45th Weather Squadron
Space Weather Support to Launch
Space Weather Workshop, April 2017

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Cape Canaveral Air Force Station
“Exploit the Weather to Assure Safe Access to Air and Space”
Background

Florida Spaceport

- KSC
- CCAFS
- Patrick AFB
• Weather Impacts
  • Launch Operations
  • Ground Operations
  • Aviation Missions
  • Special Missions
Weather Impacts to Launch

- A third of launch delays due to weather
- Nearly half of launch scrubs due to weather

1 Jan 88–29 Mar 17 (29+ Years)

Countdowns (100%)

→ Launch (62%)
  → On time (68% / 42%)
  → Delay (32% / 20%)
  → Scrub (38%)
    → Weather (31% / 6%)
    → Customer/Range Issues (69% / 14%)

→ Weather (49% / 18%)
  → Customer/Range Issues (51% / 19%)
Why is Solar Weather a Concern for Launch?

- Plasma
  - Charging
    - Biasing of instrument readings
    - Pulsing
    - Power drains
    - Physical damage

- Particle radiation
  - Ionizing & Non-Ionizing Dose
    - Degradation of microelectronics
    - Degradation of optical components
    - Degradation of solar cells
  - Single Event Effects
    - Data corruption
    - Noise on Images
    - System shutdowns
    - Circuit damage

- Neutral gas particles
  - Drag
    - Torques
    - Orbital decay

- Ultraviolet & X-ray
  - Space Erosion
  - Degradation of thermal, electrical, optical properties
  - Degradation of structural integrity

- Micro-meteoroids & orbital debris
  - 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 &gt;= 10 MeV particles)</th>
<th>Average Frequency (1 cycle = 11 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S 5</td>
<td>Extreme</td>
<td>Biological: 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. Satellite operations: 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. Other systems: Complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.</td>
<td>10⁵</td>
<td>Fewer than 1 per cycle</td>
</tr>
<tr>
<td>S 4</td>
<td>Severe</td>
<td>Biological: Unavoidable radiation hazard to astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. Satellite operations: May experience memory device problems and noise on imaging systems; star-trackers problems may cause orientation problems, and solar panel efficiency can be degraded. Other systems: Blackout of HF radio communications through the polar regions and increased navigation errors over several days are likely.</td>
<td>10⁴</td>
<td>3 per cycle</td>
</tr>
<tr>
<td>S 3</td>
<td>Strong</td>
<td>Biological: Radiation hazard avoidance recommended for astronauts on EVA; passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. Satellite operations: Single-event upsets, noise in imaging systems, and slight reduction of efficiency in solar panel are likely. Other systems: Degraded HF radio propagation through the polar regions and navigation position errors likely.</td>
<td>10³</td>
<td>10 per cycle</td>
</tr>
<tr>
<td>S 2</td>
<td>Moderate</td>
<td>Biological: Passengers and crew in high-flying aircraft at high latitudes may be exposed to elevated radiation risk. Satellite operations: Infrequent single-event upsets possible. Other systems: Small effects on HF propagation through the polar regions and navigation at polar cap locations possibly affected.</td>
<td>10²</td>
<td>25 per cycle</td>
</tr>
<tr>
<td>S 1</td>
<td>Minor</td>
<td>Biological: None. Satellite operations: None. Other systems: Minor impacts on HF radio in the polar regions.</td>
<td>10</td>
<td>50 per cycle</td>
</tr>
</tbody>
</table>

**Space Weather Monitoring**

Daily review of solar weather and expected impacts

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**Eastern Range Space Environment Situational Awareness**

- **Valid:** 22 Sep 2015 0000Z
- **Today:** 22 Sep
- **3 Day Forecast:** 22 Sep, 24 Sep, 26 Sep

**Space Weather Impacts Summary**

- **HF Comm (YELLOW or RED):** Temporarily degraded or total loss of HF radio communications.
  - Forecast **GREEN:** 22 - 25 Sep during all hrs.
- **UHF SatComm (YELLOW or RED):** Temporarily degraded or total loss of UHF radio communications.
  - Forecast **RED (Severe Condition):** 22 - 25 Sep during night hrs.
  - Forecast **GREEN:** 22 - 25 Sep during day hrs.
- **High Alt Flight Radiation (YELLOW or RED):** Increased harmful radiation dosage to personnel in high altitude operations.
  - Forecast **GREEN:** 22 - 25 Sep during all hrs.
- **Radar Interference (YELLOW or RED):** Increased interference or false returns to surveil and poleward looking radar.
  - Forecast **GREEN:** 22 - 25 Sep during all hrs.
- **GPS Error (Single Freq):** Temporarily degraded or total loss of GPS signal.
  - Forecast **GREEN:** 22 - 25 Sep during all hrs.

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**Solar Region Summary**

- **AXXX02 KWNF 180030**
- **Joint USAF/NOAA Solar Region Summary**
- **SRS Number 261 Issued at 0003Z on 18 Sep 2015**
- **Report compiled from data received at SWO on 17 Sep**
- **I. Regions with Sunspots. Locations Valid at 17/2400Z**
  - **Nbr Location Lo**
  - **Area Z**
  - **LL**
  - **NN Mag Type**
  - 2415 S20W16 235 0230 Egr 11 30 Beta-Gamma
  - 2418 S14E19 200 0210 Cso 07 04 Beta
  - 2419 N12E21 198 0100 Cao 06 08 Beta
- **IA. H-alpha Flages without Spots. Locations Valid at 17/2400Z**
  - **Nbr Location Lo**
  - **None**
- **II. Regions Due to Return 18 Sep to 20 Sep**
  - **Nbr Lat Lo**
  - **None**
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 and NOAA Space Weather Prediction Center (SWPC) products (Goddard too!)
- Indicate Solar Weather is Low/Moderate/High on 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
Exceeding Constraints: X- or M-Class Flares Preceded

- 57% X-Class
- 25% M-Class
- 11% M- & X-
- 7% Inconclusive

- X-Class Flare Occurred
- Both X- and M-Class Flare Occurred
- M-Class Flare Occurred
- Inconclusive

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

Flare
GOES X-ray Flux (5 minute data) Begin: 2001 Sep 24

Launch Delayed

Launch