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Space Weather Impacts on Aerospace and Modern Society

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Space Weather Impacts on Aerospace and Modern Society

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Space Weather = Series of physical processes starting in the sun, resulting in violent energy release into the heliosphere in forms of radiation, energetic particles and high speed streams and subsequently affecting the current systems and infrastructure in geospace; magnetosphere, ionosphere and upper atmosphere, as well as in ground. Space weather can generate geomagnetic storms which can lead to induced currents and high energy particles that can harm satellites, aeroplanes, power grids, pipelines, GPS receivers, communication systems, time stamping of financial transactions etc.

On 29th of October 2015, National Space Weather Strategy and Action Plan was released. On 13th of October 2016, President’s Executive Order -- Coordinating Efforts to Prepare the Nation for Space Weather Events.

**Magnetic Field of the Sun**
- Sun spots are localized regions of strong magnetic flux.
- They appear in pairs of opposite polarity.
- Origin of Sun’s magnetic field is not fully understood.

**Magnetic Field of the Earth**
- Earth’s magnetic field is similar to field of a bar magnet, dominated by dipolar field.
- Solar Wind interaction with the Earth’s field generates, an elongated structure, the magnetosphere.

**Solar Activity and Solar Cycle**
- Maximum activity correlates with # of sunspots.
- Time between two maximums is ~ 11 years.

**Solar Structures Driving the Space Weather**
- Prominences, Flares, Coronal Mass Ejection (CME or Ejecta), Solar Energetic Particles (SEPs), high speed streams, Stream Interaction Regions (SIRs), ICMEs and ICME sheaths.

**Earth’s Radiation Belts**
- The outer belt consists mainly of high energy (0.1 – 10 Mev) electrons, the inner belt mainly of protons above 100 MeV.

**Space Hurricanes aka Kelvin-Helmholtz waves**
- Large (18,000-55,000 km in wave length) waves that can provide seed population for radiation belt electrons.
- Can also directly heat plasma via magnetosonic waves.
- Kelvin-Helmholtz Waves can generate ULF range Pc5 waves that can accelerate radiation belt electrons.

**GPS Navigation and Space Weather**
- Space Weather variations during a mid-latitude ionospheric storm can lead to severe impacts on the FAA augmentation of GPS called the Wide Area Augmentation System (WAAS) [Dehnel, 2004].
- Associated with these events are ionospheric irregularities and scintillations that can cause GPS receivers to lose signal tracking [Ledin et al, 2002].

**Next Gen. Space Weather Prediction Mission**
- More Warning time needed! Need to develop next gen. space weather models using multi-point, multi-scale measurements in L1.
- Cube sats. will be build in ERAU research park. Carrier Spacecraft using industrial partnerships.
- Using these measurements, new space weather models can be created to be able to predict the solar wind structure and magnetic field orientation at the Earth’s Bow Shock nose.

**Extreme Space Weather**
- 1859 ‘Carrington’ event produced visible aurora even in Cuba!.
- In 1989 geomagnetic storm Knocked out power across large sections of Quebec.
- In 2012 a "Carrington-class" Solar Superstorm (Solar flare, CME, Solar EMP) was observed, its trajectory missed Earth in orbit.
- In 2015 Geomagnetic storm Stops airtraffic in Sweden.
- In 2013, Lloyd’s of London and AER estimated the current cost of a Carrington event to the U.S. alone at ~ $1-2.6 trillion.

**Space Weather Can Be Harmful**
- Strong and rapid variations in magnetic field can induce electric fields and produce currents.
- The induced currents can take down power grids etc.
- High energy particles and radiation the biggest obstacle for manned missions to Mars.
- GPS technology unreliable due to enhanced TEC.