Impact of Space Weather on the Satellite Industry

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Outline

Background
- The Issue
- The Challenge
- The Concern

The SatCAT SBIR Project
- Satellite Industry Meetings
- Prototype SatCAT tool

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.
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

3% growth & 208 B revenue (SIA 2016)

New services with large constellations

- Satellite internet
  - O3B/SES- 12 sats 8000 km (20 planned)
  - OneWeb- planned 720 1200 km (2017 launch)
  - SpaceX- proposed 4000 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
SatCAT Project

SatCAT project- funded through the NOAA Small Business Innovative Research Program.

SBIR- a way to provide innovative solutions to problems not easily addressed within the government framework.

Phase I: Two objectives
- Deliver a report on satellite industry needs related to space weather
- Build a prototype satellite charging assessment tool

Phase II:
- Continue satellite charging assessment tool development
- Approved contingent on funding
Industry Meetings

Candid and “as specific as possible” inputs drive end-product utility & effectiveness

- Focused conversations to avoid conference / workshop style setting
- 10 such meetings ensure effective range of inputs, experiences, & needs
- Included survivability engineers, customer/on-orbit response teams
- Greater interest from manufacturers
Findings

Some Findings

- Space Weather Impacts and Severity
- Managing Space Weather Issues

Details and suggested solutions in paper submitted to Space Weather Journal
Findings

Space Weather Impacts and Severity

Satellite fleet is robust to space weather impacts but not entirely impervious

- Most impacts are not considered severe or mission limiting and require simple power cycle to correct
- Some are more problematic (not yet in the public domain)

Concern that recent mild conditions promote a false sense of security

SEE were greatest concern/issue

- SEE’s are sometimes a catch-all for infrequent unexplained events
Findings

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

The extent and detail of space weather management and response varies greatly depending on the role, the impact, in house expertise, and budget.
## Findings

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

### 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

Current Method:

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
About SatCAT

Allows you to respond quickly and confidently with the right action

End product developed with focus on the customer

Combination physics & engineering based approach

RADIATION DATA/MODEL

Electron Flux

- Real time
- Assimilates data
- All orbits nowcast/forecast

ENGINEERING HAZARD MODULES

- Satellite specific
- Real charging hazards
- Voltage, Accumulated charge

DISPLAYS OUTPUTS

- Multi-day history
- Stoplight coding
- Dates of past highest levels
- Comparisons to specs/other events

Real-time Radiation Belt Forecast, 00:59, Jan 10, 2016 UTC

Preliminary. Not for publication

Van Allen Probes and GOES

Satellite specific
Real charging hazards
Voltage, Accumulated charge

Satellite specific
Real charging hazards
Voltage, Accumulated charge

Satellite specific
Real charging hazards
Voltage, Accumulated charge
How it works

Environment -< Engineering Hazard-< Displays

The Environment
At your satellite along your orbit

GOES
Direct particle flux measurements specify the environment locally at GEO

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
How it works

Environment <- Engineering Hazard <- Displays

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

Anomaly Investigation

Phase II:
• Secure user login
• Generate new data for specified orbits, shielding and materials
• View displays
• Access data
Summary

Large changes in satellite industry increase concerns regarding space weather

Report on Satellite Industry Needs
• Submitted to Space Weather Journal

SatCAT
• For operators/designers who need to maintain mission operations and resolve unavoidable satellite anomalies, SatCAT is a tool that summarizes space weather impacts to specific asset to quickly make confident decisions.
• Prototype running now
• Phase II development tentatively approved for two years to turn SatCAT into a commercial product