

Electromagnetic Pulse (EMP)

2017

What is EMP?

- **Electro Magnetic Pulse is a burst of electromagnetic radiation from an explosion or a suddenly fluctuating magnetic field**
- **EMP from a nuclear explosion high above the atmosphere**
- **EMP from a solar storm**

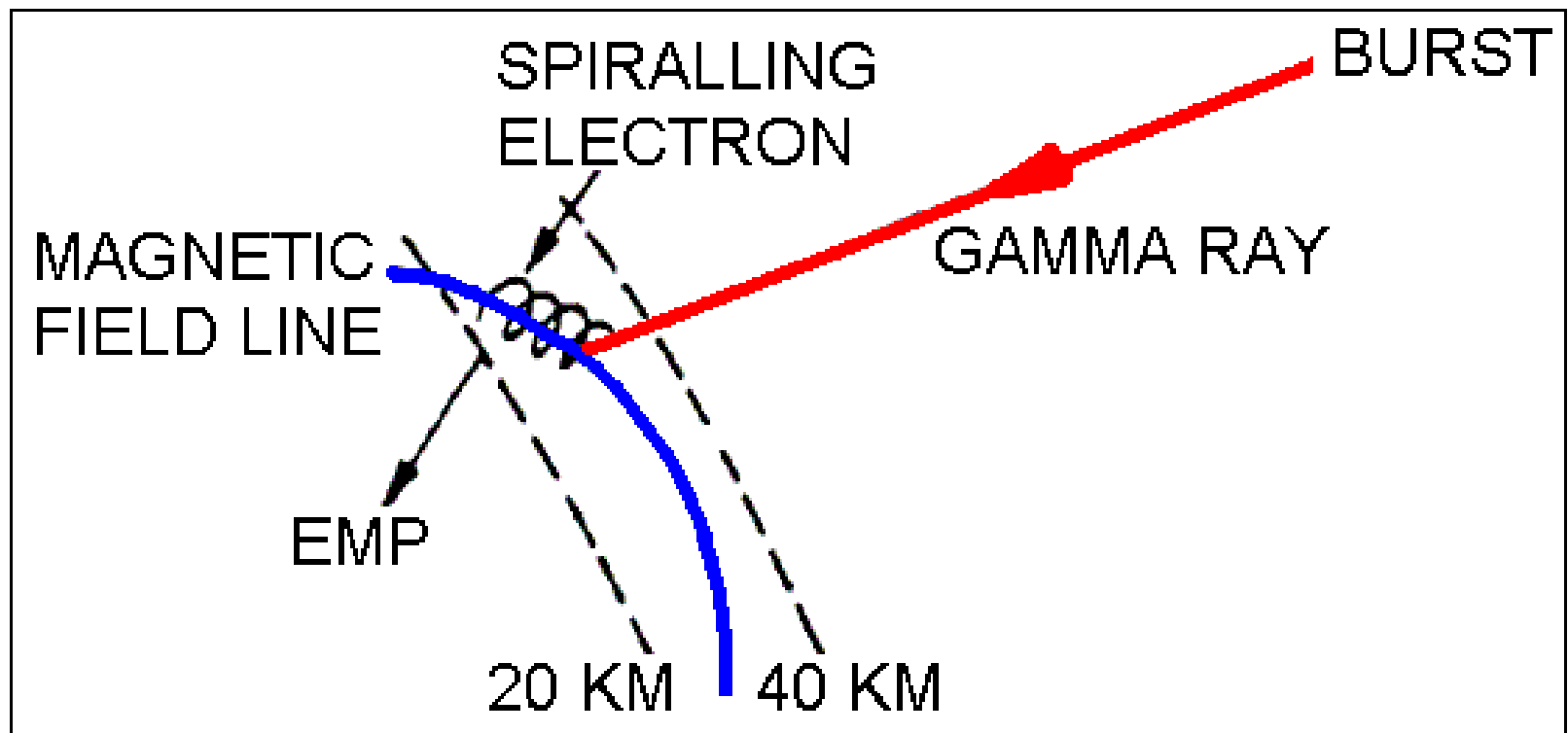
Types of EMP

- **E1 Pulse** – very fast component of nuclear EMP. It is too fast for ordinary lightning protectors and destroys computers and communications equipment.
- **E2 Pulse** – many similarities to pulses produced by lightning. Least dangerous type of EMP because of the widespread use of lightning protection.
- **E3 Pulse** – much slower pulse caused by the Earth's magnetic field being pushed out of the way by the nuclear explosion or solar storm followed by the field being restored to its natural place. This process can produce geomagnetically induced currents in long electrical conductors (like power lines) which can damage or destroy power line transformers.

Causes of EMP

- **High altitude nuclear explosion**

EMP Mechanism



Causes of EMP

- **High altitude nuclear explosion**
 - **Line of sight effects**
 - **Simple fission bomb more effective than hydrogen bomb**
 - **Russian “Super EMP” bomb**
- **Geomagnetic solar storm**
 - **Only E3 pulse**

Effects of E1 Pulse

- **E1 Pulse travels at 90% of the speed of light**
- **Peaks after 5 - 10 nanoseconds, over in 1 microsecond**
- **Normal circuit breakers do not work this fast**
- **Amplitude up to 50,000 volts/meter**
- **Circuit boards are 1 million times more sensitive than vacuum tubes**
- **Will cause integrated circuits connected to cables to overheat and give false readings, be damaged or destroyed**

SCADA

- **Supervisory Control and Data Acquisition (SCADA) systems are electronic control systems that control electrical transmission and distribution, water management and oil and gas pipelines across the United States**
- **A SCADA system physically is very similar to the internals of a desktop personal computer**
- **Tests indicate that the electronics would experience 100 to 700 ampere currents during an E1 pulse, impacting a significant portion of these systems**

Programmable Logic Controller



Effects of E2 Pulse

- **E2 Pulse is very similar to the electromagnetic pulse produced by lightning.**
- **Because of the widespread use of lightning protection technology, E2 probably is the least dangerous type of EMP**
- **Effect would be similar to thousands of lightning strikes hitting power lines simultaneously**
- **Damage from E1 Pulse immediately previously could partially degrade lightning protection**

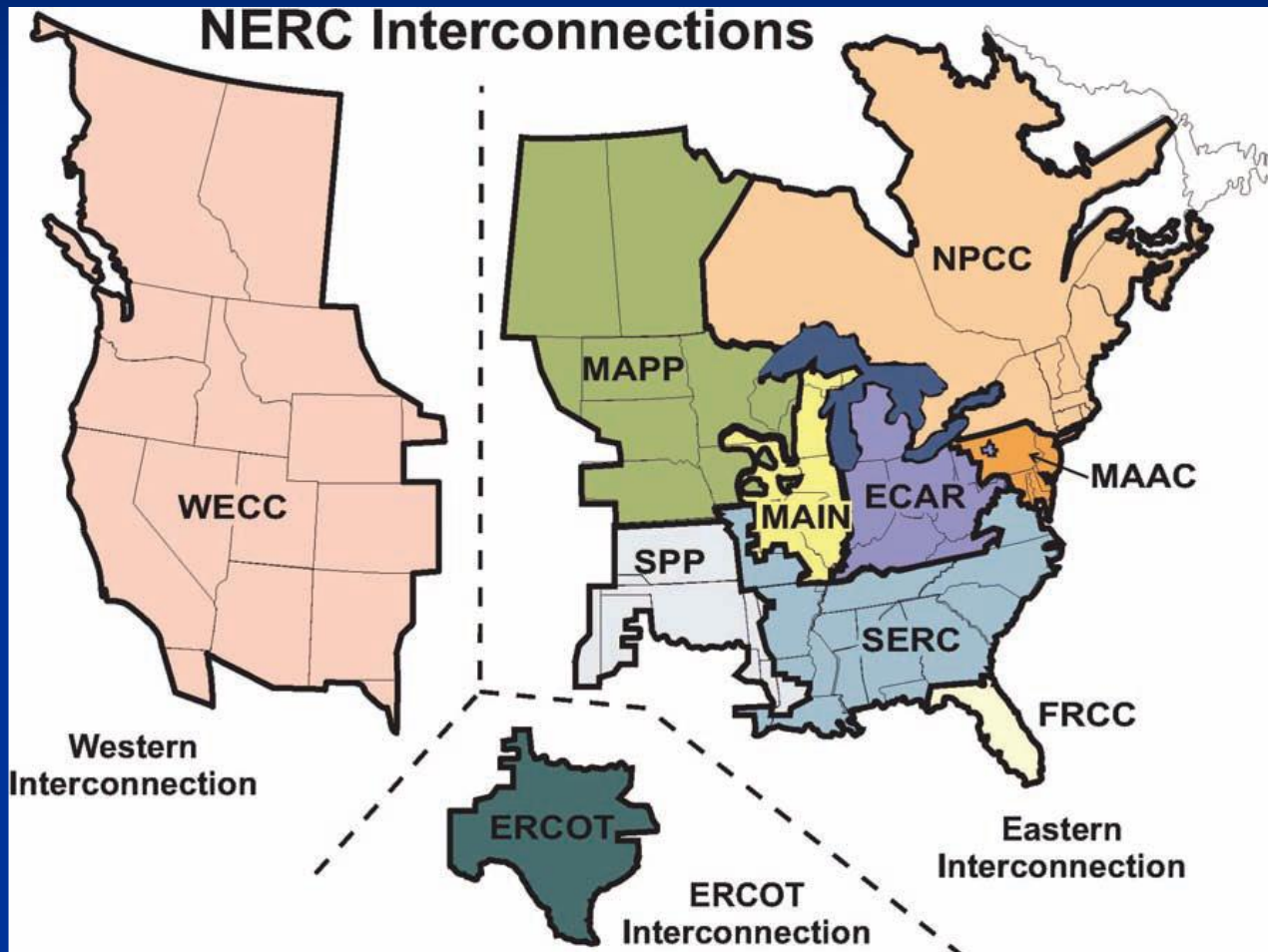
Effects of E3 Pulse

- **E3 Pulse lasts from tens of seconds to several minutes**
- **Produces direct current Ground Induced Currents (GIC) in conductors**
- **Long distance electrical power transmission lines make excellent conductors**
- **The longer the conductor and the lower its resistance, the easier the GIC can flow**
- **Direct currents of hundreds to thousands of amperes will flow into transformers, potentially causing overheating and fires**

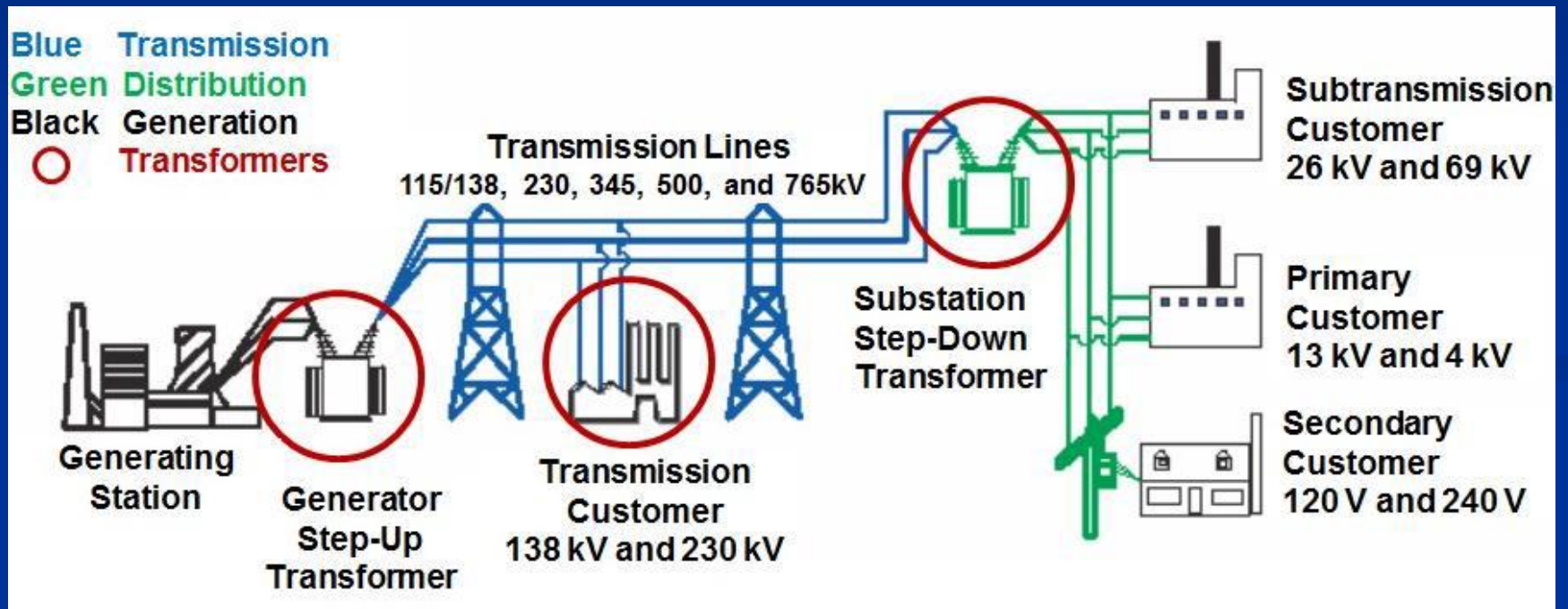
Transformer Damaged During 1989 Geomagnetic Storm



US Power Grid



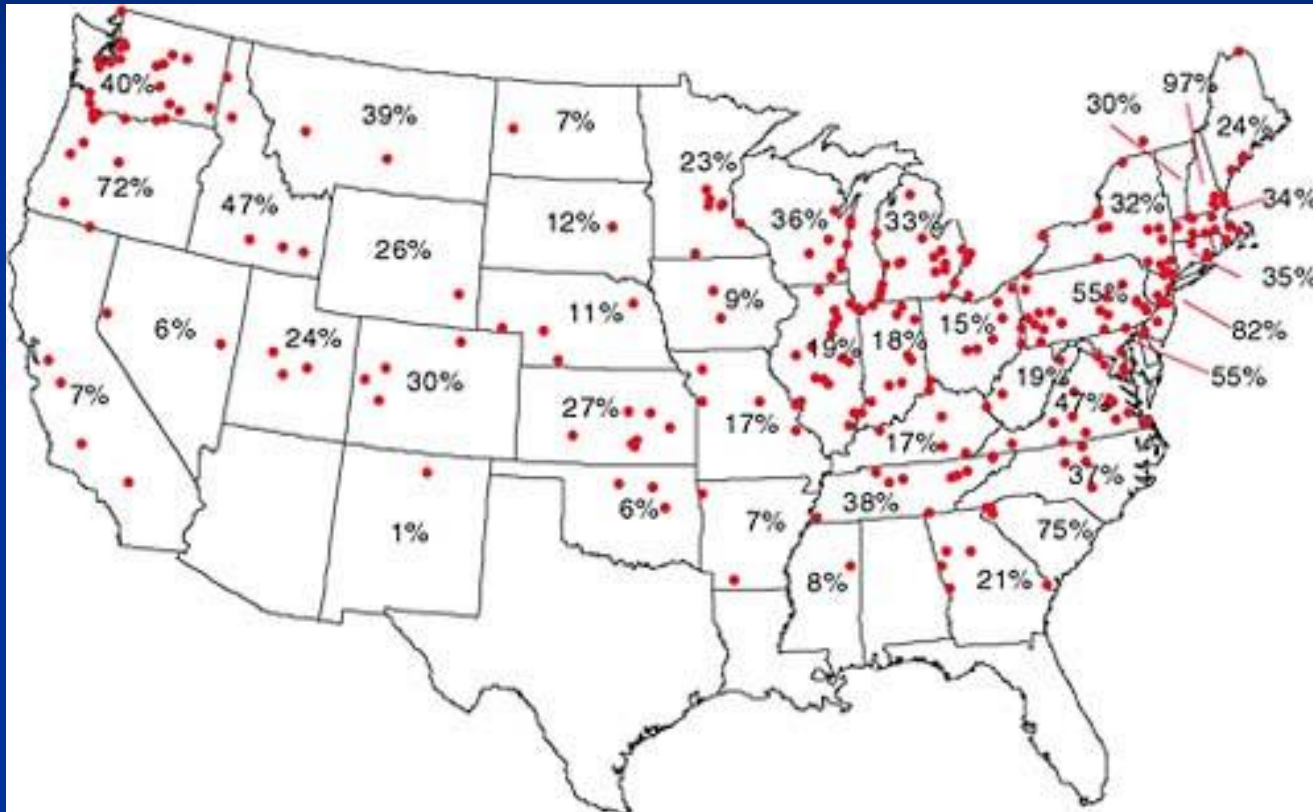
Electric Power Grid



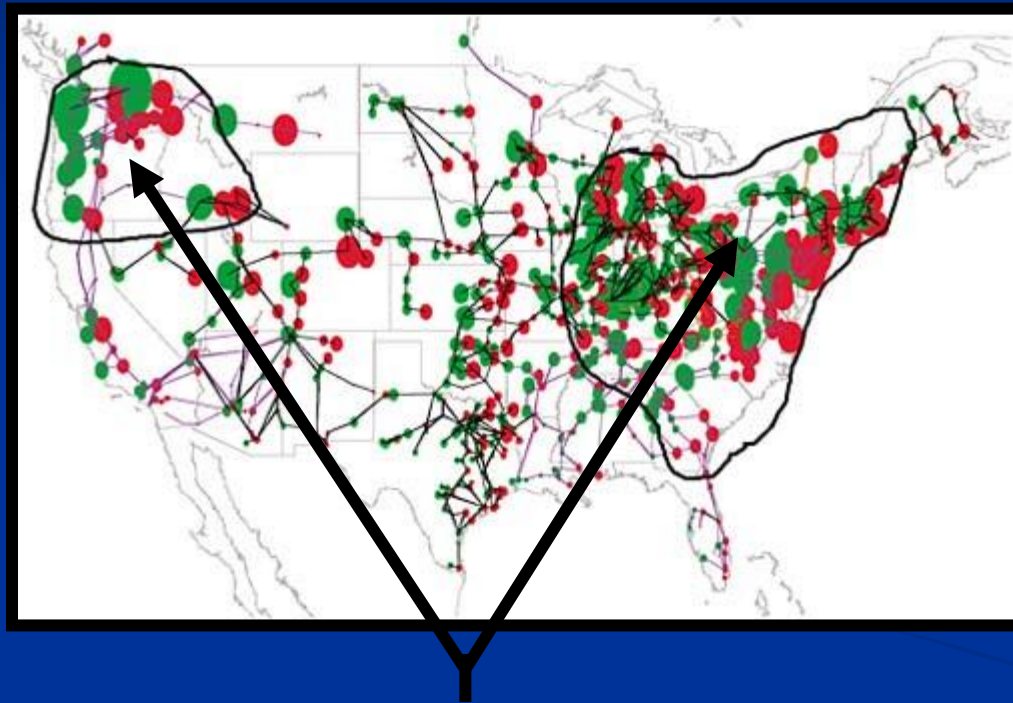
Department of Energy, 2006

At Risk EHV Transformer Capacity For a 4,800nT/min Geomagnetic Disturbance

(Source: J. Kappenman, Metatech Corp.)



Areas of Probable Power System Collapse



Areas of probable power system collapse for a 4,800nT/min geomagnetic disturbance

[From J. Kappenman, Metatech Corp., in "Severe Space Weather Events", by the Space Studies Board]

Effects on Power Grid

- **“It is the Commission’s assessment that functional collapse of the electrical power system region within the primary area of assault is virtually certain”**

2008 EMP Commission

Consequences of Power Loss

- **“Should the electrical power system be lost for any substantial period of time ... the consequences are likely to be catastrophic ... machines will stop; transportation and communication will be severely restricted; heating, cooling and lighting will cease; food and water supplies will be interrupted; and many people may die”**

2008 EMP Commission

Test and Simulation Results

- **SCADA components**
- **Power system protective relays**
- **Cars, trucks, trains, planes**
- **Communications networks**
- **Financial and banking records**

Nuclear EMP Tests

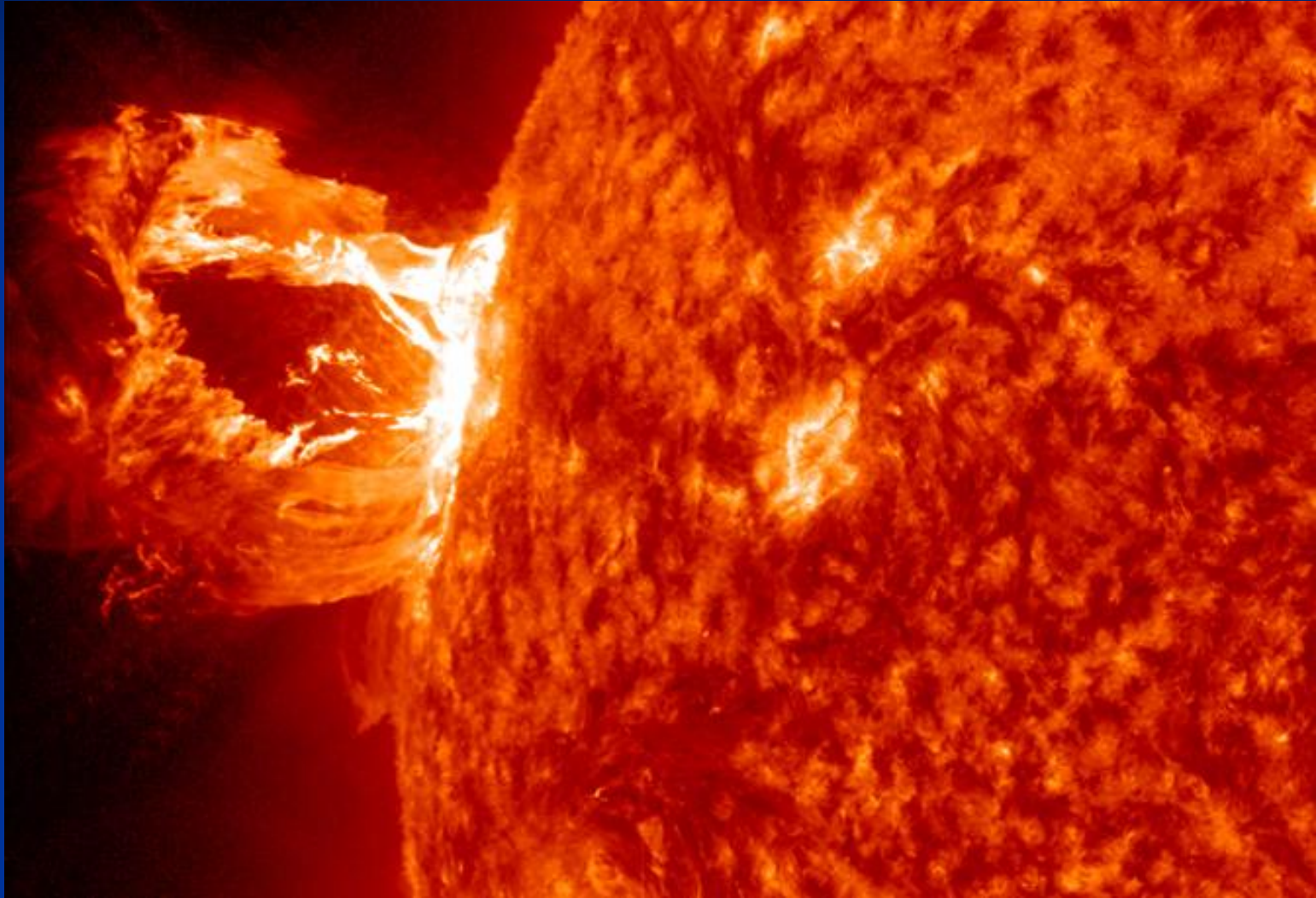
- **US – Starfish Prime (1962)**
 - **1.44 Mt burst, 250 mi altitude over Johnston Island in the South Pacific**
 - **5.6 kv/m E1 pulse in Honolulu**

- **USSR – Test 184 (1962)**
 - **300 kt burst, 180 mi altitude over Kazakhstan**
 - **1,000 to 1,300 nT/min E3 pulse**
 - **Power station 300 mi distant set on fire by E3 Pulse effects and destroyed within 10 seconds**
 - **2,500 amp current induced in overhead phone line**

Consequences

- **Light, heating, cooking**
- **Water and sewage pumping**
- **Oil and gas pipeline pumps, gas stations**
- **Transportation**
- **Telecommunications**
- **Banking and finance**
- **Food production, refrigeration and distribution**
- **Emergency services**

Geomagnetic Storms



Geomagnetic Storms

- **Sept. 1859 (Carrington event)**
 - **Strongest solar storm on record**
- **May 1921 (Railroad Storm)**
 - **4,800 nT/min**
- **March 1989 (Quebec)**
 - **480 nT/min**
 - **Knocked out power to 6 million people in 92 seconds**
- **July 23, 2012**
 - **Missed earth, est. at 75% of Carrington event**

Solar Storm Risk

- **“A Carrington-level, extreme geomagnetic storm is almost inevitable in the future.”**

Lloyd's of London, May 2013

The Threat From Iran

- Iran test fired its 800 mi range Shahab-3 ballistic missiles from ships in the Caspian Sea
- Iran detonated missiles at the top of their trajectory during those tests
- Iran is known to be designing a nuclear bomb trigger
- Iran also is working on fitting the container for a nuclear bomb into the nose cone of a Shahab-3 missile
- Iran has enough centrifuges to produce the enriched uranium for a nuclear bomb in less than two months

“A world without America is conceivable”

Mahmoud Ahmadinejad

North Korea

- **North Korea is estimated to have between 12 and 60 nuclear warheads**
- **North Korean ICBMs now can reach most of the continental U.S., including New York and Boston [Washington Post, Sep. 2017]**
- **The US believe[s] it may be possible that during 2018, North Korea will be able to [put] a miniaturized warhead on top of an intercontinental missile [CNN, Nov. 2017]**
- **Earlier this month, state news agencies in the Kim Jong Un-dictated country explicitly cautioned that it could hit the U.S. with an EMP offensive [Fox News, September 2017]**

Conventional EMP Attacks

EMP SUITCASE

COMPACT 2100 SERIES

APELc proudly introduces the latest compact directed-energy solution. This portable and rugged Gigawatt-class source generates high-amplitude electric fields suitable for affecting electronics and testing system vulnerabilities. The development of APELc's EMP Suitcase was driven by input from DoD groups that required a powerful, reliable, compact EMP source capable of disabling or defeating electronics.



125
100
75
50
25
0
-25
-50
-75

10ns

2 3 4 5 6 7

Exterior Dimensions
24.6 x 19.7 x 8.6 in.



APELc
APPLIED PHYSICAL ELECTRONICS, L.C.

www.APELc.com (512) 264-1804 Made in the USA

Kinetic Attacks on Power Grid

- **April 16, 2013 attack on Metcalf substation in San Jose, CA**
 - **Attackers cut phone lines**
 - **Snipers in 19 minutes knocked out 17 large transformers**
 - **Shell casings fingerprint free**
 - **Disappeared one minute before police arrived**
 - **No one ever caught**
 - **Dry run?**

What Can We Do Nationally

- **Reestablish the EMP Commission**
- **Conduct more tests**
- **Protect transformers and generating plants**
- **Assure availability of replacement equipment**
- **Increase number of frequency independent 'islands' in the electrical system**
- **Expand emergency power supplies**
- **Extend 'black start' capability**
- **Shield critical SCADA and communications components**

EMP Shielding

- **Mil-STD-188-125-1**
- **Clip ferrites on cables**
- **Use shielded ethernet cables**
- **Use surge protectors**
- **Switch from metal to fiber optic cables**
- **Protect critical equipment in Faraday cages**
 - **All metal exterior**
 - **No openings**

What Can We Do Locally

- **Inventory of local assets**
 - **Food and water**
 - **Gasoline, diesel, propane**
 - **Coast Guard base**
 - **Human talent**

- **Inventory of local needs**
 - **Food and water**
 - **Critical generators**
 - **Communications**
 - **Working vehicles for first responders**
 - **Fuel for first responder vehicles**