Space Weather Issues and Tools
Steve Johnson, NASA Space Radiation Analysis Group

Invited to serve as a panelist regarding Space Weather Operations and Spaceflight.

In addition, I was also asked to present a short presentation regarding SRAG operational tools and space weather as it could apply to commercial space transportation. This presentation will include basic environmental information regarding solar energetic particle events and some discussion slides regarding the operational impacts application as it may apply to commercial spaceflight.

No abstract was requested or provided.
Space Radiation Environmental Considerations for Commercial Space Flight

Steve Johnson, Neal Zapp

Space Radiation Analysis Group
Johnson Space Center

Space Weather Issues and Tools
10th Annual Commercial Space Transportation Conference
Who are we?

Space Radiation Analysis Group (SRAG)
Johnson Space Center

Monitor, Assess and Inform Mission Control of Radiation Environment Conditions.

Support mission control:
- 4 Hours/day under normal conditions
- During the course of all EVAs
- Continuous support during Solar Energetic Particle SEP events

Conduct radiation measurements on Crew (Dosimetry) and on Spacecraft

Operational Advocates for Radiation Health of Astronauts
How do we Protect the Crew from SEPs

The major real-time operational concern are Solar Energetic Particle events

Close Support with NOAA Space Environment Center
  Daily Status and Weather Reports
  Monitor real-time data feed from Radiation Detecting Satellites (GOES, ACE, SOHO)
  Data From Ground Stations

Mission Control activity
  Interpret Current Conditions and Trends as Applied to Current Mission
  Execute Computer models:
    Using real-time NOAA GOES Satellite data
    Models of the Earth’s Protective Magnetic Field
    Compare SEP Model Output against Spacecraft Measurements
  Advise Flight Management
  Crew Shielding Recommendations to Flight Surgeon
  Identify When radiation sensitive hardware will be at risk
Physics 101

THE MAGNETIC FIELD IS LIKE AN UMBRELLA PROVIDING SIGNIFICANT PROTECTION AGAINST SPACE RADIATION

GALACTIC COSMIC RADIATION (GCR) (Protons to Iron Nuclei)

SOUTH ATLANTIC ANOMALY (Protons)

INNER RADIATION BELT (Protons)

OUTER RADIATION BELT (Electrons)

SOLAR PARTICLE EVENT (Protons to Iron Nuclei)

Magnetic Axis

Spin Axis

Physics 101
Space Radiation Environment – Where are we protected?

Dose Intensity and Ground Track Location
Least Protected Zones are within the yellow areas
– this is where SEPs will pose greatest risk
Dose Intensity and Ground Track Location During A Proton Event
A Difference Plot Subtracting a Normal Day from Proton Event Day
Note: SEPs location corresponds to the ‘Yellow’ regions on the previous plot
**SEP Events as Observed at ISS (Low Earth Orbit)**

- Characterized by short high-dose passes.
  - Peaks will be 45 – 90 minutes apart:
  - **Timing is Trajectory dependent**
- Passes correspond to trajectories in zones of low magnetic protection
- Usually bunched into 8-9 hour interval each day.
- Southern regions larger Northern regions

**How would the radiation levels in orbit change during an event?**

- **Dose rate**
- **> 100 MeV protons**

**Proton Intensity from GOES**

**Model Dose Estimates**

**24 Hrs Later**

**No Exposure**
When do these Events happen?

Note: SPEs can happen anytime in the solar cycle.
Can We Forecast SEPs?

Well, no not at this time. Current State of the Art is Limited to Nowcasting. However ....

We recognize many parameters that are indicative of the “right” conditions. Some major ones are:
- Active Region magnetic complexity and size
- Recent Activity
- Region Location

It doesn’t happen all at once. Generally
- First indicator: Large X-ray flare
- If magnetically connected to the Flare region, arrival times generally 15 – 30 minutes for well connected events
- An Hour or Longer To Reach Maximum for Major events.

January 2005 was significantly outside the ‘typical’ profiles and much faster arrival and peak times! Exceptions will occur.

Considerable research into developing the capability to forecast an event
- An Active Region is a group of sunspots magnetically intertwined.
### Flight profile  

<table>
<thead>
<tr>
<th>Inclination</th>
<th>Duration</th>
<th>Risk Level</th>
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</thead>
<tbody>
<tr>
<td><strong>Suborbital</strong></td>
<td></td>
<td></td>
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<tr>
<td>Latitude &lt; 40° N/S</td>
<td>Few minutes</td>
<td>Negligible: Exposure Unlikely</td>
</tr>
<tr>
<td>Latitude &gt; 40° N/S</td>
<td>Few minutes</td>
<td>Negligible: Slight Exposure possible</td>
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<tr>
<td><strong>Orbital</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latitude &lt; 40° N/S</td>
<td>Few Orbits (hours)</td>
<td>Negligible: Extremely small</td>
</tr>
<tr>
<td>Latitude &gt; 40° N/S</td>
<td>Few Orbits (hours)</td>
<td>Minor: Trajectory Dependent</td>
</tr>
<tr>
<td><strong>Orbiting/Station</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Latitude &lt; 40° N/S</td>
<td>Days</td>
<td>Negligible: Small</td>
</tr>
<tr>
<td>Latitude &gt; 40° N/S</td>
<td>Days</td>
<td>High Risk: Risk rises as inclination rises</td>
</tr>
<tr>
<td><strong>Moon or Mars</strong></td>
<td>Doesn’t matter</td>
<td>Weeks/Months</td>
</tr>
</tbody>
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**Note:** Trapped Radiation needs to be considered for Longer duration orbital periods.
Although the true risks and exposures may be low, it will be in your best interest to protect the Transportation Operators and Passengers.

- Develop a plan to address Space Weather issues.
- Compliance With Radiation Monitoring Regulations May Be Required.
- Avoidance of SEPs Always The Best.

Suborbital and short orbital flights should be able to avoid SEPs.

A suborbital flight could be undertaken when “clear” and be completed before an event starts and achieves significant levels.

Short Orbital flights, may avoid low protection zones depending on trajectory.

And ....
Always Check With Your Friendly Neighborhood Space Weather Man
Extra Charts
P100 Mev Peak Value

Longitude

Peak Flux pfu

-100  -80  -60  -40  -20   0    20    40    60    80    100

28 Oct 03
14 Jul 00
29 Oct 03
15 Apr 01

8 Nov 00
4 Nov 01
20 Jan 05

P100 Mev Peak Value
INPUTS

> 30 MeV GOES Protons
> 100 MeV GOES Protons

ISS State Vector

Kb
Universal time

Shield Distribution

Create Differential Flux Spectrum
- Exponential fit in rigidity

Determine Spacecraft Location

Determine Geomagnetic Cutoff at Spacecraft Location

Calculate SPE Spectra at Spacecraft

Calculate SPE Dose Inside Spacecraft

OUTPUT