



INNOVATIVE SOLUTIONS TO COMPLEX PROBLEMS



Effects of Electromagnetic Energy on Electronics

NANOG – Austin, TX – February 2022

Speaker: Kyle Lyke

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NATIONAL SECURITY



INFRASTRUCTURE



ENERGY & ENVIRONMENT



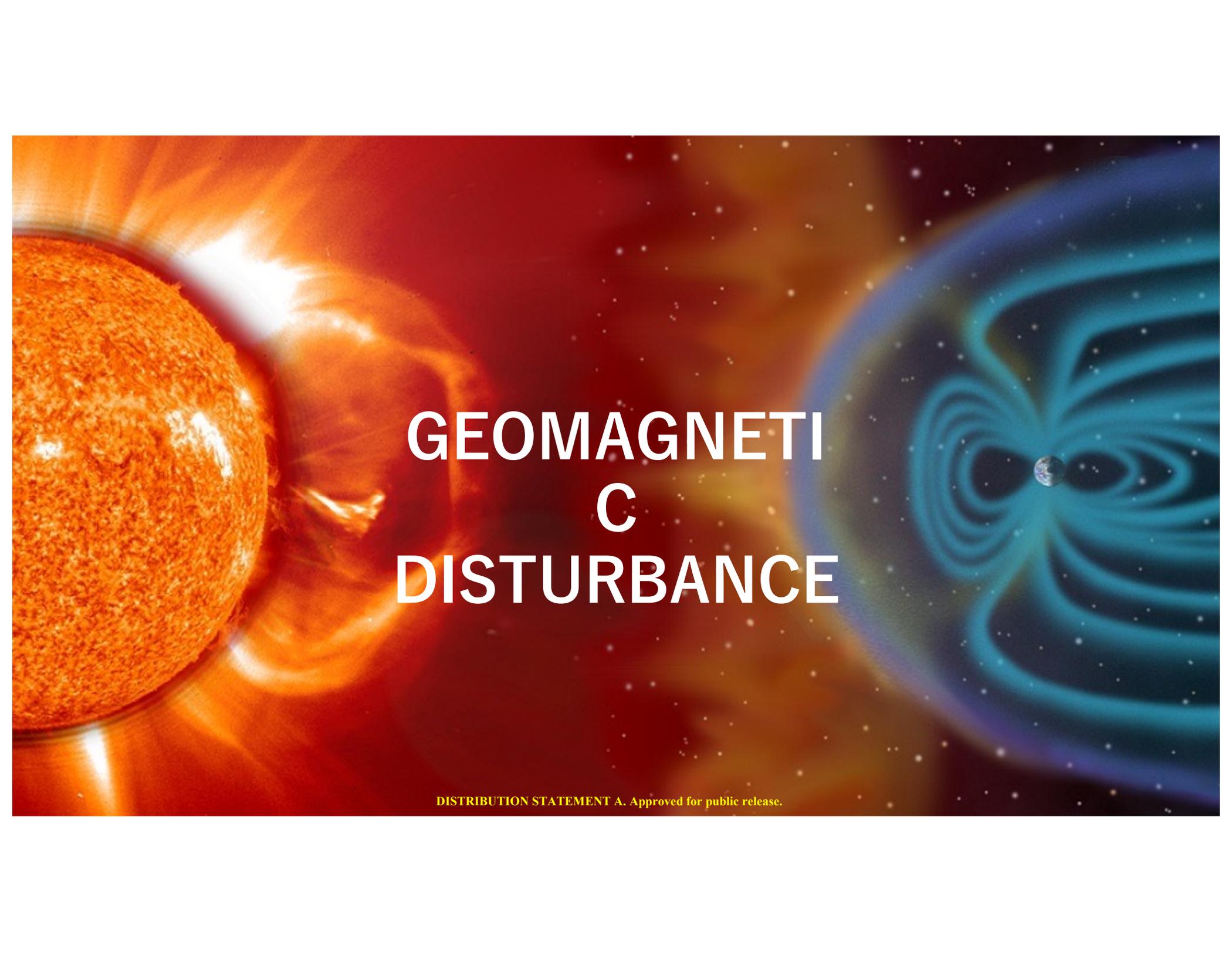
HEALTH SOLUTIONS

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Outline

- Geomagnetic Disturbances
- High-Altitude Electromagnetic Pulses
- Intentional Electromagnetic Interference
- How to Protect Your Systems

The image is a composite background. On the left, there is a close-up of the sun, showing its bright orange and yellow surface with solar flares and coronal mass ejections. On the right, there is a representation of Earth's magnetic field, depicted as blue and purple concentric loops surrounding a small Earth globe. The background is a dark space filled with numerous small white stars.

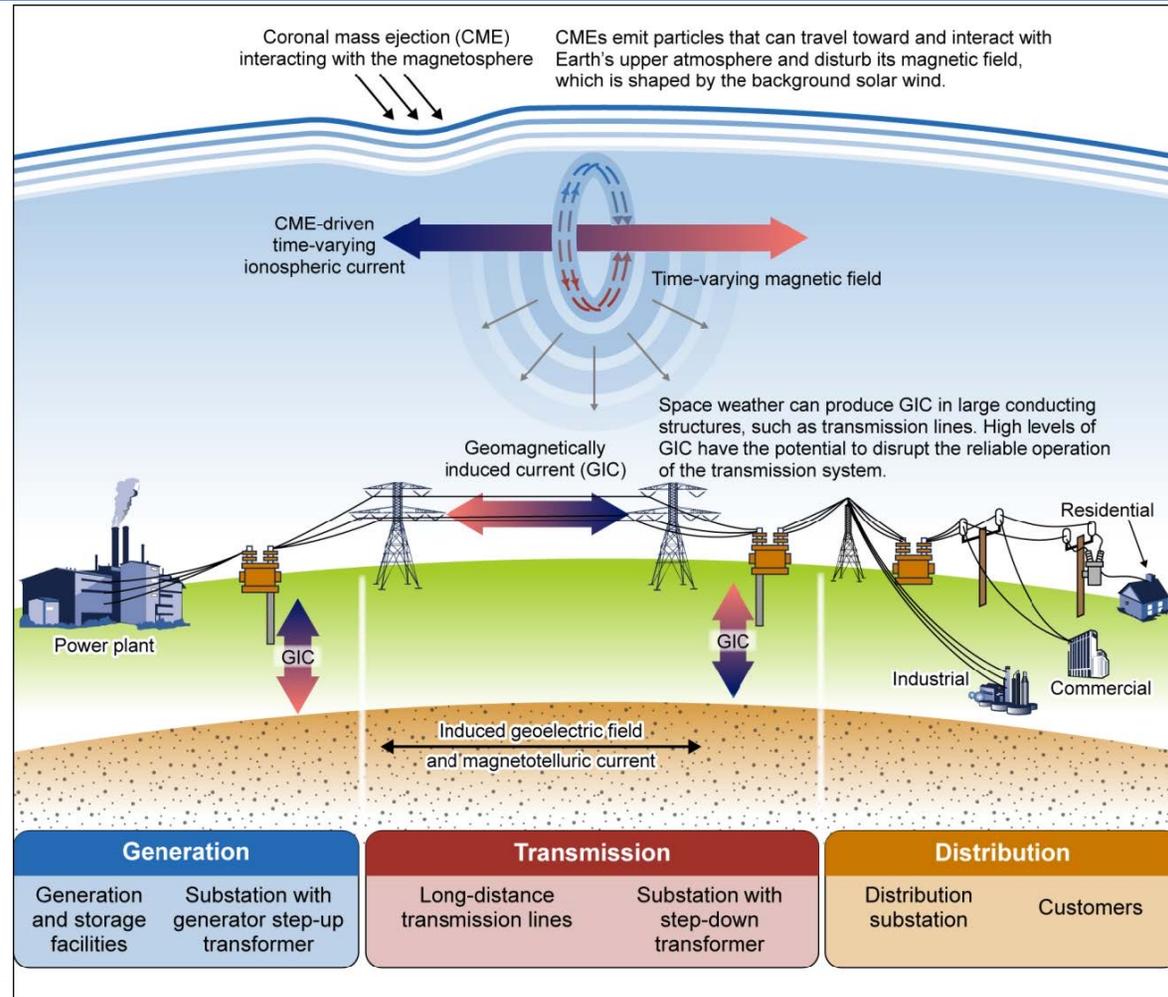
GEOMAGNETIC DISTURBANCE

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Geomagnetic Storm

- “Large Geomagnetic Disturbances Could Affect the Reliable Operation of the U.S. Electric Grid” [1]
- GMD’s produce low frequency signals that couple well to **long conductors**
 - Ethernet cables
 - Power grid infrastructure
- Executive Order 13744 directs preparation for Space Weather Events



Sources: GAO (presentation); Art Explosion (images). | GAO-19-98

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Hydro-Quebec Event, 1989

- Large impulses in the geomagnetic field along the US-Canada border over the course of days
- Led to the failure of the Quebec power grid^[2]
- North American Electric Reliability Council (NERC) reported ~200 anomalies in the power grid
- Transformer at Salem Nuclear Plant, NJ damaged beyond repair



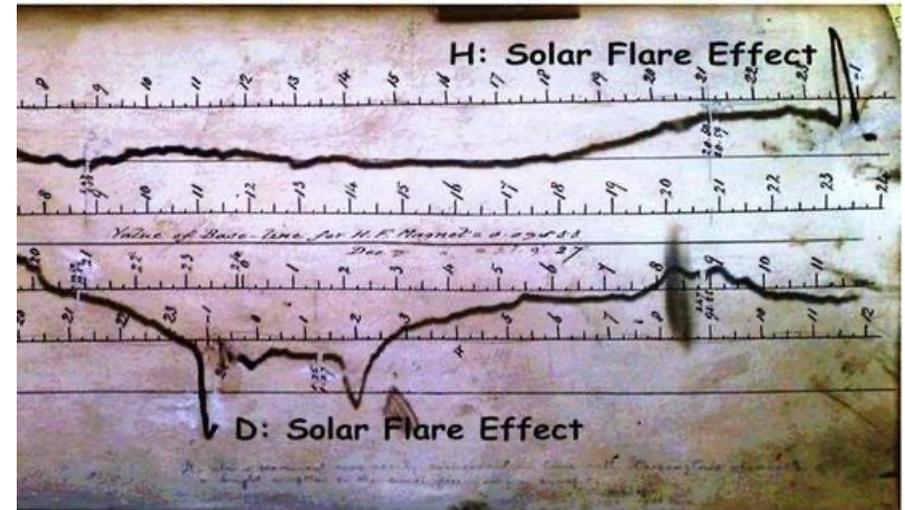
Heating so intense insulation was burned away and wires melted together

Image Credit: *Space New: Solar Shield*, Lake County News, 2010



Carrington Event, 1859 [3]

- Auroral displays observed in Hawaii, the Caribbean, Central America, and Chile
- Telegraph messages were corrupted, and networks malfunctioned
 - Some operators reported electrical shocks
- A similar event today could leave 20-40 million people without power for months and cause \$0.6-2.6 Trillion^[4]



A magnetogram recorded at the Greenwich Observatory in London during the Carrington Event of 1859. The lower line (D) represents compass direction; the upper line (H) represents horizontal force.



Government Addressing Space Weather Threats



“...result in direct or cascading failures across key services such as electric power, communications, water supply, healthcare, and transportation.”

NATIONAL SPACE WEATHER STRATEGY AND ACTION PLAN

Product of the
SPACE WEATHER OPERATIONS, RESEARCH, and MITIGATION
WORKING GROUP
SPACE WEATHER, SECURITY, and HAZARDS SUBCOMMITTEE
COMMITTEE ON HOMELAND and NATIONAL SECURITY
of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

March 2019

Executive Order 13744—Coordinating Efforts To Prepare the Nation for Space Weather Events

October 13, 2016

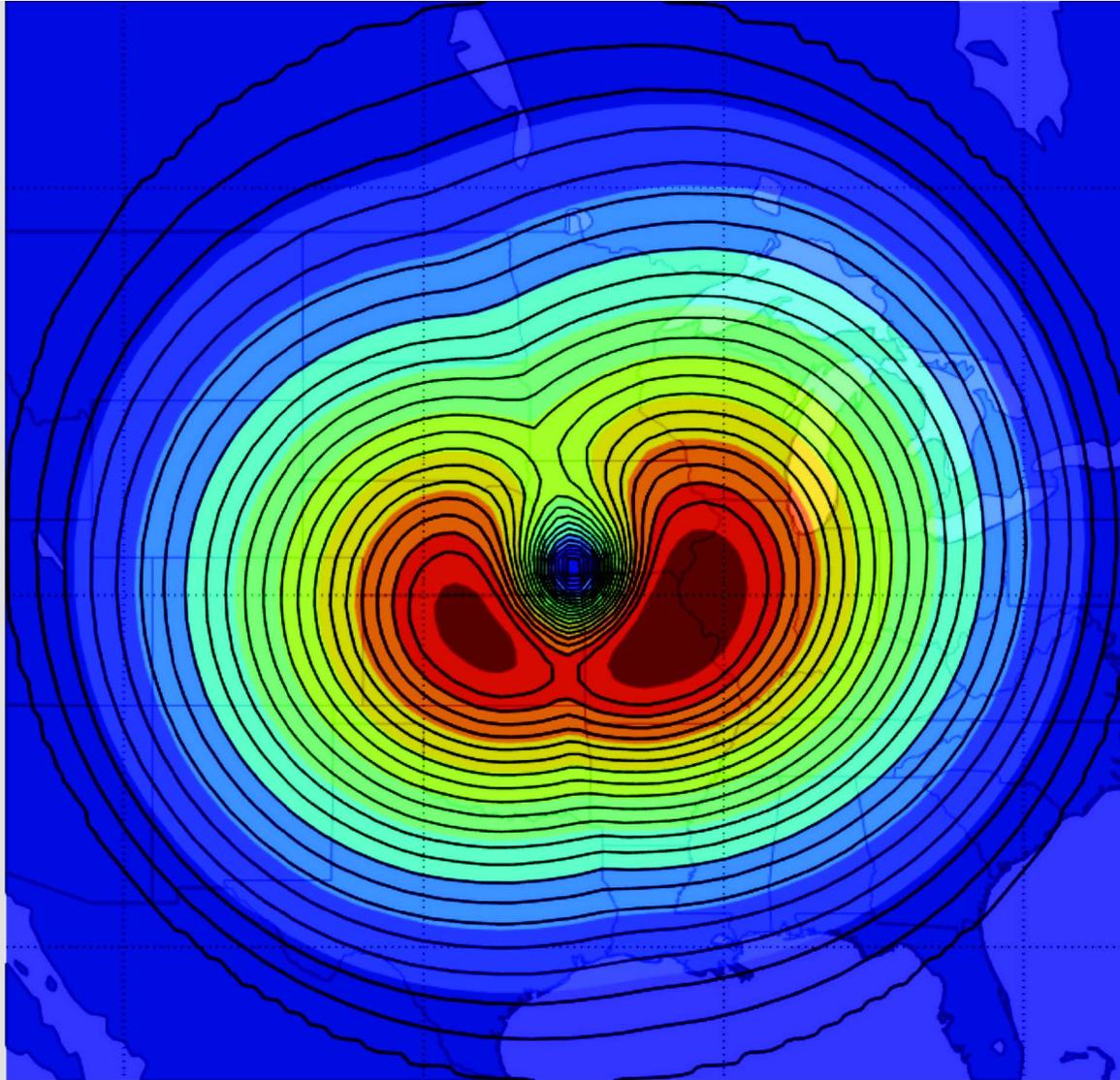
By the authority vested in me as President by the Constitution and the laws of the United States of America, and to prepare the Nation for space weather events, it is hereby ordered as follows:

Section 1. Policy. Space weather events, in the form of solar flares, solar energetic particles, and geomagnetic disturbances, occur regularly, some with measurable effects on critical infrastructure systems and technologies, such as the Global Positioning System (GPS), satellite operations and communication, aviation, and the electrical power grid. Extreme space weather events—those that could significantly degrade critical infrastructure—could disable large portions of the electrical power grid, resulting in cascading failures that would affect key services such as water supply, healthcare, and transportation. Space weather has the potential to simultaneously affect and disrupt health and safety across entire continents. Successfully preparing for space weather events is an all-of-nation endeavor that requires partnerships

“...effects on critical infrastructure systems and technologies, such as the Global Positioning System (GPS), satellite operations and communication, aviation, and the electrical power grid.”

emia, the media, the insurance industry, non-are for space weather events to minimize the he Federal Government must have (1) the event, (2) the plans and programs necessary to mitigating actions for an impending space plans, protocols, and standards required to d during a credible threat, and (4) the ability to e weather. Executive departments and agencies (agencies) must coordinate their efforts to prepare for the effects of space weather events.

High Altitude Electromagnetic Pulse

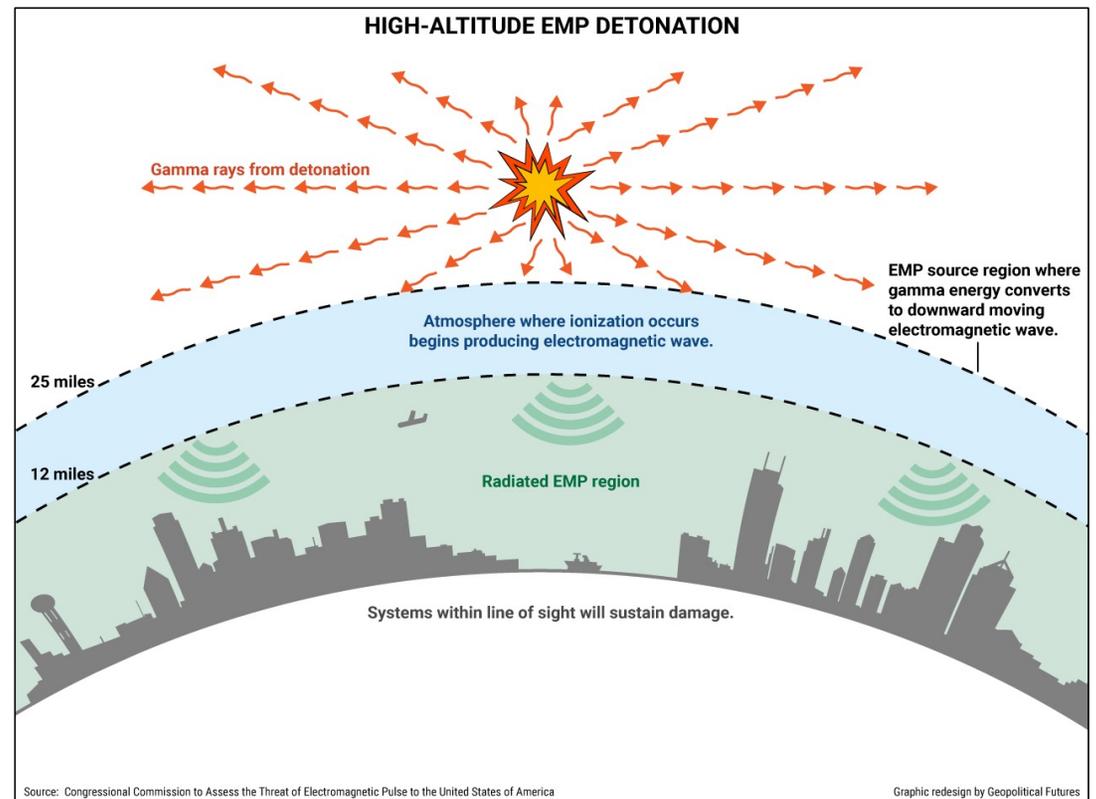


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High Altitude Electromagnetic Pulse (HEMP)

- HEMP affects continent-sized regions
- Results in electric fields tens of thousands of volts/meter
- Reaches large field levels in nanoseconds
- Dangerous to digital control systems, security systems, computers, ethernet switches, routers, etc.





Starfish Prime Nuclear Test (July 9, 1962)

- 1.4 Megaton nuclear weapon detonated 250 miles above Johnston Atoll
- EMP caused affects in Hawaii, nearly 1000 miles away^[5]
 - Damaged 5 satellites
 - Power surges, blown fuses, destroyed transformers
 - Telephone and radio service disrupted
 - Streetlights blown
 - Burglar alarms triggered

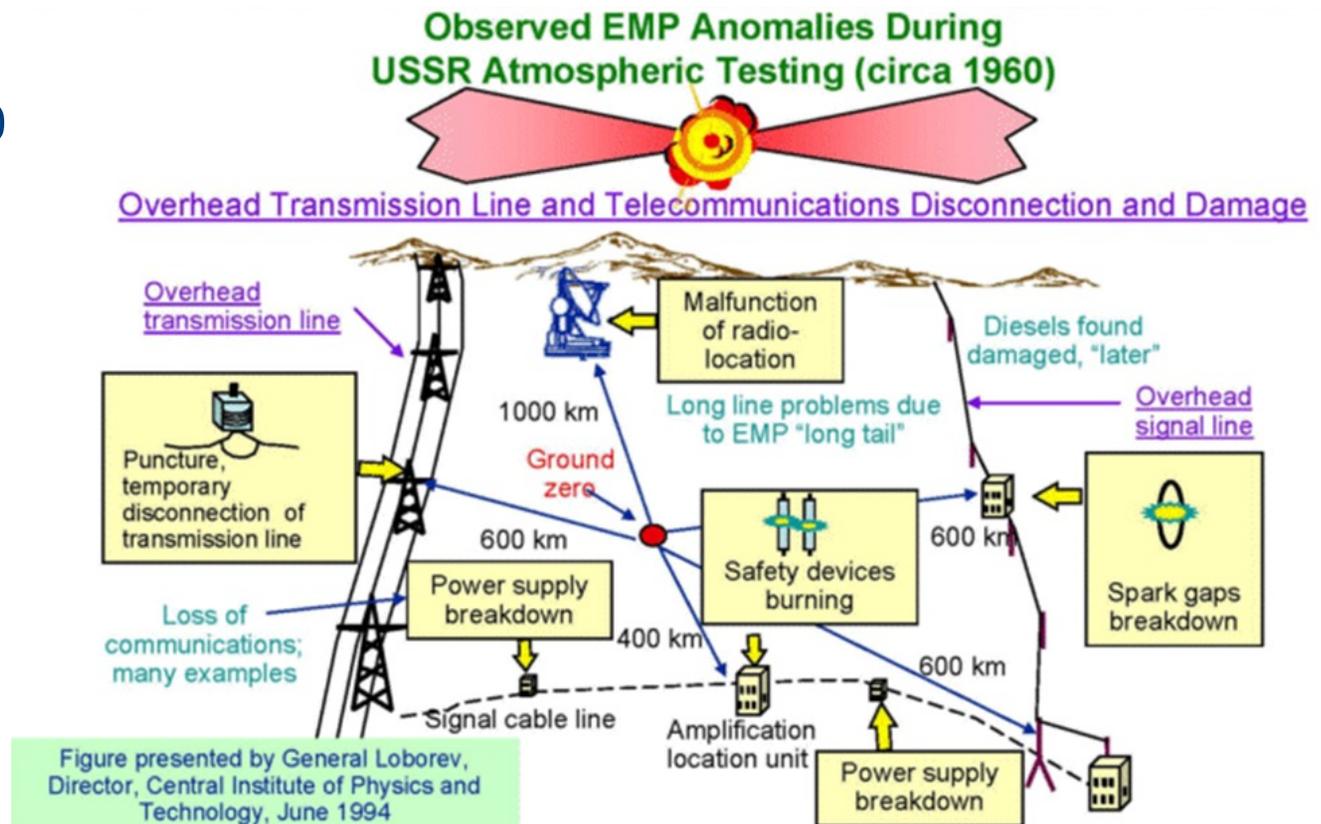


Actual footage from the Starfish Prime Test



K-3/#184 Nuclear Test, October 22, 1962

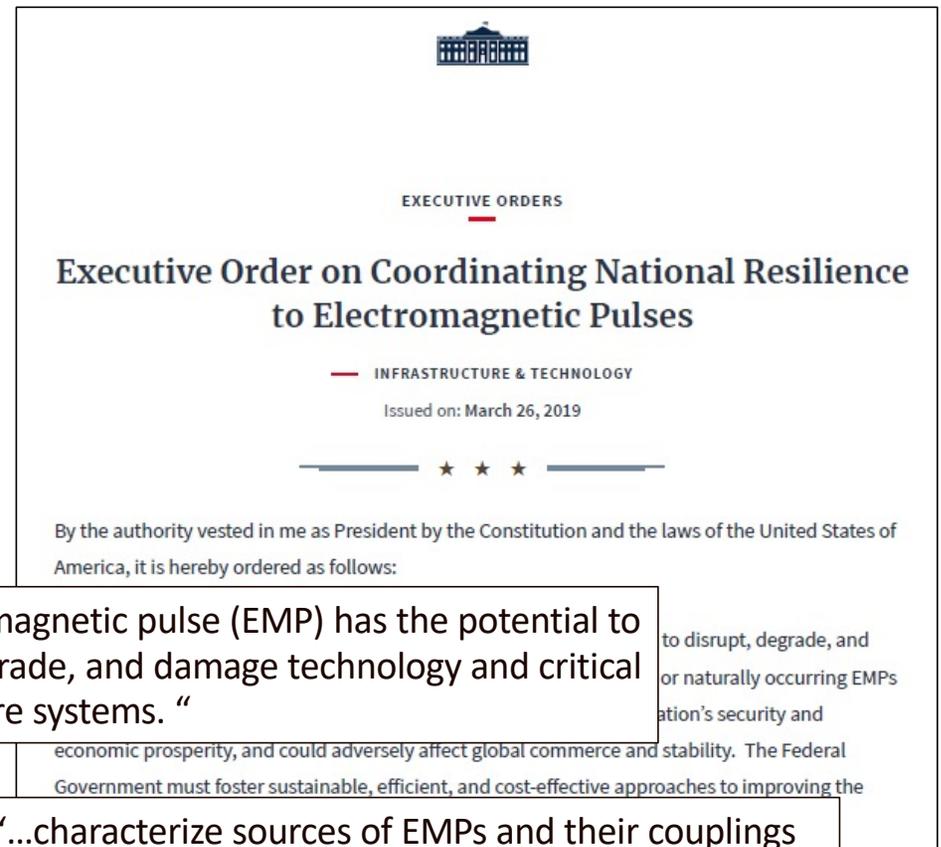
- 300 kiloton nuclear weapon detonated 180 miles above ground
- Effects observed at various distances from ground zero
 - Power Supplies
 - Radio Equipment
 - Transmission Lines





Executive Order on EMP

- Executive Order 13865 directs the strengthening of critical infrastructure
 - Power Grid
 - Cybersecurity of Federal Networks
 - Banking and Finance Systems



“An electromagnetic pulse (EMP) has the potential to disrupt, degrade, and damage technology and critical infrastructure systems. “

to disrupt, degrade, and or naturally occurring EMPs ation’s security and

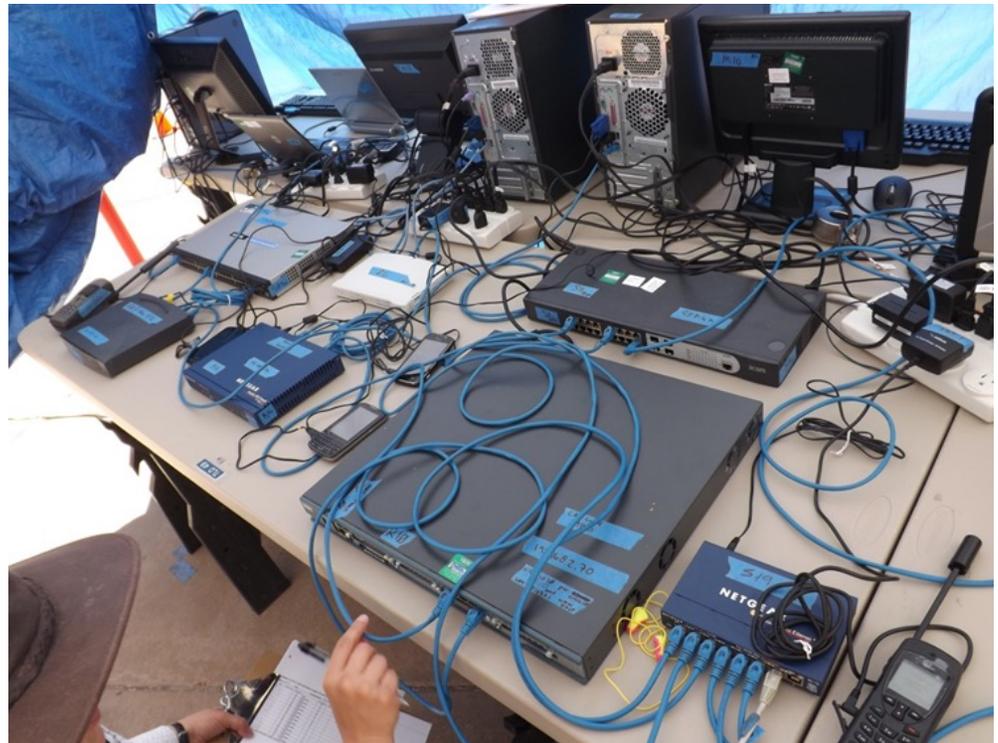
economic prosperity, and could adversely affect global commerce and stability. The Federal Government must foster sustainable, efficient, and cost-effective approaches to improving the

“...characterize sources of EMPs and their couplings to the electric power grid and its subcomponents...”



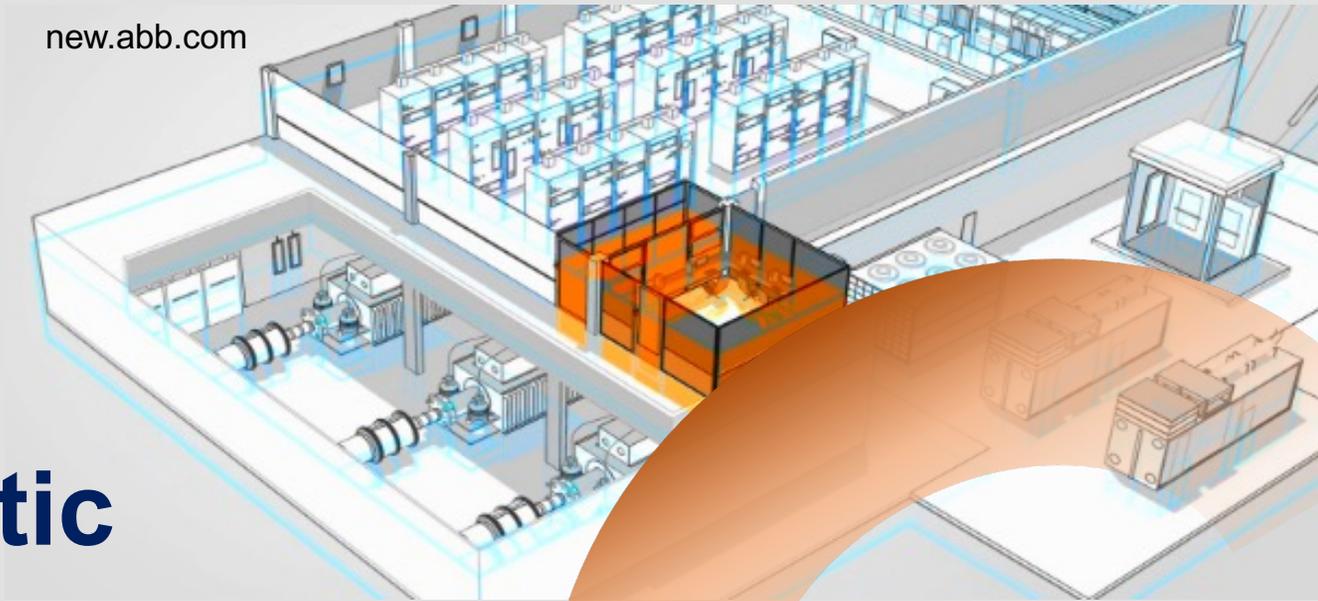
IT Infrastructure is Vulnerable to EMP

- EMP tests have been conducted on
 - Desktops and Servers
 - Routers
 - Switches
 - Firewalls
 - Media Converters
 - Laptop
 - Tablets
 - P2P Systems
 - Wi-Fi Meshes
 - VOIP Phones
 - Smart Phones
 - RFID Readers
 - Security Camera
 - Radio Systems



Commercial IT Equipment tested at the HERMESIII Facility [6]

new.abb.com

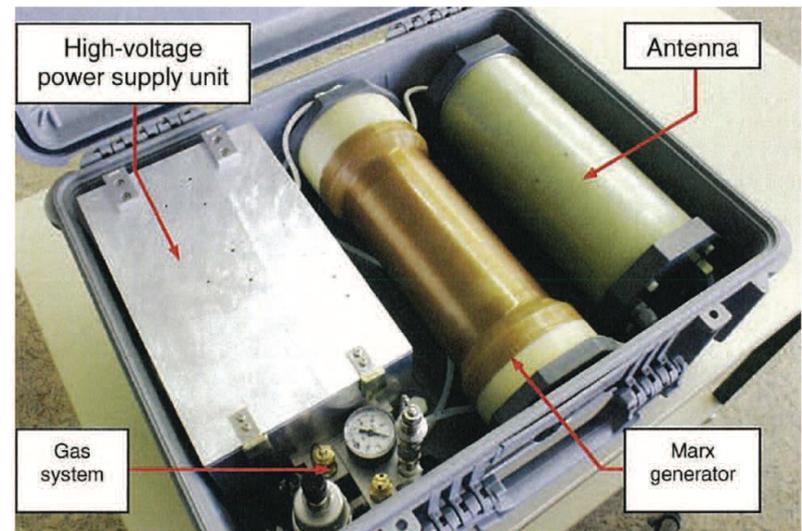


Intentional Electromagnetic Interference



Intentional Electromagnetic Interference (IEMI)

- *“Intentional malicious generation of electromagnetic energy introducing noise or signals into electric and electronic systems, thus disrupting, confusing or damaging these systems for terrorist or criminal purposes.” [7]*
- Can target specific devices or cause general disruption



HPM Generator Diehl DS 110 [8]



Reports of Criminal IEMI Attacks [9]

Case	Technology	Motivation	Result	Skill Level
Gaming Machine	RF Gun/EM Disruptor	Robbery	System Malfunction	Amateur/Internet
Jewelry Store	EM Disruptor	Robbery	System Malfunction	Amateur/Technician
Police Radio Communication	Jammer	Suppression/Denial of Service	Degradation	Technician
Car Security System	GSM Jammer	Suppression/Denial of Service	Loss of Main Function	Amateur/Internet
NL Bank	HPM Source	Payback/Criminal Damage	Loss of Main Function	Amateur/Internet



EMI Devices Readily Available for Purchase



RF Suitcase HPM Source

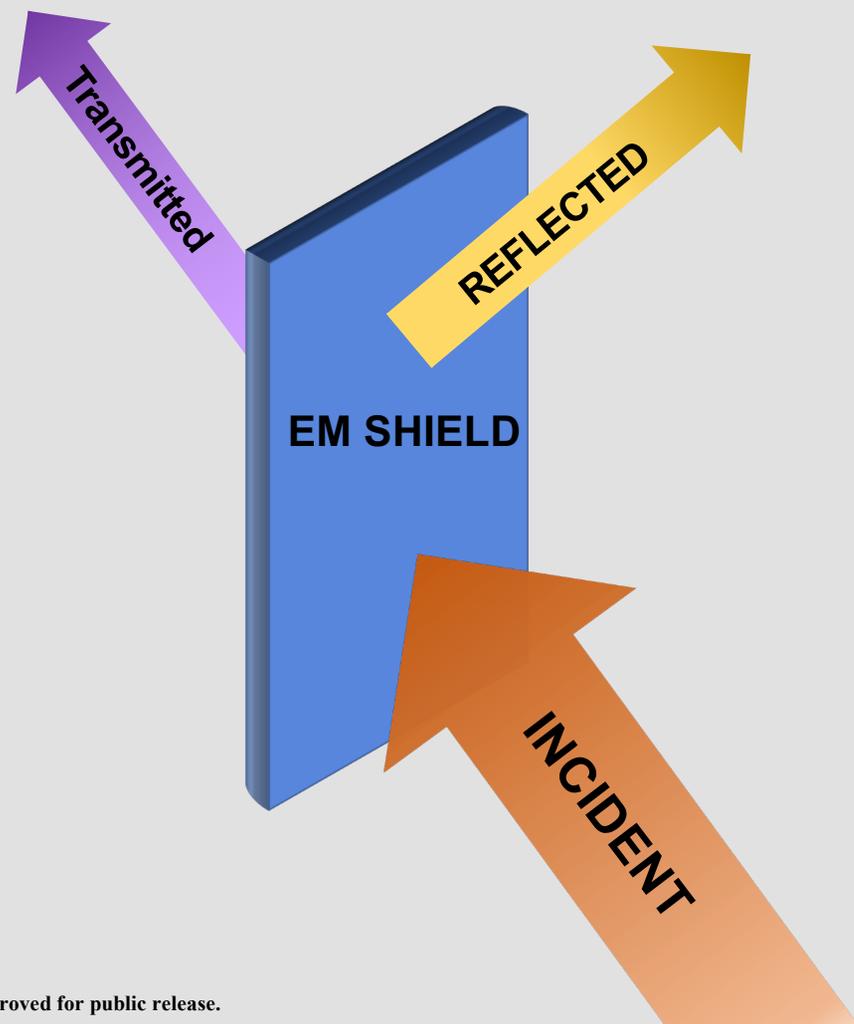


4G/5G/WiFi Jammer



GPS Jammer

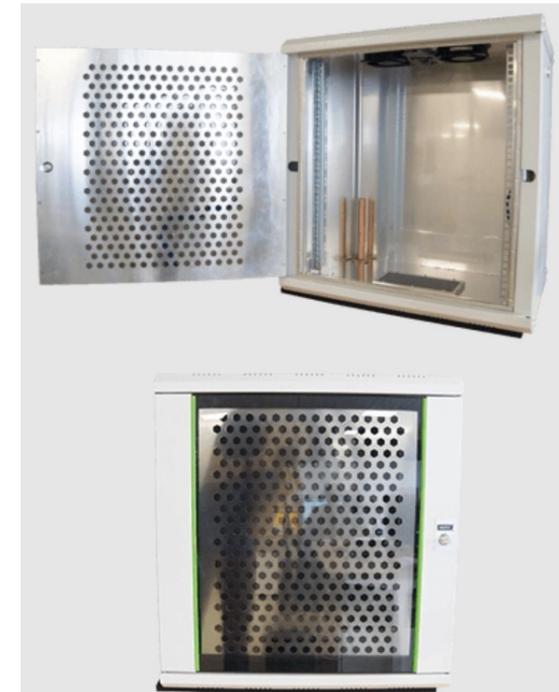
Electromagnetic Shielding and Hardening





Shielding and Hardening

- Attenuate the signal to safe levels
- Protect against radiated energy
 - Faraday Cages
 - Waveguides Below Cutoff
- Protect against conducted energy
 - Filters
 - Ferrites
 - Transient Voltage Suppression
 - Metal Oxide Varistors (MOV's)
 - Gas Discharge Tubes (GTD)
 - TVS Diodes



Example RF Shielded Rack

Image Credit: Holland Shielding Systems



Mitigation

- Know where your power comes from
 - Implement an UPS, ATS and Generator and ensure critical equipment is connected
- Keep distance between critical equipment and publicly accessible locations
 - Distance will attenuate any IEMI threats
- Use non-conductive material when possible (i.e., fiber optic cables)
 - Insulating material will not pick up currents



← Automatic Transfer Switch

Uninterruptible Power Supply →



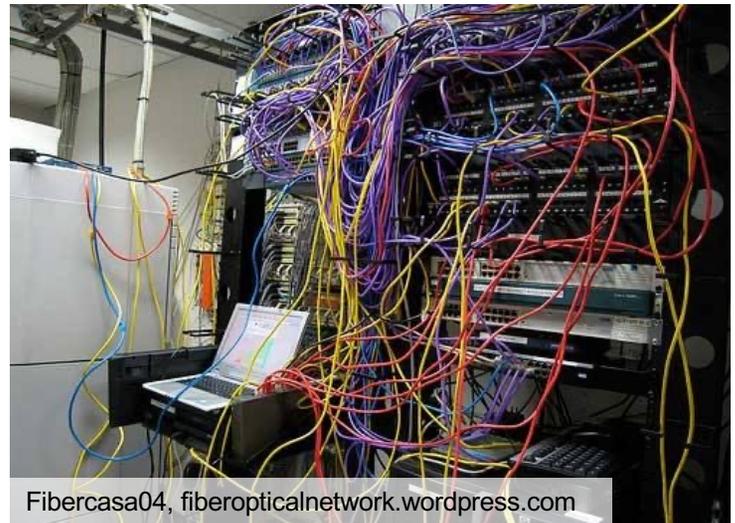


What You Can Do Now

- Minimize the length of ethernet cables
- Use fiber optic when able
- Install ferrites on conductors
- Use Delta-Wye Transformers
- Rehearse power outage and recovery procedures



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Fibercasa04, fiberopticalnetwork.wordpress.com



Thank you!

Questions?



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