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Space Weather and Technological Impacts

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Introduction

• The National Space Weather Program defines space weather as “conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health.”
• As we approach Solar Maximum in 2013-2014, society is at risk due to impacts space weather storms have on our heavily reliant technological infrastructure.

• The Global Forecasting System (GFS)-based technologies which society’s become extremely dependent on since last the solar cycle will be fully tested for the first time.
• The NOAA Space Weather Prediction Center (SWPC) navigation customer list was analyzed to investigate the types of companies reliant on GPS.
• The AMS held a policy workshop titled, “Satellite Navigation & Space Weather: Understanding the Vulnerability & Building Resilience” to help better characterize satellite navigation’s vulnerability to space weather and how to build resilience for the future.

Overview of space weather

Space Weather is a consequence of the behavior of the Sun and the nature of Earth’s magnetic field and atmosphere. The Sun, like Earth, experiences seasonal changes that occur on a period of 11 Earth years, solar maximum and minimum. During solar max, activity on the Sun is high and numerous events occur.

• Sunspots are dark areas on the solar surface and contain strong magnetic fields that are constantly shifting. An average sunspot is about as large as the Earth and groups of sunspots are often identified as sites of flares.
• Solar flares are intense, short-lived releases of energy. They are seen as bright areas on the Sun in optical wavelengths and as bursts of noise in radio wavelengths and can last from minutes to hours. Flares are our solar system’s largest explosive events.
• Coronal Mass Ejections (CME) are sudden and violent releases of gas and magnetic fields. A large CME can contain 10^20 grams (a billion tons) of matter that can be accelerated to several million meters per hour in a spectacular explosion impacting up to a planet or spacecraft in path.
• Solar Radio Bursts (SRB) are emissions of the Sun in radio wavelengths from coronal mass ejections, and utilized both for navigation and monitoring. Radio waves produced during solar eruptions on the Sun can cripple the GPS and other communication technologies by acting like noise interfering with radio waves.

• The region between the Sun and Earth, the interplanetary medium, is a turbulent region dominated by solar wind, lasting an average of approximately 25-100 km/s (about 800,000 to 2,000,000 miles per hour). Characteristics of the solar wind, such as density, composition, and magnetic field strength, vary with changing conditions on the Sun.
• Aurora is a solar-induced geomagnetic storm. The solar wind energizes electrons and ions in the magnetosphere entering the Earth’s upper atmosphere near the polar regions. When the particles strike the molecules of the thin, high altitude atmosphere, energy from these impacts becomes visible as auroras. As a geomagnetic storm, the auroras spread equatorward.

Technological impacts

Adverse conditions in the space environment can cause disruptions of the electric power industry, aviation, communication and navigation system, satellite operations, and space flight leading to a variety of socioeconomic losses.

• Electronic power industry - power companies transmit alternating current to their customers via long transmission lines. Direct currents induced there in those geographic storms are harmful to electrical transmission equipment. In 1883-84 a geomagnetic storm led to the collapse of the Hydro-Quebec power grid, leaving 6 million Canadians without power for 5 hours.
• Aviation – the airline industry faces risks during high latitude and polar routes which includes disruptions in high frequency (HF) communications, GPS errors and rejection errors in humans and avionics.
• Navigation and Communication Systems – ionospheric storms are space weather induced disturbances that can affect HF communications and for GPS signals, ionospheric scintillation can create a timing error or a signal that saturates a receiving causing a loss lock on the signal.
• Satellite Operations – geomagnetic storms and increased solar UV emission head Earth’s upper atmosphere, causing ionisation, which increases drag on satellites in space, causing them to slow and change orbits. Energetic solar particles on cause single event upsets which often cause physical damage to microchips and charge software commands in satellite-based computers. Bulk charging occurs when energetic particles, primarily electrons, penetrate the outer casing of a satellite and deposit their charge in its internal parts.
• Space Flight – astronauts in space can be subjected to potentially lethal doses of radiation. The generation of high energy particles into long GPS, collision course, leads to ionization damage and, potentially, cancer. Large doses can be fatal immediately.

Closer look at GPS

Since the last solar max, our society has become extremely dependent on GPS often referred to as the “third utility” behind electricity, water, and natural gas. Precision GPS is now required by numerous aspects of our daily lives, including safety and security. Issues such as power grid, aviation, navigation, and also the economy have shifted from those typically associated with a third utility to those previously thought of as “low” priority. The potential impacts to critical infrastructures from GPS outages are staggering.

• Energetic particles from the Sun’s outer atmosphere can directly damage satellites and onboard hardware, potentially disabling entire navigation systems.
• The loss of a single GPS satellite orbiting the Earth can cause a 15-foot loss in a single oil drilling operation in the Gulf

Critical GPS usage

• National Security- GPS used to enable DoD forces worldwide to strategically maneuver into a militarily advantageous location.
• GPS provides critical services to deployed forces around the globe from the infantryman walking the streets of Fallujah, to ships combing piracy off the coast off Somalia, to aircraft puncturing our country’s borders.
• Oil Drilling – GPS used for precise location requiring near pinpoint accuracy.
• From disaster impacts could result in a $1 billion loss in a single oil drilling operation in the Gulf

Unique GPS application

In 2007, NASA scientist Tony Song developed a Tsunami prediction method using GPS. It was successfully demonstrated during the Feb 27, 2010 magnitude 8.8 Chilean earthquake earning number 84 of Discover magazine’s top 100 scientific stories of 2010.

Song’s prediction method estimates the energy an underwater earthquake transfers to the ocean to generate a tsunami. It relies on data from coastal GPS stations near an epicenter, along with information about the local continental slope. When the Feb 27, 2010 earthquake struck, a ground motion was detected by the NASA/GPS network’s station in Santiago, Chile, which data made available to Song within minutes of the earthquake, enabling him to derive the tsunami’s motion. Based on GPS data, Song calculated the tsunami’s source energy, making it the first to do so. The system’s 10-point basis based on the 11-day period detected a shift in the ground motion detected by GPS indicating the slip of the fault transferred minimal kinetic energy to the ocean.

AAMS Policy Workshop

AAMS Policy Workshop held in Fall 2010 participants included GPS government and industry leaders, space weather scientists and information providers, and policymakers. By understanding the risks and preparing the GPS community with strategies for mitigating potential impacts can be the best approach.

Key points for building resilience: space and engineering
• Conduct further research in understanding space weather and its impacts
• Develop and maintain operational capabilities for space weather and other geophysical events
• Develop better space weather products

Key points for building resilience: policy
• Investment in research
• International collaboration
• Identification and evaluation of risks
• Strengths integrity and robustness of the system

GPS industry

The NOAA SWPC navigation customer list was analyzed to investigate the types of companies reliant on GPS. 54% out of 233 customers were identified and categorized into military (5%), civil government (34%), academic (20%), and industry (67%).

SWPC Navigation Industry Customers chart shows industry organizations as a percentage of type of company.

• All ratings company categories
• All categories include individuals and companies, domestic and international
• A majority of the industries provide GPS services and could experience tremendous economic impacts during signal errors or interruptions

Some companies use GPS to improve safety and efficiency of systems, i.e. emergency response groups.

Some companies use GPS for the economic value, whether it be the money making consulting or the money saving businesses (commercial agreements).