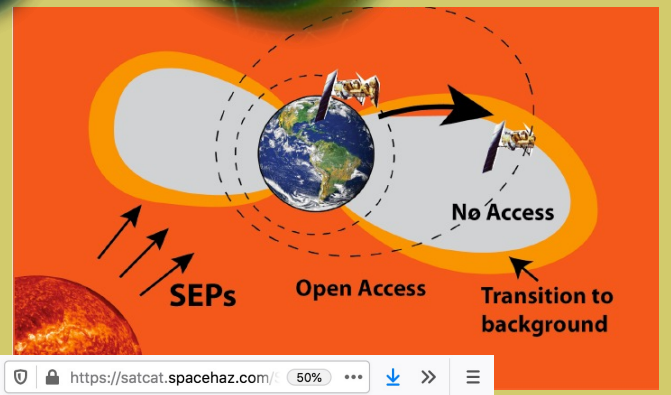
Determine whether your system is susceptible to ion impacts and monitor for future events

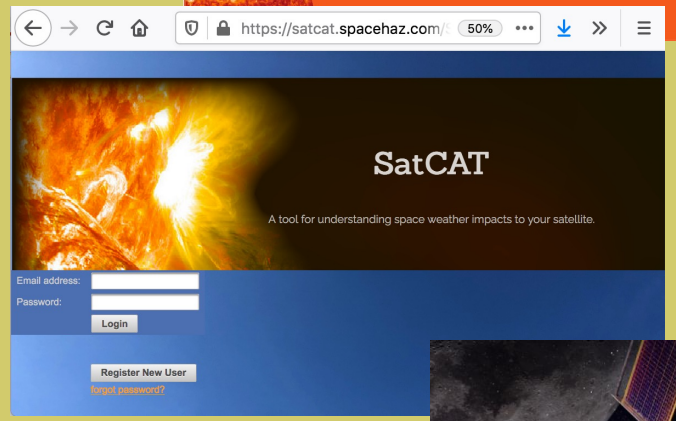
Example using SPAM to show the SEU rate along the NOAA 18 satellite orbit (polar at ~850 km) for a generic device

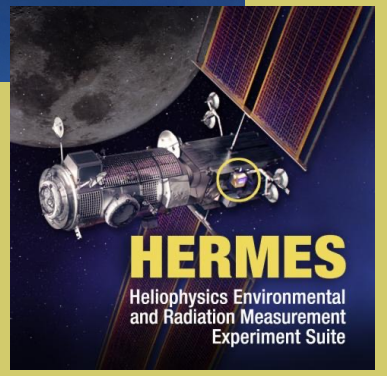
SUMMARY

We develop commercial models and applications for understanding unique real time space weather impacts to satellite systems.









SEE

- SPAM model, SPAM/SatCAT application

Internal charging

- SHELLS-hires model, SatCAT application

Surface charging (coming soon)

- Scopuli environment model

Lunar Orbit (coming soon)

- surface charging environment and impacts