

## What is a Space Weather Anomaly?

An unexplained error in satellite functioning that causes data loss or interruption.

There are 131 anomalies that are being investigated to attempt to find the cause of the disturbance.

## Methodology:

- Data was gathered from various online catalogs.
- Anomalies were plotted over top the data to see if any spikes lined up.
- Depending on which graph had a spike, anomalies were categorized by the type of space weather anomaly believed to have caused the event.

## Indices Definitions:

Dst – Measures the worldwide magnetic storm level through the observation of the intensity of the ring current.

Kp – Measures the worldwide geomagnetic level from auroral activity at mid-latitudes.

AE – Measures various events in the auroral zone. A large spike is called a magnetospheric substorm.

These three indices detect the most information that will be useful in determining space weather anomalies. High values of magnetic storms, auroral activity, or magnetospheric substorms will indicate a large amount of surface charging on satellites.

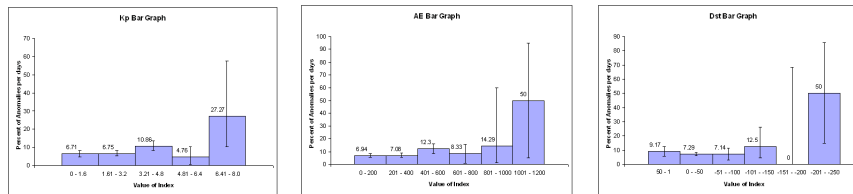
## The Next Steps:

- Analyze the data from Cluster up to present day.
- Analyze data from other spacecraft
- Use all the data to create a more specific prediction method

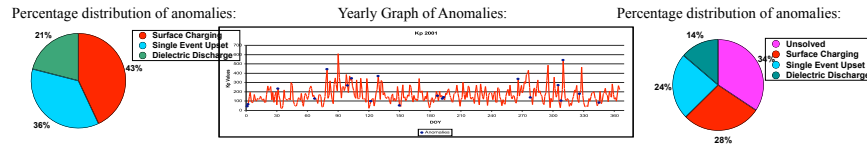
# The Cluster Space Weather Anomalies

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As spacecraft orbit Earth they are subject to bombardment from particles from the sun and other space weather effects. This bombardment can cause an anomaly, which is an interruption of data flow to Earth caused by the particle's interference. There are three main types of anomalies caused by space weather: surface charge, deep dielectric discharge, and single event upset. **The goal of this project was to analyze the 131 anomalies that occurred on the Cluster Spacecraft from August 2000 through March 2005, and determine how many were the result of space weather, which type of anomalies they were, and if possible predict when more anomalies will occur.** There were 86 anomalies that were the result of space weather, with 37 surface charging, 31 single event upsets, and 18 deep dielectric discharging. It has been shown that anomalies are more likely to occur the higher the space weather indices are. Also, the longer the satellites remain in orbit, a higher percentage of anomalies due to space weather occur. Lastly, the prediction of future anomalies was correct with a margin of 12% error.



These bar graphs show the percent chance that anomalies will occur when the indices are in a given range. (The error bars represent a 90% statistical confidence level based on the available sample size)



## Other Statistics

- Anomalies per year are increasing (23, 26, 29, 31).
- 2004 was the year with the most anomalies (31), however, if 2005 continues its trend (10 anomalies in 3 months) there will be 40.
- Cluster Spacecraft 3 has the most anomalies (47) whereas Spacecraft 4 has the least (21).

## Conclusions

- Out of 131 anomalies, 86 have a large value for something relating to space weather (65.6%).
- 8.8 anomalies predicted, 12 actually occurred in the first 3 months of 2005.
- Surface Charging is the most common type of anomaly.
- Prediction of future anomalies is probable, however, predicting which type of anomaly is less likely.
- Anomalies are more likely to occur at higher values of the indices.

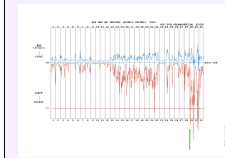
## Types of Space Weather Anomalies

**Surface Charging** - When a charge from geomagnetic storms is built up on the spacecraft thus resulting in electrical discharge.

**Single Event Upset** - When a high energy particle happens to hit a device in just the right spot to cause disruption.

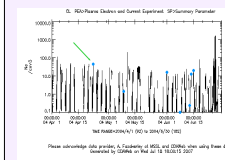
**Deep Dielectric Discharge** - When a charge builds and discharges within a spacecraft after long bombardment from solar particles.

## Surface Charge



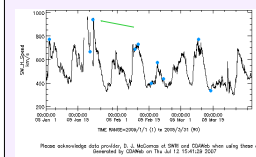
There is a large spike on the Dst and AE indices which indicates a large charge being built up on the spacecraft causing surface charging.

## Deep Dielectric Discharge



There is a large spike on the electron density which indicates a large buildup of energetic particles causing deep dielectric discharging.

## Single Event Upset



There is a large spike in the solar wind which indicates an increase of solar particles hitting the satellite causing single event upsets.

## Bibliography:

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- Coordinated Data Analysis Web (CDAWeb). *Goddard Space Flight Center*. Robert McGuire. 23 Jul. 2007. <[http://cdaweb.gsfc.nasa.gov/istp\\_public/](http://cdaweb.gsfc.nasa.gov/istp_public/)>.
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