Space weather studies for the satellite insurance industry

A.J. Coates, N.B. Crosby, D.R. Linder and D.O. Kataria
Mullard Space Science Laboratory, University College London

1. Space weather predictive tool development
2. ‘Black box’ prototype development

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Space weather effects on spacecraft

- **Surface charging**: well known, differential charging a possible problem. Current balance with natural environment, photoelectrons and secondary particles.
- Related anomalies peak in morning hours, where injected particles a maximum.
- **Deep dielectric charging due to MeV ‘killer’ electron penetration an increasing problem**.
- **SEUs** due to solar protons, galactic cosmic rays, radiation belt particles peak where rigidity lowest or radiation belts hit atmosphere.

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1. Space weather predictions

- Predictions of ‘killer’ electron environment
- Based on upstream solar wind conditions
- STRV, CRRES data (Iles et al, this study) and studies by others (e.g. Blake et al, Li et al) have shown links between solar wind and MeV electrons
- Here we extend to anomalies
- Depends on current values and recent history, corresponds to event initiation and build-up of fluxes
- Used solar wind data from known events for testing, on-line predictions use real time data to provide warnings for next 24-48 hours

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**Solar Wind Data**

Upper panel: day of month as a function of solar wind velocity (Vsw).
Lower panel: day of month as a function of interplanetary magnetic field (Bz).

Radiation Belt Data

Geostationary transfer orbit

Space Technology Research Vehicle (STRV)
Sept. 1994 through March 1998
Apogee: 35795 km
Perigee: 200 km

Cold Ion Detector (CID)
(measures electrons > 750 keV)

Combined Release and Radiation Effects Satellite (CRRES)
July 1990 – October 1991
Apogee: 35788 km
Perigee: 305 km
Medium Electron A (MEA)
(0.153 MeV to 1.582 MeV)

Anomaly Data

EXTREME EVENTS STUDIED

- Bastille day event (14 July 2000)
- Telstar 401 (11 Jan. 1997)
- Galaxy 4 (19 May 1998)

Model - PART I

CURRENT CONDITIONS
- Solar Wind Velocity (Vsw)
- Interplanetary Magnetic Field (Bz)

SHORT-TERM HISTORY
- (6 hours)
- delta_t = O Flag_index(i) / 6
  where: i = [1,6]

Eqn: RISK = (Vsw/500)^2 x (-Bz) x (delta_t/6)

Flag 1 (GREEN or AMBER)

PART I
CURRENT AND IMMEDIATE SHORT-TERM CONDITIONS
onset of disturbed conditions

Medium and long term

- Two other parts to model
- Medium term (6h)
- Long term (48h)
2. ‘Black box’ project - aims

- Develop prototype ‘killer electron’ detector
- Minimum spacecraft resources (target 600g)
- Energy spectra 300 keV-3 MeV, angular information needed
- Data required at all stages of solar cycle, all altitudes to improve models
- Data needed to evaluate risk in region of detector, post-event analysis
- Goal to fly instrument on commercial and other satellites
- Evaluate resources for flight model production

Conclusions

- Link between upstream solar wind conditions, measured ‘killer electron’ populations and satellite anomalies
- Development of model based on upstream solar wind conditions (Vsw and Bz)
- The model predicts some anomalies (e.g. ESDs) with skill much better than pure chance
- Web-site including prediction tool based on real-time data, and general information is in final stage of development
- Prototype ‘Black box’ works successfully, flight opportunities being sought