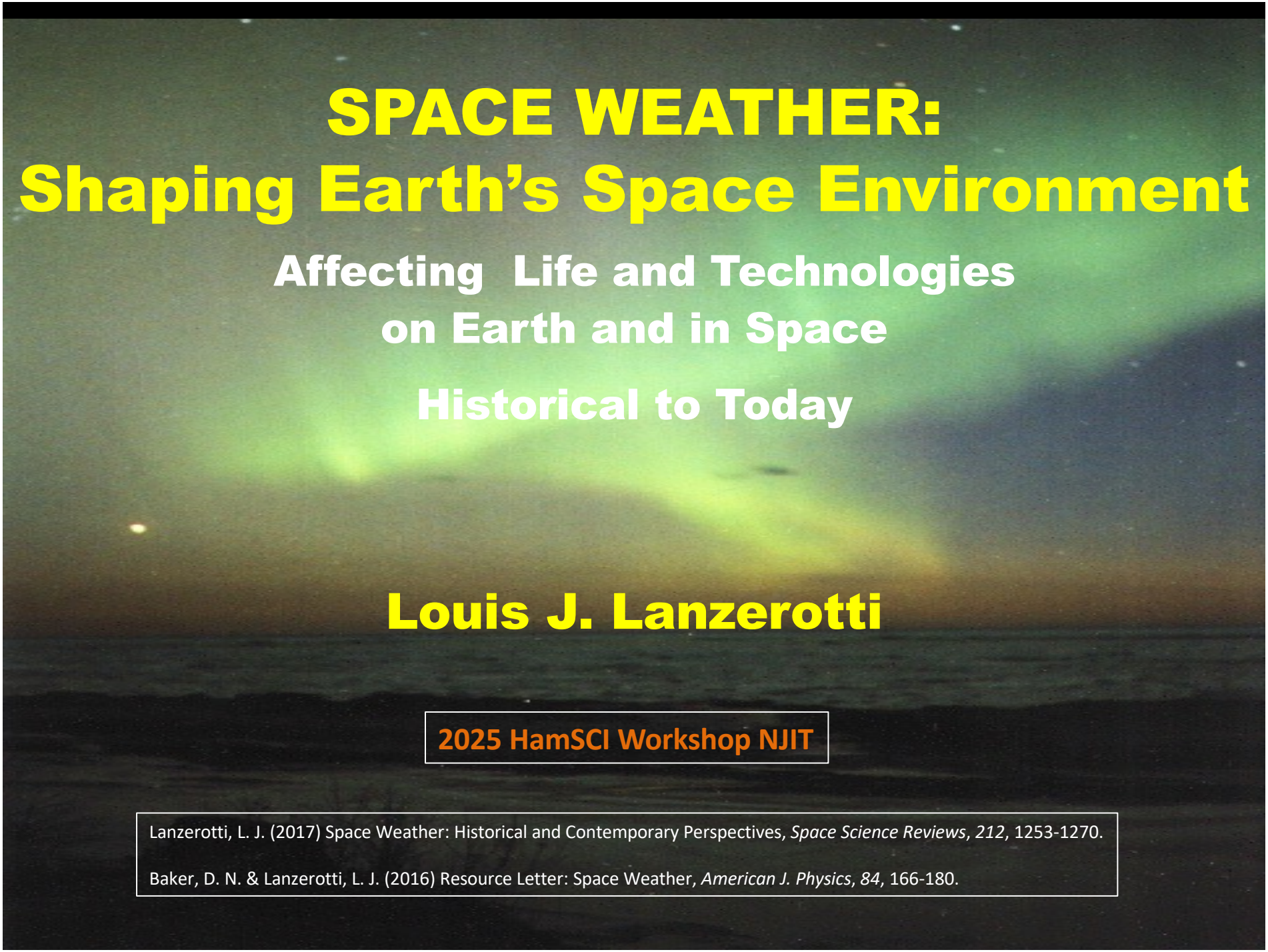


SPACE WEATHER:
Shaping Earth's Space Environment

Affecting Life and Technologies on Earth and in Space

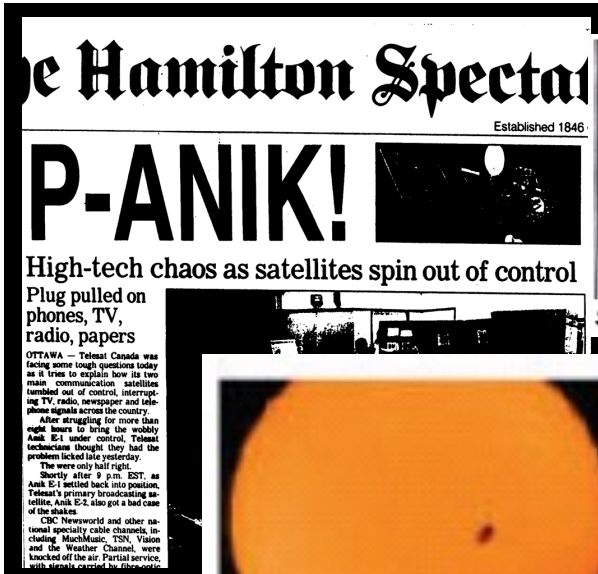
Historical to Today

Louis J. Lanzerotti

2025 HamSCI Workshop NJIT

Lanzerotti, L. J. (2017) Space Weather: Historical and Contemporary Perspectives, *Space Science Reviews*, *212*, 1253-1270.

Baker, D. N. & Lanzerotti, L. J. (2016) Resource Letter: Space Weather, *American J. Physics*, *84*, 166-180.



e Hamilton Spectat

Established 1846

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,

Italy Blames Disruption of Comsat NATO Uses on Strong Solar Activity

PETER B. de SELDING, PARIS

The Italian Defense Ministry lost control of its

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

In response to *Space News* questions, the Italian joint de-

software modernization on the satelli point ing li

***Space News*, January 15, 2007**

Space Station Glitch Possibly Caused by Solar Flare

By Tariq Malik

Staff Writer

posted: 15 December 2006

11:49 am ET

YAHOO! NEWS

Space weather could wreak havoc in gadget-driven world

by Kerry Sheridan

Sun Feb 20, 5:46 pm ET

Minnesota Now with Cathy Wurzer

Northern lights solar storm interrupted tractor GPS system, halting planting for Minnesota farmers

Cathy Wurzer and CJ Younger May 13, 2024 2:24 PM

MONDAY, JULY 17, 2000

Solar storm ends up just a nuisance

REUTERS

WASHINGTON — A severe geomagnetic storm that hit Earth over the weekend interfered with data from at least one U.S. weather satellite and some power systems, government scientists said yesterday.

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

Solar flare may disrupt communications

WASHINGTON (AP) —

arge solar flare was repor

Wednesday and forecaster

varned of potential electri

nd communications disru

tions.

The flare was reported

PLANET EARTH

Magnetic North Pole Shifts, Forces Runway Closures at Florida Airport

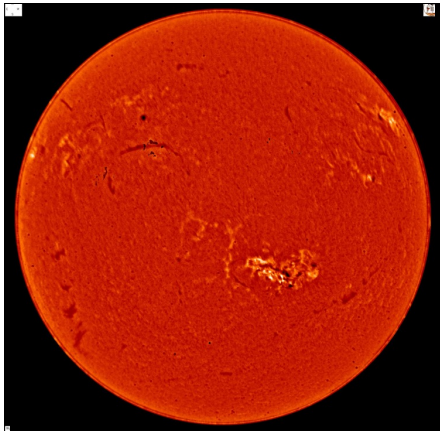
By Jeremy A. Kaplan

Published January 06, 2011 | FoxNews.com

THE NEW YORK TIMES, WEDNESDAY, MARCH 8, 1989

Largest Solar Flaring in 5 Years Could Break Up Communications

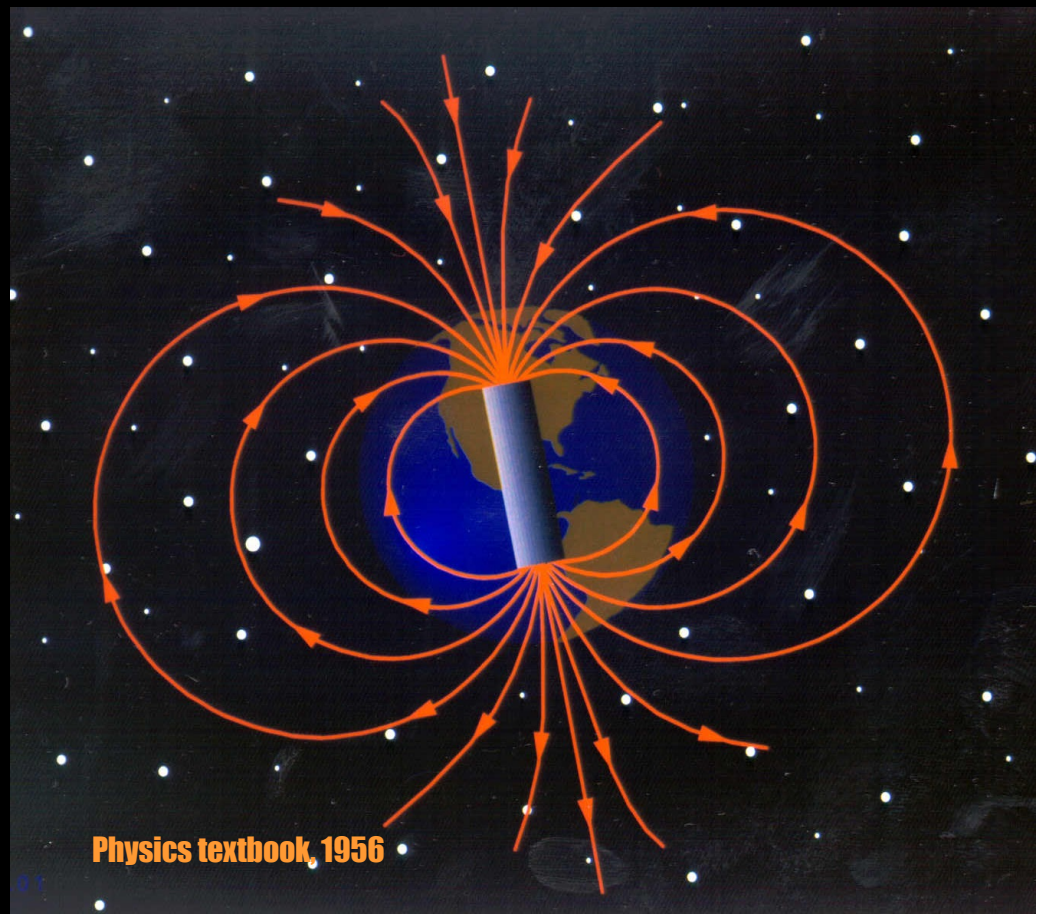
By WILLIAM K. STEVENS

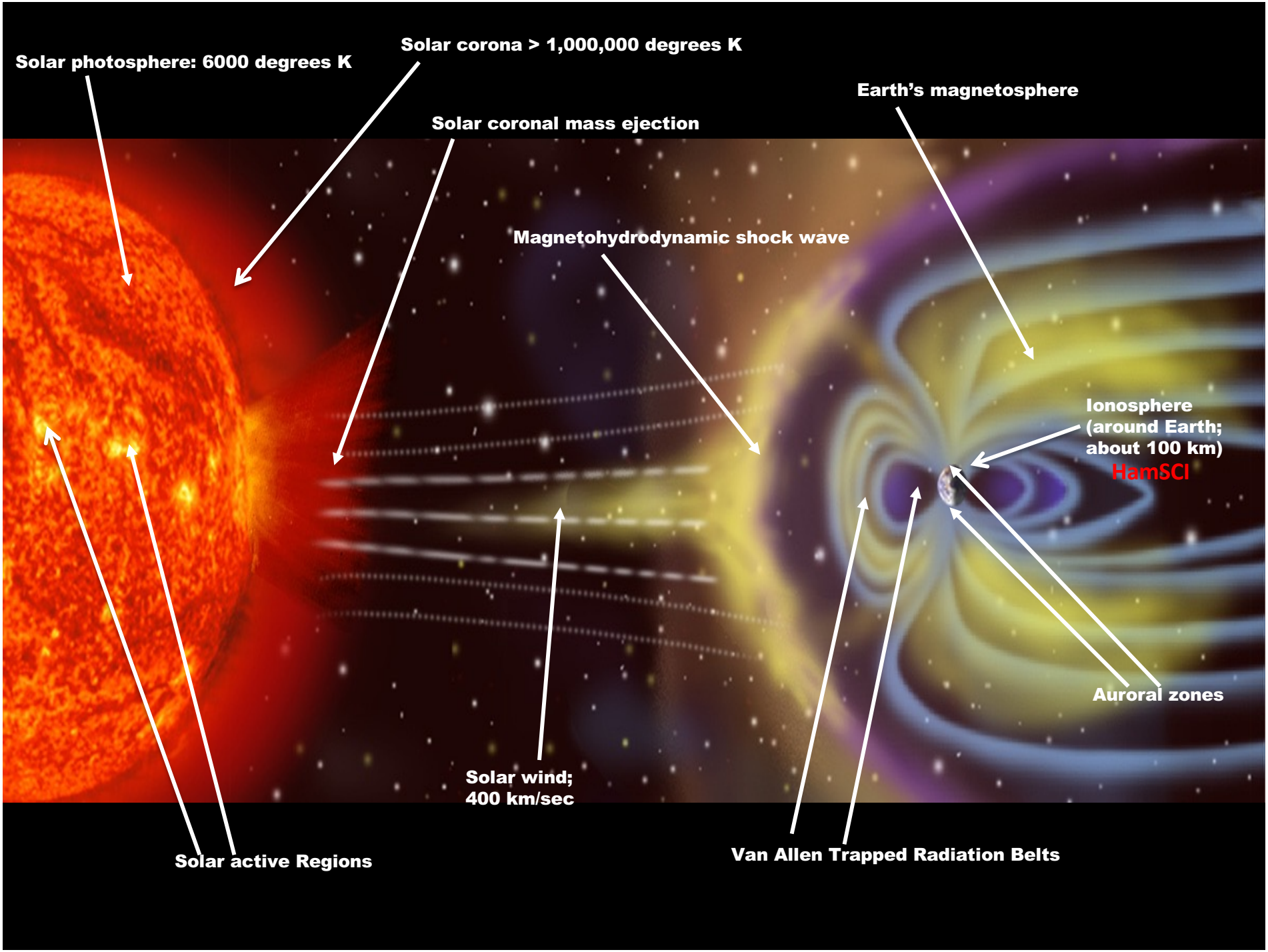


Big Bear Solar Observatory 8 May 2024

Empty space

Feb. 20, 2011




Solar photosphere: 6000 degrees K
Solar corona > 1,000,000 degrees K
Earth's magnetosphere
Solar coronal mass ejection
Magnetohydrodynamic shock wave
Ionosphere
(around Earth;
about 100 km)
HamSCI
Auroral zones
Solar wind;
400 km/sec
Solar active Regions
Van Allen Trapped Radiation Belts

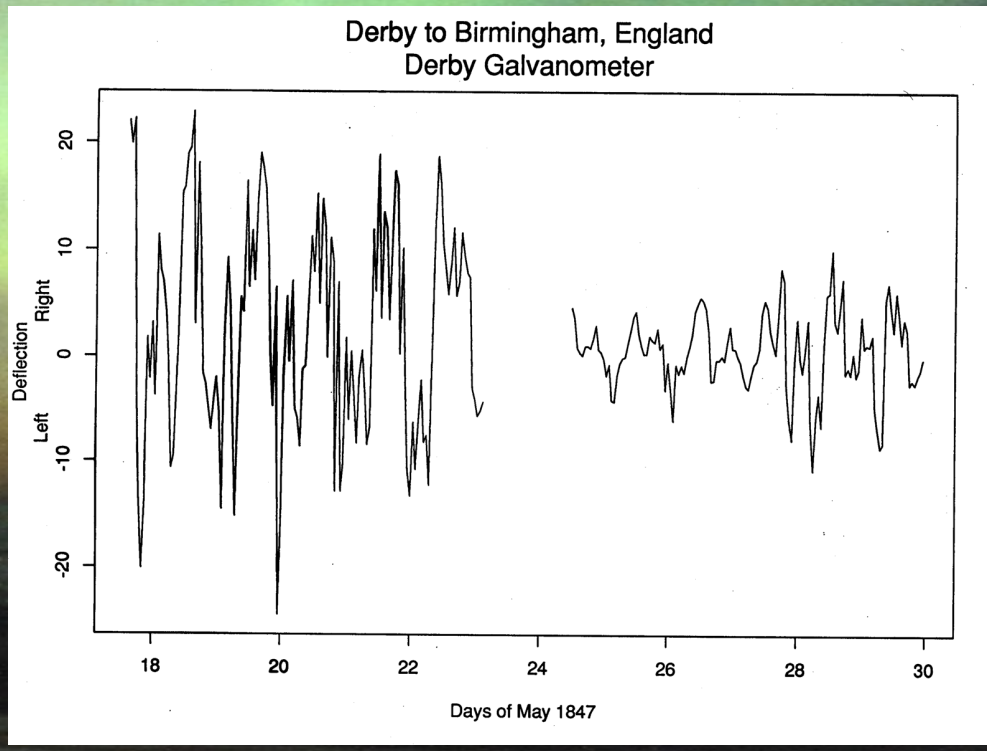

Space Weather --
Historical perspective

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

Fig. 1.5 William Barlow
Painting by John Collier

"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"

DISCOVERY OF A SOLAR FLARE

With the Author's compts

OBSERVATIONS

OF THE

SPOTS ON THE SUN

FROM NOVEMBER 9, 1853, TO MARCH 24, 1861,

MADE AT REDHILL,

BY

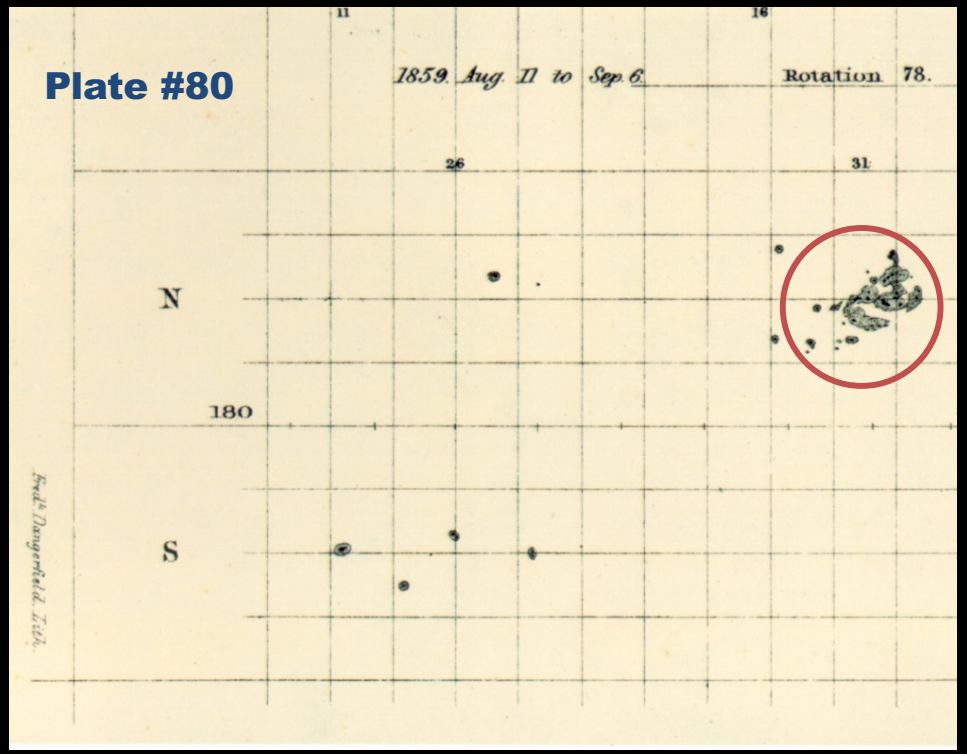
RICHARD CHRISTOPHER CARRINGTON, F.R.S.

ILLUSTRATED BY 166 PLATES.

The publication of this work was aided by a Grant from the Fund placed at the disposal of the Royal Society by Her Majesty's Treasury.

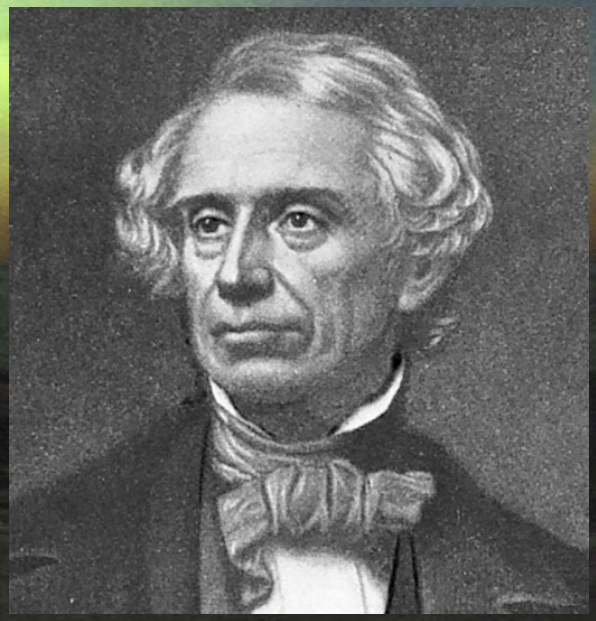
WILLIAMS AND NORGATE,
14, HENRIETTA STREET, COVENT GARDEN, LONDON;
AND
20, SOUTH FREDERICK STREET, EDINBURGH.
1863.

"The observation of this very splendid group on September 1st [1859] has had some notoriety. ... I ... witnessed a singular outbreak of light which lasted about 5 minutes, and moved sensibly over the contour of the spot ...."



MAGNETIC STORM:
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, Wurtemburg, Austria, Tuscany, …"



Samuel F. B. Morse

MAGNETIC STORM:
AUGUST 28 to SEPTEMBER 4, 1859

Arching and sparking of telegraph keys and armatures were reported from a wide range of stations, includi[illegible]., England, Scandi[illegible], France, Switze[illegible]Wurtemburg, Austria

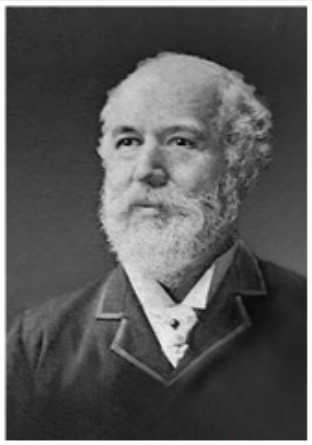


Fig. 1.11 George Prescott
Photograph courtesy of the Kingston Historical Museum, Kingston, New Hampshire.

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

MAGNETIC STORM

Originating from solar effects?

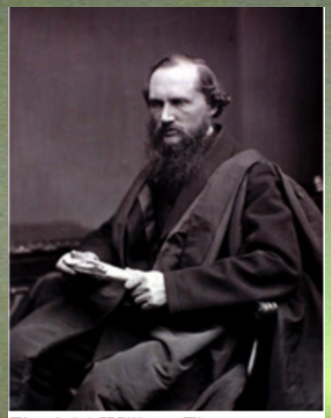


Fig. 1.14 William Thompson (Lord Kelvin)

Lord Kelvin, 1892 Presidential address to the Royal Society of London said "NO"

MAGNETIC STORM

14-15 May 1921

SUNSPOT AURORA PARALYZES WIRES

Unprecedented Disturbance Is Attributed to Solar Manifestations.

BROADWAY LIGHTS DIMMED

Theatre Crowds Returning Home Amazed at the Brilliancy of the Skies.

An aurora borealis unparalleled in dimensions in the memory of telegraph wire chiefs last night gripped telegraph wires from the Atlantic Coast to the Mississippi, so that service virtually was ended near midnight.

The American Telegraph and Telephone Company, operating many leased wires for newspapers, reported that the disturbance was unprecedented in the memory of men thirty years in the service. At times every wire was "down" and operators could not get them back into service, although they kept trying to communicate with city after city.

New York Times 15 May 1921

MAGNETIC STORM:

March 24, 1940

First widespread effects on power distribution systems

- Numerous Problems (Transformer Tripping; Reactive Power Surges) on Other Systems; e.g.: Philadelphia Electric; Public Service NJ; Central Maine; Northern States Power (MN); Eastern MA Electric

- Transformer Tripping, Ontario Hydro Electric
  4 Transformer Banks, Chats Falls, Nia
  6 Transformer Banks, Abatibi System

- Widespread effects on Radio- and

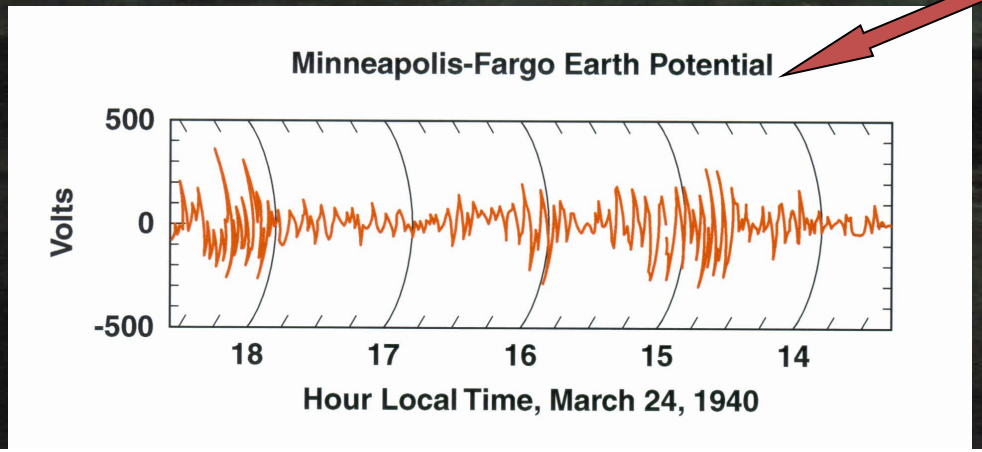
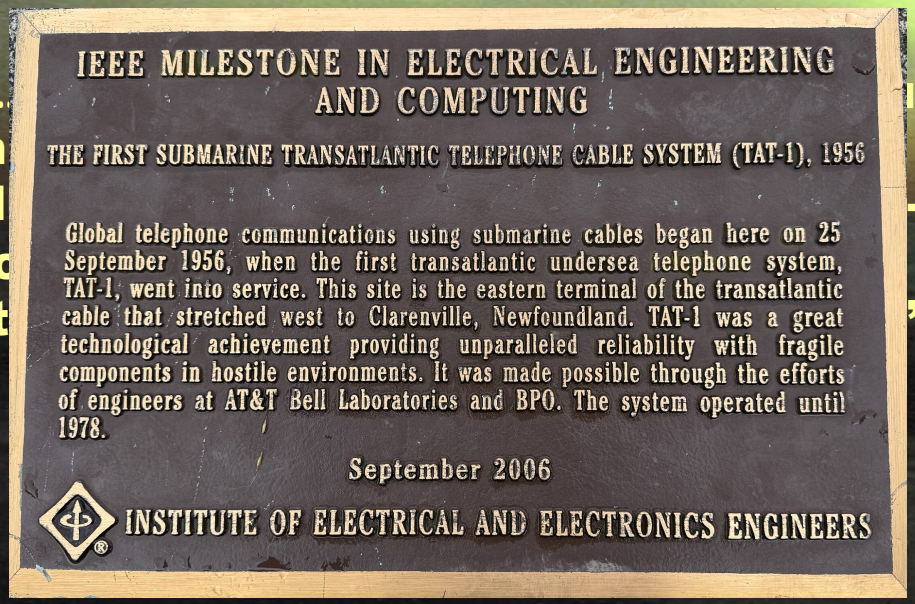


Fig. 1.16 Areas of high Earth resistivity (black shaded areas) with locations (open circles) shown of AT&T Long Lines system telecommunications problems during the Easter Sunday, 24 March 1940, geomagnetic storm. Adapted from Germaine (1940).

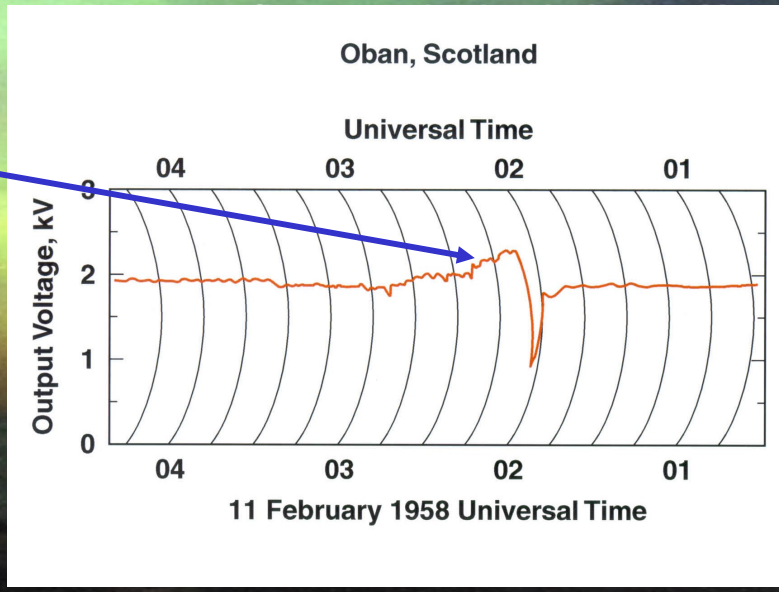
MAGNETIC STORM:

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*."*

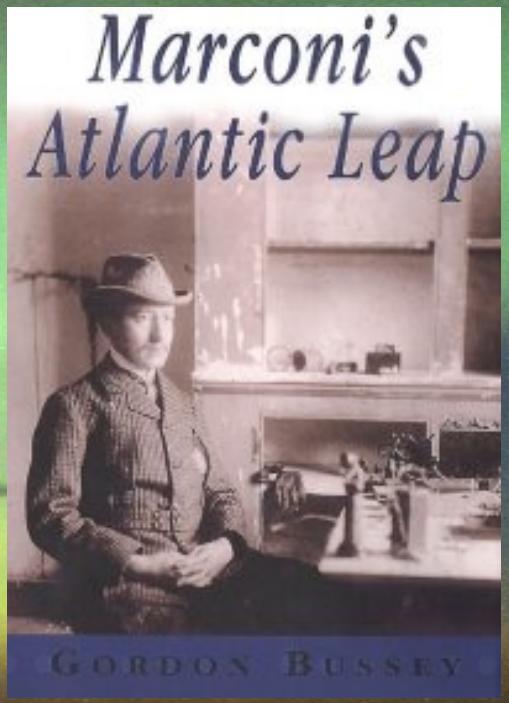


First trans-Atlantic voice cable
Clarenville, Newfoundland, to Oban, Scotland



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

EARLY WIRELESS COMMUNICATIONS



Guglielmo Giovanni Maria Marconi
12 December 1901 dot dot dot from Poldhu, Cornwall, to St. John's, Newfoundland
(Thought to be about 850kHz (about 350m) in daylight across Atlantic)
1909: Nobel Prize in Physics

EARLY WIRELESS COMMUNICATIONS

Marconi and assistants launching kite-supported aerial, Signal Hill, St. John's, Newfoundland, December 1901. To receive signal from Poldhu, Cornwall

Signal Hill, 2011

Curiously, the disturbance that tied up the land wires seemed to strengthen the signals of the wireless apparatus. Operators in the special wireless station of THE NEW YORK TIMES reported that their signals from Berlin and the La-fayette station at Bordeaux were much stronger from 10:30 o'clock last night until after midnight, the period of the greatest disturbance on the land wires.

New York Times 15 May 1921

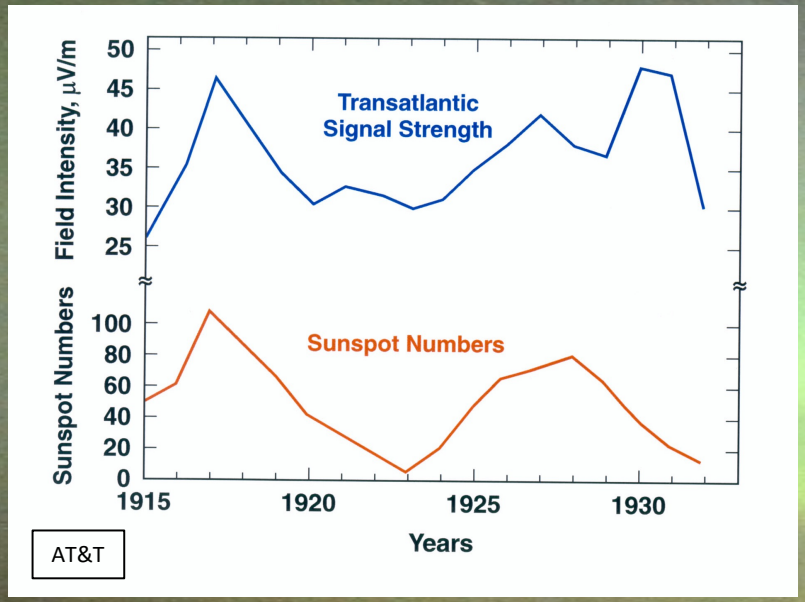
EARLY WIRELESS COMMUNICATIONS

Marconi and assistants launching kite-supported aerial, Signal Hill, St. John's, Newfoundland, December 1901. To receive signal from Poldhu, Cornwall

Signal Hill, 2011

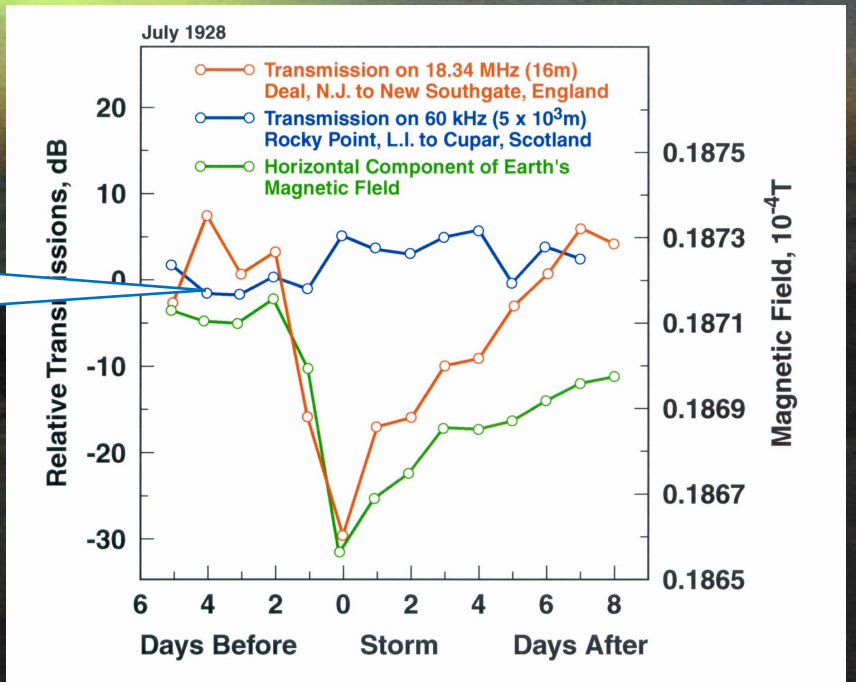
"... times of bad fading practically always coincide with the appearance of large sun-spots and intense aurora-boreali usually accompanied by magnetic storms ...." These are "... the same periods when cables and land lines experience difficulties or are thrown out of action."
(G. Marconi, *Radio Communications*,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

EARLY WIRELESS COMMUNICATIONS

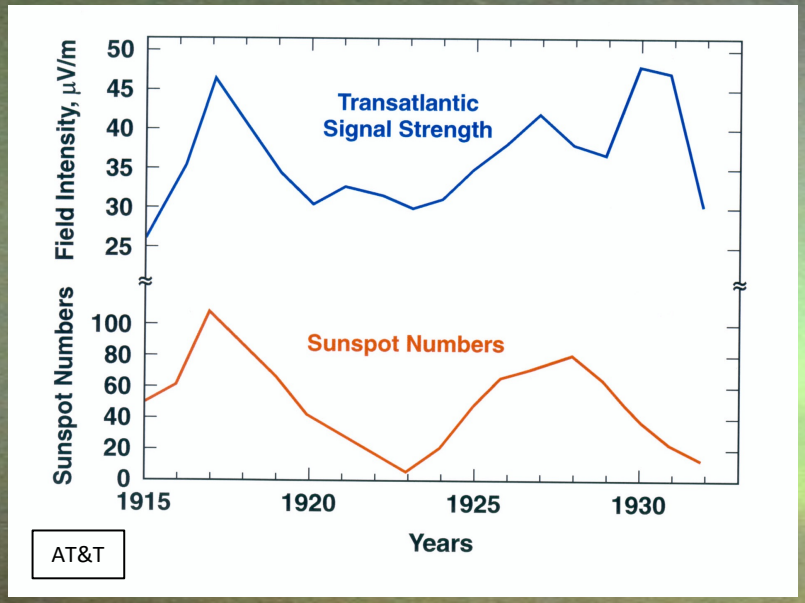


Low frequency reception (BLUE) stable

High frequency reception (red) follows magnetic field storm (green)



EARLY WIRELESS COMMUNICATIONS

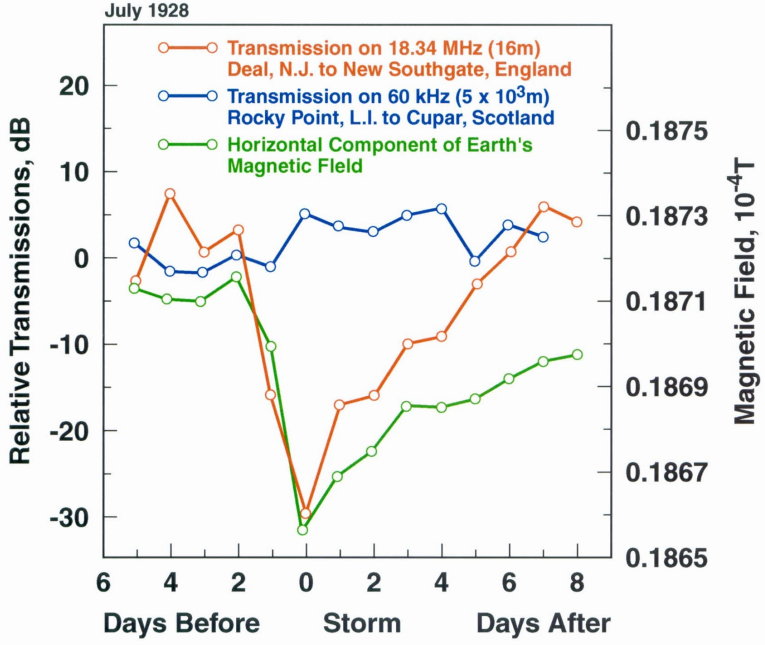


An operator of RCA Communications said that while conditions had been "none too good" during the past week, an almost complete interruption of short-wave traffic between New York and London was experienced yesterday about 1 A. M. Almost all traffic was shifted to the long-wave circuits, which are less affected by the earth's magnetic condition resulting from sunspots, now at a high peak.

NEW YORK, SUNDAY, JANUARY 23, 1938.

Violent Magnetic Storm Disrupts Short-Wave Radio Communication

Transoceanic Services Transfer Phone and Other Traffic to Long Wave Lengths as Sun Spot Disturbance Strikes



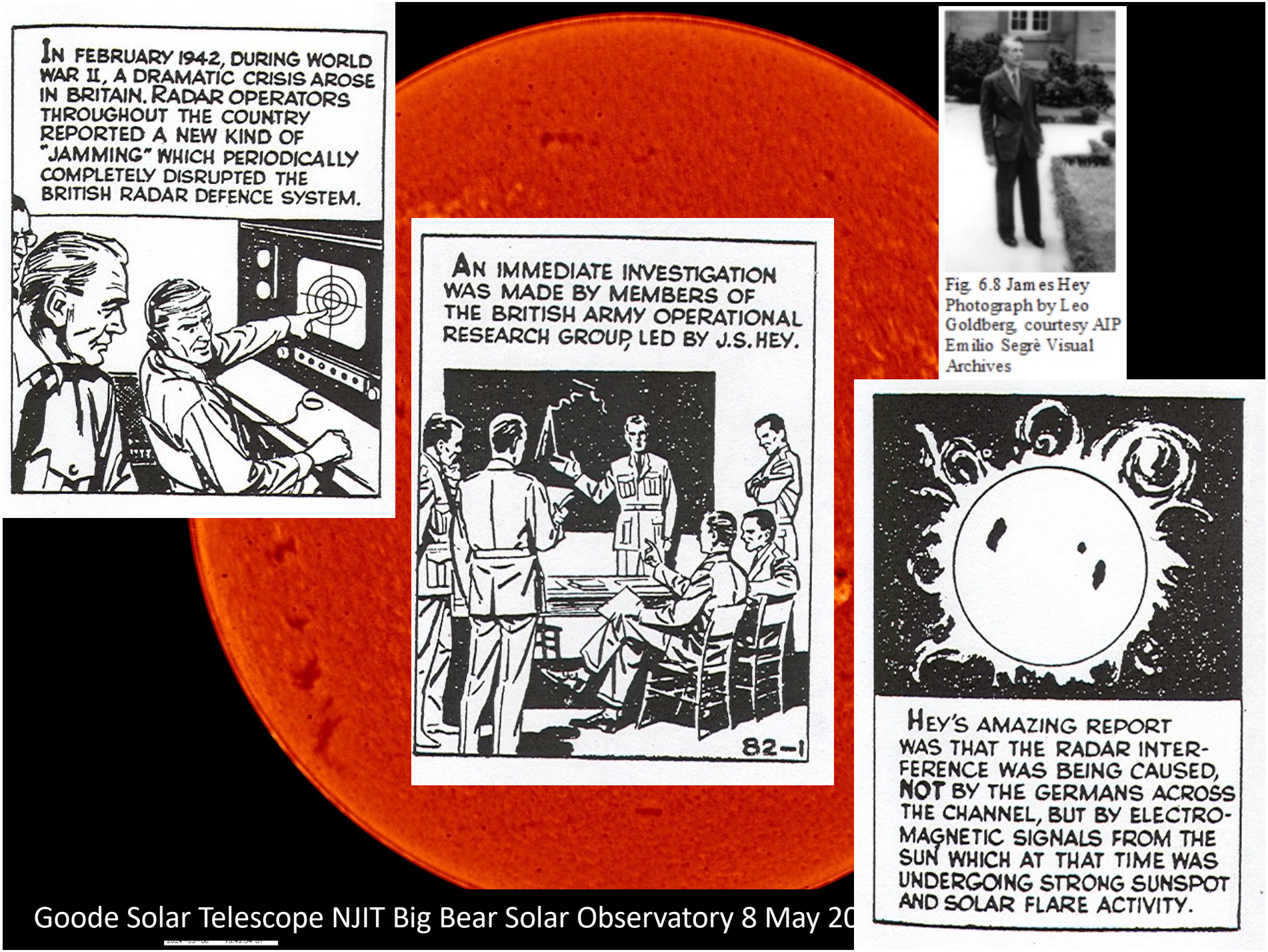
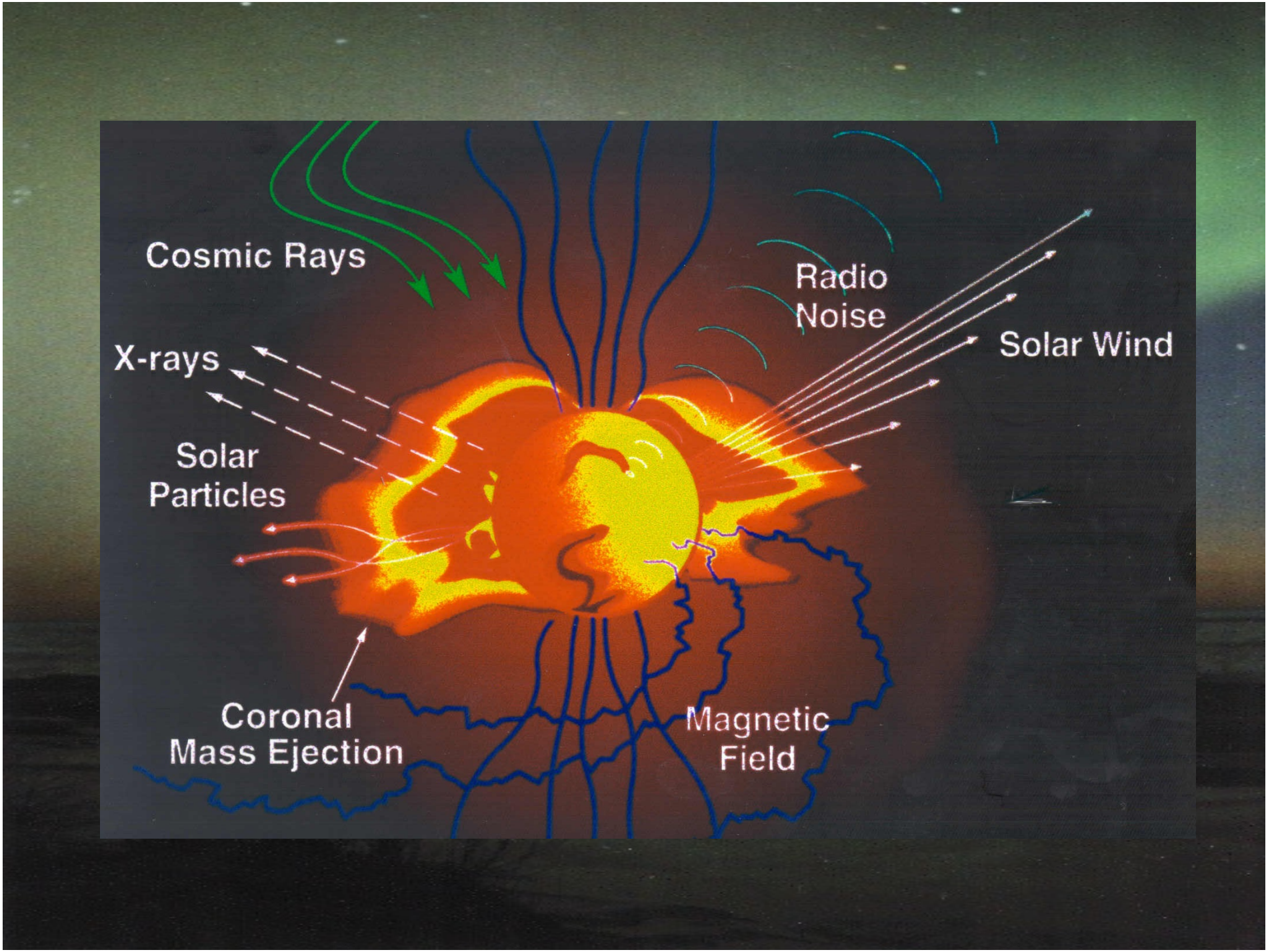


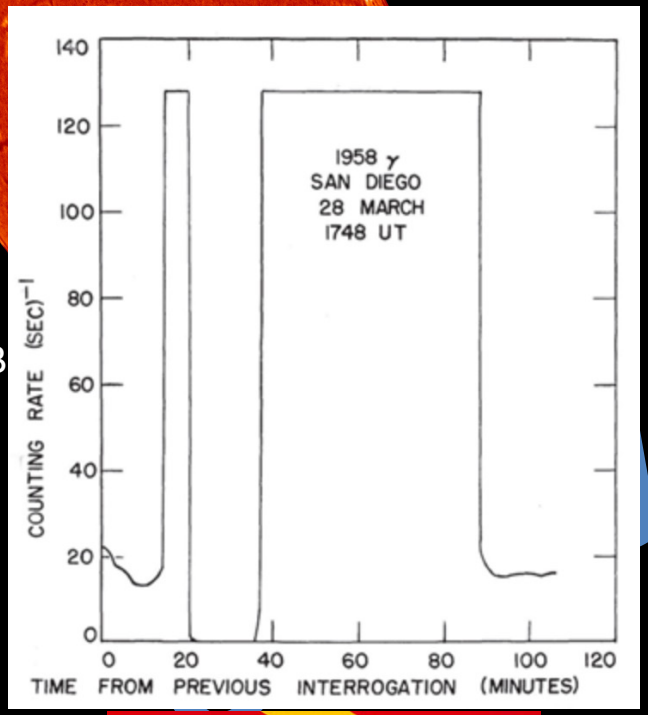
Fig. 6.8 James Hey Photograph by Leo Goldberg, courtesy AIP Emilio Segrè Visual Archives

Goode Solar Telescope NJIT Big Bear Solar Observatory 8 May 20


Space Weather --
Contemporary


Cosmic Rays
Radio
Noise
Solar Wind
X-rays
Solar
Particles
Coronal
Mass Ejection
Magnetic
Field

The satellite era: Sputnik 1 (1957) and Explorer 1 (1958)



Explorer 1 January 1958

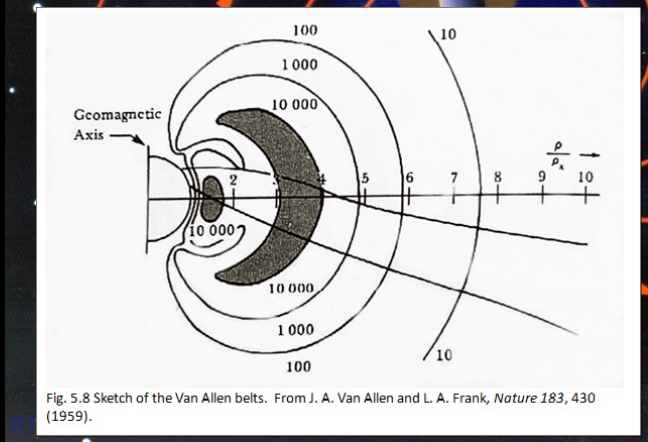


Fig. 5.8 Sketch of the Van Allen belts. From J. A. Van Allen and L. A. Frank, *Nature 183*, 430 (1959).

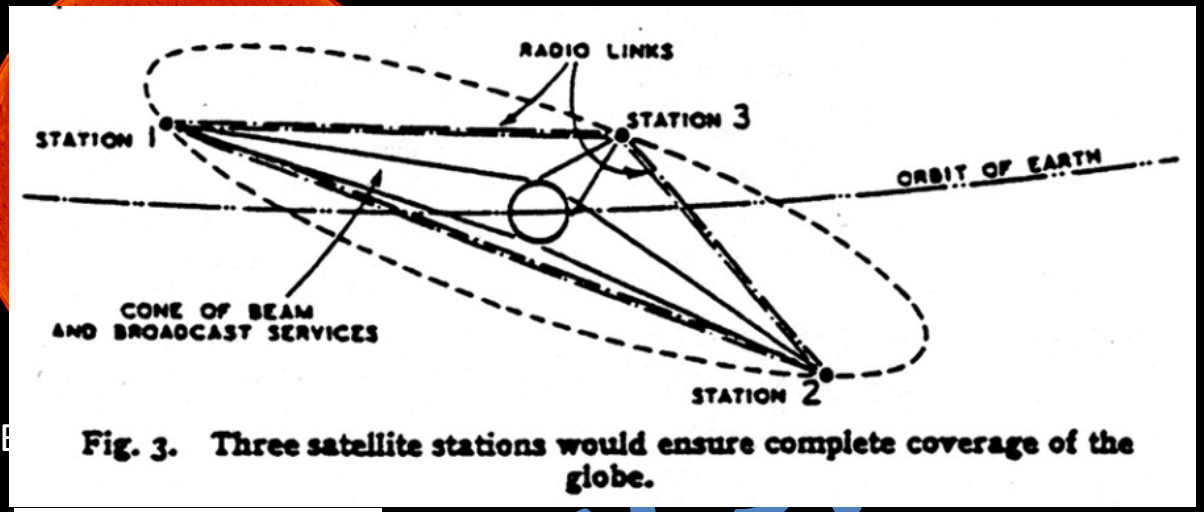
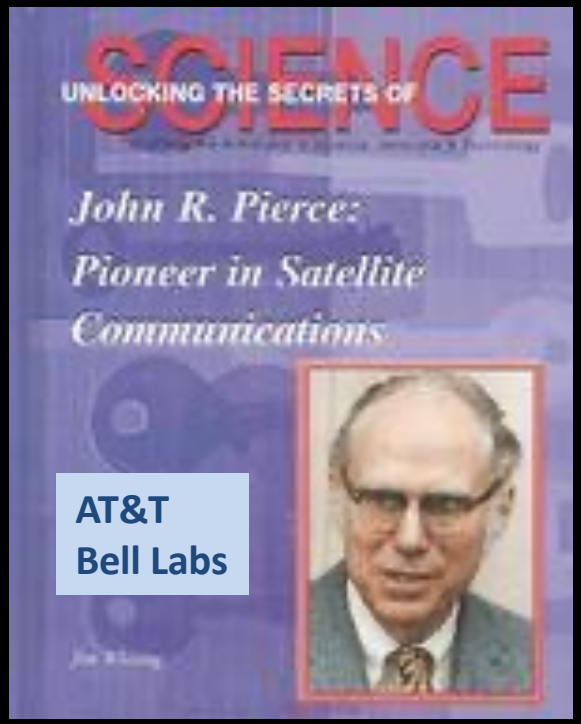


Fig. 3. Three satellite stations would ensure complete coverage of the globe.

Wireless World, 1945

Three human-tended geosynchronous communication satellites

Sir Arthur Clark 1945



Telstar 1 1962
Low Earth Orbit

Harold Rosen
Hughes Aircraft

Syncom 3 1963
Geosynchronous Orbit

Sir Arthur Clark 1945

Major Space Environment Hazards

***Fortune* magazine February 10, 2022**

How Elon Musk's SpaceX lost 40 Starlink satellites —reportedly worth as much as $20 million—all at once

www.spacenews.com

SPACE NEWS

April 26, 2010

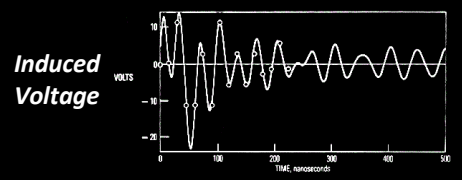
Orbital Blames Galaxy 15 Failure on Solar Storm

4 SPACE NEWS www.spacenews.com

January 10, 2011

Intelsat Moving Recovered Galaxy 15 To Test Location

PETER B. de SELDING, PARIS



Time

Sun 'ejection' killed TV satellite

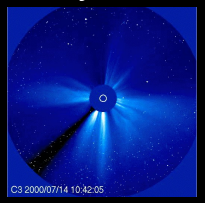
January 21, 1997Web posted at: 10:10 p.m. EST

AT&T Telstar 401 Satellite

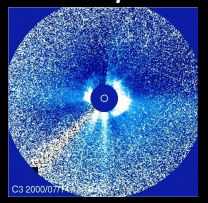
Major Space Environment Hazards

False stars in star tracker CCDs

Before



During exposure to multi-MeV protons



Before *After*

Surface degradation from radiation

Solar array power decrease due to radiation damage

Single event effects in microelectronics

1101 ⇒ 0101

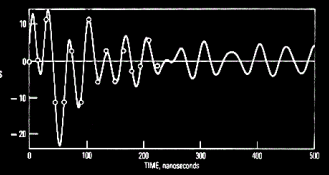
Electronics degrade due to total radiation dose

Solar array arc discharge

Spacecraft components become radioactive

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

Induced Voltage



Time

(The Aerospace Corporation)

Weather in space: Effects on technologies

- **IONOSPHERE VARIATIONS**
  - **Induction of electrical currents in the Earth**
    - **Power distribution systems**
    - **Long communication cables: land and sea**
    - **Pipelines**

Time-varying electrical currents in the ionosphere

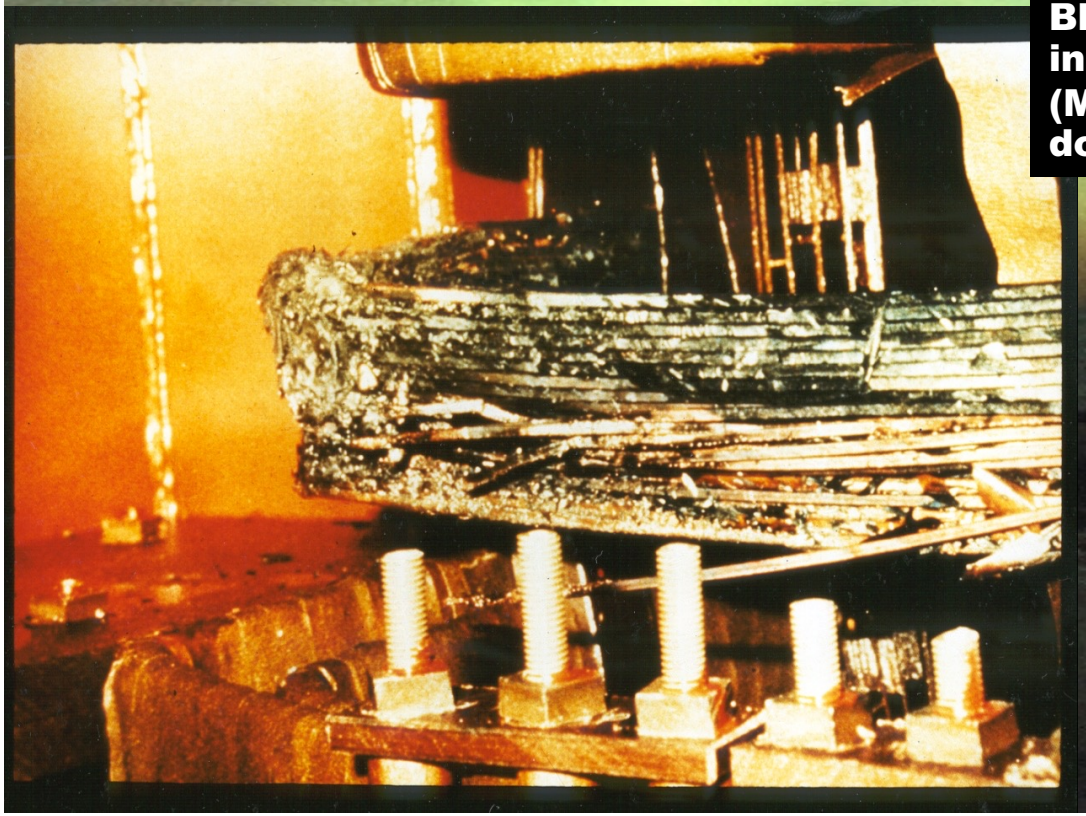
produce time-varying magnetic fields at Earth's surface

which in turn produce electrical currents flowing in the Earth

Earth electrical currents (telluric currents) seek highest conducting path: cables, pipelines, power grids

Weather in space: Effects on technologies

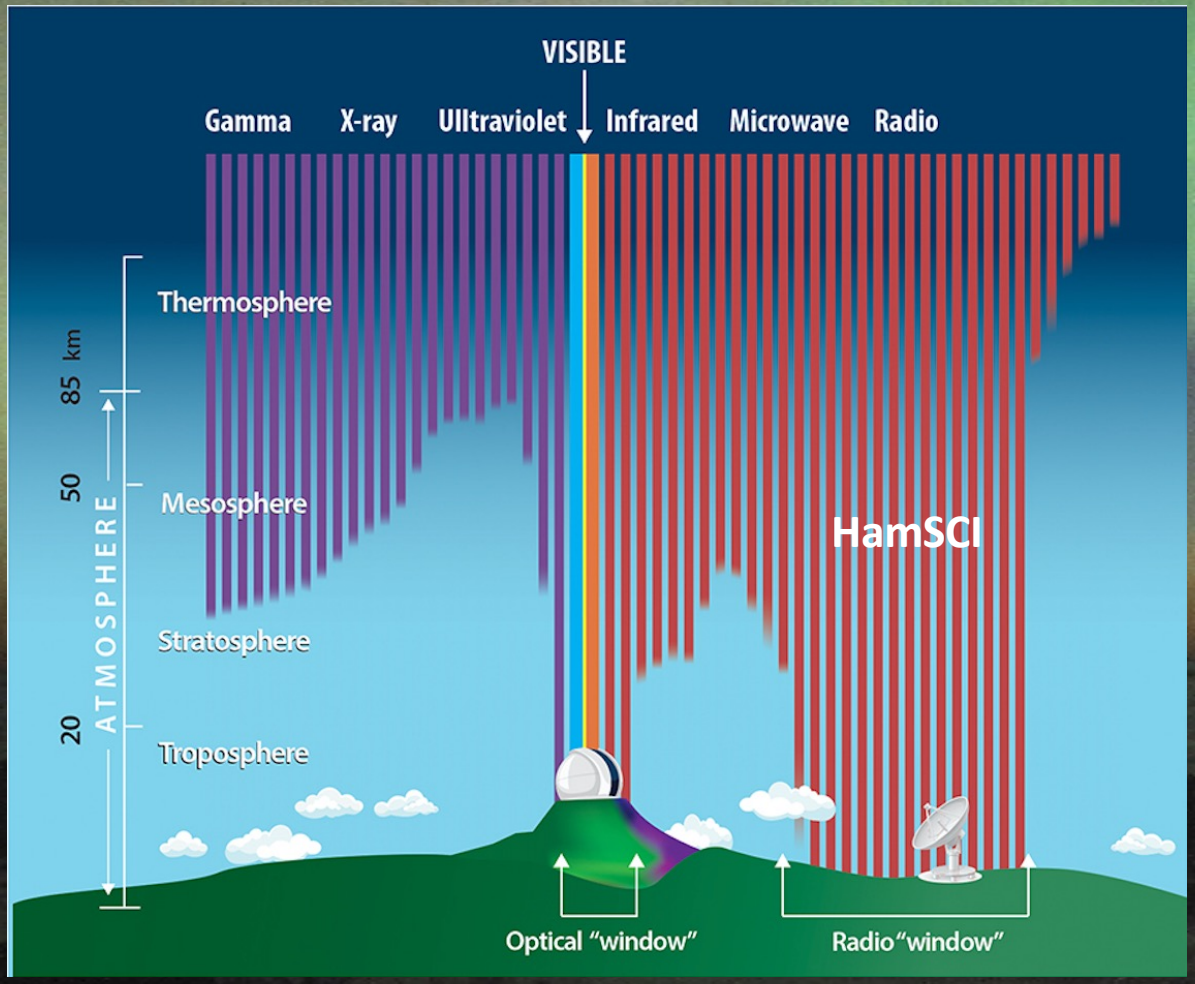
- IONOSPHERE VARIATIONS
  - Induction of electrical currents in the Earth
    - Power distribution systems
    - Long communication cables: land and sea
    - Pipelines



Blown electrical distribution transformer in New Jersey
(March 1989 superstorm that brought down Quebec power grid in 90 seconds)

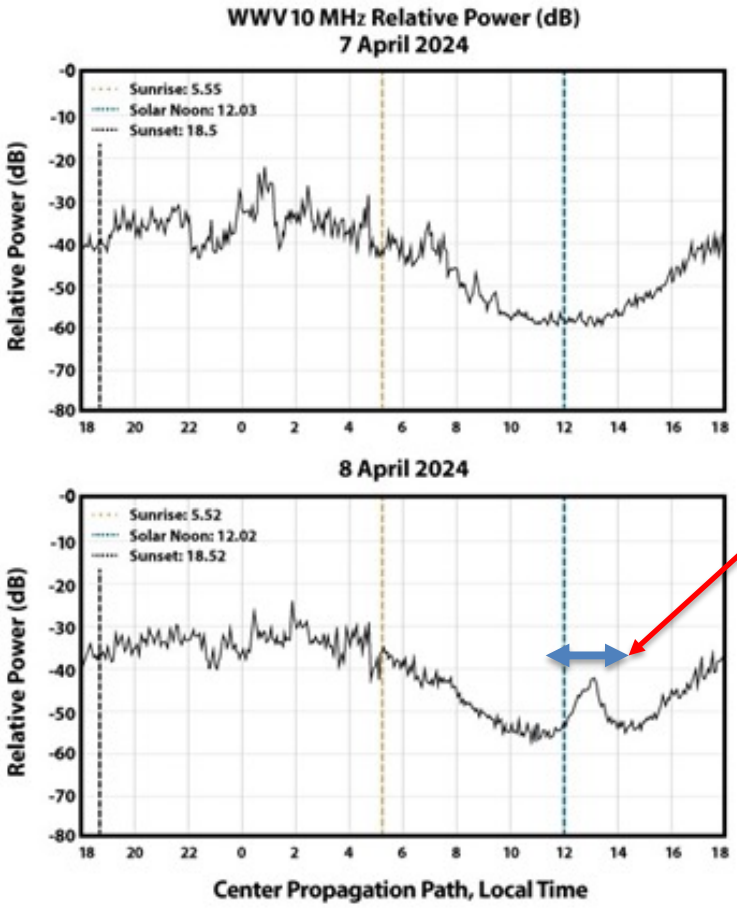
Weather in space: Effects on technologies

- IONOSPHERE VARIATIONS



Weather in space: Effects on technologies

♦ **IONOSPHERE VARIATIONS** Sunlit and Dark 2024 Eclipse



Approximate 2024 Eclipse Interval

Fig. 6.6 Effect of 2024 U.S. eclipse on HF propagation.
Credit: G. Perry and S. Fernandes, New Jersey Institute of Technology.

Weather in space: Effects on technologies

- **IONOSPHERE VARIATIONS**
  - **Wireless signal reflection, propagation, attenuation**
  - **Satellite signals, communications, GPS, etc.: interference, scintillation**

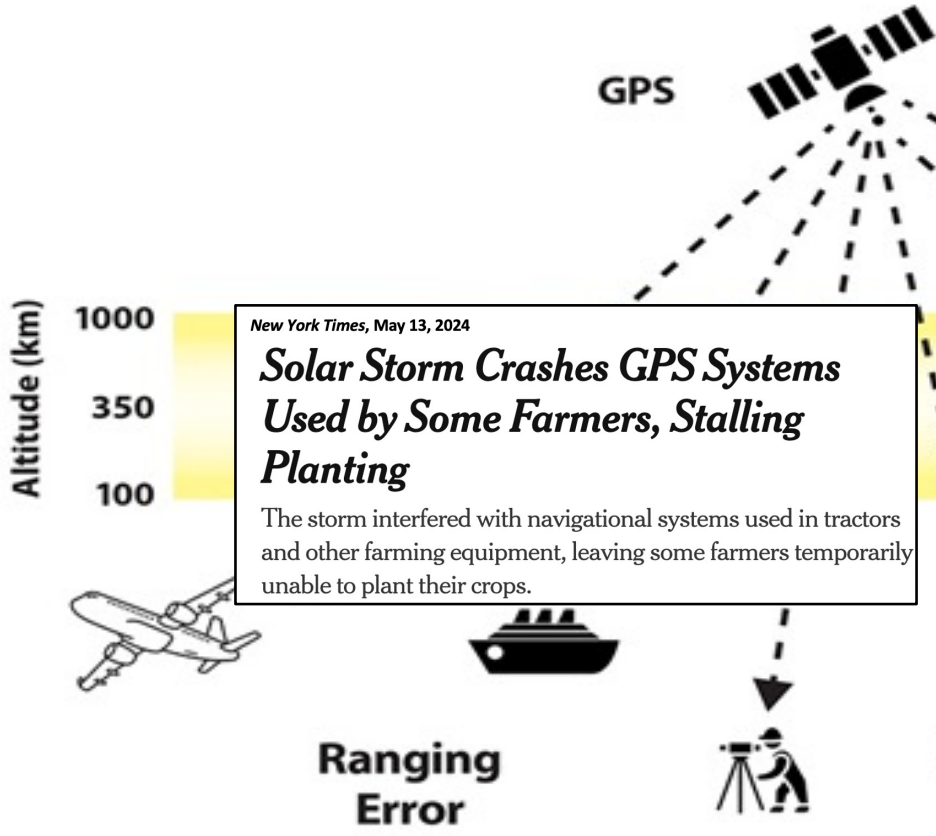


Fig. 6.6. Ionosphere effects on GPS signals

New York Times, May 13, 2024

Solar Storm Crashes GPS Systems Used by Some Farmers, Stalling Planting

The storm interfered with navigational systems used in tractors and other farming equipment, leaving some farmers temporarily unable to plant their crops.

New York Times 13 May 2024

A tractor at O'Connor Family Farms near Blooming Prairie, Minn. Tiffany Graham

Weather in space: Effects on technologies

- **IONOSPHERE VARIATIONS**
  - **Solar X-rays – ionization of E-region**
  - **Solar X-rays first measured by Herbert Friedman using captured V2 rocket at White Sands Missile Range NM 29 September 1949**

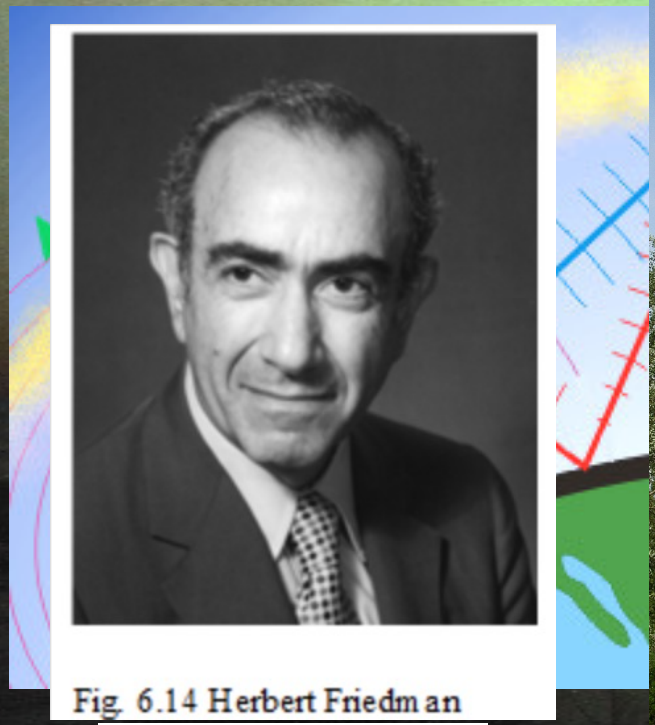
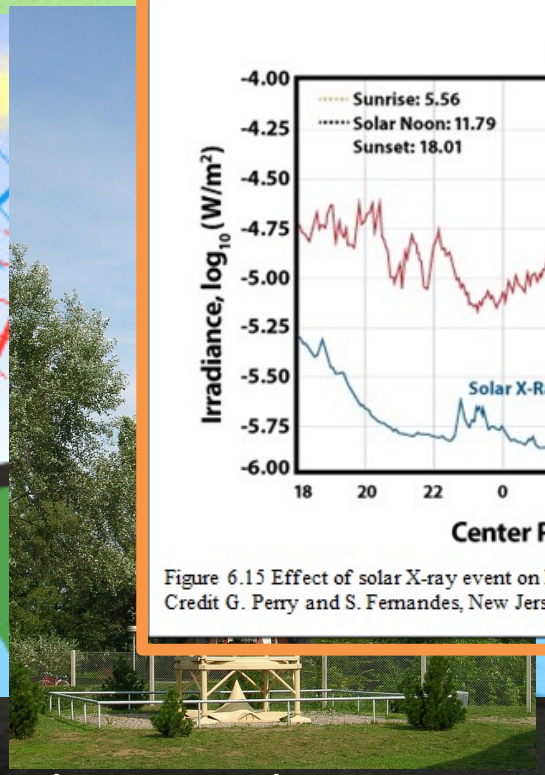


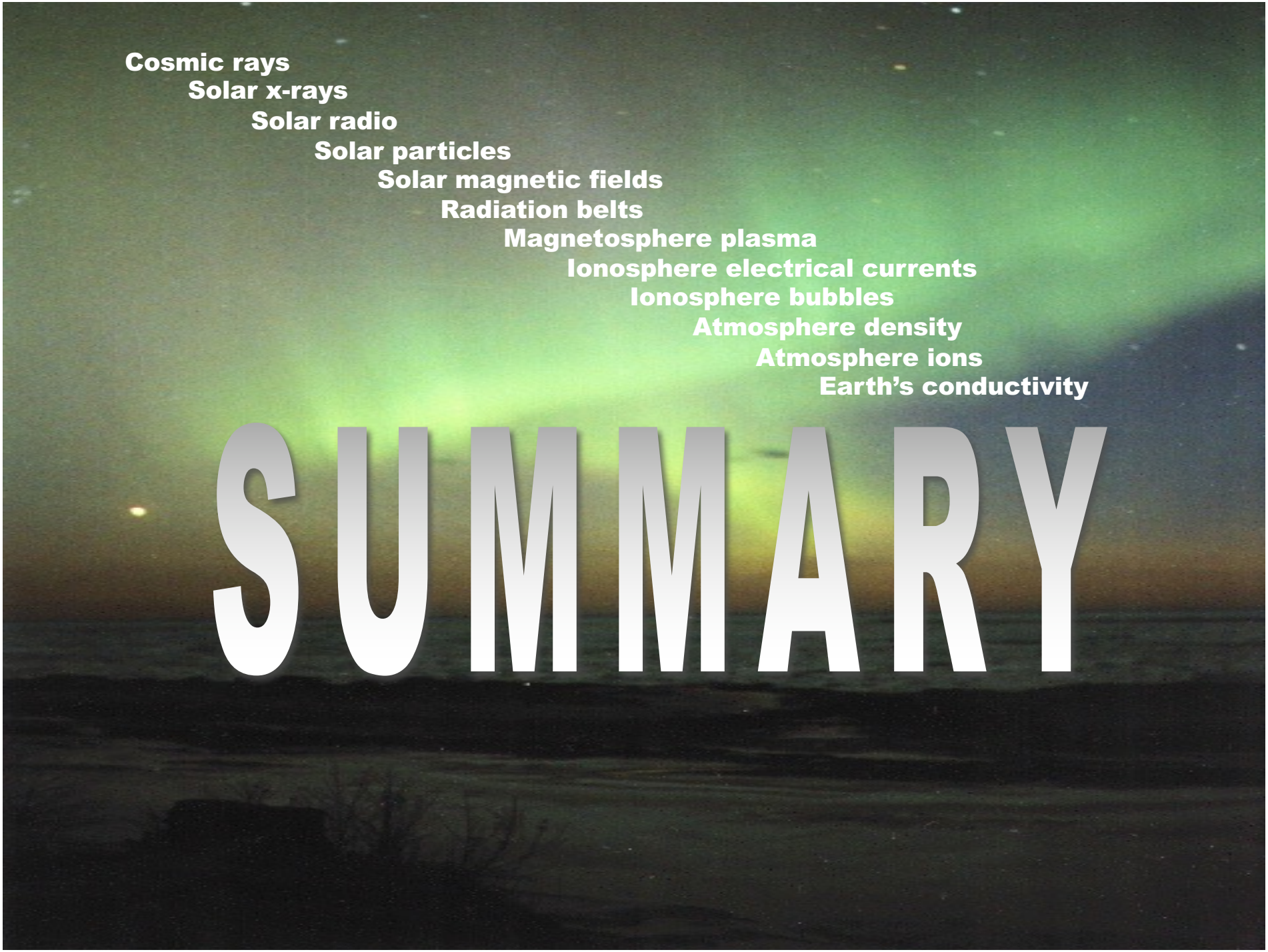
Fig. 6.14 Herbert Friedman

Naval Research Laboratory

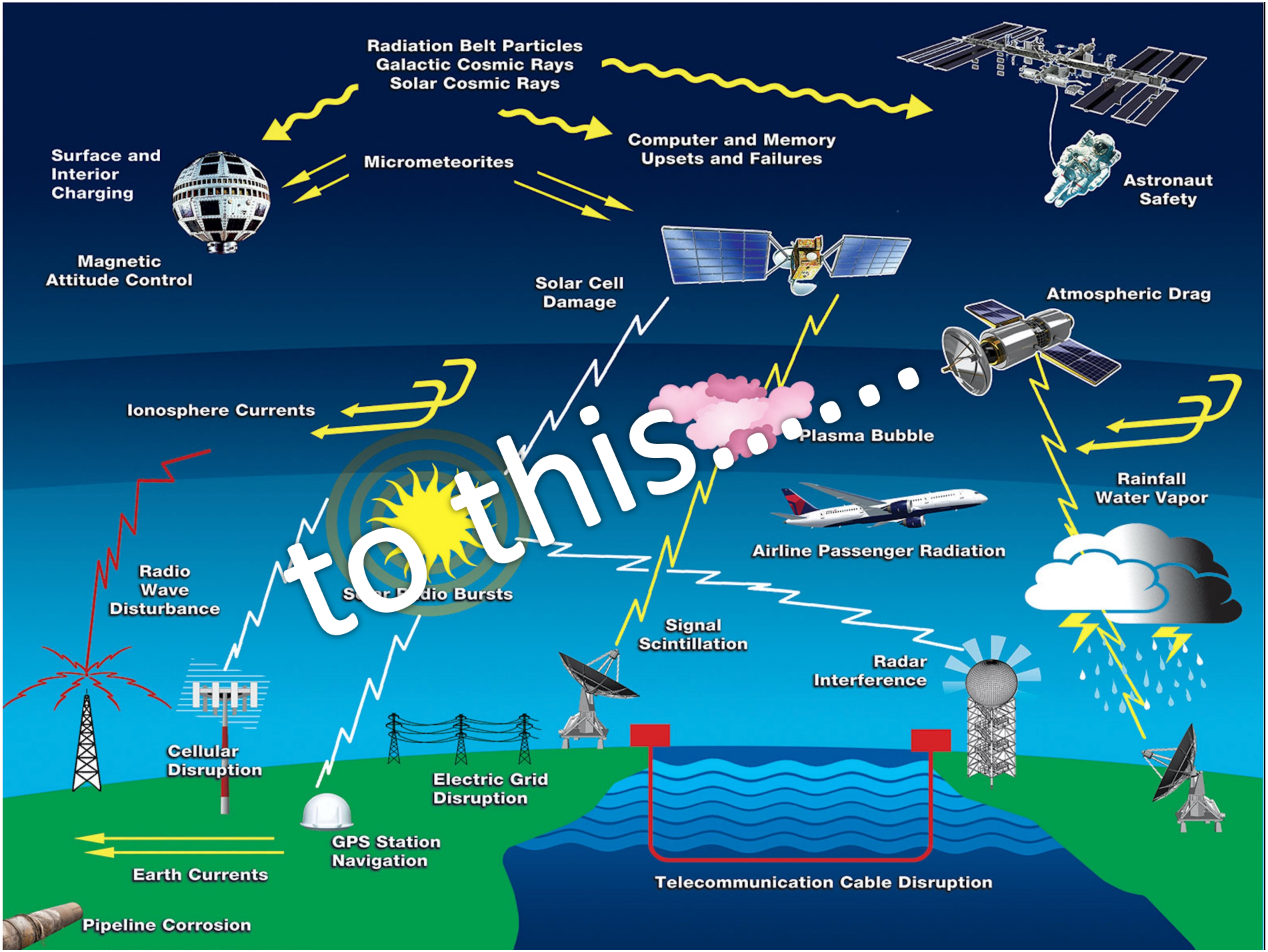


V2 Rocket, Peenemude Museum Germany

Figure 6.15 Effect of solar X-ray event on HF propagation
Credit G. Perry and S. Fernandes, New Jersey Institute of Technology.


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

From this


Radiation Belt Particles
Galactic Cosmic Rays
Solar Cosmic Rays
Surface and Interior Charging
Micrometeorites
Computer and Memory Upsets and Failures
Astronaut Safety
Magnetic Attitude Control
Solar Cell Damage
Atmospheric Drag
to this.....
Ionosphere Currents
Plasma Bubble
Rainfall Water Vapor
Airline Passenger Radiation
Radio Wave Disturbance
Signal Scintillation
Radar Interference
Cellular Disruption
Electric Grid Disruption
GPS Station Navigation
Earth Currents
Telecommunication Cable Disruption
Pipeline Corrosion

2025 HamSCI Workshop NJIT

Lanzerotti, L. J. (2017) Space Weather: Historical and Contemporary Perspectives, *Space Science Reviews*, *212*, 1253-1270.

Baker, D. N. & Lanzerotti, L. J. (2016) Resource Letter: Space Weather, *American J. Physics*, *84*, 166-180.