Surface charging is the result of a current balance on the surface of a spacecraft. The currents of satellite thrusters can push a spacecraft from an initial energy $E_0$ to a final energy $E = E_0 + q\phi$ during this time period.

Temporal variations of the spacecraft potential through a charging event are important since extreme potentials may reach kilovolt levels in auroral charging environments, but Mean potentials over the period of a charging event never exceed a few hundred volts to few kilovolts negative frame potentials.

Auroral charging is most common during solar minimum conditions and most commonly encountered in the midnight sector of the auroral oval (Frooninckx and Sojka, 1992; Wahlund et al. 1999; Ericksson and Wahlund, 2005; Anderson 2000, 2001, 2012). However, we find that auroral charging events continue to occur on DMSP F16 for the current near solar maximum conditions of Solar Cycle 24. The relatively low activity of Cycle 24 compared to the recent cycles included in the previous studies results in sufficiently low ambient plasma densities to allow auroral charging to persist through the current solar maximum.

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The F10.7 index as a function of time showing solar variability over the current and recent solar cycles. Depleted electron densities resulting in stronger auroral charging is typically expected during solar minimum when solar EUV levels are low.

1. Satellite is in darkness
2. An intense, energetic electron (> 14 keV/particle) precipitation event is required (flux > 10^6 electrons cm^-2 s^-1 sr^-1)
3. Locally depleted (< 10^5 cm^-3) ambient plasma density

Surface charging is the result of a current balance on the surface of a spacecraft. The currents of importance to surface charging are: Incident ions, incident electrons, backscattered electrons, conduction currents, secondary electrons, photoelectrons, and active current sources (beams, thrusters).

Auroral charging is readily identified from the "ion line" signature that appears in ion electrostatic analyser records. The ion line is the result of ambient low energy ions accelerated by the spacecraft potential from an initial energy $E_i$ to a final energy $E = E_i + q\phi$ where $q$ is the charge of the ion and $\phi$ the spacecraft surface potential in volts.

Examples shown here result from an effort to characterize extreme auroral charging events. These events are encountered infrequently by spacecraft in polar low Earth orbit but are the kind of event that drive spacecraft operations in auroral charging environments. We focus on the extreme potentials, duration the potentials exceed a threshold value, and mean potentials because the information is needed by spacecraft designers for evaluating the response of the spacecraft to the charging environment.

Past studies have reported auroral charging events predominantly during solar minimum conditions. However, we have observed charging events on DMSP F16 of nearly -1000 V during the approach to solar maximum conditions due to the lower than average solar activity in Solar Cycle 24. We focus this study on the solstices (Nov, 2011 - Jan, 2012, May - July, 2012, and May - July, 2013) due to the larger likelihood of encountering charging events in order to document auroral charging for Solar Cycle 24 solar maximum conditions.

Temporal variations of the spacecraft potential through a charging event are important since extreme potentials are generally only a subset of the charging event.

Frame potentials may reach kilovolt levels in auroral charging environments, but the duration of charging at these most extreme levels are limited to periods of a few seconds to perhaps ten to fifteen seconds.

Mean potentials over the period of a charging event never exceed a few hundred volts.

No charging events were seen in the northern hemisphere winter months for periods included in this study.

Future work will include time periods from Solar Cycle 24 not included in this study to more fully characterize the auroral charging environment for this solar maximum period. A paper to Geophysical Research Letters is in work.

**Conditions Required for Auroral Charging**

1. Satellite is in darkness
2. An intense, energetic electron (> 14 keV/particle) precipitation event is required (flux > 10^6 electrons cm^-2 s^-1 sr^-1)
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**Conclusions**

- Examples shown here result from an effort to characterize extreme auroral charging events. These events are encountered infrequently by spacecraft in polar low Earth orbit but are the kind of event that drive spacecraft design. We focus on the extreme potentials, duration the potentials exceed a threshold value, and mean potentials because the information is needed by spacecraft designers for evaluating the response of the spacecraft to the charging environment.
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**Abstract**

It has been well established that polar orbiting satellites can experience mild to severe auroral charging levels (on the order of a few hundred volts to few kilovolts negative frame potentials) during solar minimum conditions (Frooninckx and Sojka, 1992; Anderson and Koons, 1996; Anderson, 2012). These same studies have shown a strong reduction in charging during the rising and declining phases of the past few solar cycles with a nearly complete suppression of auroral charging at solar maximum. Recently, we have observed examples of high level charging during the recent approach to Solar Cycle 24 solar maximum conditions not unlike those reported by Frooninckx and Sojka (1992). These observations demonstrate that spacecraft operations during solar maximum cannot be considered safe from auroral charging when solar activity is low. We present a survey of auroral charging events experienced by the Defense Meteorological Satellite Program (DMSP) F16 satellite during Solar Cycle 24 maximum conditions. We summarize the auroral energetic particle environment and the conditions necessary for charging to occur in this environment, we describe how the lower than normal solar activity levels for Solar Cycle 24 maximum conditions are conducive to charging in polar orbits, and we show examples of the more extreme charging events, sometimes exceeding 1 kV, during this time period.

**Solar Cycle**

The F10.7 index as a function of time showing solar variability over the current and recent solar cycles. Depleted electron densities resulting in stronger auroral charging is typically expected during solar minimum when solar EUV levels are low.

**Auroral Charging Study Periods**

- Red: Frooninckx and Sojka, 1992
- Grey: Anderson, 2012
- Blue: Current study

**Frequency and Distribution of Auroral Charging**

- (a) DMSP Charging Frequency: December 1986 – January 1987
- (b) DMSP Charging Frequency: May 21 – July 21, 2012
- (c) DMSP Charging Frequency: May 21 – July 21, 2013
- (d) Distribution of DMSP Charging Events
- (e) DMSP Charging Power: May 21 – July 21, 2012
- (f) DMSP Charging Power: May 21 – July 21, 2013

**Summary**

<table>
<thead>
<tr>
<th>Date</th>
<th>Charging Event</th>
<th>Potential (volts)</th>
<th>Charge (10^6 cm^-2 s^-1 sr^-1)</th>
<th>Flux (10^6 electrons cm^-2 s^-1 sr^-1)</th>
</tr>
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<tbody>
<tr>
<td>May 21 – July 21, 2012</td>
<td>2012-06-10</td>
<td>150</td>
<td>1150</td>
<td>1150</td>
</tr>
<tr>
<td>May 21 – July 21, 2013</td>
<td>2013-06-11</td>
<td>170</td>
<td>1700</td>
<td>1700</td>
</tr>
</tbody>
</table>