The background of the slide is a photograph of the aurora borealis (Northern Lights) over a dark, silhouetted landscape. The aurora is a vibrant green and yellow glow that stretches across the sky, with some darker spots and a small bright star visible on the left side. The overall scene is dark, with the aurora providing the primary light source.

# Space Weather

Growth in Importance for Economy and Security

**Louis J. Lanzerotti**

**New Jersey Institute of Technology**

**Alcatel-Lucent Bell Laboratories (ret)**

**Editor, *Space Weather: The International Journal of Research and Applications***

# Theme:

As technological innovations produce new capabilities and complexities, the opportunities for unexpected impacts of the solar-terrestrial environment on new developments has always occurred  
---- from the 1840s telegraphs to today

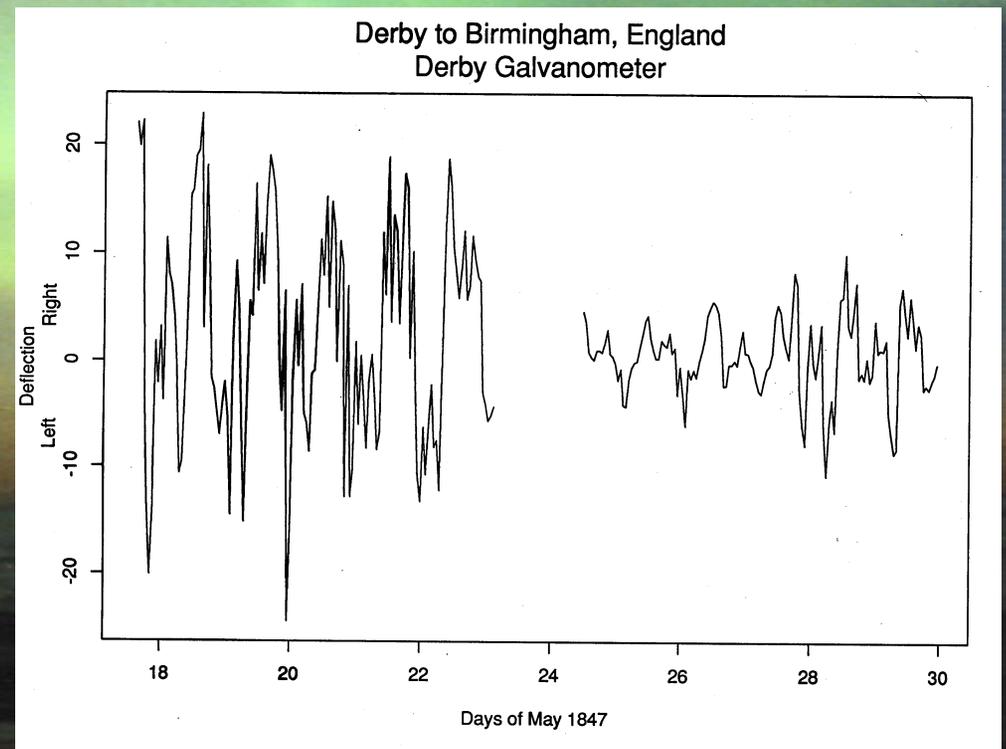
Increasingly sophisticated technologies require increasingly sophisticated understanding of the natural environment in which they operate

# TELEGRAPH in 1840's

W. H. Barlow, "On spontaneous electrical currents observed in the wires of the electric telegraph", *Phil. Trans. R. Soc.*, 61, 1849

**"THE OBSERVATIONS DESCRIBED ... WERE UNDERTAKEN IN CONSEQUENCE OF CERTAIN SPONTANEOUS DEFLECTIONS HAVING BEEN NOTICED IN THE NEEDLES OF THE ELECTRIC TELEGRAPH ON THE MIDLAND RAILWAY, THE ERECTION OF WHICH WAS CARRIED OUT UNDER MY SUPERINTENDENCE AS THE COMPANY'S ENGINEER."**

**"... in every case which has come under my observation, the telegraph needles have been deflected whenever aurora has been visible"**



# **MAGNETIC STORM:**

**March 24, 1940**

- ❖ Numerous Problems (Transformer Tripping; Reactive Power urges) on Other Systems; e.g.: Philadelphia Electric; Public Service NJ; Central Maine; Northern States Power (MN); Eastern MA Electric
- ❖ Transformer Tripping, Ontario Hydro Electric Commission
  - 4 Transformer Banks, Chats Falls, Niagara District (220kV)
  - 6 Transformer Banks, Abatibi System (132 kV)

 **First widespread effects on power distribution systems**

## **IN BRIEF**

March 1989

### **Blackout darkens Quebec**

**MONTREAL** — A massive power outage yesterday left more than 3 million people in Quebec without heat and light, crippling Montreal's underground

*The Washington Post*

2011

### **As the sun awakens, the power grid stands vulnerable**

By [Brian Vastag](#), Published: June 20

The sun is waking up.

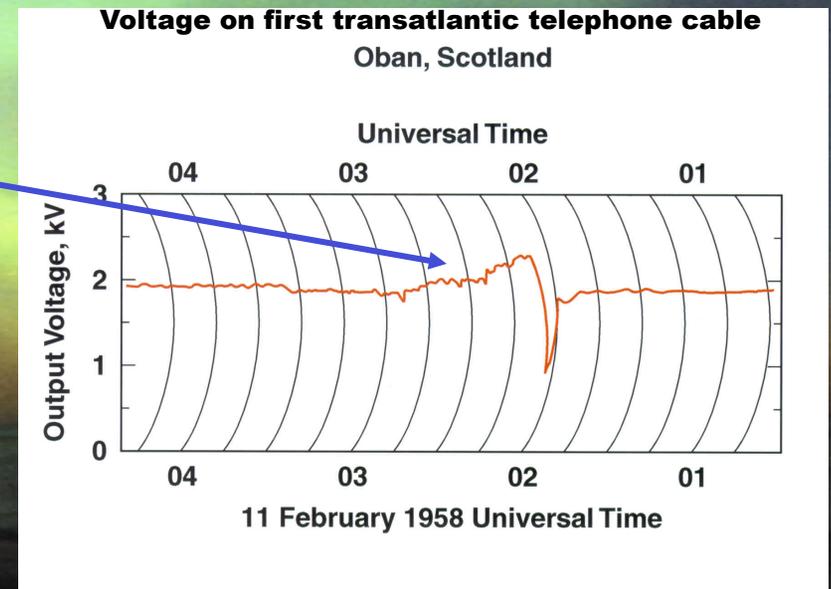
# MAGNETIC STORM:

February 10, 1958

“At almost the exact moment when the magnetograph traces leaped and the aurora flared up, huge currents in the earth, induced by the heavenly turbulence, manifested themselves not only in power lines in Canada but in cables under the north Atlantic.”\*

“... Circuit breakers began tripping out in Ontario transformer stations, plunging the Toronto area into a temporary darkness broken only by the strange light of the aurora overhead”\*

First trans-Atlantic voice cable  
Clarenville, Newfoundland, to Oban, Scotland



\* John Brooks, “A Reporter at Large; The Subtle Storm,” *New Yorker*, February 19, 1959

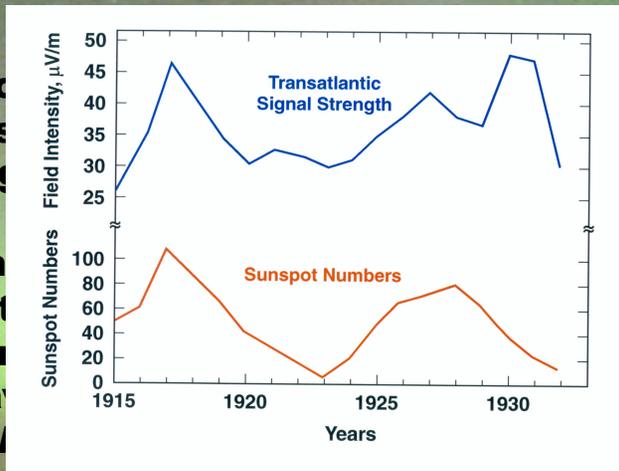
**4 August 1972:** AT&T L4 cable Chicago to San Francisco.

Several hour power supply disruption in Plano, Illinois, repeater station

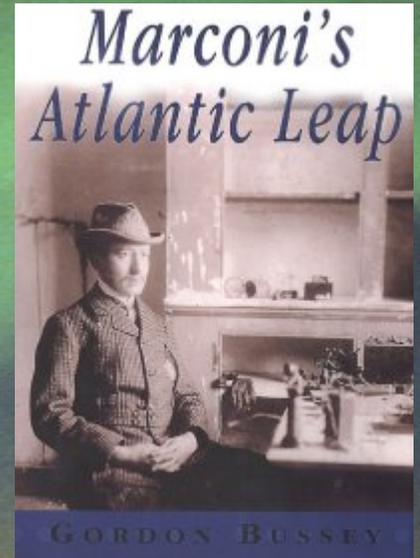
# EARLY WIRELESS COMMUNICATIONS

## Space Weather

“The opinion has been expressed that the distances being covered by radio waves are propagated into space and are continually falling in accordance with the inverse square law. It is in accordance with that portion of the spectrum of the sun will have in it facing the sun, and a long Hertzian wave. G. Marconi, *Smithsonian*



... for shorter distances are in accordance with the inverse square law, then facing the sun, which is not apparent to the eye. G. Marconi, *Smithsonian*, 1914-15, 1906



“... times of bad fading practically always coincide with the appearance of large sun-spots and intense aurora-boreali usually accompanied by magnetic storms ....” These are “... the same periods when cables and land lines experience difficulties or are thrown out of action.” G. Marconi, *Radio Communications*, 1928.

**1996**  
**NASA Says Solar Flare Caused Radio Blackouts**  
WASHINGTON, July 13 (AP) — A strong solar flare early Wednesday

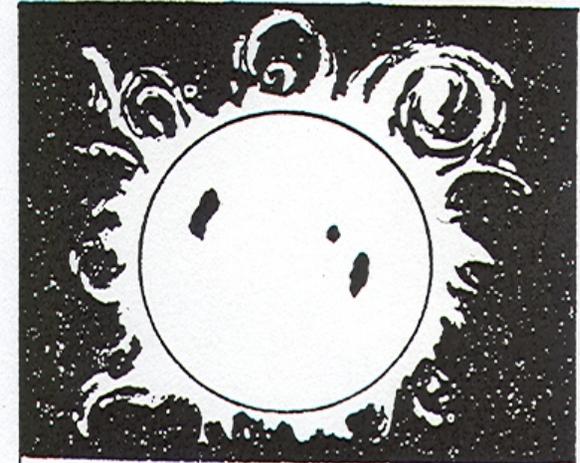
**Solar Storms Cut Airplane Radio Contact**  
By Tom Cohen  
Associated Press  
posted: 04:00 am ET  
30 October 2003

TORONTO (AP) — Airplanes flying north of the 57<sup>th</sup> parallel experienced some disruptions in high frequency radio communications Wednesday due to the geomagnetic storm from solar flares.

IN FEBRUARY 1942, DURING WORLD WAR II, A DRAMATIC CRISIS AROSE IN BRITAIN. RADAR OPERATORS THROUGHOUT THE COUNTRY REPORTED A NEW KIND OF "JAMMING" WHICH PERIODICALLY COMPLETELY DISRUPTED THE BRITISH RADAR DEFENCE SYSTEM.

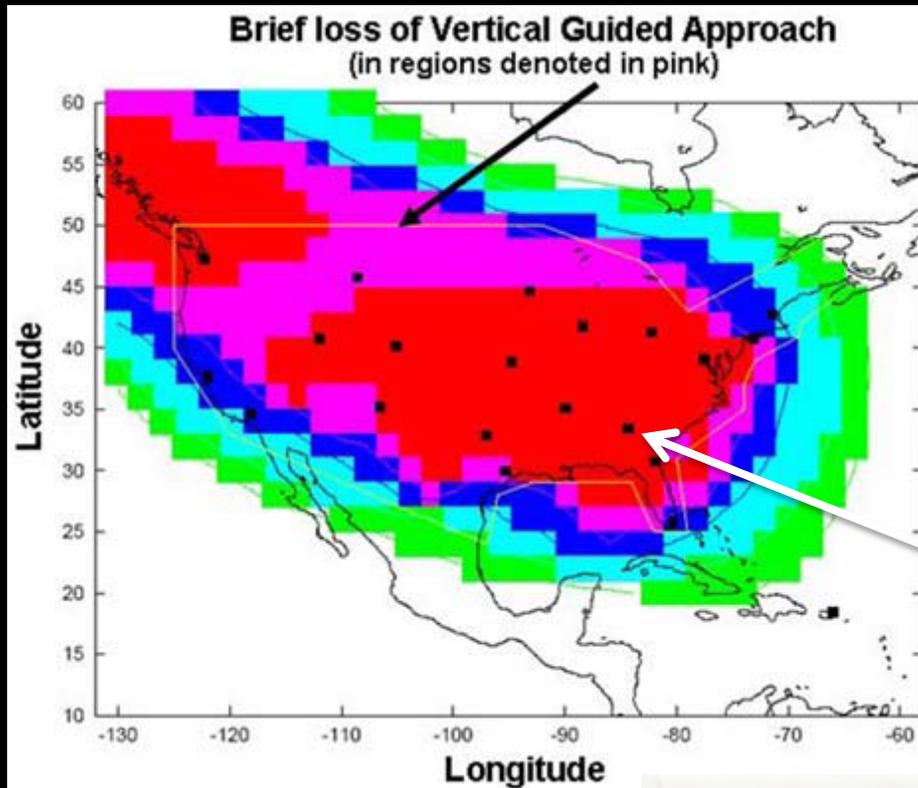


AN IMMEDIATE INVESTIGATION WAS MADE BY MEMBERS OF THE BRITISH ARMY OPERATIONAL RESEARCH GROUP, LED BY J.S. HEY.



HEY'S AMAZING REPORT WAS THAT THE RADAR INTERFERENCE WAS BEING CAUSED, NOT BY THE GERMANS ACROSS THE CHANNEL, BUT BY ELECTROMAGNETIC SIGNALS FROM THE SUN WHICH AT THAT TIME WAS UNDERGOING STRONG SUNSPOT AND SOLAR FLARE ACTIVITY.

Interference by  
solar radio noise



**WAAS coverage and availability of the vertical guided approach service on 6 December 2006.**

**The Effect of Intense December 2006 Solar Radio Bursts on GPS Receivers**  
Alessandro P. Cerruti, et al., *Space Weather*, 2008. Cornell University

**Number of receivers severely impacted by solar radio burst**

**Yellow:** all currently available geodetic quality receivers available through the Wide Web, including from the GPS from the IGS and Continuously Operating Reference System (CORS) network

**Red:** all receivers severely impacted during peak of solar radio burst: 19:30-19:40 UT.

**BBC NEWS**

**SCIENCE & ENVIRONMENT**

7 March 2011 Last updated at 19:08 ET

**UK 'over-reliant' on GPS signals, engineers warn**

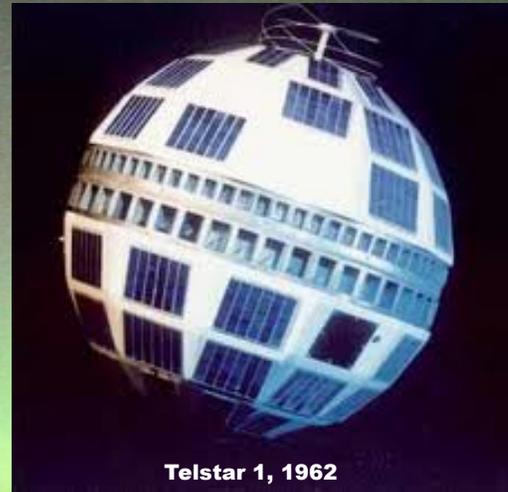
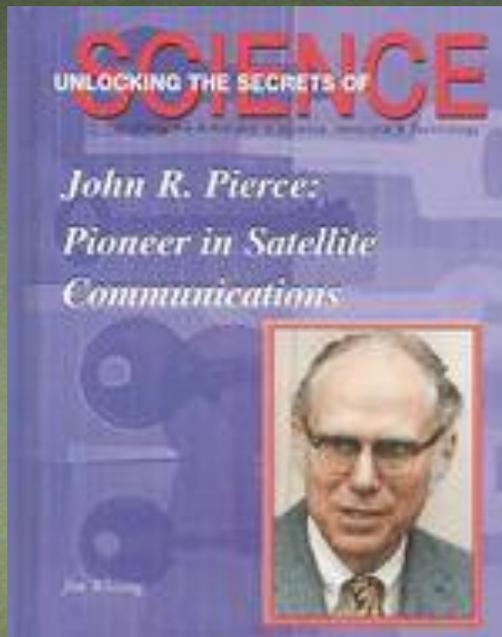
Position: 34°03'44.98"N, 99°42'15.40"W

Image MASA  
Image © 2007 TerraMetrics  
Image © 2007 DigitalGlobe

Streaming: 100%

Google

Eye alt: 6453.91 mi



Telstar 1, 1962



Syncom 3, 1963

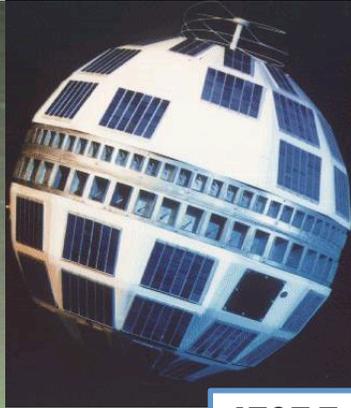


Sir Arthur Clark

## Sun 'ejection' killed TV satellite

January 21, 1997 Web posted at: 10:10 p.m. EST

AT&T Telstar 401 Satellite



**AT&T Telstar 1**  
**Launch: 10 July 1962**  
**Failed: February 1963**  
**Radiation Damage**

## Italy Blames Disruption of Comsat NATO Uses on Strong Solar Activity

PETER B. de SELDING, PARIS

The Italian Defense Ministry lost control of its Comsat satellite because we really didn't know what was going on.

In response to *Space News* questions, the Italian joint defense staff blamed the problem on software modernization on the satellite, which is at the halfway point in its scheduled operating life.

software modernization on the satellite, which is at the halfway point in its scheduled operating life.

Space News, January 15, 2007

# P-ANIK!



## High-tech chaos as satellites spin out of control

Plug pulled on phones, TV, radio, papers

OTTAWA — Telesat Canada was facing some tough questions today as it tries to explain how its two main communication satellites tumbled out of control, interrupting TV, radio, newspaper and telephone signals across the country. After struggling for more than eight hours to bring the wobbly Anik E-1 under control, Telesat technicians thought they had the problem licked late yesterday. The were only half right. Shortly after 9 p.m. EST, as Anik E-1 settled back into position, Telesat's primary broadcasting satellite, Anik E-2, also got a bad case of the shakes. CBC Newsworld and other national specialty cable channels, including MuchMusic, TSN, Vision and the Weather Channel, were knocked off the air. Partial service, with signals carried by fibre-optic



January 1994

April 26, 2010

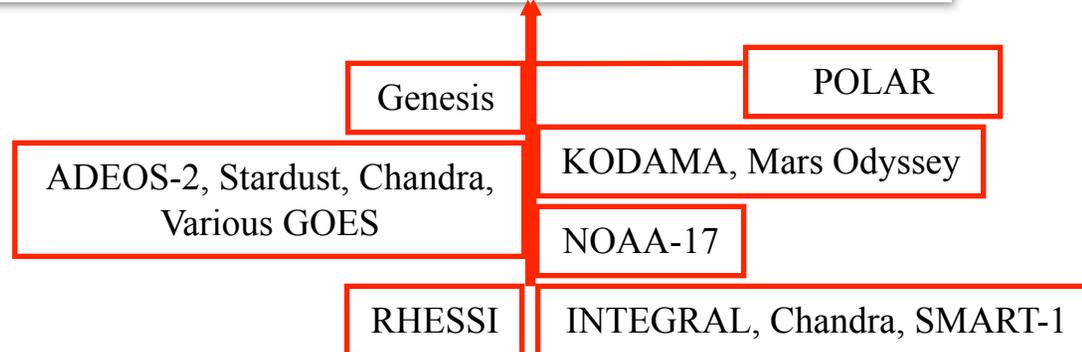
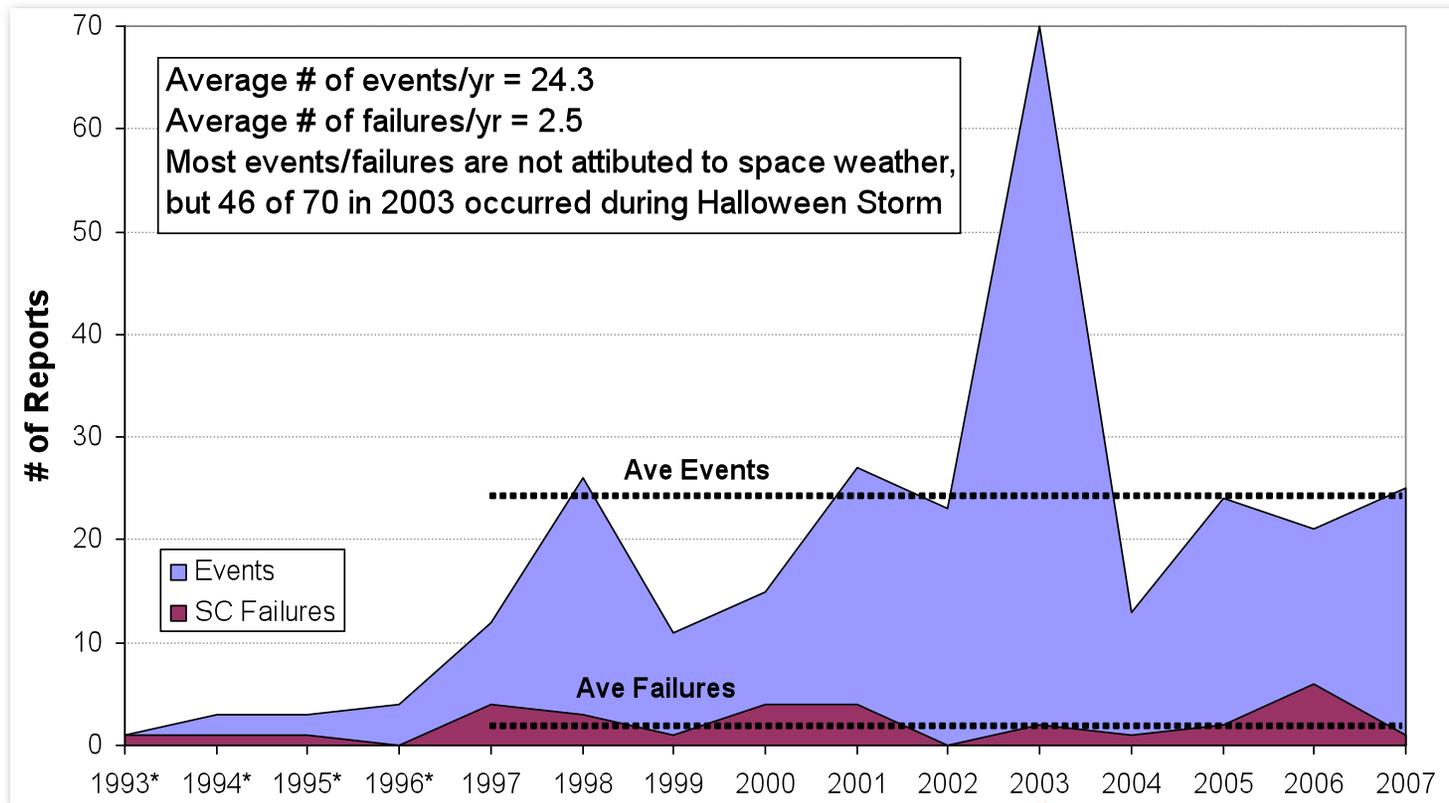
# Orbital Blames Galaxy 15 Failure on Solar Storm

January 10, 2011

# Intelsat Moving Recovered Galaxy 15 To Test Location

PETER B. de SELDING, PARIS

# Spacecraft Anomalies and Failures



SOURCE: National Academy Workshop on the Societal and Economic Impacts of Severe Space Weather Events Washington, D.C., May 2008. Organizer and Chair: Professor Daniel Baker, U. of Colorado

# The Societal and Economic Impacts of Severe Space Weather Events

- *May 22-23, 2008 in D.C.*  
*The National Academies*
- *~ 80 attendees: academia, industry, government, industry associations*
  - **Association reps aggregated data and helped avoid concerns about proprietary or competition-sensitive data**
- *Analyses in specific areas; e.g., GPS, power industry, aviation, military systems, human and robotic exploration beyond low-Earth orbit*
- *Econometric analysis of value of improved SWx forecasts*



**Organizer and Chair:**  
**Professor Daniel Baker, U. of Colorado**

[ [http://www.nap.edu/catalog.php?record\\_id=12507](http://www.nap.edu/catalog.php?record_id=12507) ]

# Low Frequency/High Consequence Events:

*Increasing Societal 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 Washington, D.C., May 2008. Organizer and Chair: Professor Daniel Baker, U. of Colorado

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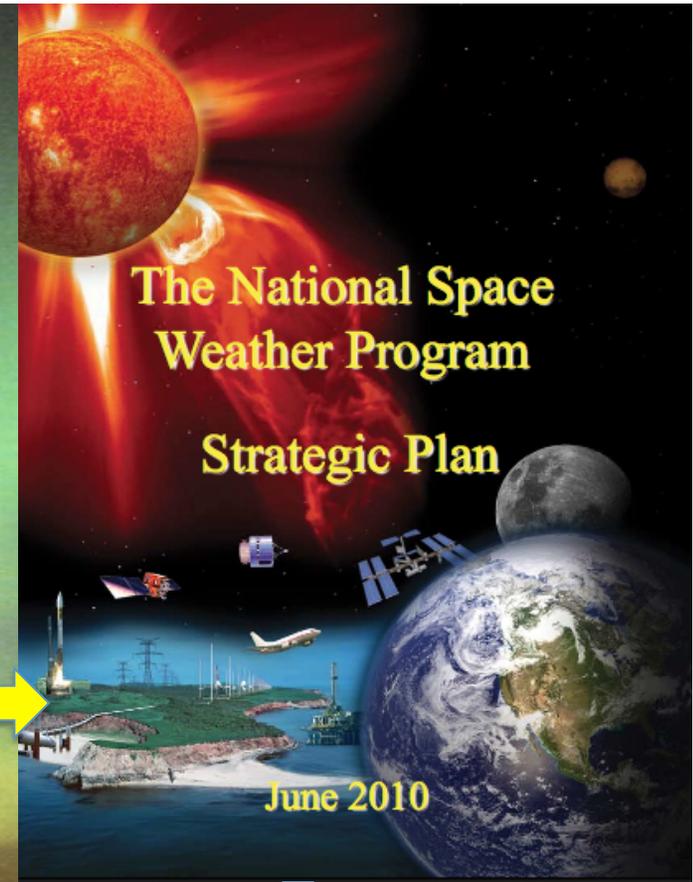
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**Report  
of the  
Assessment Committee  
for the  
National Space Weather Program**

FCM-R24-2006



June 2006

Office of the Federal Coordinator for Meteorological Services  
and Supporting Research (OFCM)  
8455 Colesville Rd, Suite 1500  
Silver Spring, MD 20910

- I. Discover and understand the physical conditions and processes that produce space weather and its effects.*
- II. Develop and sustain necessary observational capabilities.*
- III. Provide tailored and accurate space weather information where and when it's needed.*
- IV. Raise national awareness of the impacts of space weather.*
- V. Foster communications among government, commercial, and academic organizations.*

# New Drivers for Space Weather Understanding

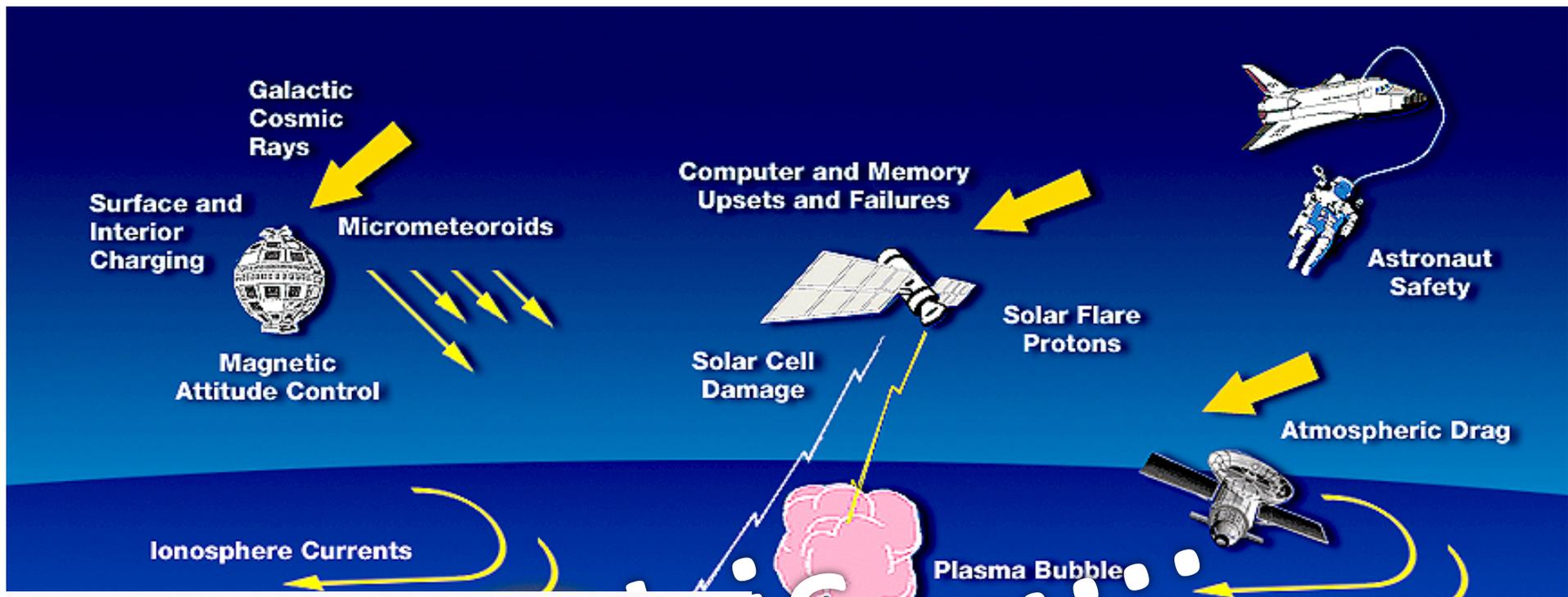
*Evolving landscape: New technologies and capabilities drive demand for space weather products*

- Civil Precision GNSS Users
- Next Generation Air Transportation System
- Increased Vulnerability of Power Grid
- Satellite/Launch Industry
- Exploration Missions to the Moon and beyond
- Commercial Space Enterprise
- Arctic Economic Development



**From this**





The New York Times Reprints

March 10, 2011

## Celestial Storm Warnings

By JOHN P. HOLDREN and JOHN BEDDINGTON

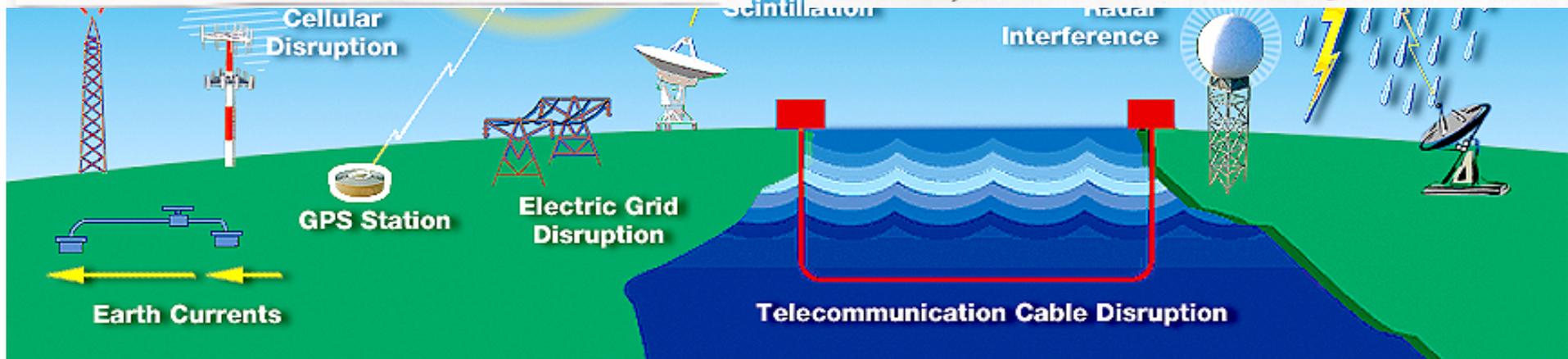
The New York Times

June 16, 2011

## How's the Weather?

By MADHULIKA GUHATHAKURTA and DANIEL N. BAKER

LATELY, the Sun has been behaving a bit strangely.

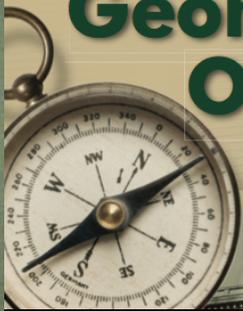


# Space Weather

QUARTERLY

Volume 8, Issue 2, 2011 www.agu.org/journals/spaceweather  
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

## Canada's Geomagnetic Odyssey



# Space Weather

QUARTERLY

Volume 6, Issue 3, 2011 www.agu.org/journals/spaceweather  
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

## Geomagnetic Storms Over India

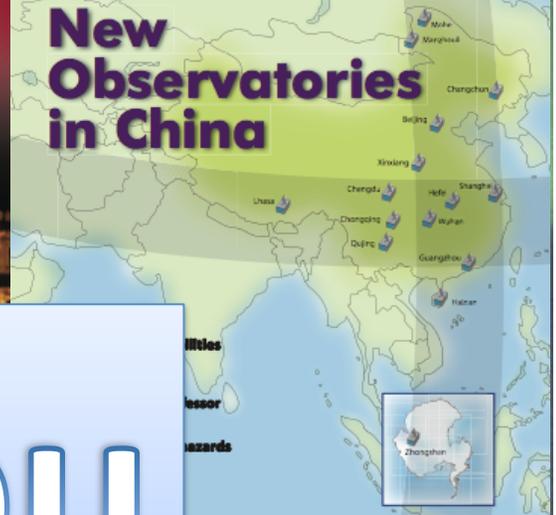


# Space Weather

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Volume 7, Issue 3, 2010 www.agu.org/journals/spaceweather  
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## New Observatories in China



# Thank You

# Space Weather

Volume 7, Issue 2, 2010 www.agu.org/journals/spaceweather  
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## Risks in GPS-Reliant Industries

**News:**  
Detailed images  
of the Sun unveiled

**Feature:**  
A scientist describes  
his research approach

**Technical:**  
Space weather effects  
on pipelines in Australia



## Protecting Lunar Colonies From Space Radiation



**News:** Proposed U.S. space weather budget

**Feature:** New directions for radiation belt research

**Technical:** Validating community models

# Space Weather

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Volume 7, Issue 4, 2010 www.agu.org/journals/spaceweather  
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## Smartphone Apps Sun-Earth Conditions in Real Time



**News:**  
International organizations focus on space weather

**Feature:**  
A decade of space weather events, discoveries, and publications

**Technical:**  
Quiet time relativistic electrons