



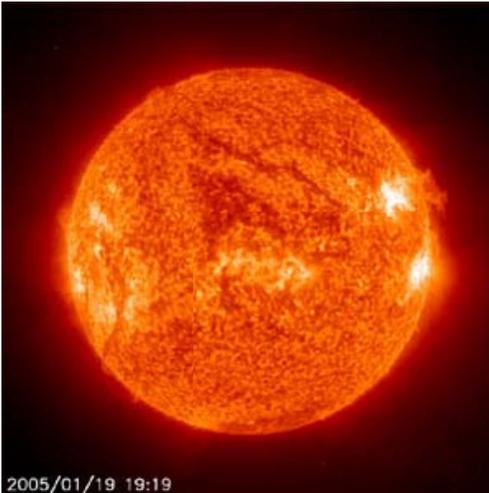
SPACE WEATHER:

Affecting Life and Technologies
on Earth and in Space

Louis J. Lanzerotti

New Jersey Institute of Technology
Alcatel-Lucent Bell Laboratories (ret)
Editor, *Space Weather: The International Journal of Research and Applications*

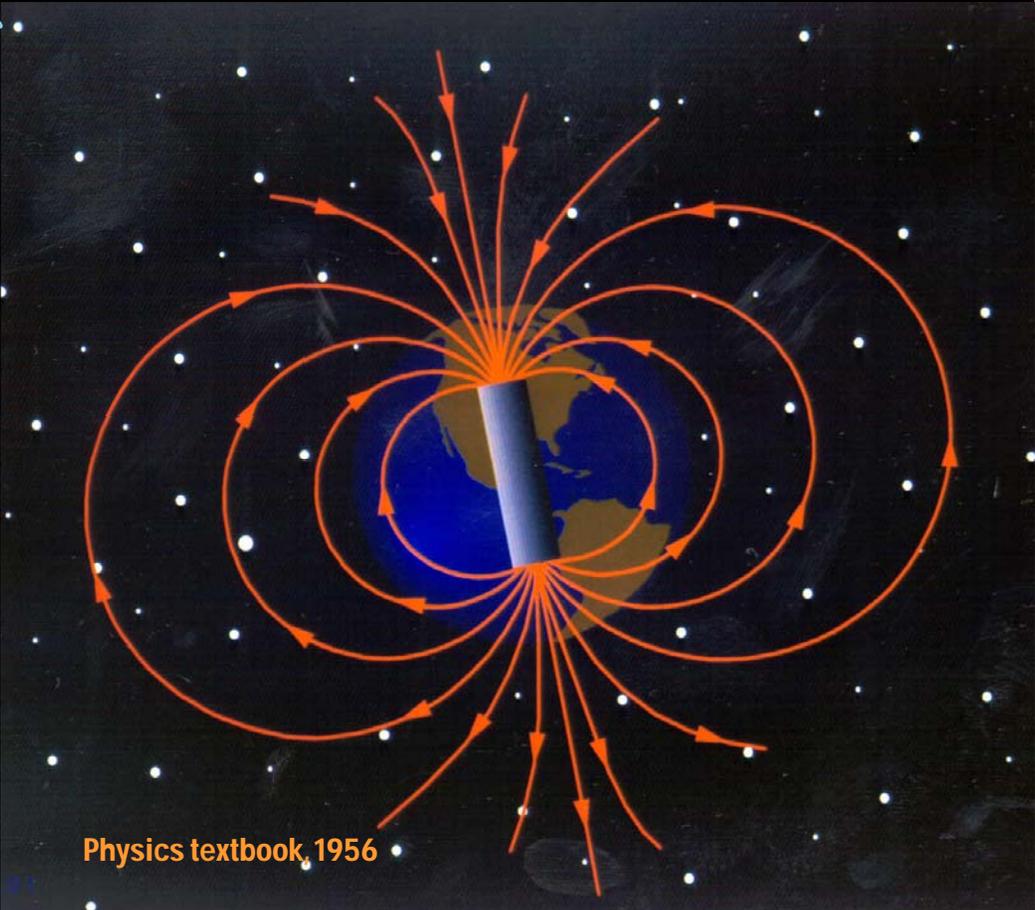
Space Weather Enterprise Forum 2012
Washington, D.C.



2005/01/19 19:19

Feb. 20, 2011

Empty space

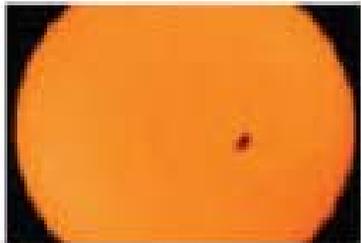


Physics textbook, 1956

Solar storm delivers a glancing blow to Earth – and a warning

The solar storm caused by a massive eruption two days ago arrived at Earth Wednesday but it was only a taste of what scientists say might come – and the world is not prepared

By Mark Clayton, Staff writer / June 9, 2011



Space Station Glitch Possibly Caused by Solar Flare

By [Tania Malik](#)
Staff Writer
posted: 19 December 2008
11:49 am ET

Updated at 2:40 p.m. EST

Solar Storms Cut Airplane Radio Contact

By Tom Cohen
Associated Press
posted: 04:00 am ET
30 October 2003

A4 Daily Record, Morris County, N.J., Thursday, September 8, 2005

Solar flare may disrupt communications

WASHINGTON (AP) — A reported...
sters
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lisrup-
ted by

PLANET EARTH

Magnetic North Pole Shifts, Forces Runway Closures at Florida Airport

By Jeremy A. Kaplan
Published January 06, 2011 | FoxNews.com

Italy Blames Disruption of Comsat NATO Uses on Strong Solar Activity

PETER B. de SELDING, PARIS
cause we really didn't know what was going on."
software modernization on the satellite, which is at the halfway point in its scheduled operating life."
The Italian Defense Ministry lost control of its Comsat...
In response to *Space News* questions, the Italian joint de-

Space News, January 15, 2007

The Washington Post

2011

As the sun awakens, the power grid stands vulnerable

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

The sun is waking up.

MONDAY, JULY 17, 2000

Solar storm ends up just a nuisance

REUTERS

YAHOO! NEWS

Space weather could wreak havoc in gadget-driven world

by Kerry Sheridan
Sun Feb 20, 5:46 pm ET

YAHOO! NEWS

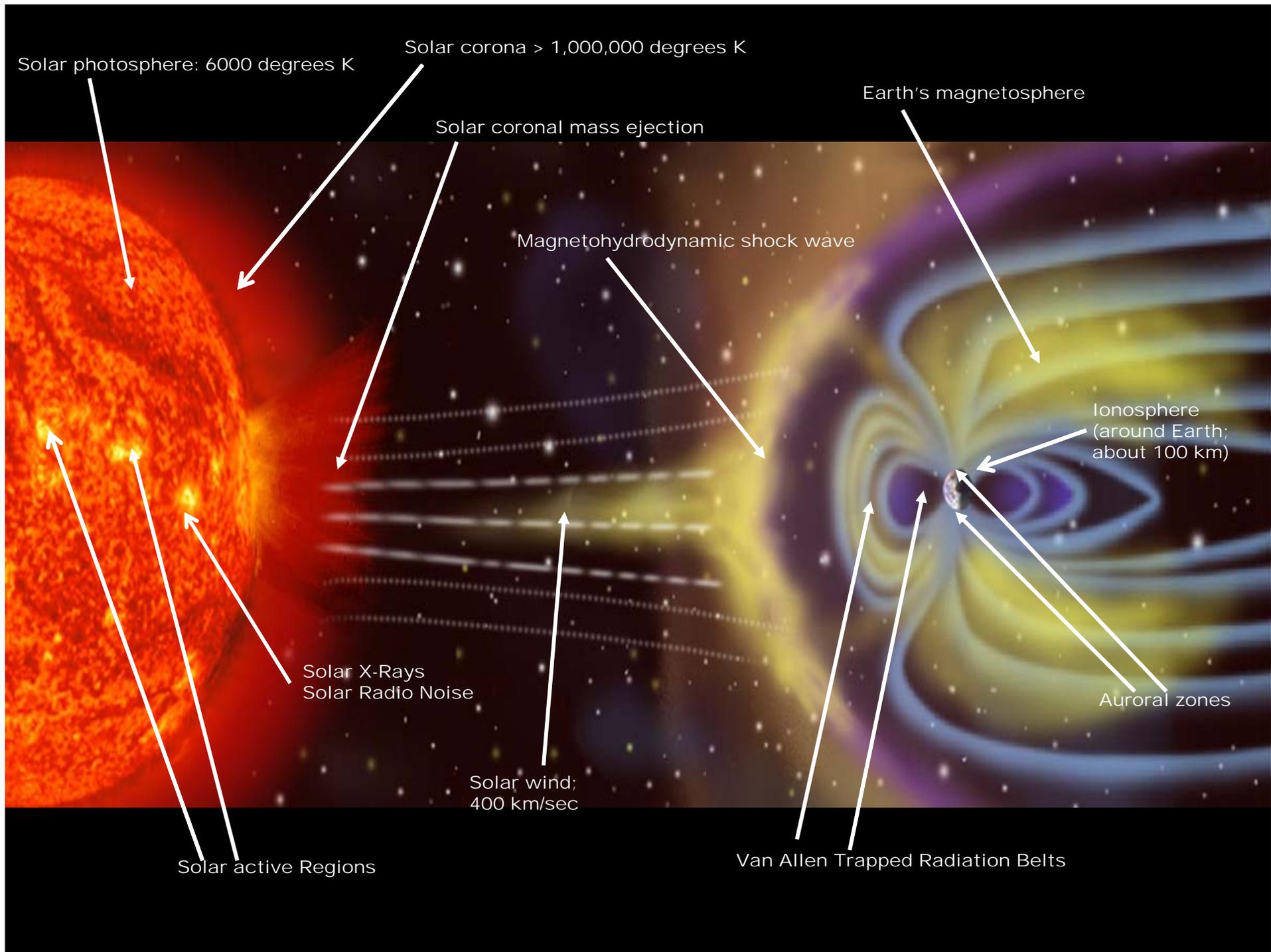
Major Solar Flare Erupts, May Make Auroras Visible in Northern U.S.

Space.com
Thu Mar 10, 4:45 pm ET

THE NEW YORK TIMES, WEDNESDAY, MARCH 8, 1989

Largest Solar Flaring in 5 Years Could Break Up Communications

By WILLIAM K. STEVENS



The historical record demonstrates that space weather processes often provide surprises in the implementation and operation of new electrical technologies:

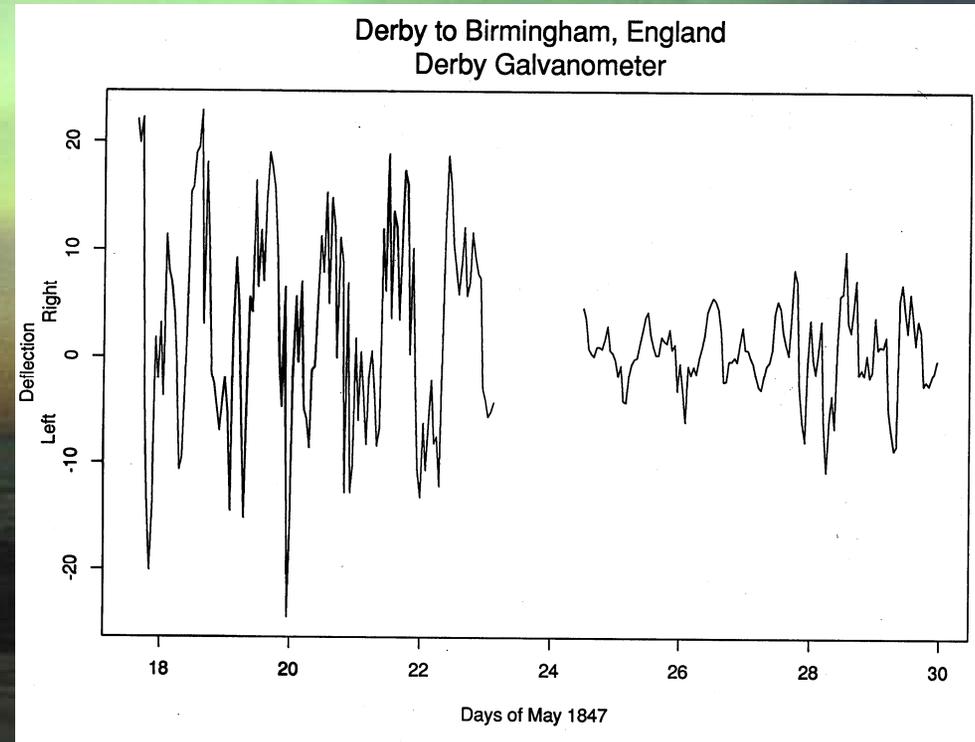
The Telegraph



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"

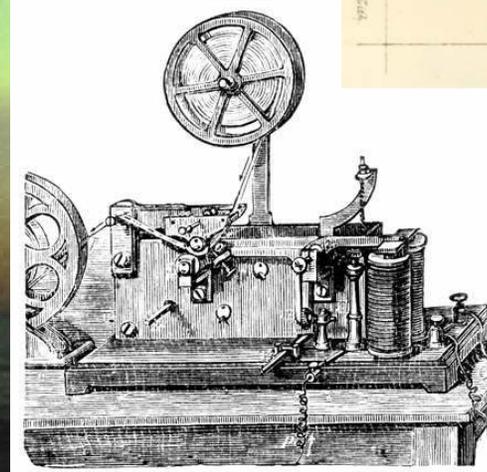
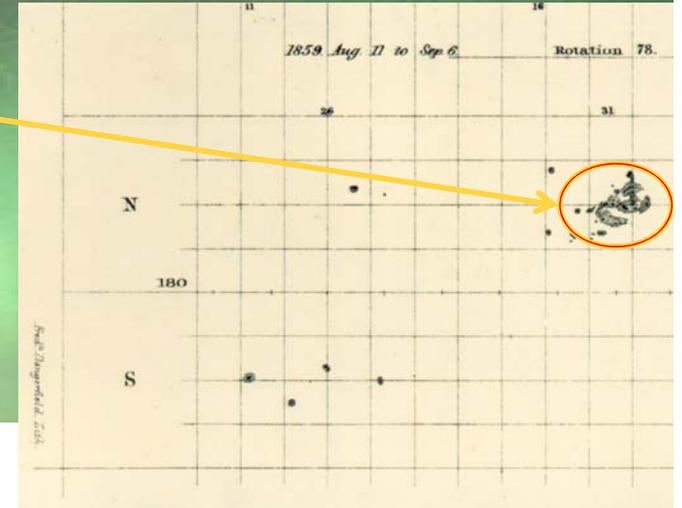


The historical record demonstrates that space weather processes often provide surprises in the implementation and operation of new electrical technologies

Carrington Event

AUGUST 28 to SEPTEMBER 4, 1859

Arching and sparking of telegraph keys and armatures were reported from a wide range of stations, including "eastern U.S., England, Scandinavia, Belgium, France, Switzerland, Prussia, Wurtemberg, Austria, Tuscany, ..."



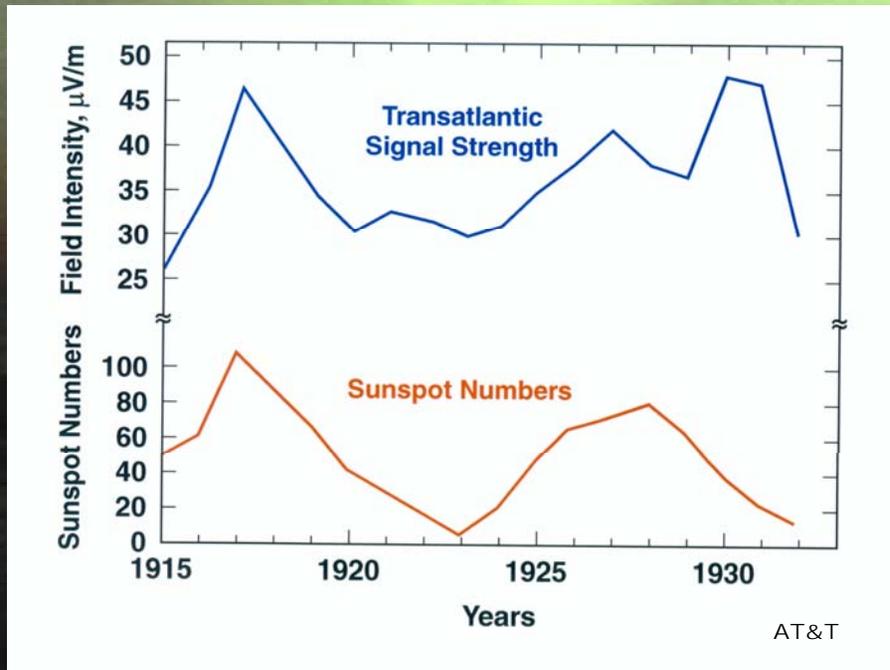
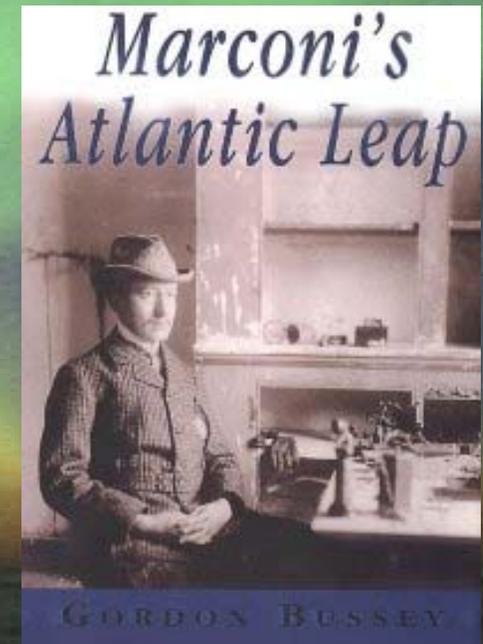
For the line from Boston to Portland (Maine), on "Friday, September 2d, 1859" the operators "continued to use the line [without batteries] for about two hours, when, the aurora having subsided, the batteries were resumed." (G. B. Prescott, *Am. J. Sci. Arts*, 29, 92, 1860)

The historical record demonstrates that space weather processes often provide surprises in the implementation and operation of new electrical technologies:

Wireless Communications

“... times of bad fading practically always coincide with the appearance of large sun-spots and intense aurora-boreall 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, *Radlo Communications*, 1928.

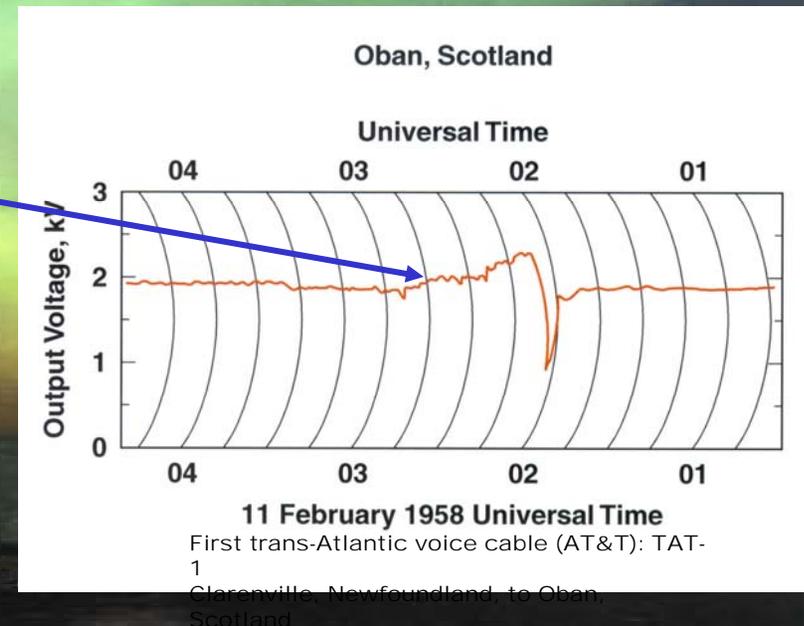


The historical record demonstrates that space weather processes often provide surprises in the implementation and operation of new electrical technologies:

Ocean Telephone Cables Electric Power Systems

“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” *



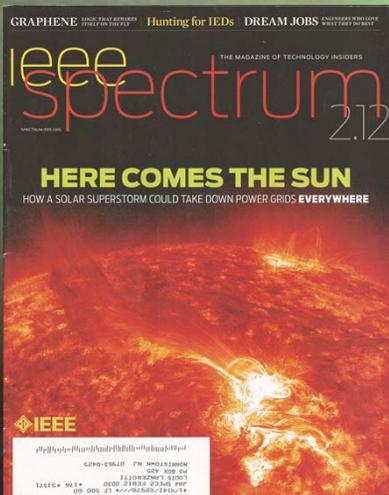
* John Brooks, "A Reporter at Large; The Subtle Storm," *New Yorker*, February 19, 1959

The historical record also demonstrates that as the complexity of systems increase, including their interconnectedness and interoperability, they can become more susceptible to space weather effects:

Power distribution systems

Long communication cables: land and sea

Pipelines



March 24, 1940

Transformer tripping, Ontario Hydro Electric
4 transformer banks, Chats Falls, Niagara District
6 transformer banks, Abatibi System

February 10, 1958

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

March 10, 1989

St. 1972: AI&L4 cable Chicago
hour power supply disruption in Pla

SPACE WEATHER, VOL. 2, S10003, doi:10.1029/2003SW000005, 2004

Space weather and the electricity market:
An initial assessment

Kevin F. Forbes

Department of Business and Economics, Catholic University of America, Washington, DC, USA

O. C. St. Cyr

Department of Physics, Catholic University of America, Washington, DC, USA

NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

IN BRIEF

SPACE WEATHER, VOL. 10, S05001, doi:10.1029/2011SW000752, 2012



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

Did geomagnetic activity challenge electric power reliability during solar cycle 23? Evidence from the PJM regional transmission organization in North America

Kevin F. Forbes¹ and O. C. St. Cyr^{2,3}

The historical record also demonstrates that as the complexity of systems, **Radars and GHz Band** interconnectedness and interoperability can become more susceptible to space weather effects:

Radar and GHz Band



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.

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



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.



(12) **United States Patent**
Kochanski et al.

(10) Patent No.: US 7,826,795 B2
(45) Date of Patent: Nov. 2, 2010

(54) METHODS AND APPARATUS FOR MITIGATING THE EFFECTS OF SOLAR NOISE AND THE LIKE ON A WIRELESS COMMUNICATION SYSTEM

(58) Field of Classification Search 455/524, 455/63.1, 67.11, 503, 506, 67.16, 134, 562.1, 455/62, 423, 424, 501, 505, 67.13, 114.2, 455/114.3; 398/41, 118; 342/203, 156, 123
See application file for complete search history.

(75) Inventors: Gregory P. Kochanski, Dunellen, NJ (US); Louis J. Lanzerotti, New Vernon, NJ (US); George E. Rittenhouse, Holmdel, NJ (US); David J. Thomson, Murray Hill, NJ (US)

(56) **References Cited**

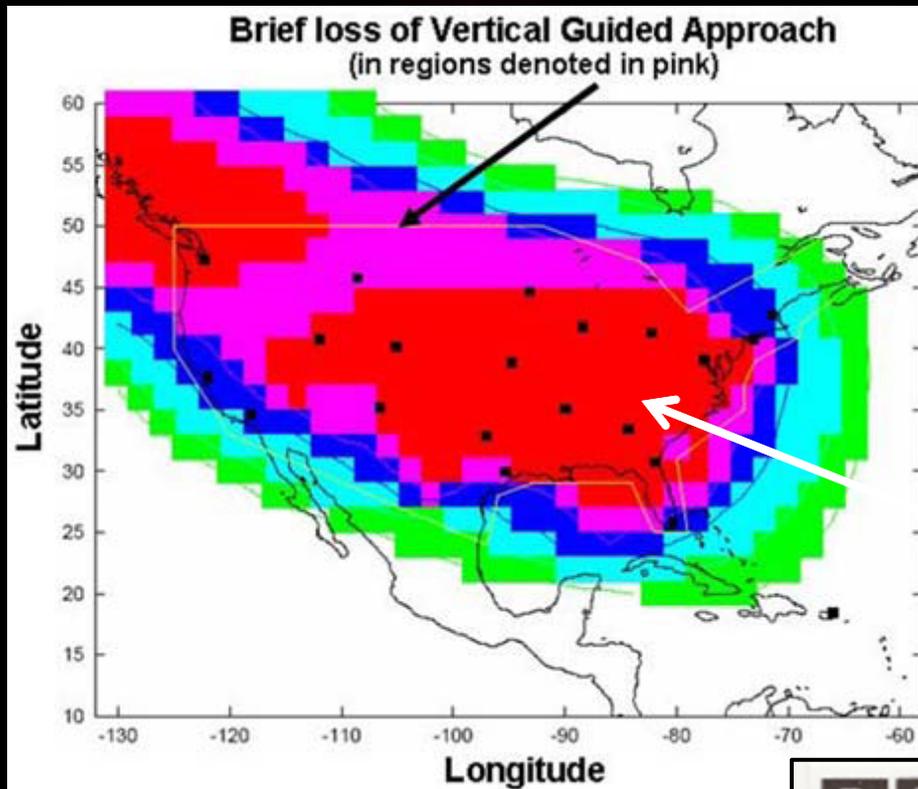
U.S. PATENT DOCUMENTS

5,640,442 A * 6/1997 Fitzgerald et al. 455/524
5,940,033 A * 8/1999 Locher et al. 342/378
6,304,760 B1 * 10/2001 Thomson et al. 455/503
6,678,176 B2 * 1/2004 Lumsden 363/95

(73) Assignee: Alcatel-Lucent USA Inc., Murray Hill, NJ (US)

* cited by examiner

Solar radio noise continues to surprise



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 World Wide Web, including from the GPS receivers from the IGS and Continuously Operating Reference System (CORS) networks.

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

Pointer: 34°03'44.98"N, 99°43'15.40"W

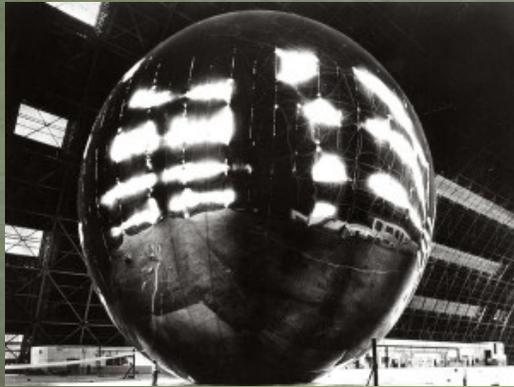
Image MASA
Image © 2007 TerraMetrics
Image © 2007 DigitalGlobe

Streaming 100%

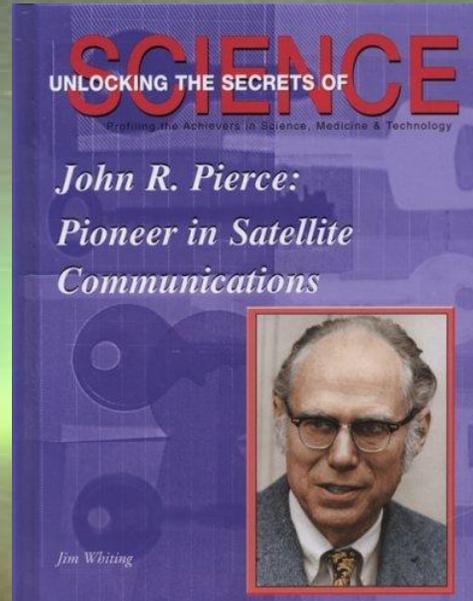
Google

Eye alt: 6453.91 mi

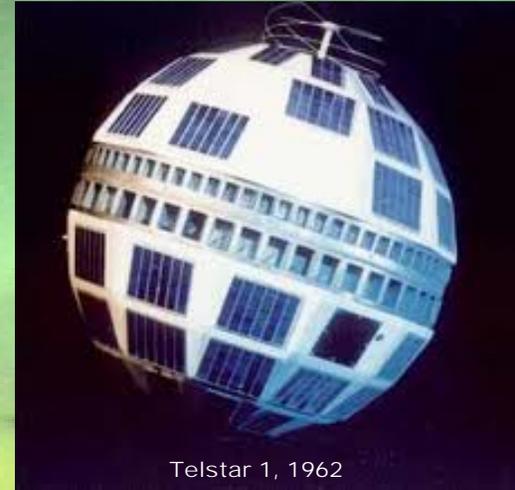
The historical record also demonstrates that as the complexity of systems increase, including their interconnectedness and interoperability, they can become more susceptible to space weather effects:



Echo 1, 1960
Passive reflector



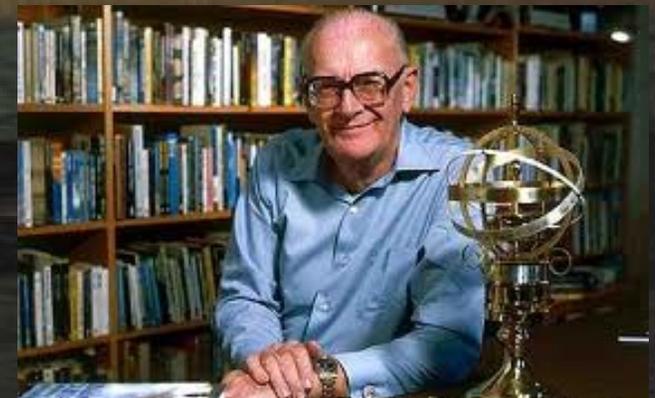
John R. Pierce



Telstar 1, 1962



Syncom 3, 1963

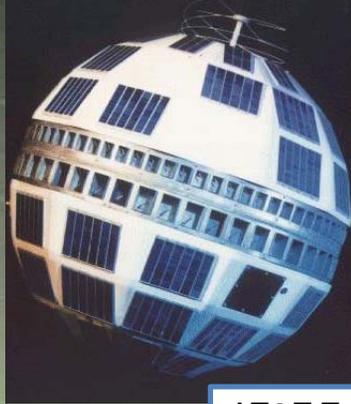


Sir Arthur Clark

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

P-ANIK!



High-tech chaos as satellites spin out of control

Plug pulled on phones, TV, radio, papers

OTTAWA — Telecom 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, Telecom 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, Telecom'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



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 1 satellite

cause we really didn't know what was going on."

In response to *Space News* questions, the Italian joint defense staff blamed the

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

Space News, January 15, 2007

April 26, 2010

Orbital Blames Galaxy 15 Failure on Solar Storm

4

January 10, 2011

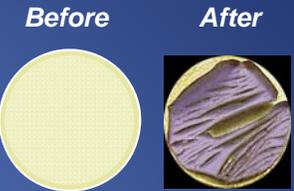
Intelsat Moving Recovered Galaxy 15 To Test Location

PETER B. de SELDING, PARIS



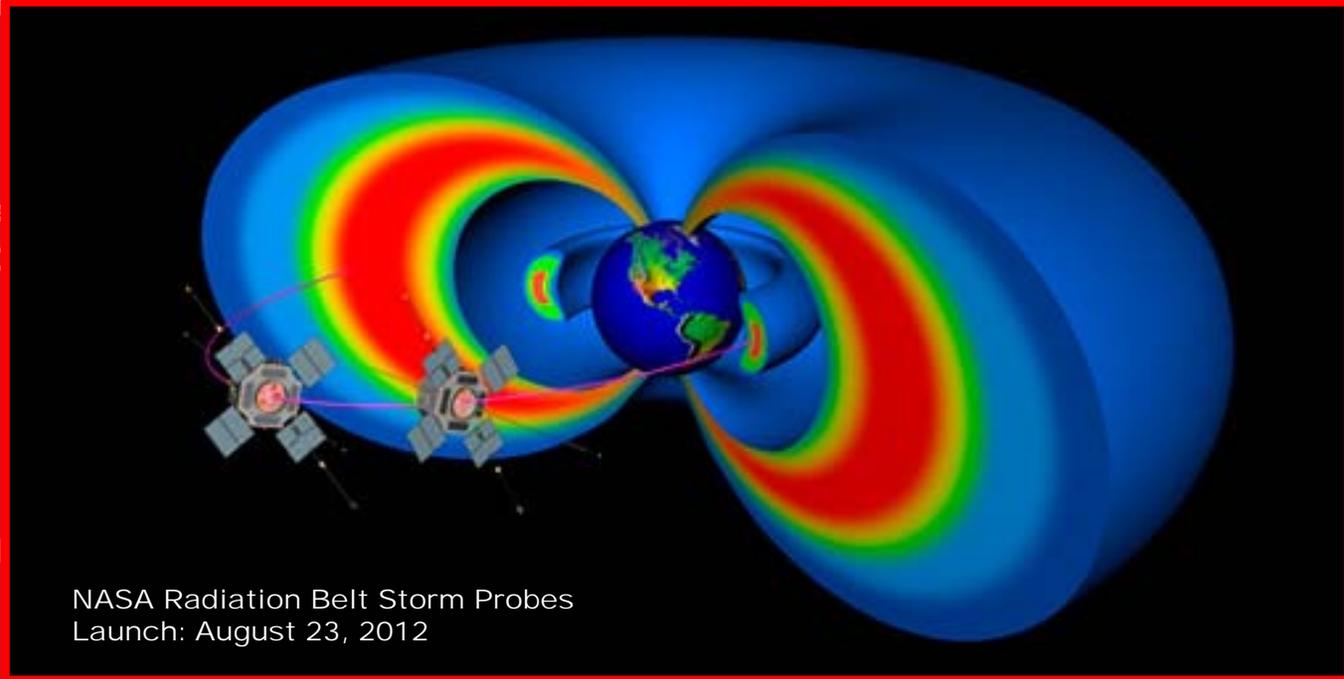
Major Space Environment Hazards

False stars in star tracker CCDs



Solar array power decrease due to radiation damage

Surface degradation from radiation



Single event effects
110

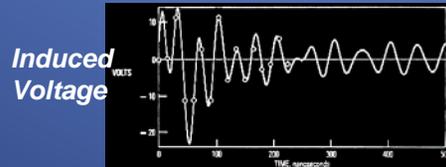
radiation dose

Spacecraft components

solar array arc charge

NASA Radiation Belt Storm Probes
Launch: August 23, 2012

Electromagnetic pulse from vehicle discharge
(on surface, behind thin shielding, or deep inside)



Time

(The Aerospace Corporation)

The historical record also demonstrates that as the complexity of systems increase, including their interconnectedness and interoperability, they can become more susceptible to space weather effects:

SPACE RADIATION

Astronaut safety
Airline passenger safety

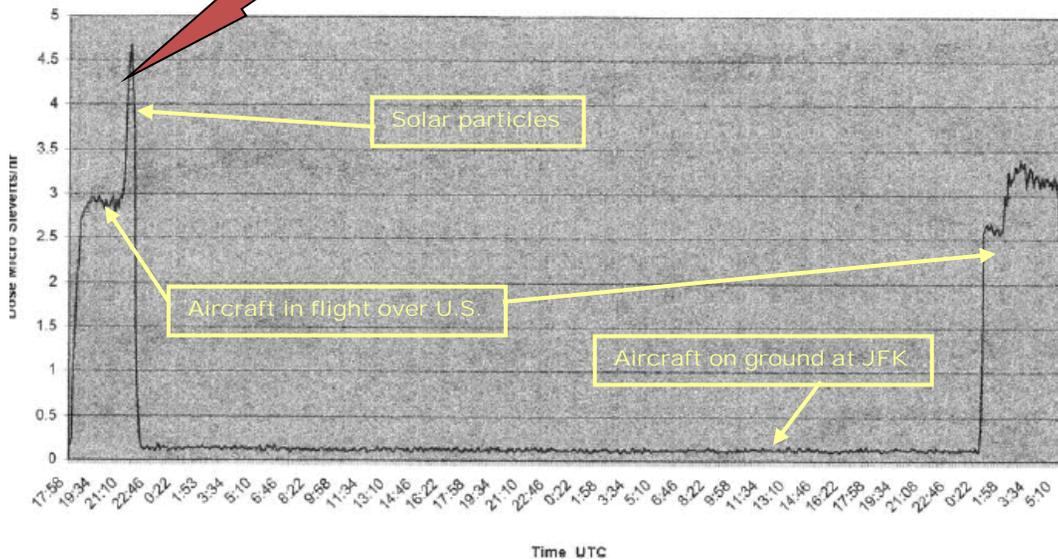
SPACE WEATHER, VOL. 5, S08002, null PP., 2007
doi:10.1029/2007SW000333

Commercial Space Tourism and Space Weather

Ronald Turner
Analytic Services, Inc., Arlington Virginia USA

Observation of solar p
Los Angeles to New York
Ian L. Getley
Department of Aviation, University of New South Wales, Sydney, Australia

LAX-JFK 29thOct2003 (37,000FT, LAST HR 39,000FT) = 12.0 MicroSv. JFK-LAX 1stNov2003(39,000ft most of flt)= 16.0 MicroSv



SPACE WEATHER, VOL. 1, NO. 1, 1005, doi:10.1029/2003SW000011, 2003

A systematic global mapping of the radiation field at aviation altitudes

E. G. Stassinopoulos
NASA Goddard Space Flight Center, Greenbelt, Maryland, USA

C. A. Stauffer
Stinger Ghaffarian Technologies, Greenbelt, Maryland, USA

G. J. Brucker¹
Radiation Effects Consultants, Inc., West Long Branch, New Jersey, USA

SPACE WEATHER, VOL. 3, S01004, doi:10.1029/2004SW000110, 2005

Radiation dose along North American transcontinental flight paths during quiescent and disturbed geomagnetic conditions

Ian L. Getley
Department of Aviation, University of New South Wales, Sydney, New South Wales, Australia

M. L. Duldig
Space and Atmospheric Sciences, Australian Antarctic Division, Kingston, Tasmania, Australia

D. F. Smart and M. A. Shea
Space Vehicles Directorate, Air Force Research Laboratory, Hanscom Air Force Base, Bedford, Massachusetts, USA

The historical record also demonstrates that as the complexity of systems increase, including their interconnectedness and interoperability, they can become more susceptible to space weather effects:

SPACE RADIATION and DISTURBANCES

Airline Operations: North Polar Routes

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 57th parallel experienced some disruptions in high frequency radio communications Wednesday due to the geomagnetic storm from solar flares.



Sunstorm Watch: Planes rerouted as massive solar storm brushes by Earth

Published March 08, 2012 | FoxNews.com

Print

Cosmic rays
Solar x-rays
Solar radio
Solar particles
Solar magnetic fields
Radiation belts
Magnetosphere plasma
Ionosphere electrical currents
Ionosphere bubbles
Atmosphere density
Atmosphere ions
Earth's conductivity

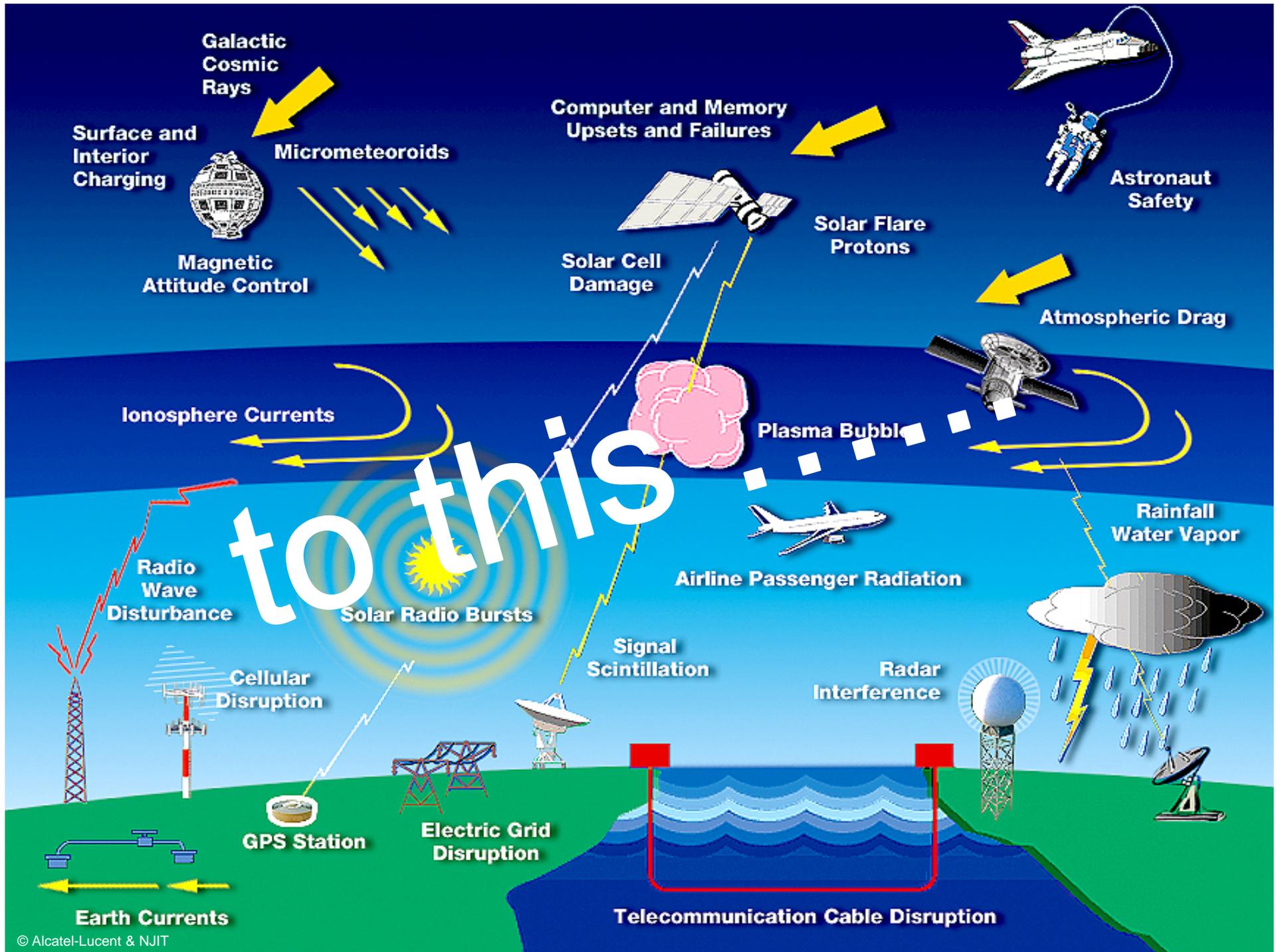
SUMMARY

As the complexity of systems increase, including their interconnectedness and interoperability, they can become more susceptible to space weather effects

Solar-produced effects at Earth: "It is not a matter of if, it is simply a matter of when and how big"
Jane Lubchenco, Administrator, National Oceanic and Atmospheric Administration
20 February 2011

From this





Space Weather

QUARTERLY

Volume 8, Issue 3, 2011 www.ags.org/journals/spaceweather
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

Geomagnetic Storms Over India

News: Improving models of induced currents in Europe

Feature: The USGS Geomagnetism Program

Technical: Total ionizing dose at the Moon



Space Weather

QUARTERLY

Volume 7, Issue 4, 2010 www.ags.org/journals/spaceweather
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

Smartphone Apps Sun-Earth Conditions in Real Time

News: International organizations focus on space weather

Feature: A decade of space weather events, discussed in billions

Technical: Quiet time relativistic electrons

Space Weather

QUARTERLY

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

Canada's Geomagnetic Odyssey

Space Weather

QUARTERLY

Volume 9, Issue 1, 2012 www.ags.org/journals/spaceweather
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

National Response to a Severe Space Weather Event

Meeting: U.S.-U.K. Space Weather Workshop

Feature: Five Curious Questions: From the Curious to the Disquieting: The Evolution of the Prime Minister's Office as a Case Study for the Arctic

Space Weather

QUARTERLY

Volume 8, Issue 4, 2011 www.ags.org/journals/spaceweather
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

From Space Down to Earth

An Interview With Kathryn Sullivan

Space Weather

QUARTERLY

Volume 9, Issue 2, 2012 www.ags.org/journals/spaceweather
THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS

New Observatories in China

Meeting: Conference and Inner

Feature: New South Programs

Technical: Ionospheric and Global

News: Power grid vulnerabilities

Feature: An interview with a space weather professor

Technical: Galactic cosmic ray hazards

THANK YOU!

Space Weather Enterprise Forum 2012
Washington, D.C.