Radiation and Plasma Effects Working Group

- Surface Charging *few eV - keV electrons, plasma density* (Leads: J. Minow, D. Pitchford, N. Ganushkina) SSA-6 **TEAM AGENDA**
- Internal Charging *keV–MeV electrons* (Leads: P. O'Brien, Y. Shprits) SSA-6 **TEAM AGENDA**
- Single Event Effects *MeV–GeV protons, ions* (Leads: M. Xapsos, J. Mazur, P. Jiggens) SSA-3,SSA-6 **TEAM AGENDA**
- Total Dose *keV–MeV electrons, keV–GeV protons, GCR ions* (Leads: I. Jun, T. Guild, M. Xapsos) SSA-6 **TEAM AGENDA**
- Radiation effects for aviation (Leads: K. Tobiska, M. Meier) SSA-6 **TEAM AGENDA**

Plasma/neutrals across a broad energy range and with different origins

Ring current, aurora, plasma sheet, Radiation belt electrons, trapped proton belt, SEPs, GCRs , terrestrial gamma ray flash

What we have done so far

- Identified different users
- Identified focus (mostly on space environment)
- Identified energy spectra is needed for all impact quantification
- Identified key physical parameters/quantities for the effects
- Metrics (nontrivial)
  - Headline type/signature type (easily understood by satellite/aviation users)
  - Comprehensive science type
- Metrics
  - Statistical evaluation using O'Brien "green anomalies" technique (instantaneous value over statistical average)
  - Event/interval type of validation
  - Sensitivity study (vary space weather environment to see changes in impacts)

Interaction with Other Teams

- Katherine Winters – launch commit considerations
- Key team members participated in Tuesday's SEP session
- Get ideas from other focus teams
- Surface charging ←-→ auroral dynamics
- Will do more during the remainder of the workshop and onward

Issues or Problems Impeding Progress

- Need spectra/dose measurements
- Standardized dosimeter, cross-calibration, interpretation of dose measurements inside shielding such as aircraft, ISS
- Recommend NASA missions have environment/effects sensors (dosimeters)

Team plans for the rest of the week

Further refine metrics/identify tasks

Surface Charging Status

- Initial effort will focus on high priority GEO, MEO, GTO, and LEO polar environments where surface charging can exceed hundreds of volts

- User groups include spacecraft designers, operational situational awareness, anomaly investigations, and impact on science measurements

- Metrics (team is evaluating options):
  - Statistical evaluation using O'Brien "green anomalies" technique (instantaneous value over statistical average)
  - Parameters used for inputs to charging models
    - GEO, MEO, GTO: Ne, Te, Ni, Ti or other
    - LEO polar (auroral): Ne, E_{beam}, ΔE_{beam}, and other Fontheim parameters
    - Flux spectra at different locations

- Environment models (initial focus):
  - Ovation – CCMC implementation
  - LANL model (Vania Jordanova)
  - IMPTAM (Natalia Ganjushkina)), run online in near-real time since 2013

- Spacecraft charging models (secondary effort)
  - NASCAP
  - SPIS
  - SPENVIS, MUSCAT, and other small group charging codes

Internal Charging Metrics

- We designate a small number of headline metrics, plus an expanded set of comprehensive metrics. The program should mark progress via the headline metrics, while individual projects mark progress with the comprehensive metrics.
- Internal charging **headline metrics**:
- User Metrics: % Green anomalies for 24-hour average current beneath 100 mils Al spherical, gamma=1
  - GEO (GOES)
  - GTO (RBSP)
- Science Metrics: Omnidirectional differential or integral flux
  - >2 MeV @ GOES, 5 minute averages
  - 1 MeV @ RBSP, 1 minute averages (includes inner zone)
- Internal charging events/intervals
  - 2015 has some nice big storms, RBSP data to validate
  - The March, April, June, and July 2015 storms
- Internal charging "comprehensive" metrics:
- User Metrics: % Green anomalies for 6, **24**, 72-hour average current beneath 40, **100**, 350 mils Al spherical, gamma=1
  - **GEO (GOES)**
  - **GTO (RBSP)**
  - LEO (POES)
  - HEO (TWINS-2)
  - GPS
- Science Metrics: **Omnidirectional** *and locally mirroring* differential or integral flux
  - 0.1, 0.3, 1 MeV, **>2 MeV @ GOES,** (or LANL) **5 minute averages**
  - 0.1, 0.3, **1 MeV**, 2 MeV **@ RBSP, 1 minute averages (includes inner zone)**

Internal Charging Metrics (continued)

- We are not currently addressing how the metrics account for model error: is it really a “Green” anomaly if the model error bar included some yellow?
- We are not addressing mission design specs (Satellite design users, govt agency, insurers): out of scope, and hard to validate a 95% confidence value for 10-year worst case without 200 years of data. Best we could do is attempt to specify 3 largest events in GOES >2 MeV since 1986 as 1 in 10 year worst case.
- How do we address designer, insurer, govt agency needs? By including most severe, well-observed events in our validation set.

- <u>Models:</u>
- VERB, Salammbo, RBE/CRCM, DREAM, BAS, Rice REM
- CRRESELE in Ap mode
- GREEP, Ukhorskiy nearest neighbors, SWPC REFM, NARMAX

Total Ionizing Dose (and Displacement Damage Dose)

- Identify user groups
  - Satellite designer (SD) for both commercial and government
  - Satellite operators and anomaly analysts (SOAA) for both commercial and government
  - Scientists (SCI) for both academia and government
- Identify physical parameters/metrics for each user group
  - SD: Dose-depth for the mission
  - SOAA: Dose-depth from launch to given time
  - SCI: proton and electron energy spectra
    - Electrons for > 100 keV
    - Protons for > 1 MeV
- Identify empirical models for each metric
  - Trapped: AE8/AP8; AE9/AP9/SPM; IGE2006/POLE (other older models are also available (e.g., CRESSELE, CRESSPRO, etc.))
  - Solar: King; JPL; ESP/PSYCHIC; SAPPHIRE
- Identify physical model for each metric
  - Trapped: SALAMMBO; DREAM
  - Solar: SOLPENCO
- Error metrics to consider:
- Long-term variability of trapped particles (data-based statistical analysis?) at different locations within planetary magnetosphere(s)
- Most of the error metrics used for Internal Charging Working Group seem to apply here, too.
- Statistics of solar proton environment: fluence spectra
- Model predicted dose vs. measured dose (e.g., CRaTER instrument)
- Measured solar proton event spectra for individual events vs. physical model prediction

SEEs: Identified empirical/statistical models

- Trapped protons
  - AP9 (also AP8 still used in some standards);
  - PSB97 + update (local model based on SAMPEX/PET)
- SEPs
  - ESP-PSYCHIC
  - JPL
  - MSU
  - SAPPHIRE
- GCRs
  - ISO-15390 GCR model
  - Badhwar-O'Neill (BON)
  - DLR GCR model
- Magnetospheric Modelling codes:
  - ESHIEM-MSM (magnetospheric shielding code)
  - Shea and Smart model

Relevant parameters

a) SD+SLAO (SEU rate): proton fluxes (>30 MeV & > 50 MeV) [radiation belt peak vales (5-minute); worst-case SEP values; worst-case solar particle event (SPE) fluence]

b) SD (SEL/SEB probability): proton fluences (>30 MeV & > 50 MeV) [Orbit-averaged radiation belt flux (fluence); cumulative SEP fluence]

c) SD+SLAO+SO: Abundance ratios and charge states of SEP heavy ions (Z>2) [extension to event-to-event variability/ distributions if possible]

d) SD+SLAO: LET behind nominal shielding** (1 g.cm^{-2})

***application of particle transport codes as black box only to derive useful quantities*

Validation methods

a). Statistical evaluation using O'Brien "green anomalies" technique

b. Event /interval based

Radiation Effects for Aviation

- Aviation models (Daniel Matthia)
  - More than dozens of models are available worldwide
    - Monte Carlo transport
    - Deterministic transport
    - Data-driven models
- Aviation radiation data for scientific modeling and operations (Kent Tobiska)
  - ARMAS project (which incorporate USAF's REACH effort)
  - Measurements in Europe/elsewhere in the world
- D-index for communicating with users/public (Matthias Meier)-- A new Space Weather Index for Aviation based on dose rate, not on >10 MeV proton flux outside the magnetic/atmospheric shielding
  - Due to magnetic and atmospheric shielding, only particles > 500 MeV matters to aviation

Leverage the LWS institute SAFESKY effort: PI Kent Tobiska