Space weather studies for the satellite insurance industry

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1. Space weather predictive tool development
2. 'Black box' prototype development

Funded by Tsunami initiative –
DTI with major London-based satellite insurers

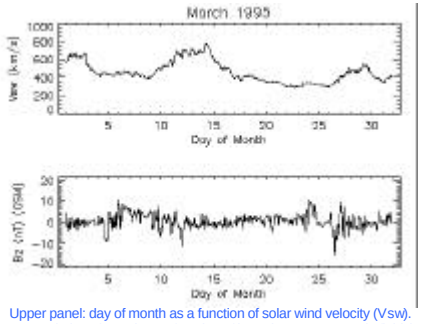
Space weather effects on spacecraft

- **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

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

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).
Courtesy of Omniweb, <http://nssdc.gsfc.nasa.gov/omniweb/>

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)

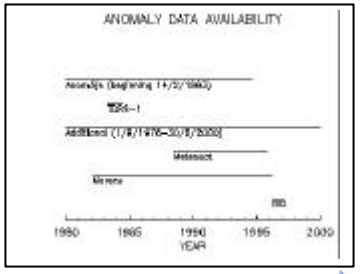
Combined Release and Radiation
Effects Satellite (CRRES)
July 1990 – October 1991
Apogee: 35768 km
Perigee: 305 km

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)
- Anik E-1/E-2 (20/21 Jan. 1994)



Model - PART I

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

CURRENT CONDITIONS

Solar Wind Velocity (Vsw)

Interplanetary Magnetic Field (Bz)

SHORT-TERM HISTORY
(6 hours)

delta_t = Ó Flag_index(i) / 6

where: i= [1,6]

Eq1: RISK= $(Vsw/500)^2$ x (-Bz) x (delta_t/6)

Flag1
(GREEN or AMBER)

Medium and long term

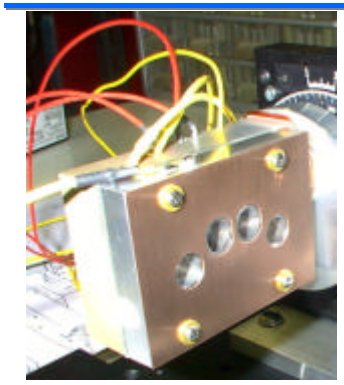
- Two other parts to model
- Medium term (6h)
- Long term (48h)

Web-based Satellite Risk Tool

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

Prototype Black Box



About 8cm across

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