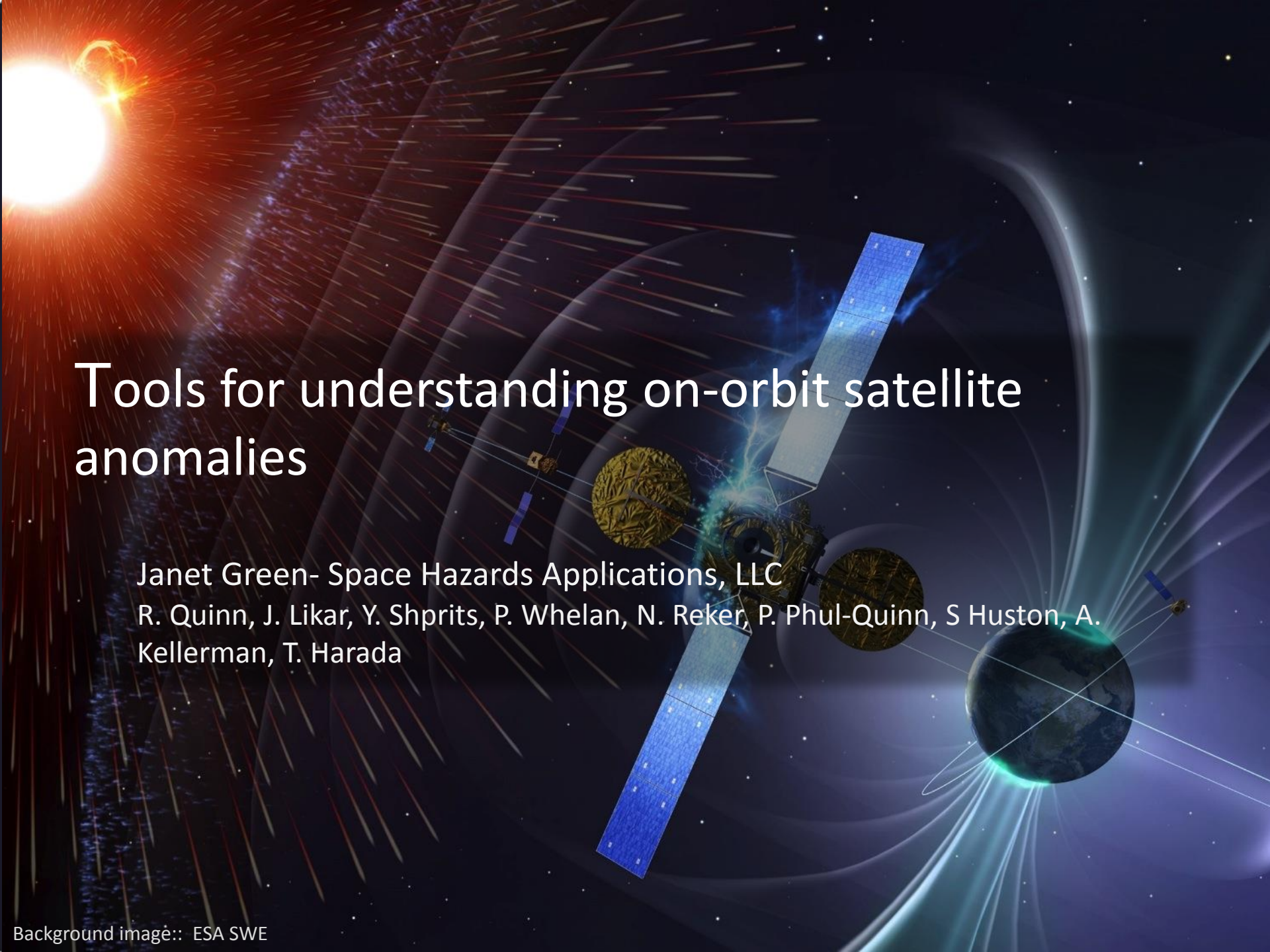


Tools for understanding on-orbit satellite anomalies

Janet Green- Space Hazards Applications, LLC
R. Quinn, J. Likar, Y. Shprits, P. Whelan, N. Reker, P. Phul-Quinn, S Huston, A. Kellerman, T. Harada

Background image:: ESA SWE

Outline

Background

- The Issue
- The Challenge
- The Concern

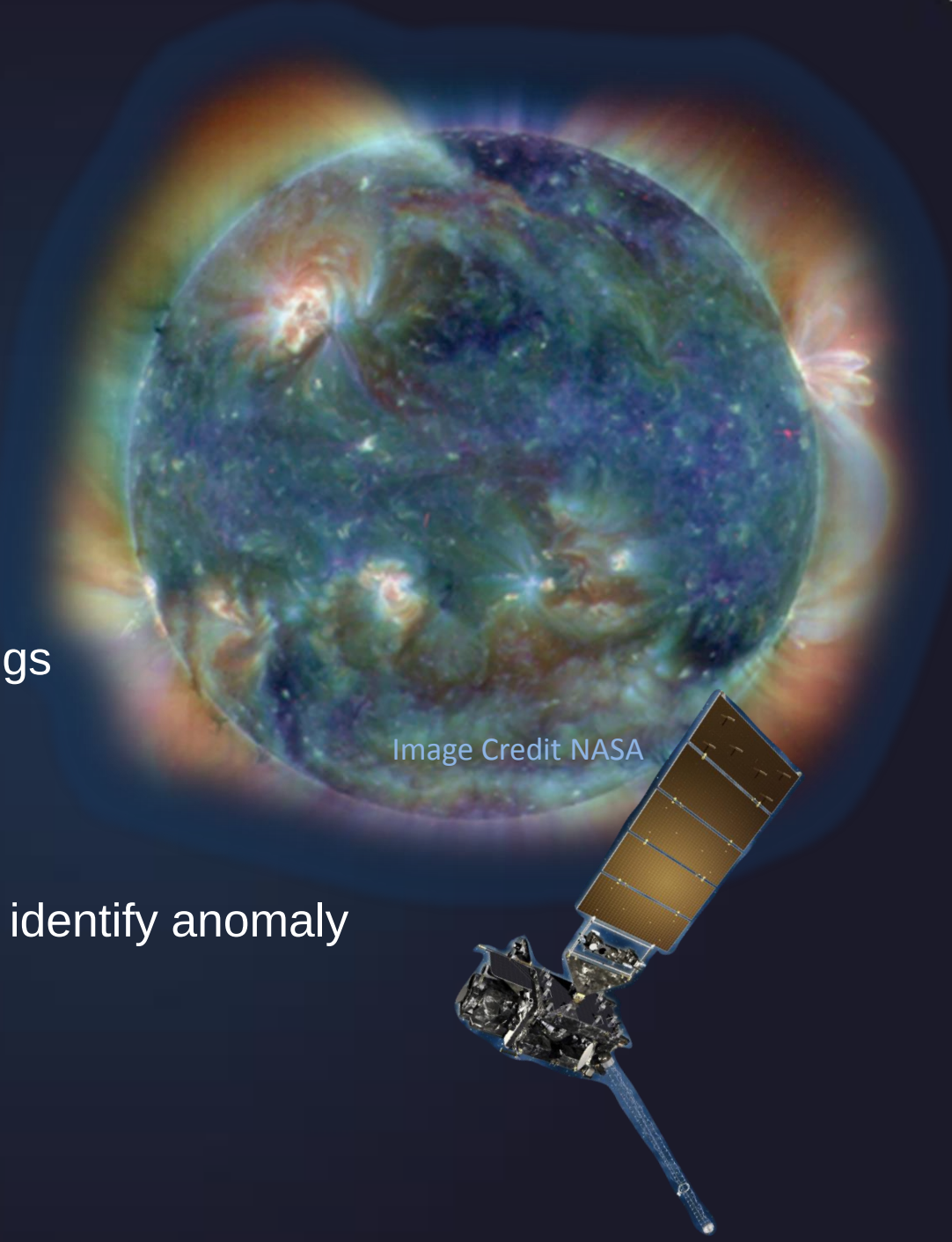
The SatCAT Project

- Satellite Industry Meetings
- Prototype Software

The SANDI Project

- Method to automatically identify anomaly drivers

Summary



The Issue

Space weather causes satellite anomalies and disrupts operations

Surface Charging:

Charged particles collect on satellite surfaces producing high voltages, damaging arcs (electrostatic discharges), and electromagnetic interference.

Internal Charging:

Energetic electrons accumulate in interior dielectrics (circuit boards or cable insulators) and on ungrounded metal (spot shields or connector contacts) leading to electrical breakdown in the vicinity of sensitive electronics.

Single Event Upsets:

Energetic ion passage through microelectronic device node causes instantaneous catastrophic device failure, latent damage, or uncommanded mode / state changes requiring ground intervention.

Total Ionizing Dose:

Energy loss (deposited dose) from proton or electron passage through microelectronic device active region accumulates over mission (or step-wise during high dose rate events) causing device degradation and reduced performance at circuit or system level.

Image Credit NASA/SDO

The Challenge

Effects are caused by distinct particle populations that intensify under varying conditions and in different regions

Surface Charging:

Low to medium energy particles associated with substorms during moderate Kp activity in the dusk magnetospheric regions.

Internal Charging:

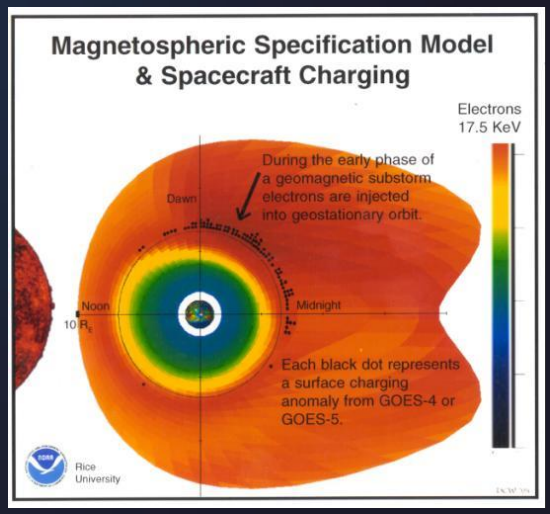
Higher energy electrons associated with some storms that peaks around L=4

Single Event Upsets:

Solar Proton Events associated with solar flares and coronal mass ejections

Total Ionizing Dose:

All of the above.



The Concern

Growing Industry and Increasing Reliance

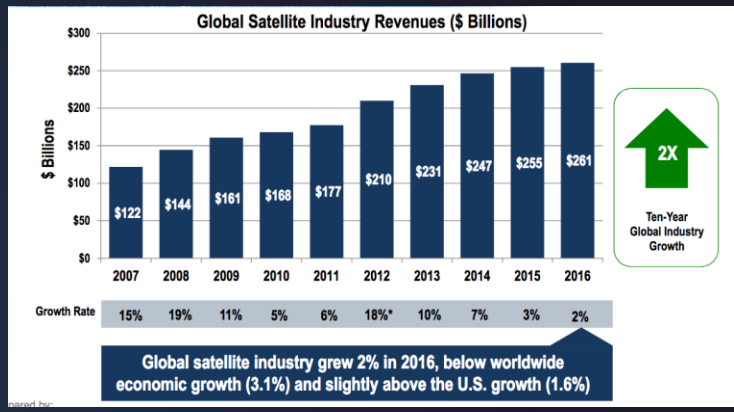
2% growth & 216 B revenue (SIA 2017)

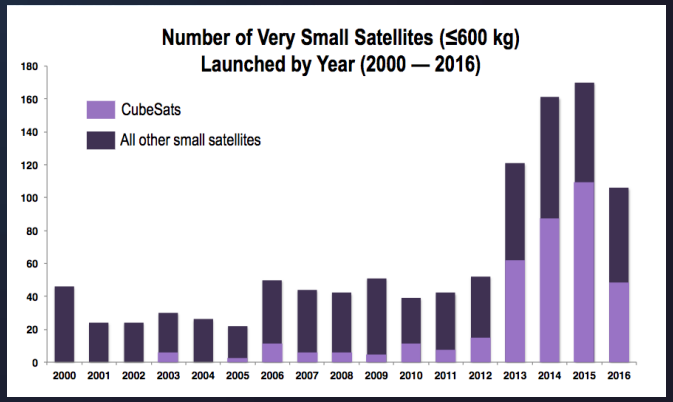
New services with large constellations

- Satellite internet
  - O3B/SES- 12 sats 8000 km (20 planned)
  - Oneweb- planned 720 1200 km
  - SpaceX- proposed 4425 satellite constellation
- Satellite Imaging
  - Earth observation services revenues grew 10%
  - Digital Globe, Terra Bella, Planet Labs
  - Uses: port traffic, mining development, agriculture, forestry

New Technology

- Electric orbit raising





SIA 2017

SatCAT Project

NOAA SBIR funded project

Phase I (Completed):

- Met with satellite industry stakeholders to understand their needs related to space weather

  Green, J. C., J. Likar, and Y. Shprits (2017), Impact of space weather on the satellite industry, Space Weather, 15, 804–818, doi:10.1002/2017SW001646.

- Built ‘proof of concept’ satellite charging assessment tool

Phase II (May 2017-May 2019):

- Web app with basic functionality is complete
- Will work with users to test functionality in the next year
- Will test utility by comparing to Scatha electro-static discharges

Findings

Management of space weather issues is a shared responsibility between manufacturers and operators

Operational Phase

Operators

- Monitor telemetry and look for issues
- Confer with manufacturers when anomalies occur
- Investigate response but not cause

Manufacturers

- Customer response team guides actions
- May do simple investigations but cost is not covered in contract
- Larger investigation (ARB) only if impact affects future satellites

Some anomalies go undiagnosed due to

- Lack of specific quick attribution tools and training
- Lack of information sharing between ops and manufacturers
- Lack of anomaly sharing within the industry

Attribution Challenge

Anomaly Investigation/Monitoring

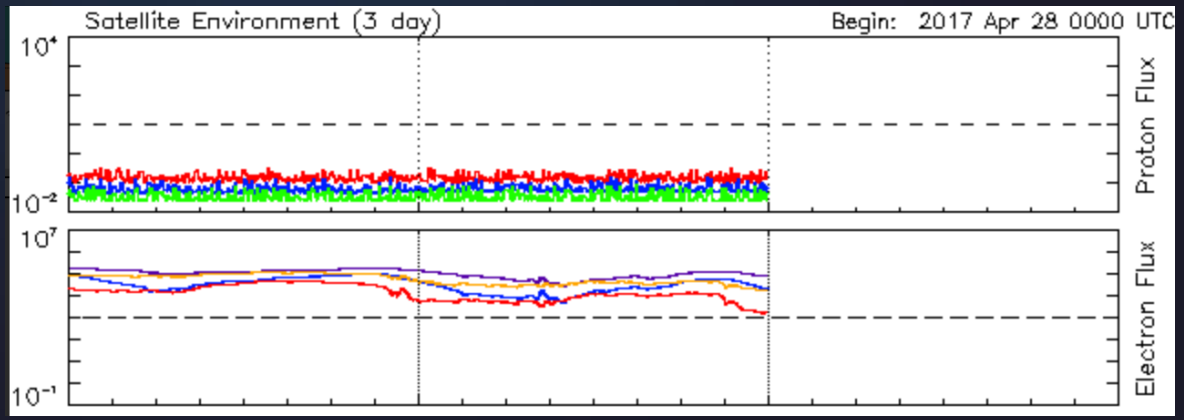
Most referred to NOAA GOES particle environment plots

- Difficult to compare to full mission
- Fluxes still need to be translated into one of the four specific hazards
- Fluxes at GEO do not describe full magnetosphere

Need for O2R2C

Operations-to-Research-to-Customer

Attribution is a research project requiring significant time and expert knowledge



About SatCAT

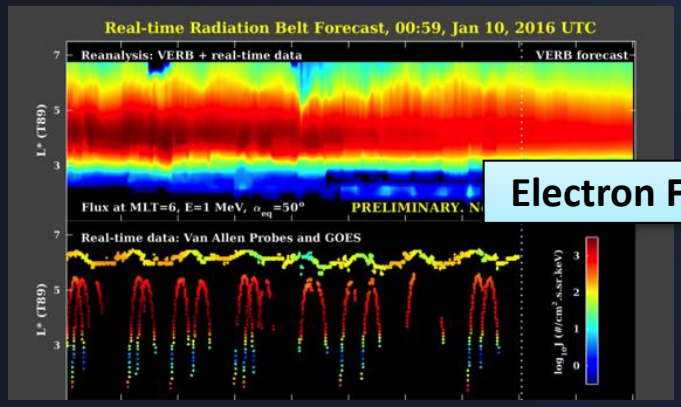
Allows you to respond quickly and confidently with the right action

The Satellite Charging Assessment Tool

- Is an online interactive tool that allows users to generate, display, and analyze an accumulated charge history for a user specified satellite, shielding, and materials

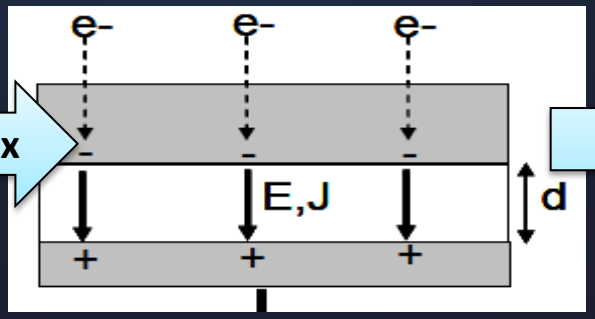
- Provides recent mission history and updates in real time

RADIATION ENVIRONMENT



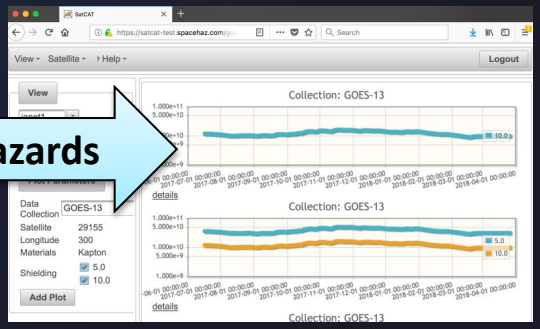
Electron Flux

ENGINEERING HAZARD



Hazards

DISPLAYS OUTPUTS



How it works

Environment -< Engineering Hazard-< Displays

The Environment

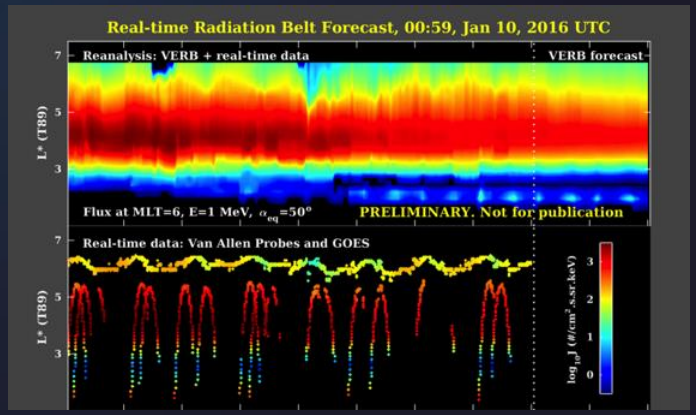
At your satellite along your orbit

Image Credit NOAA/NASA

Image Credit NASA

VERB

Data assimilative physics based model specifies the environment globally

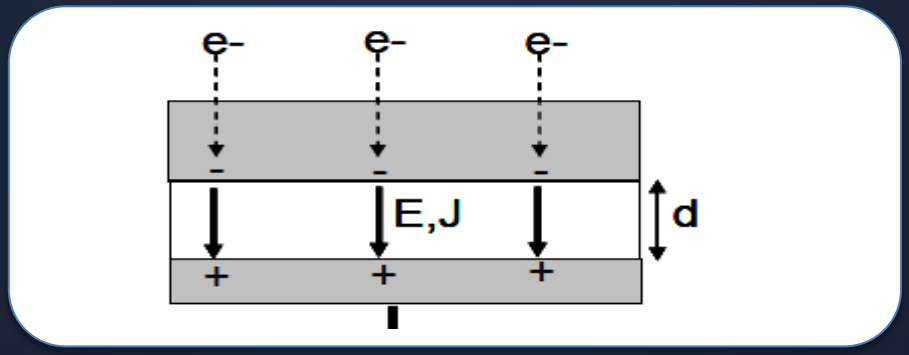


How it works

Environment -< Engineering Hazard-< Displays

The Hazard

At your satellite along your orbit
for your architecture



Internal Charging

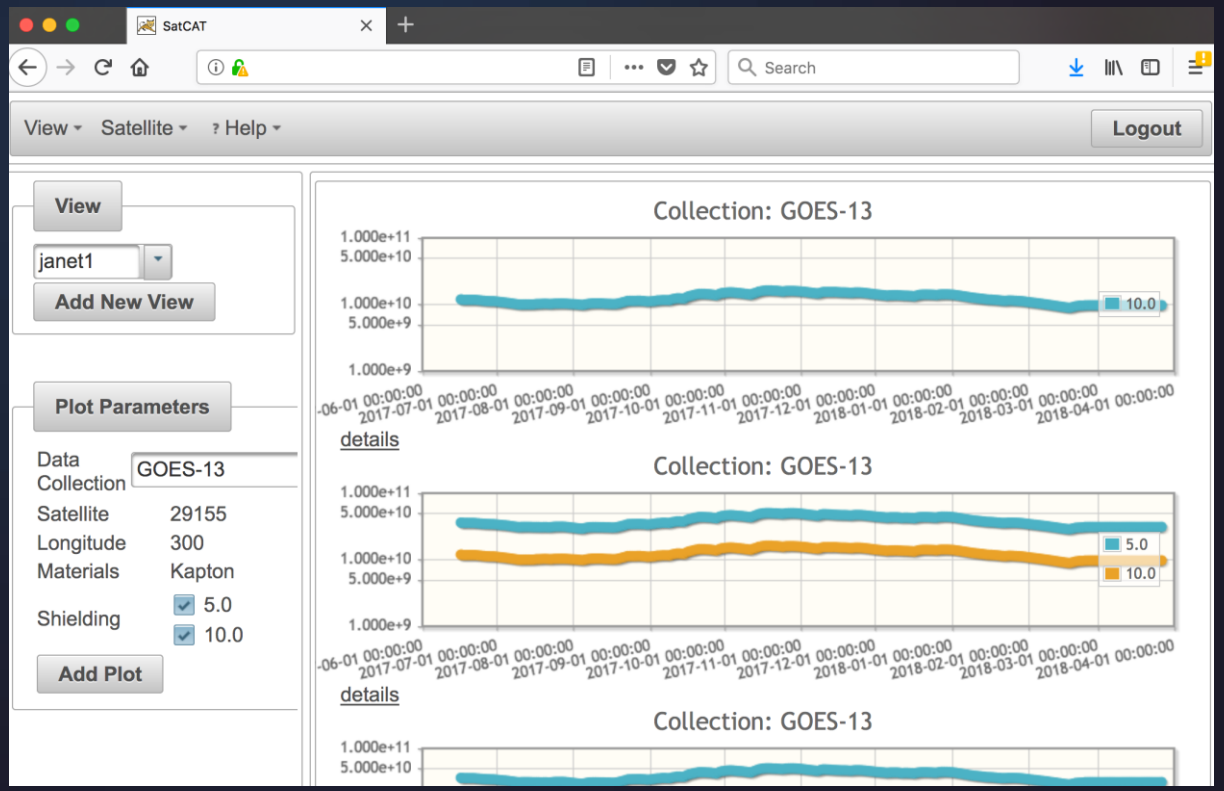
Total charge accumulation calculated for chosen layers of shielding and dielectric materials [Bodeau, 2010]

How it works

Environment -< Engineering Hazard-< Displays

Displays

The hazard at the satellite
along its orbit
for its architecture,
thresholds
and events

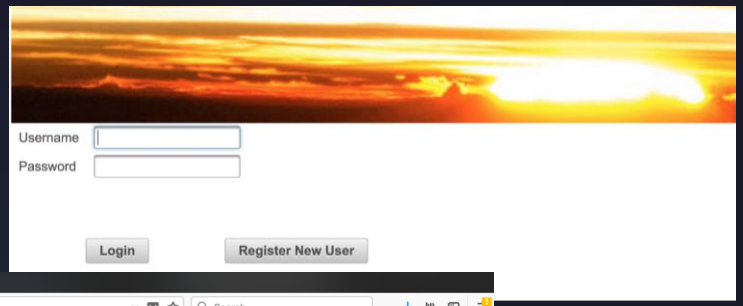


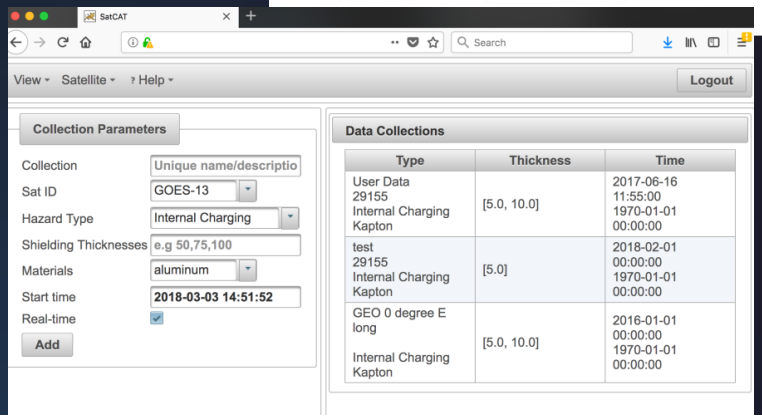
User Interface

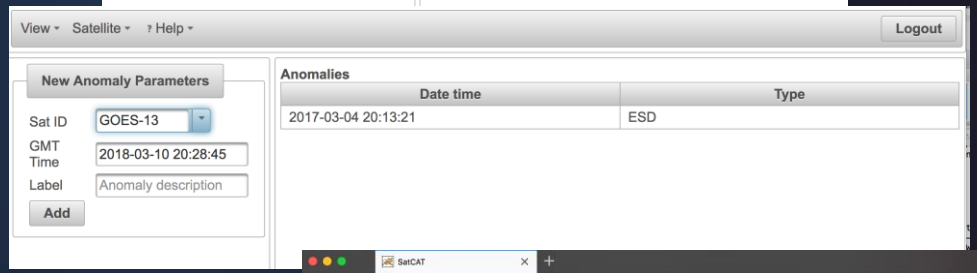
Anomaly Investigation

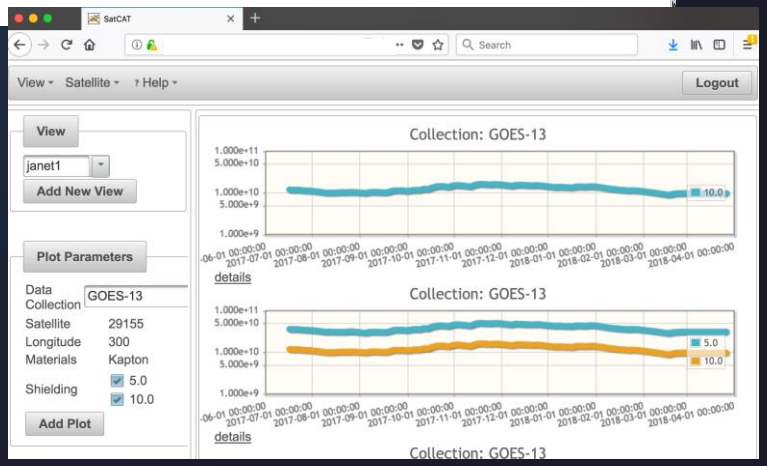
Phase II:

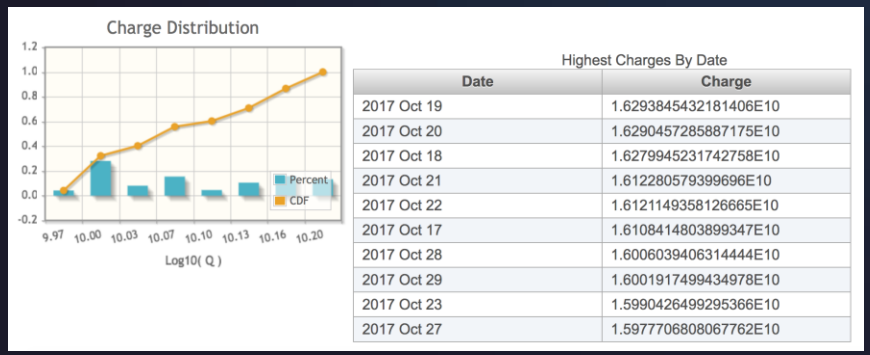
- Secure user login
- Generate new data for user orbits, shielding and materials
- Add anomaly lists
- View displays
- Access data





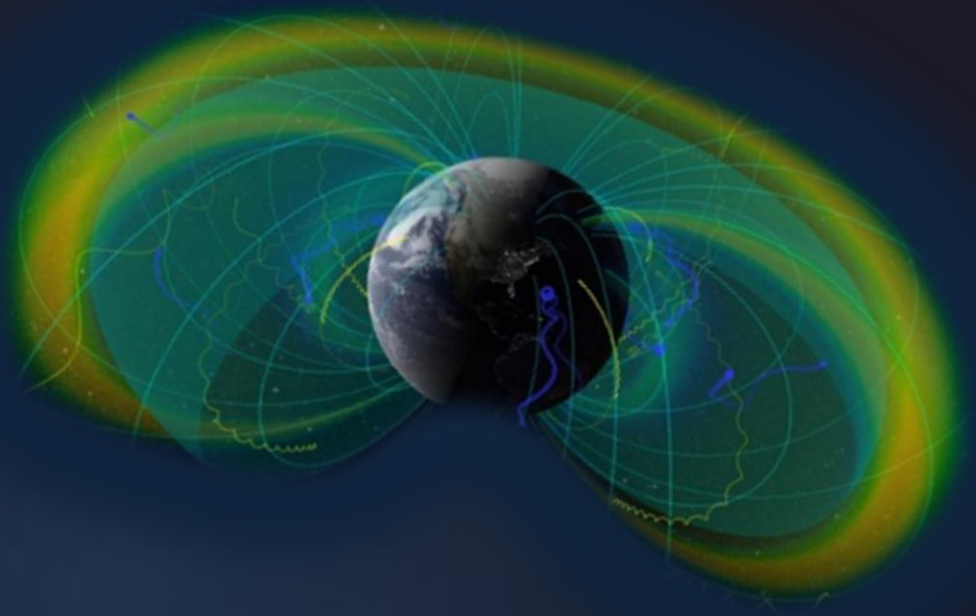






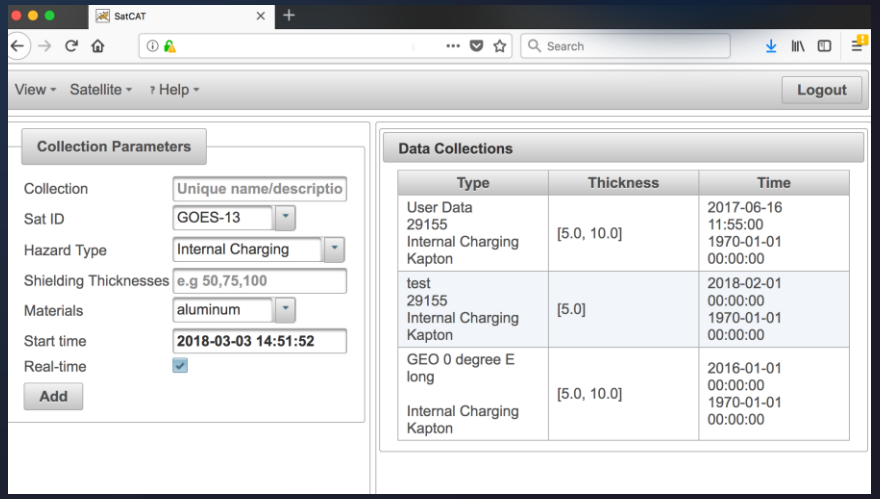
What's Next

Anomaly Investigation



Phase II:

- User test
- Validation against Scatha electrostatic discharges
- Final prototype available May 2019



SANDI

Satellite Anomaly Driver Identification

AFRL SBIR Project

Phase 1 (Completed)

- Demonstrated the ability to take a heterogeneous list of different types of anomalies along with measured particle fluxes and identify the most likely driver using statistical and machine learning techniques (GEO)

Phase 2 (Proposed)

- Will test other orbits
- Will test ability to combine data from multiple satellites
- Will add a web user interface

Summary

Large changes in satellite industry increase concerns regarding space weather

Report on satellite industry needs

SatCAT

- Is a tool that provides internal charging history for specific satellites and configurations.
- Looking for users to test the product

SANDI

- Takes a heterogeneous list of different types of anomalies along with measured particle fluxes and identifies the most likely driver using statistical and machine learning techniques (GEO)