

Space Weather

The background of the slide features a stylized visualization of space weather. On the left, a large, textured orange sphere represents the Sun. From the Sun, a series of white, curved lines representing magnetic field lines or solar wind flow outwards. In the center-right, a smaller, reddish-brown sphere represents Earth, surrounded by a complex, multi-lobed structure representing the Earth's magnetosphere and its interaction with the solar wind. The entire scene is set against a dark, reddish-brown background with scattered white stars.

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Definition of Space Weather:

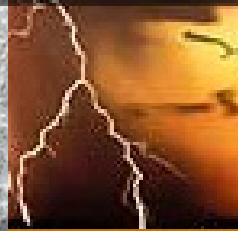
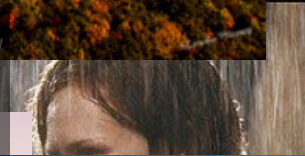
The condition or event in space and in the upper atmosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.

What's this Space Weather Thing?

Weather on Earth



- Precipitation
- Light Displays
- Power of Nature
- Societal Danger



Weather in Space?



- **Precipitation**
- **Light Displays**
- **Power of Nature**
- **Societal Danger**

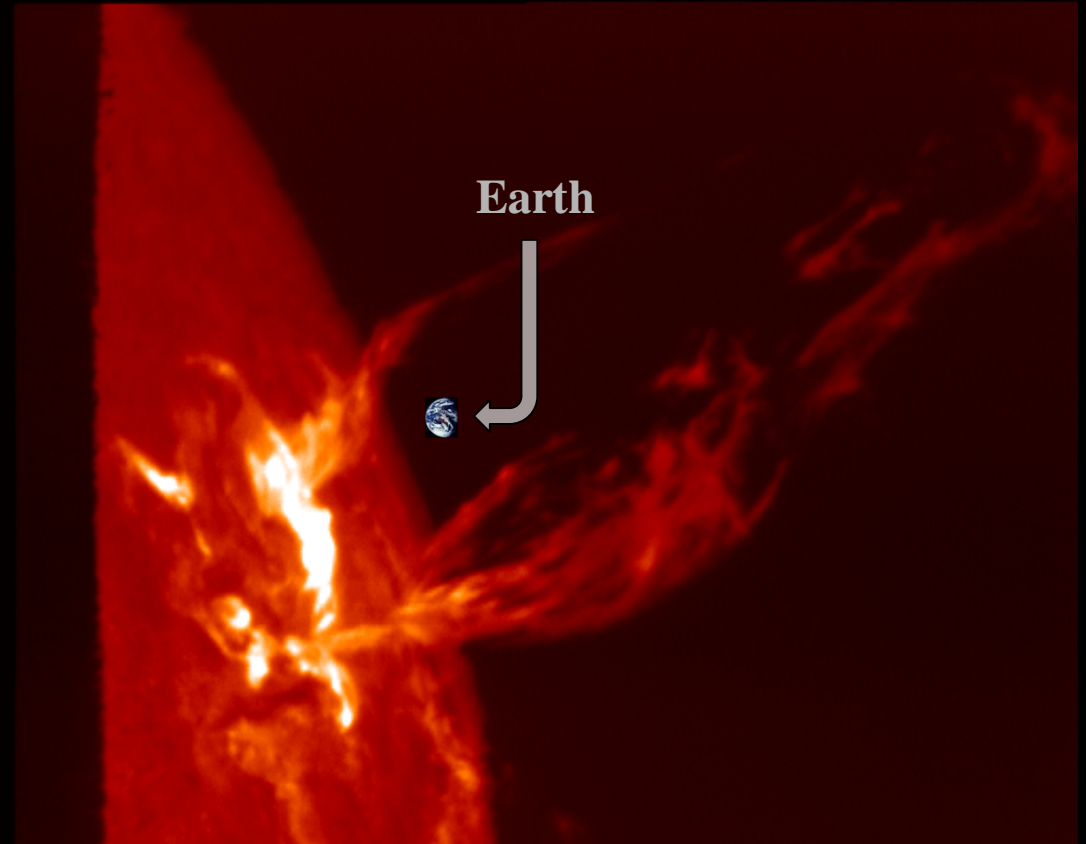
Shock and Awe?

Start at the Sun

Flare or Coronal Mass Ejection:

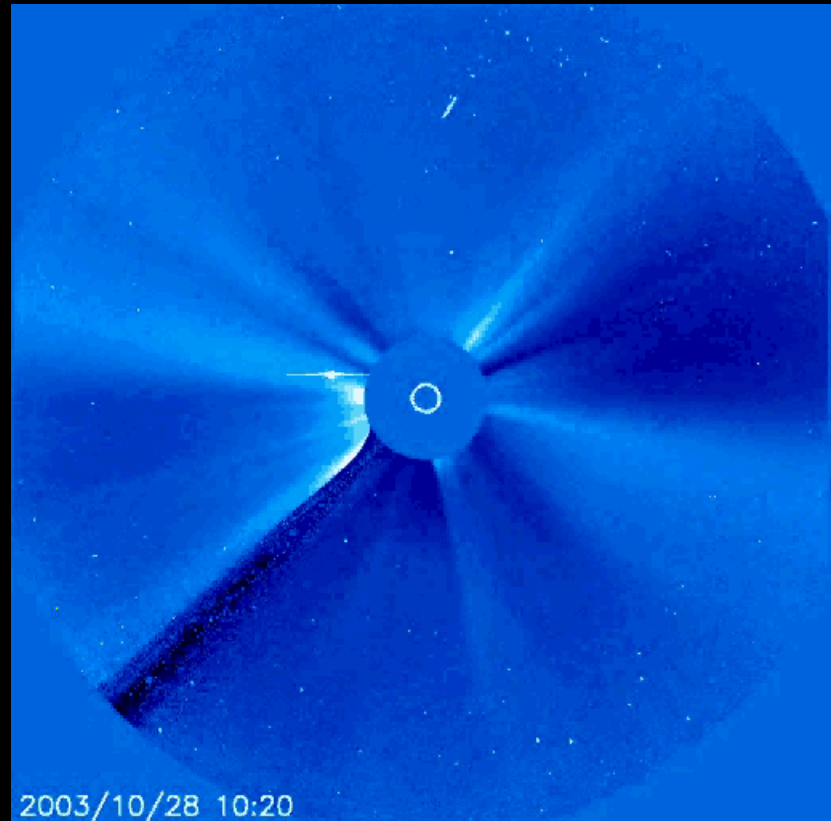
Violent release of as much a billion tons of matter.

Can be equivalent of 40 billion Hiroshima-sized atomic bombs.

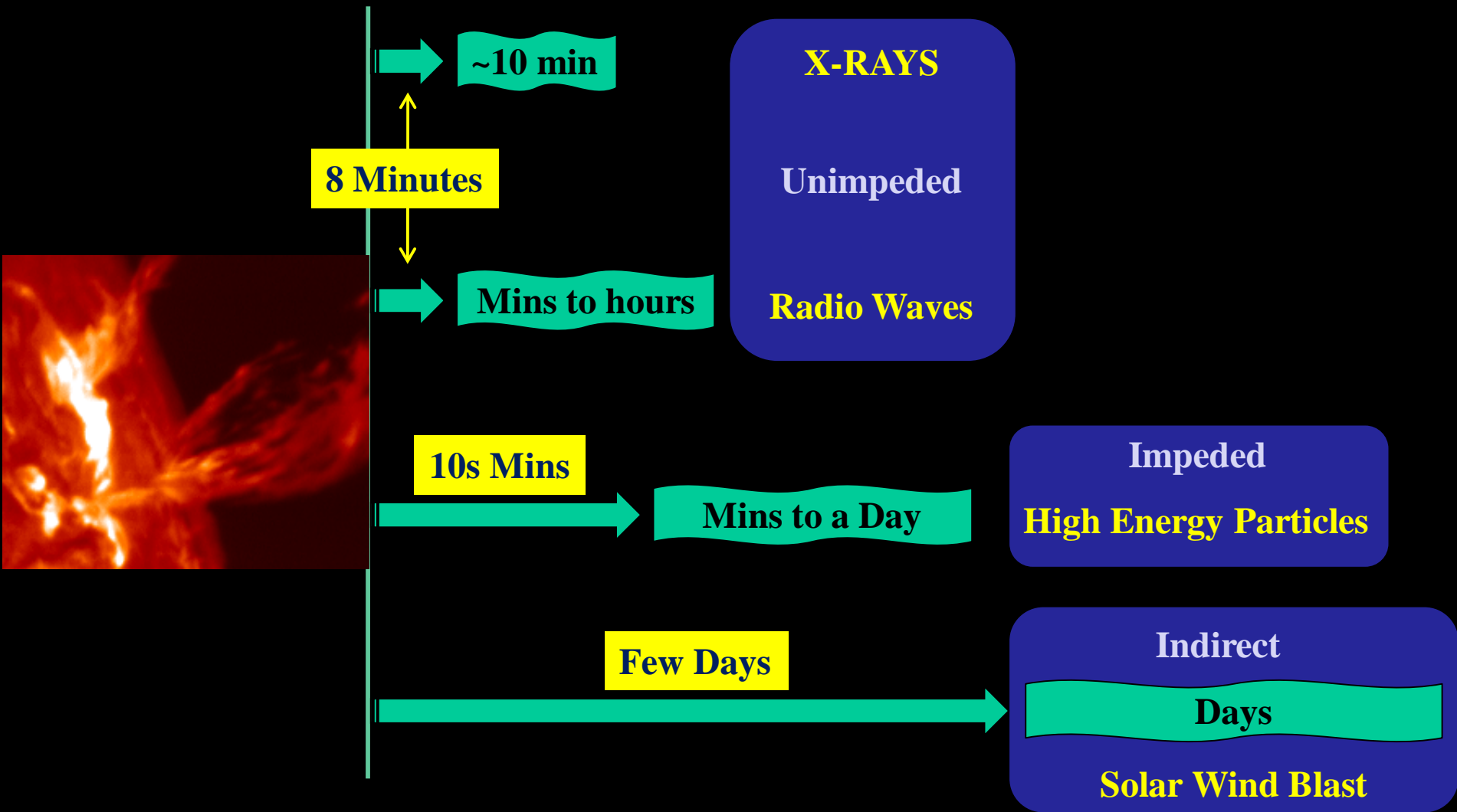


Weather at the Sun or Elsewhere Means There are Events

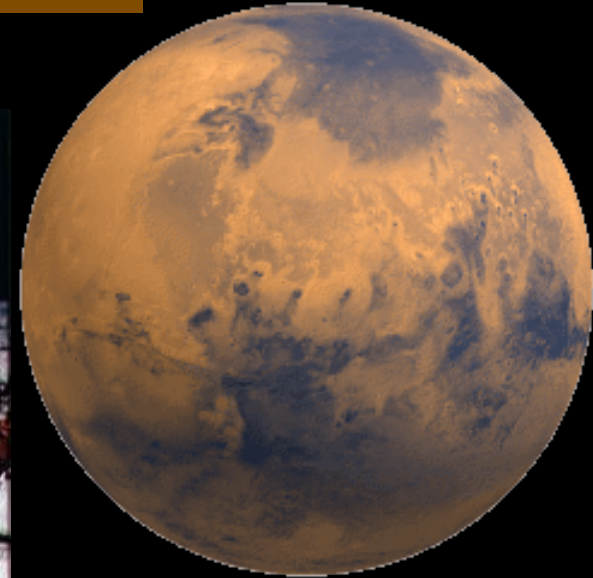
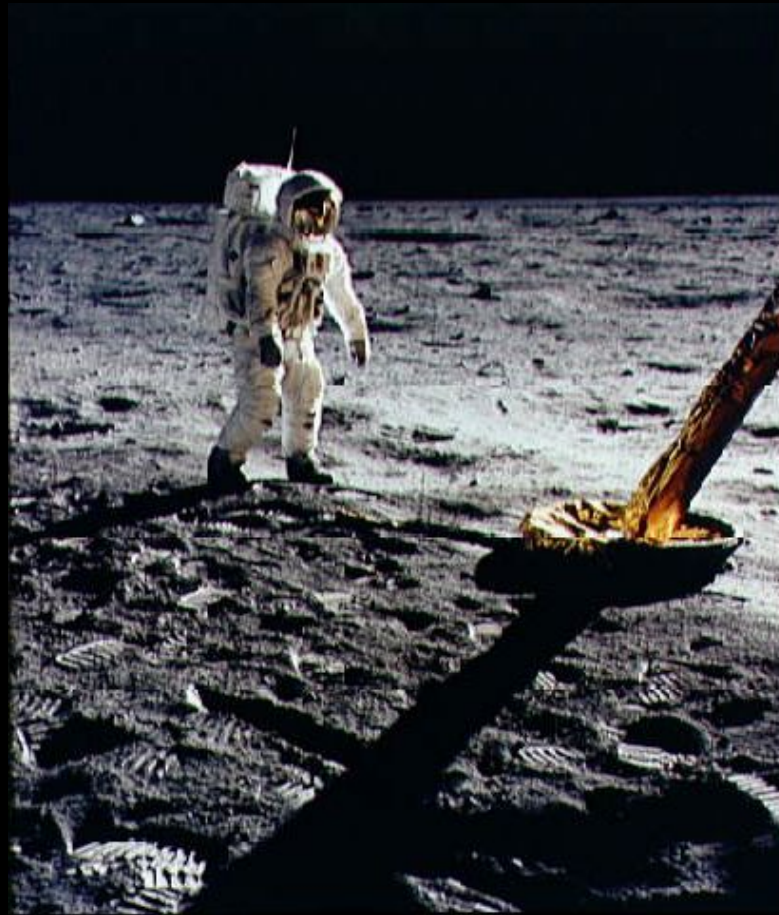
- **What do you see?**
- **Near the Sun?**
- **Far from the Sun?**



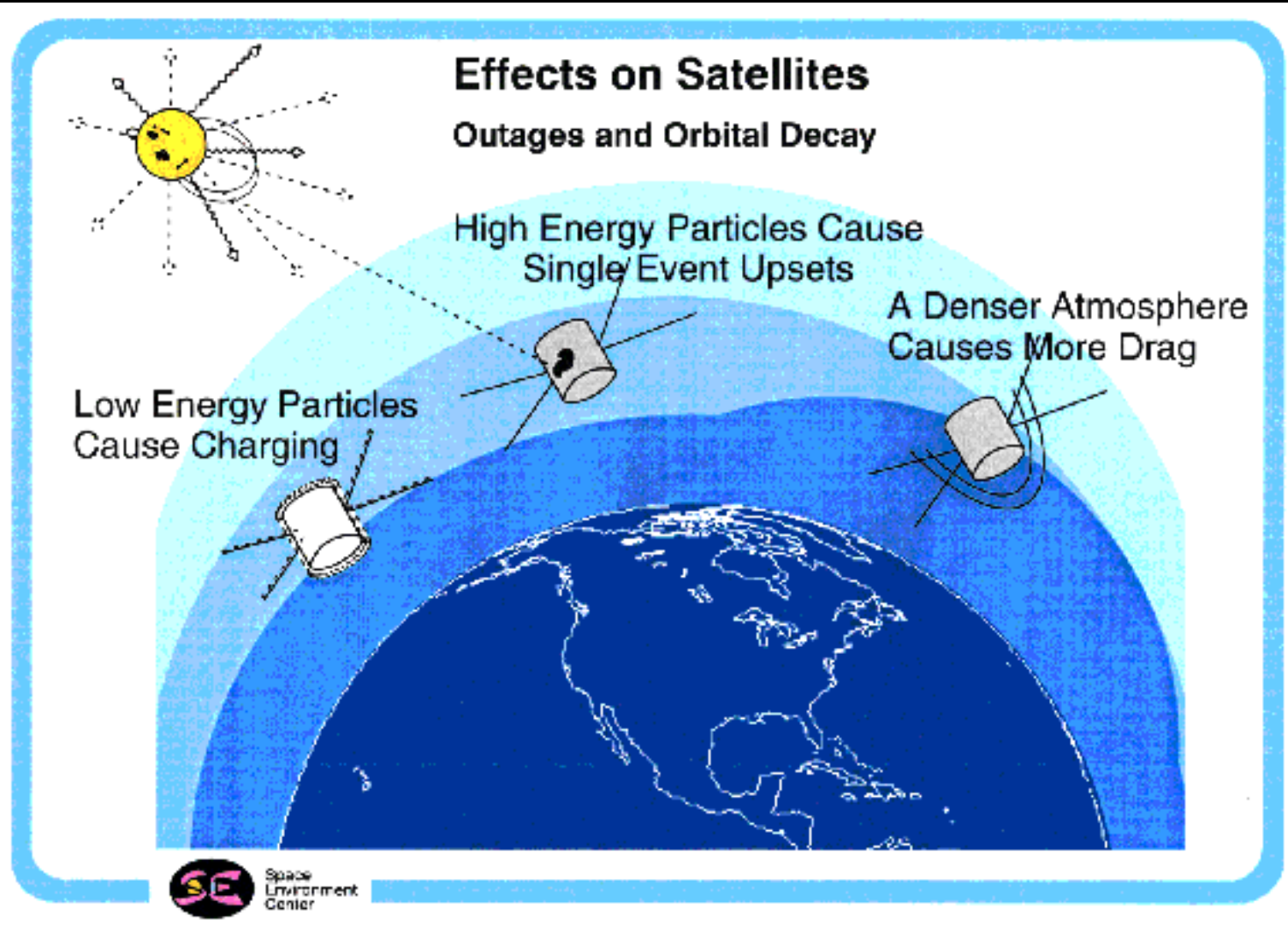
Time Scale for Solar Effects at Earth



Hazards to Humans in Space

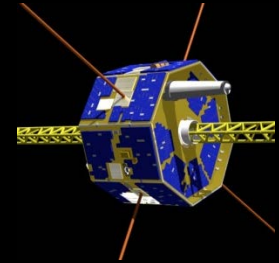


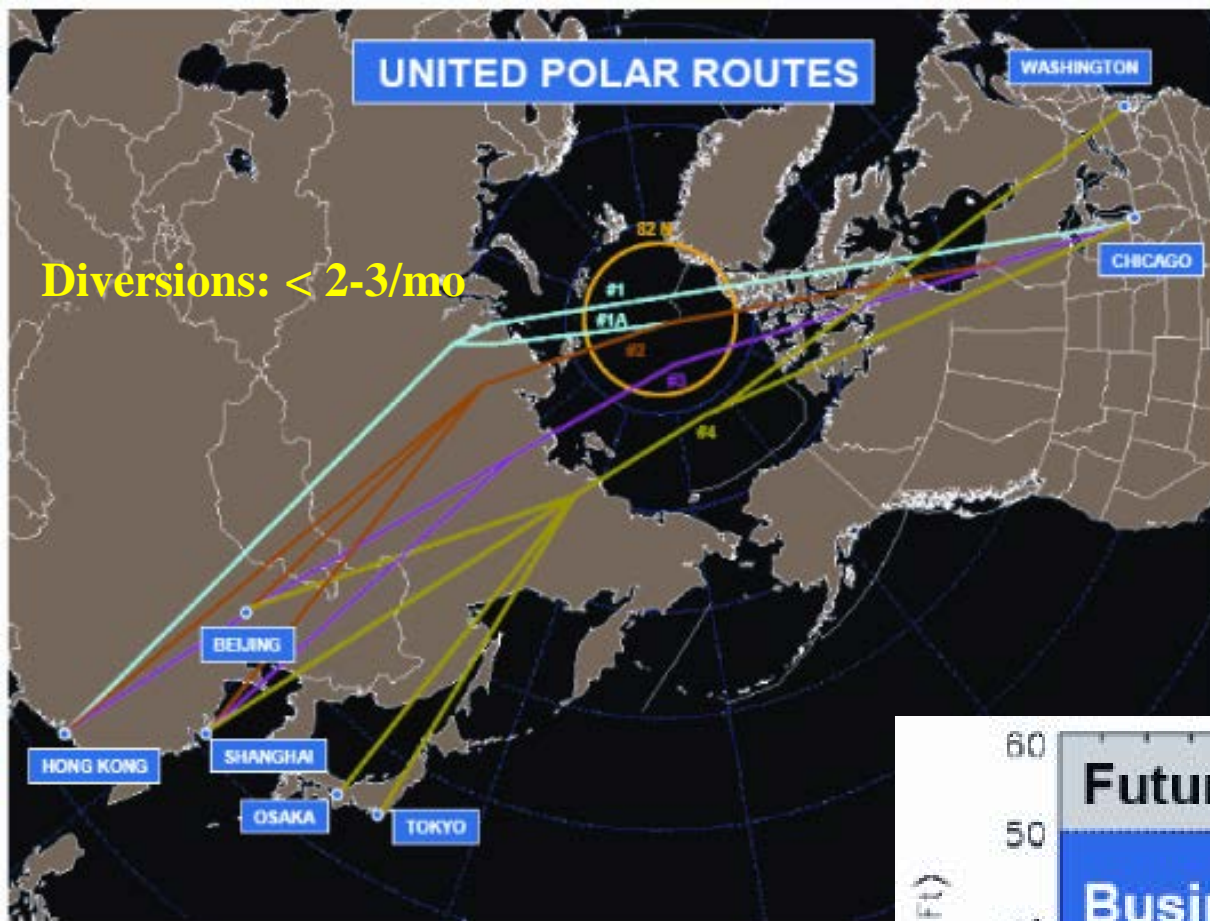
Satellite Hazards



Risks for Electronics

- In space single event upsets (SEUs) cause satellite control errors, risking damage or loss
- In aircraft SEUs cause upsets of about 1 per 200 hours of operation measured on a Boeing 777 autopilot: (designed for 1:1 million); pacemakers have been used to measure SEUs in commercial aircraft
- On the ground SEUs are thought to have caused power losses in German high-speed trains in the 1990's from cosmic radiation.





**Transpolar
Flights and
cosmic
radiation risks
are increasing**

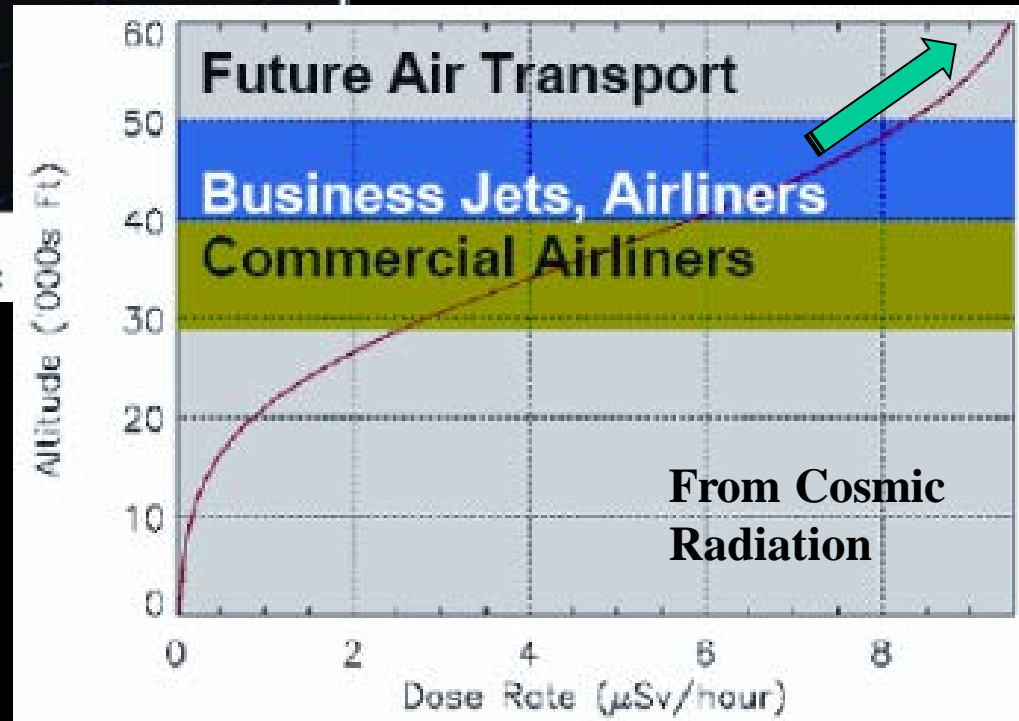


Figure 1. Polar Routes used by United Airlines (source:

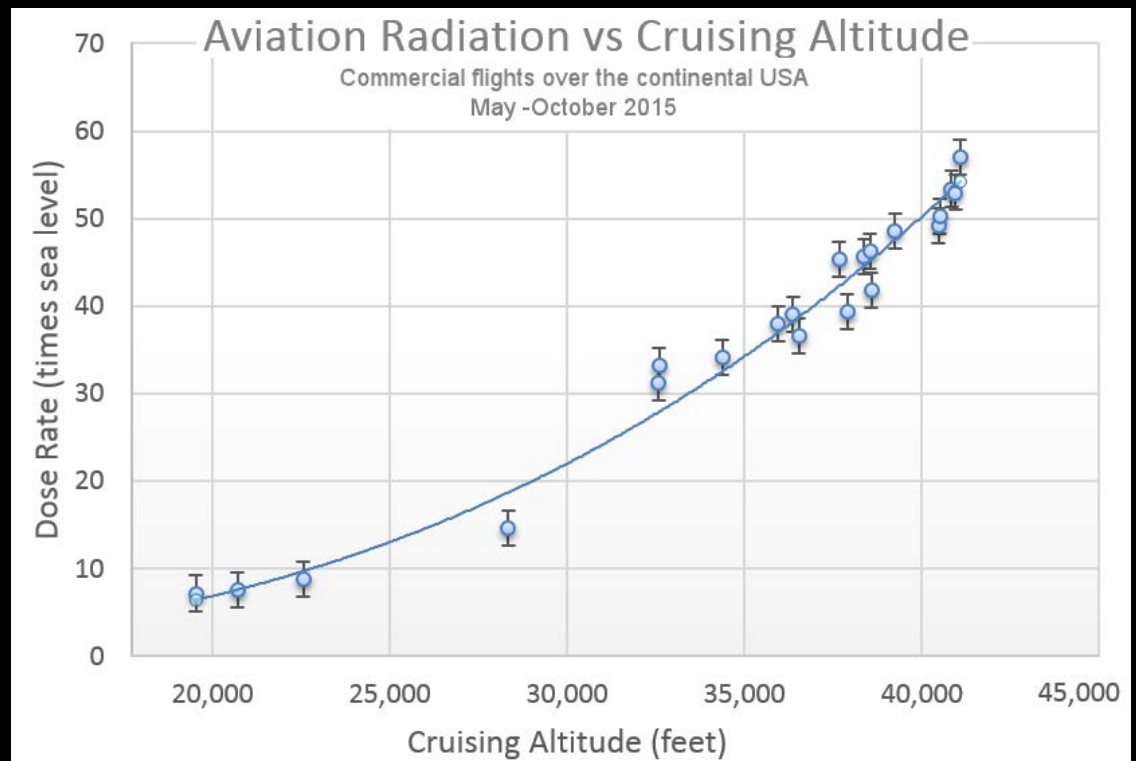
**From the American
Meteorological Society &
SolarMetrics Policy Workshop
Report March 2007**

**Max permissible mean dose
rate limit: 7.5 mSv/hour**

Spaceweather.com and the Students of Earth to Sky Calculus

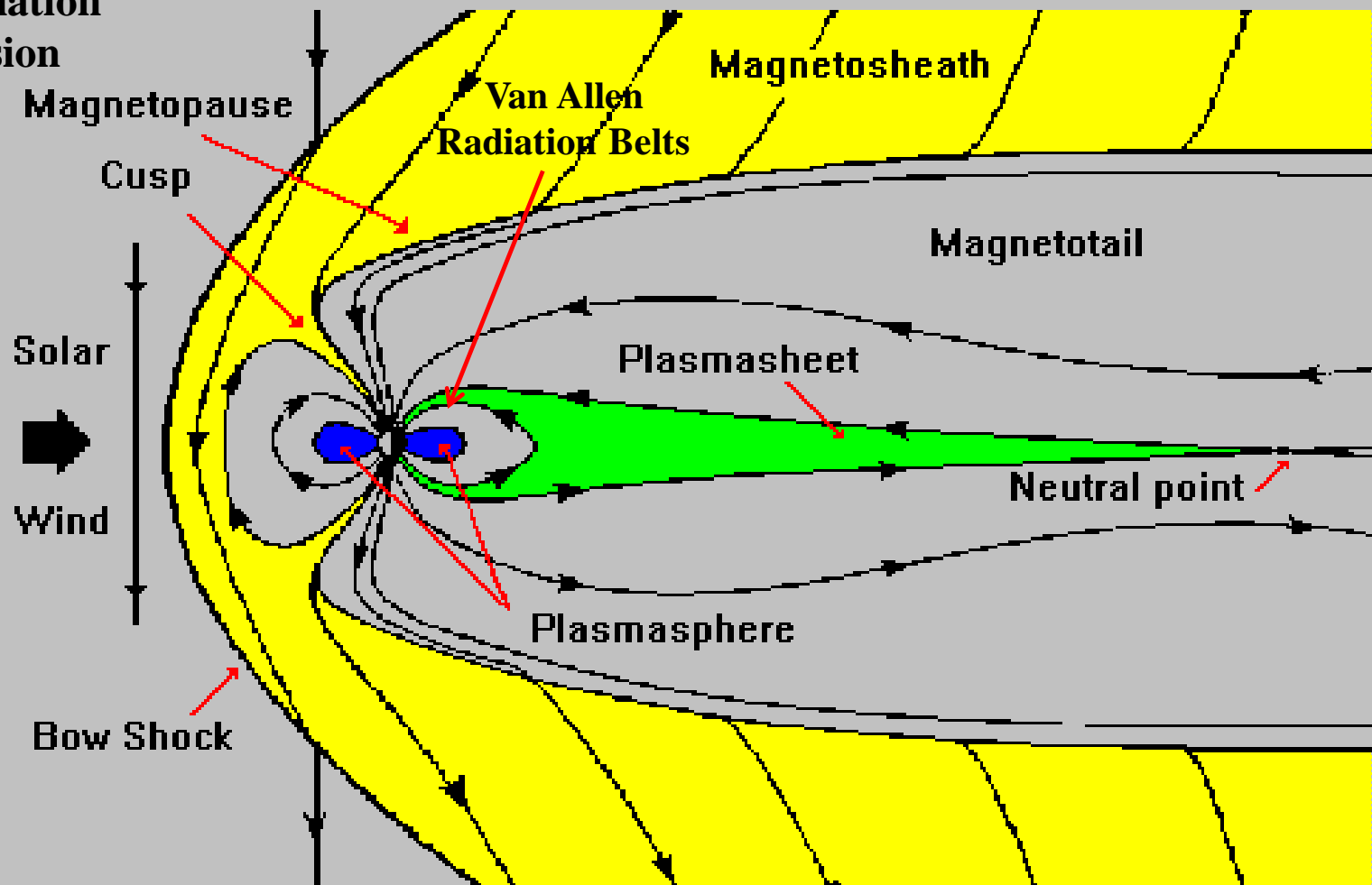
May to October 2015 this group has been bringing their cosmic radiation detectors on commercial aircraft. This chart summarizes their results from inside the airplane on 18 flights in the continental USA.

Cosmic radiation comes from outside the solar system. High solar activity reduces how much reaches Earth, low solar activity like that now coming allow more to reach Earth. Stay tuned for continued reporting in future months...



Earth's Magnetic Environment “The Magnetosphere”

Precipitation
Electric Currents
Ionospheric scintillation
10MW radio emission
Radiation



The biggest shown on Earth... Precipitating high energy particles



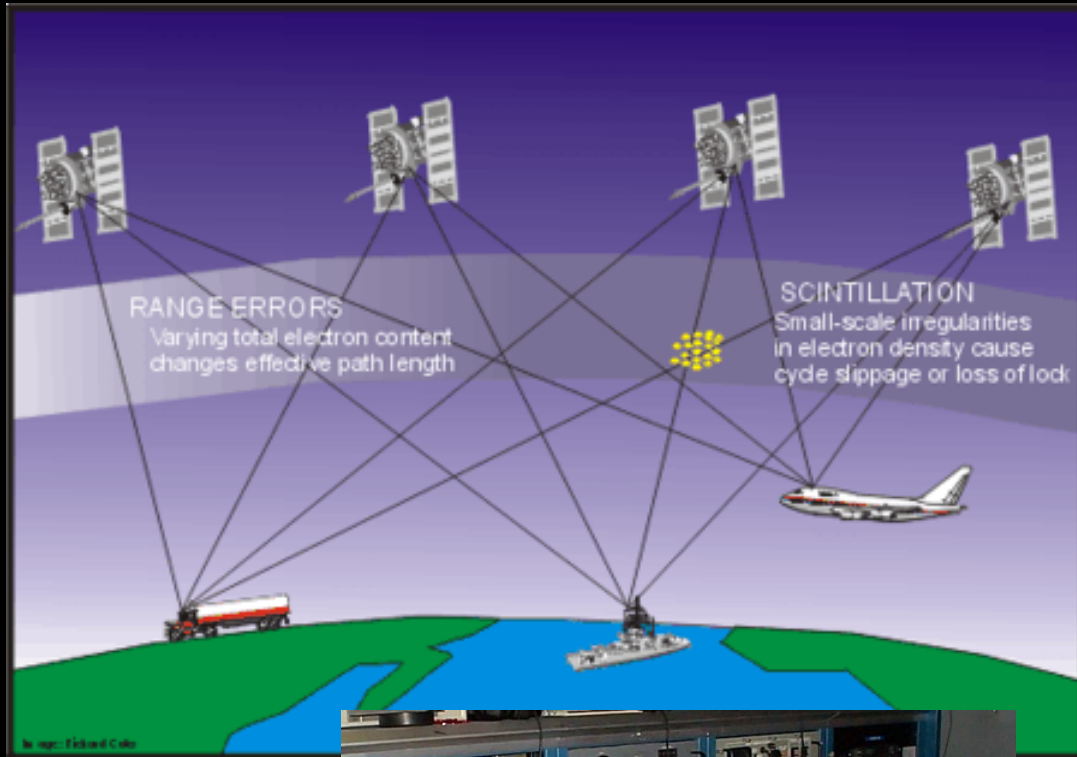
Fairbanks, Alaska

Disruption of:

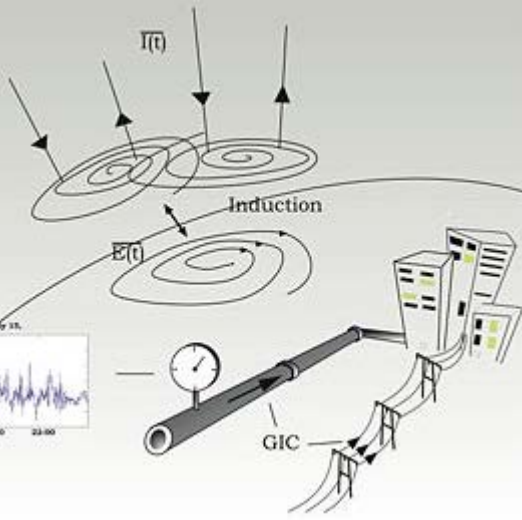
HF

Communication

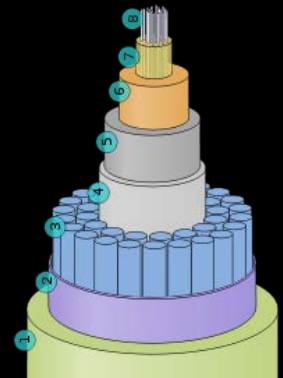
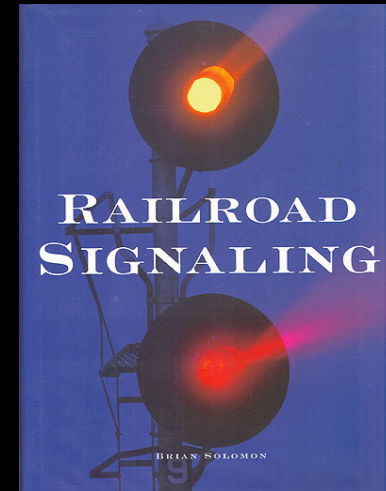
Navigation



Ground Induced Currents (GIC)



- **Railroads:**
 - Sweden in 1982, railway signals failed to switch correctly
 - Norway in 2000, 19 lives were lost
- **Deep Sea Cables:**
 - Space Weather can generate hundreds to thousands of volts



Pipeline Corrosion



**To Fight
Corrosion**

**Applied
Voltage**

-

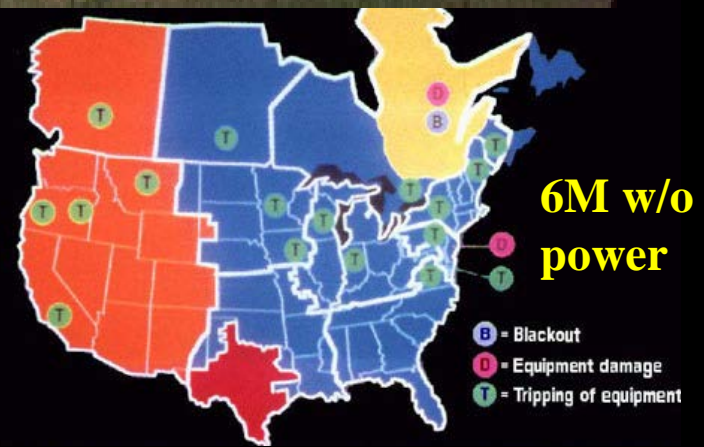
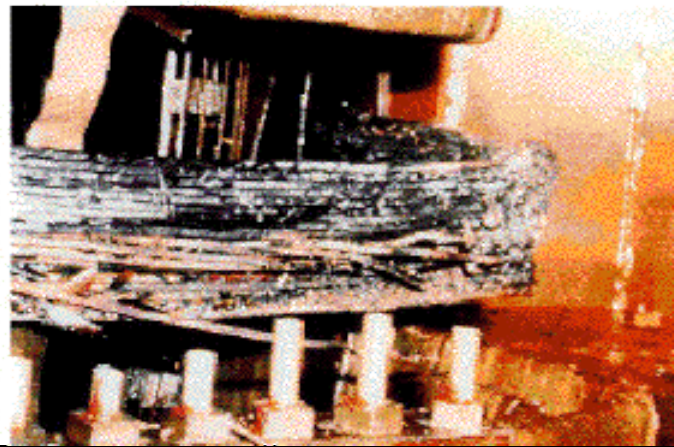
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Electrical Power Disruption Due to Induced Electric Currents

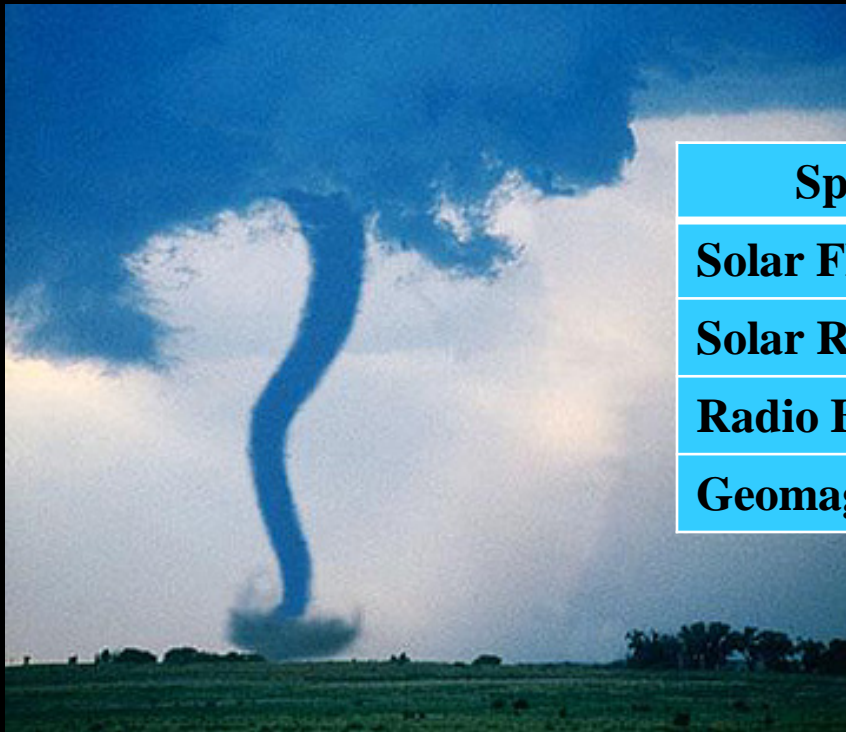









PJM Public Service
Step Up Transformer

Severe internal damage caused by
the space storm of 13 March, 1989



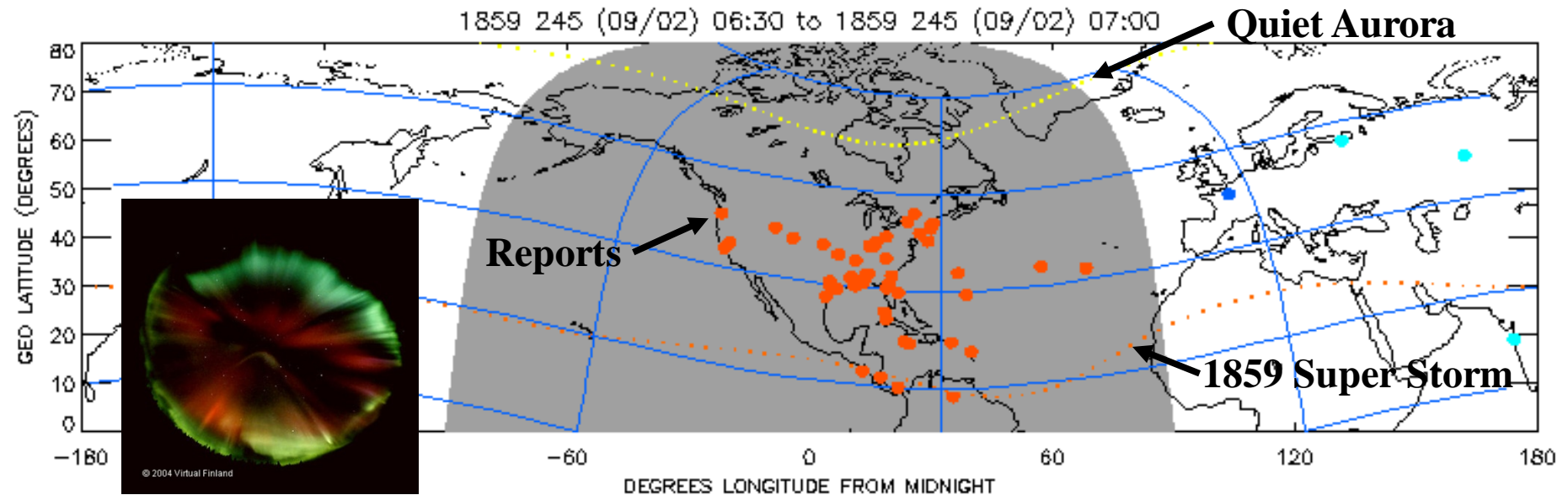
Atmospheric storms are measured.
Space storms are too.



Space Storm	Minor  Extreme
Solar Flares	B  C  M  X
Solar Radiation	S1  S5
Radio Blackouts	R1  R5
Geomagnetic Storms	G1  G5

September 2, 1859 Event

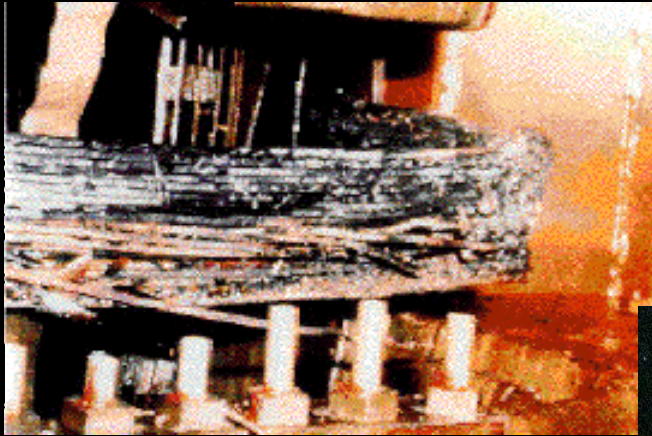
3X recent storm strength / 1/3 strongest ever



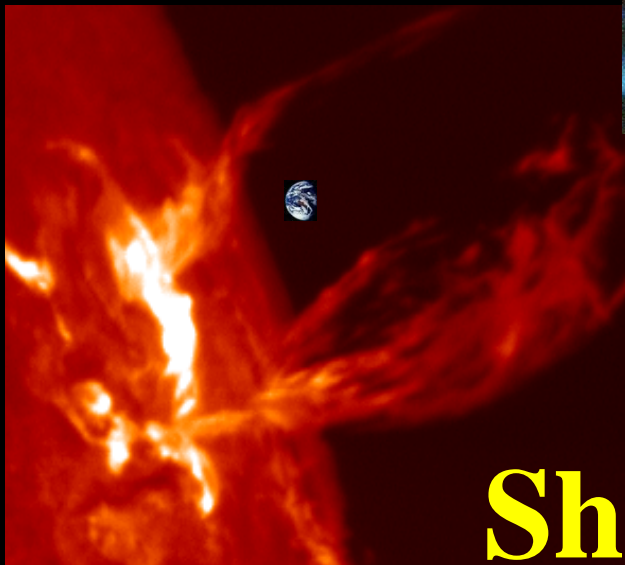
- Messenger (deck log: Lat. 49°) “we witnessed the most magnificent display of the aurora boreales (sic) imaginable ... the whole firmament was a blaze of Crimson shooting up from all points of the compass but the most splendid from the South W. I have not the language to describe it”

Courtesy James L. Green, NASA/GSFC

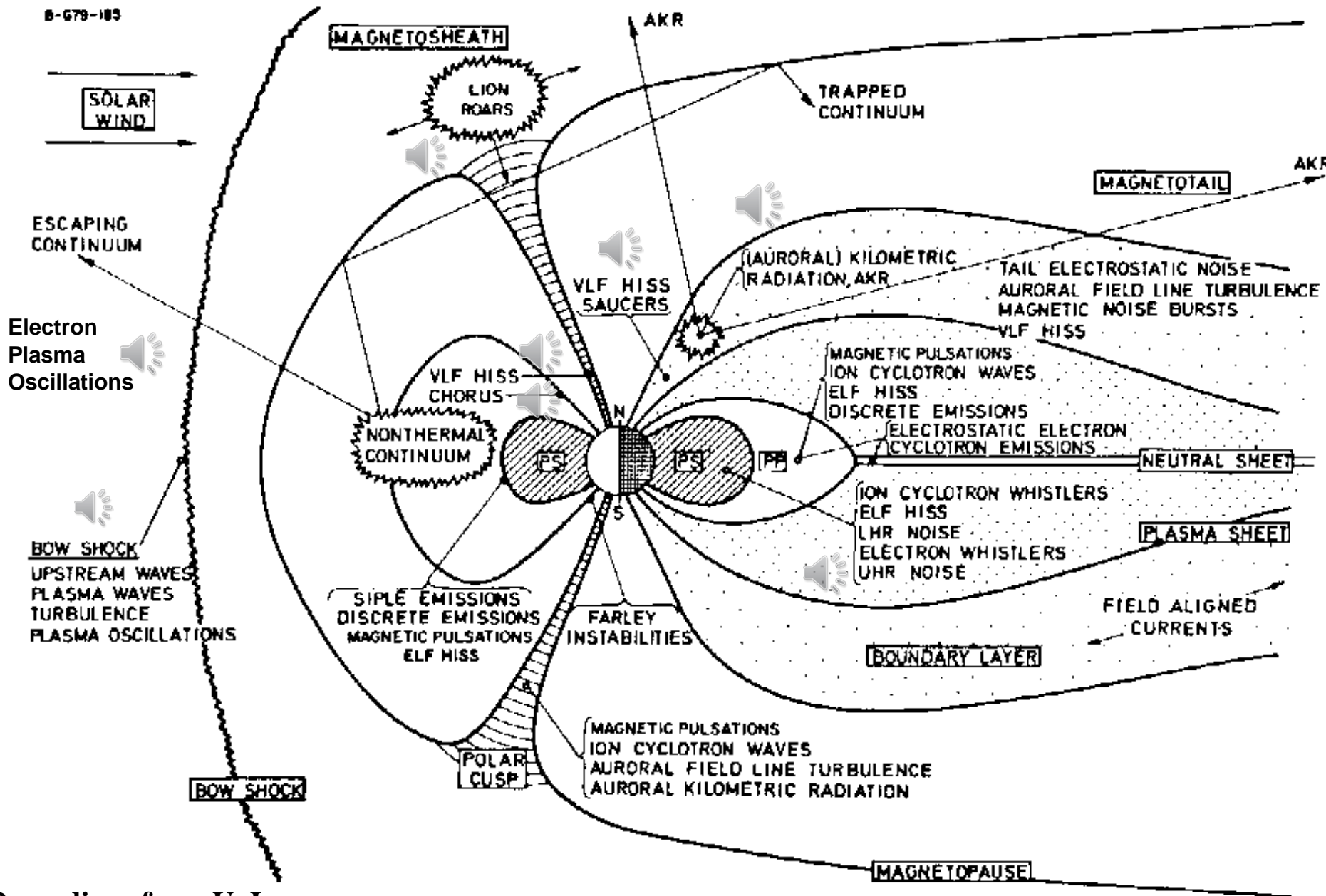
Weather in Space



- Precipitation
- Light Displays
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Shock and Awe



Recordings from U. Iowa Professor Donald Gurnett

PS = PLASMASPHERE PP = PLASMAPAUSE