45th Weather Squadron
Space Weather Support to Launch

29 September 2015

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Cape Canaveral Air Force Station
Our Mission

“Exploit the Weather to Assure Safe Access to Air and Space”
Background

- Weather Impacts
  - Launch Operations
  - Ground Operations
  - Aviation Missions
  - Special Missions
Weather Impacts to Launch

- Over a third of launch delays due to weather
- Nearly half of launch scrubs due to weather

1 Jan 88–15 Jul 15 (27+ Years)

Countdowns (100%)

Launch (55%)

On time (50% / 28%)

Weather (36% / 10%)

Customer/Range Issues (64% / 18%)

Delay (50% / 27%)

Weather (47% / 21%)

Customer/Range Issues (53% / 24%)

Scrub (45%)

(% of Previous / % of All Countdowns)
Why is Solar Weather a Concern for Launch?

- Plasma
  - Ionizing & Non-Ionizing Dose
    - Charging
      - Biasing of instrument readings
      - Pulsing
      - Power drains
      - Physical damage
      - Degradation of micro-electronics
      - Degradation of optical components
      - Degradation of solar cells
  - Single Event Effects
    - Degradation of micro-electronics
    - Data corruption
    - Noise on Images
    - System shutdowns
    - Circuit damage
  - Neutral gas particles
  - Ultraviolet & X-ray
  - Micrometeoroids & orbital debris
- Drag
  - Torques
  - Orbital decay
- Surface Erosion
  - Degradation of thermal, electrical, optical properties
  - Degradation of structural integrity
- Impacts
  - Structural damage
  - Decompression

**Why is Solar Weather a Concern for Launch?**

For example, for Solar Radiation Storms:

<table>
<thead>
<tr>
<th>Scale</th>
<th>Description</th>
<th>Effect</th>
<th>Physical measure (flux level of $\geq 10$ MeV particles)</th>
<th>Average Frequency (1 cycle = 11 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 5</td>
<td>Extreme</td>
<td><strong>Biological:</strong> Unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. <strong>Satellite operations:</strong> Satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. <strong>Other systems:</strong> Complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.</td>
<td>$10^5$</td>
<td>Fewer than 1 per cycle</td>
</tr>
<tr>
<td>S 4</td>
<td>Severe</td>
<td><strong>Biological:</strong> Unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. <strong>Satellite operations:</strong> May experience memory device problems and noise on imaging systems; star-tracker problems may cause orientation problems, and solar panel efficiency can be degraded. <strong>Other systems:</strong> Blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.</td>
<td>$10^4$</td>
<td>3 per cycle</td>
</tr>
<tr>
<td>S 3</td>
<td>Strong</td>
<td><strong>Biological:</strong> Radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. <strong>Satellite operations:</strong> Single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. <strong>Other systems:</strong> Degraded HF radio propagation through the polar regions and navigation position errors likely.</td>
<td>$10^3$</td>
<td>10 per cycle</td>
</tr>
<tr>
<td>S 2</td>
<td>Moderate</td>
<td><strong>Biological:</strong> Passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk. <strong>Satellite operations:</strong> Infrequent single-event upsets possible. <strong>Other systems:</strong> Small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.</td>
<td>$10^2$</td>
<td>25 per cycle</td>
</tr>
<tr>
<td>S 1</td>
<td>Minor</td>
<td><strong>Biological:</strong> None. <strong>Satellite operations:</strong> None. <strong>Other systems:</strong> Minor impacts on HF radio in the polar regions.</td>
<td>$10$</td>
<td>50 per cycle</td>
</tr>
</tbody>
</table>

Source: Space Weather Prediction Center, [http://www.swpc.noaa.gov/noaa-scales-explanation](http://www.swpc.noaa.gov/noaa-scales-explanation)
Space Weather Monitoring

Daily review of solar weather and expected impacts

Eastern Range Space Environment Situational Awareness

Space Weather Impacts Summary

Solar Flare Probabilities: M: 40% X: 0% P: 10%

Solar Region Summary

AXXX02 RWNE 180030
Joint USAF/NOAA Solar Region Summary
SRS Number 261 Issued at 0030Z on 18 Sep 2015
Report compiled from data received at SWO on 17 Sep
I. Regions with Sunspots. Locations Valid at 17/2400Z
Nmbr Location Lo Area Z LL NN Mag Type
2149 21016 235 0210 Eqm 11 00 Beta-Sunmax
2418 12419 220 0210 Eqm 07 04 Beta
2419 N12E21 198 0100 Eqm 06 08 Beta
IA. H-alpha Flages without Spots. Locations Valid at 17/2400Z
Nmbr Location Lo
None
II. Regions Due to Return 18 Sep to 20 Sep
Nmbr Lat Lo
None

For more detailed information go to:
http://weather.af.mil/confluence/display/AFWIRE/180030spaceWeatherMainPage
http://weather.aff.mil/confluence/display/AFWIRE/180030spaceWeatherMainPage
Forecasting Space Weather for Launch

- Observe current sun spot complexity and location
- Review recent space weather events (i.e. CMEs, Solar Flares)
- Review Air Force 557 WW (formerly AFWA) and NOAA Space Weather Prediction Center (SWPC) products (Goddard too!)
- Indicate Solar Weather is Low/Moderate/High on L-3, L-2, and L-1 Launch Forecasts
Monitoring Space Weather for Launch

- Launch Weather Officer contacts 557 WW Space Weather Operation Center for update
- Monitor live data during the launch countdown. Report space weather to customer during periodic briefings during the countdown
- Report any trends toward or violations of customer space weather constraints
- Customer determines whether or not they will launch given the situation
Eastern Range Launch Related Events

Exceeding Constraints: X- or M-Class Flares Preceded

- X-Class Flare Occurred: 57%
- Both X- and M-Class Flare Occurred: 11%
- M-Class Flare Occurred: 25%
- Inconclusive: 7%

June 2, 1996 – Sep 22, 2015
Example: Kodiak Launch Sep 2001

Timeline

- Sep 21: Scrub due to winds gusting to 45 knots
- Sep 22: Scrub due to mandatory telemetry radar system down
- Sep 23: Thick Cloud and low-cloud ceiling scrubbed launch
- Sep 24: Weather looked promising until X-class solar flare erupted
  - Constraint = 10 MeV
    Proton Flux < 10pfu
  - Result: 5 day launch delay to protect sensitive avionics
- Sep 29: Launch and successful deployment of 4 satellites
Data: Kodiak Launch 2001

Launch Delayed

Launch

Updated 2001 Sep 26 23:56:03 UTC
NOAA/SEC Boulder, CO USA