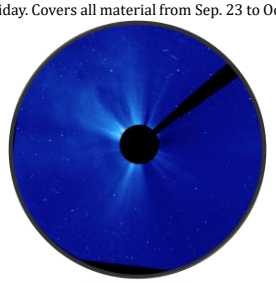
Today's Class: Space Weather

- Reading: Why Space Radiation Matters a:t https://www.nasa.gov/analogs/nsrl/why-space-radiation-matters
- Exam 2 on Friday. Covers all material from Sep. 23 to Oct. 21



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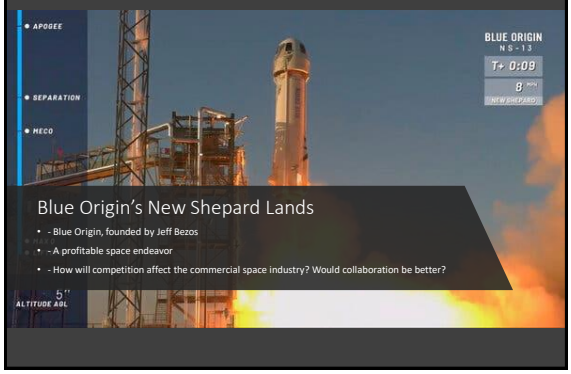
Space in the News
Presented by Lucius Wang



Blue Origin's New Shepard Lands

- - Blue Origin, founded by Jeff Bezos
- - A profitable space endeavor
- - How will competition affect the commercial space industry? Would collaboration be better?

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Last Class

- The Sun is a mass of incandescent gas
- A gigantic nuclear furnace
- Where hydrogen is built into helium
- At temperatures of millions of degrees

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Today's Class

- The Sun-Earth Connection.
- The Solar Wind & Coronal Mass Ejections.
- Space Radiation Effects:
  - Damage to electronics on spacecraft.
  - GPS satellites
  - Airlines flying over the poles
  - Electrical power grid

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Understanding Sun-Earth Connections

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Space Weather

The state of the space environment at a particular time and place, with respect to magnetic and electric fields, energy, and plasma or neutral density.

Space weather refers to the background and dynamic conditions on the Sun, in the space environment and in the upper atmosphere that can influence or disrupt society and technology in space and on the ground.

Disruptions may include: communications, navigational satellite positioning and timing signals, spacecraft operations and instruments, railways, electric power delivery, astronauts, aviation flight crews and passengers.

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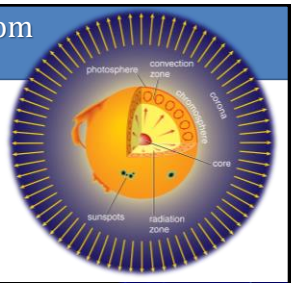
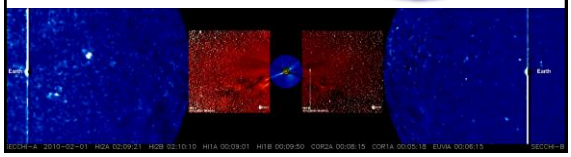
Radiation flows from the Sun

- Solar wind: particles (electrons, protons etc.) streaming into space at 500 km/sec
- Coronal Mass Ejections





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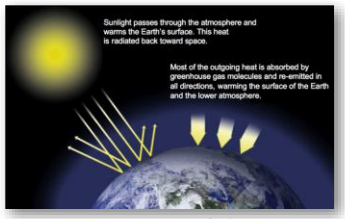
Class Exercise

A hot topic today is the role of humans in global climate change. But, some claim that part or all of climate change is due to the Sun. Could this be true? Argue how the Sun could affect Earth's climate.



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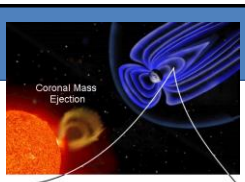

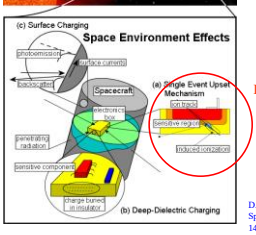

High-Energy Ion Effects

D.N. Baker "How to Cope with Space Weather," *Science*, *297*, 1486, 2002

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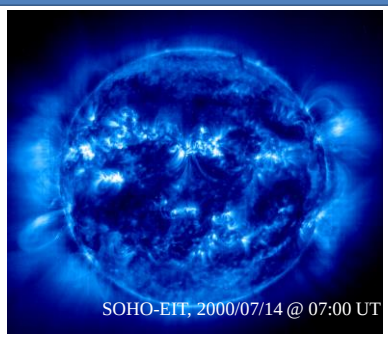
The Active Sun: July 2000



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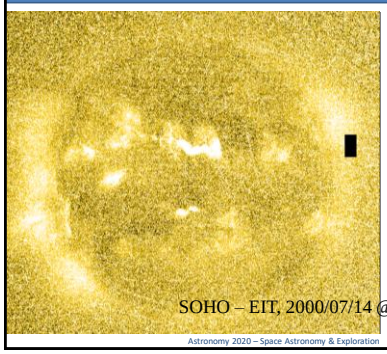
Background Due to Solar Particles



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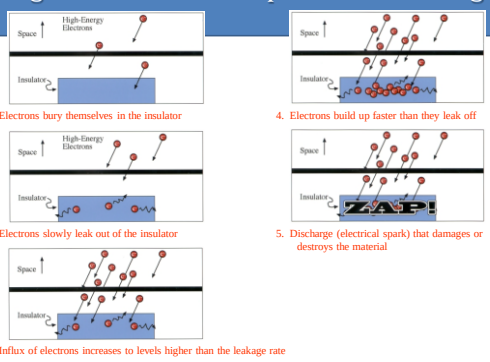
Energetic Electrons: Deep-Dielectric Charging



1. Electrons bury themselves in the insulator
2. Electrons slowly leak out of the insulator
3. Influx of electrons increases to levels higher than the leakage rate
4. Electrons build up faster than they leak off
5. Discharge (electrical spark) that damages or destroys the material

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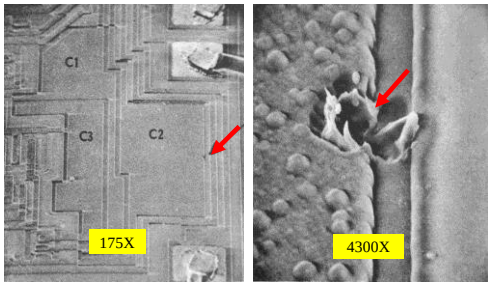
Radiation Damage to Electronics



HA-2700 surface damage in the C2 MOS capacitor (Courtesy of JPL)

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GPS Growth

Global Positioning System used: In-vehicle navigation systems, railway control, highway traffic management, emergency response, commercial aviation, and much more…

NAVSTAR - USA
GLONASS - Russia
Galileo - Europe

GPS Global Production Value—expected growth:
2003 - $13 billion
2008 - $21.5 billion
2017 - $757 billion
Industrial Technology Research Institute (ITRI) – Mar 2005

Space weather creates positioning errors larger than 50 meters
—A mid-latitude problem (where most users reside!)

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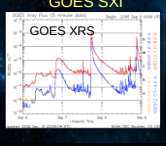
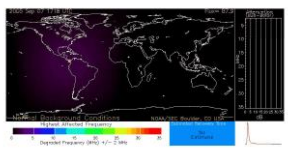
Airlines and Space Weather





Loss of High Frequency (HF) communications during a solar flare. The night-side of the Earth is unaffected

Image from NASA SOHO Satellite

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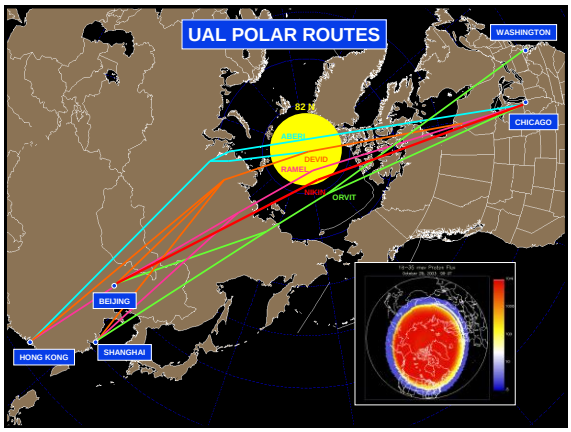

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Effects of Space Weather

Industry-specific Space Weather Impacts

- Electric power, spacecraft, aviation, and GPS-based positioning industries can be adversely affected by extreme space weather
- January 2005: 26 United Airlines flights diverted to nonpolar or less-than-optimum polar routes during several days of disturbed space weather
- October-November 2003: FAA's recently implemented GPS-based Wide Area Augmentation System disabled for 30 hours
- January 1994: Outage of two Canadian telecommunications satellite. 6-month recovery

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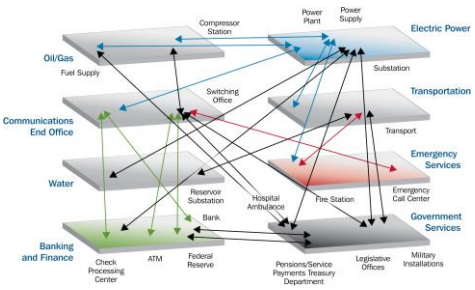
The Interdependencies of Society



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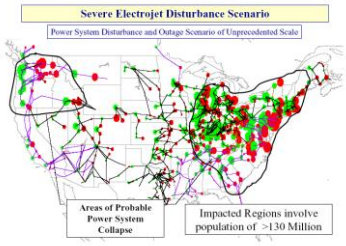
Regional Power Grid Disruptions



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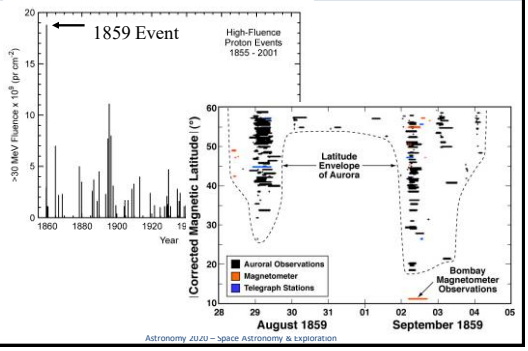
Extreme Event: Carrington 1859



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Low Frequency/High Consequence:
Increasing Power Grid Vulnerability

"The grid is becoming increasingly vulnerable to space weather events"

Future Directions in Satellite-derived Weather and Climate Information for the Electric Energy Industry – Workshop Report Jun 2004

$1-2 trillion | Potential loss due to widespread power grid Blackout following severe geomagnetic storm

4-10 years | Recovery time from a widespread power grid Blackout following severe geomagnetic storm

Source: National Academy Workshop on the Societal and Economic Impacts of Severe Space Weather Events held in Washington, D.C., May 2008.

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Summary

- The challenges of space weather affect all developed countries and both civilian and military systems
- Work on space weather specification, modeling, and forecasting has great societal benefit: It is basic research with a high public purpose
- Future space exploration and most modern human endeavors will require major advances in physical understanding and improved transition of space research to operations
- How do we adequately deal with the very real threats without being unduly sensationalist, i.e., avoid the "Chicken Little" syndrome?

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