
EMP is Real Science

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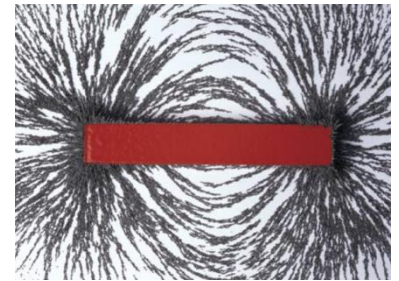
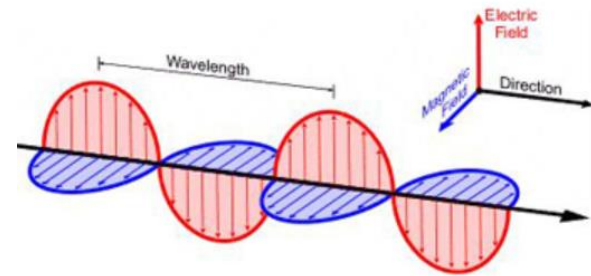
What is EMP?

- Electromagnetic Pulse (EMP)
 - A Transient Electromagnet Disturbance
 - A Short Burst of Electromagnet Energy
 - Sources Include
 - Natural Sources
 - Lightning
 - Electrostatic Discharge
 - Meteoric EMP
 - Solar Weather
 - Man Made Sources
 - Non-Nuclear EMP Weapon
 - Nuclear Weapon
 - The Energy Transferred by
 - Electric Field
 - Magnetic Field
 - Electromagnetic Radiation
 - Electrical Conduction



Electric & Magnetic Field Interaction

- The Electromotive Force Was Studied Heavily in the 19th Century
 - There is a close coupling between Electric Fields and Magnetic Fields of Energy
 - Nerds of the Time (i.e. Scientist) Discovered this and Characterized the Relationship
- Electric Field
 - Produced by a Charged Particle in Space
 - May Also be Produced by a Varying Magnetic Field
- Magnetic Field
 - Produced by a Charged Particle Moving in Space
- Electromagnetic Field
 - Caused by the Motion of an Electric Charge
 - Produced by the Mutual Interaction Between Electric and Magnetic Fields.



We Use This Relationship Every Day

- You've Seen It, You've Used It
- Our Electric Grid Uses It
- School Kids Study it
- Faraday's Law of Induction and Maxwell's Equations
 - A Time Varying Magnetic Field Produces an Electromotive Force Which Can Establish a Current in an Electric Circuit



emf = $-\frac{d\Phi}{dt}$
I Know, Eyes Glaze Over Here

This is **Not** Science Fiction – It's Real Science!

Natural Sources

- Lightning and Electrostatic Discharge
 - We've All Experienced This
 - Very Localized Effects
 - The Grid Deals With this on A Regular Basis (Especially Here in Colorado)
- Meteoric EMP
 - A Rare Event and Other Effects May Be More Predominant.
 - If Solar Weather Is Mitigated, EMP From this Type of Event Would Not Be of Significant Concern
- Solar Weather
 - Significant Effects Have Been Observed
 - This Has Impacted Significant Areas In The Past and Will In The Future



Solar Weather Effects

- Storms on the Sun's Surface

- Storms on the Surface of the Sun Cause Massive Eruptions
 - These Eruptions Can Result in Ejection of Mass from the Surface or Corona of the Sun Into Space (Known As Corona Mass Ejection or CME)
 - This Mass is Made Up of Highly Charged Particles that Move At Tremendously High Speeds
- These Eruptions are Accompanied by High Energy Radio Emissions



- Solar Particle Event (SPE)

- When Particles from CMEs Interact with an Object We Have a Solar Particle Event
- The Northern Lights or Aurora Borealis Are the Result of SPE
- In Space SPEs Can Disrupt or Even Damage Spacecraft Electronic Equipment (1989 Event)
 - Humans in Space Are Also In Danger
 - Earth's Atmosphere Protects Us From the Direct Impact of Particles



- When CMEs Reach Earth They React With the Earth's Magnetic Field

- Radio Waves Preceding, During or Following the CME will Also React with this Field
- Variations in the Earth's Magnetic Field Can Affect Electronics on the Earth
 - Charged Particles Rarely Reach the Earth's Surface but Charged Particles Moving thru the Earth's Magnetic Field Will Disrupt it
 - Remember Faraday Said that a Varying Magnetic Fields Will Cause Electric Current to Flow
 - High Rate Changes Can Cause Significant and Sometimes Damaging Currents
 - Long Transmission Lines are Particularly Susceptible (Volts/Meter)



Man Made Sources

- Non-Nuclear EMP Weapons
 - RF Weapons
 - Microwave Weapons
 - Impulse Generators
 - Tesla Generators
 - Direct Energy Weapons (DEW)
- Nuclear Weapons
 - Ground Detonation
 - High Altitude Detonation



Non-Nuclear EMP Weapons

- Common Applications
 - Medical
 - Transmission Electron Microscopy
 - Engineering Testing
 - EMI/EMC
 - EMP Testing
 - Law Enforcement
 - Research in High Speed Chase Mitigation Weapon
- Localized Effects (Approx. 1000 yards or Less)
- Technology Is Advancing
 - RF Jamming is in Use Around the World Already
 - Greater Range
 - Lower Input Power
 - Portability



Electromagnetic EMP Blaster Gun, Gen II

Nuclear Weapons

- Ground Detonation
 - Line Of Sight (Range)
 - Low Altitude Blast Limits the Range
 - Atmospheric Effects
 - Gama Rays Absorbed Close to the Blast
 - Energy Absorbed by the Atmosphere
 - Air Molecules Produce Electrons Rapidly and Close to the Blast
 - The Earth Boundary Limits the Effects on the Magnetic Field
- High Altitude Detonation
 - Line of Sight & Thus Target Area is Greatly Extended
 - Detonation Over Central U.S. Could Impact all of the Contiguous Continental States, Parts of Mexico and Canada
 - Both N. Korea and Iran Have Discussed this Openly
 - Both Are Practicing Today
 - Both Have Threatened Us and our Allies

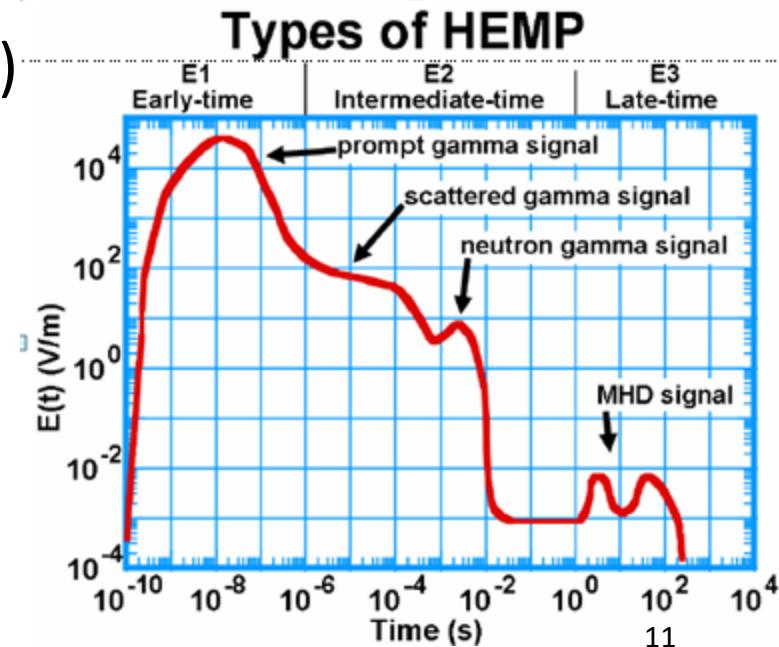


Back to Science

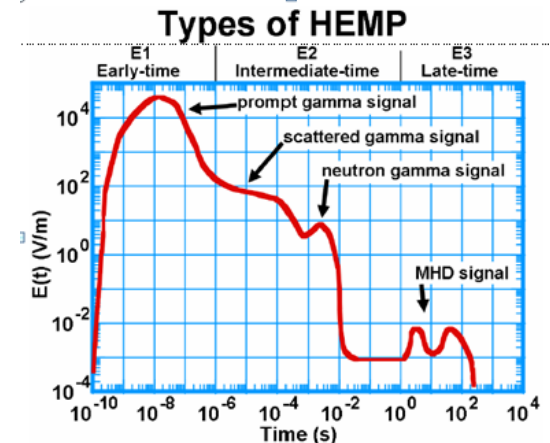
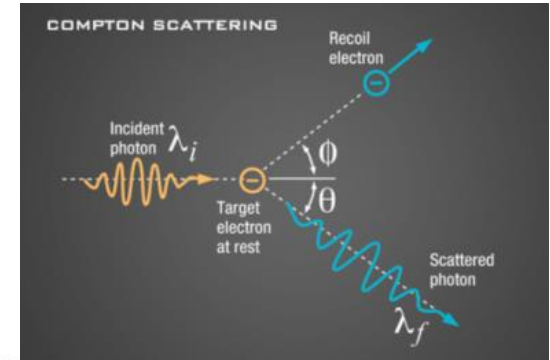
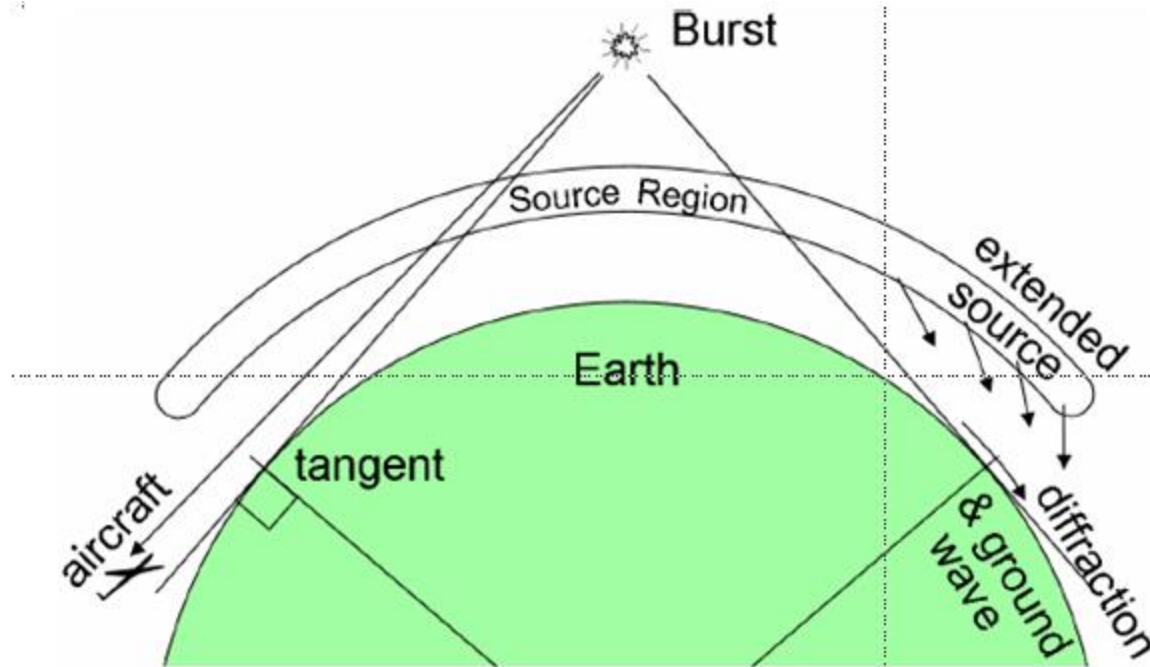
- EMP Damage Can Occur at Distances of Tens, Hundreds, or Thousands of kilometers from a Nuclear Explosion
 - Depending on
 - Weapon Yield
 - Altitude of the Detonation.
 - In 1962 a High-Altitude U.S. Nuclear test at [Johnston Atoll](#), some 1,300 km (800 miles) to the Southwest of Hawaii
 - Electronic Components in Street lights in Hawaii Failed
 - Numerous Automobile Burglar Alarms in Honolulu were Activated
- For a High-Yield Explosion of Approximately 10 megatons Detonated 320 km (200 miles) above the Center of the Continental United States, almost the entire Country, as well as parts of Mexico and Canada, would be Affected
- Procedures to Improve the Ability of Networks, especially Military Command and Control Systems, to withstand EMP are known as “hardening.”

HEMP Effects

- E3 Late-Time Effects (Low Frequency)
 - Similar to the Effects of the Sun on Earth's Magnetic Field
- E2 Intermediate-Time Effects
 - Similar to Lightning Effects
- E1 Early-Time Effects (High Frequency)
 - Small Wavelength Signals With Large Potentials
 - Small Distance Provide Good Coupling (Centimeter Wavelengths)
 - Much Faster Rise Times than Seen In Lightning Strikes

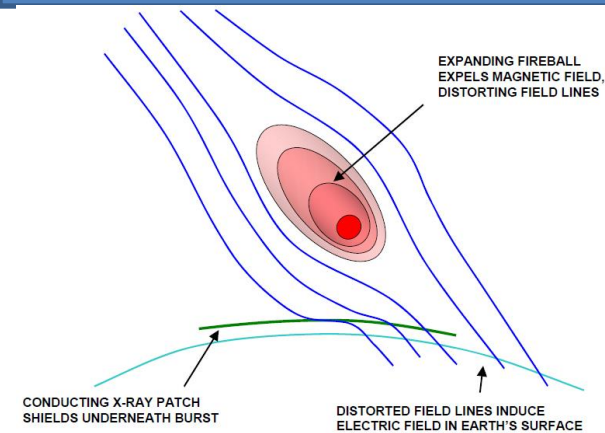


The E1 Pulse

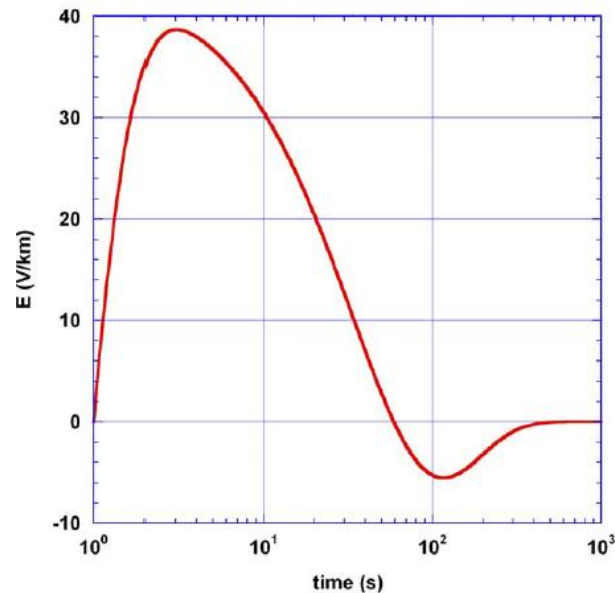


- Gama Rays Will React With the Earliest Electrons They Find.
 - In the Vacuum of Space Few Are Found
 - At Low Altitudes Electrons Are Found Early
 - At High Altitude The Source Region Provides Electrons for Compton Scattering
- The Electromagnetic Fields are Created by the Motion of the Electrons
 - Short Wave Length (High Frequency)

The E3 Pulse



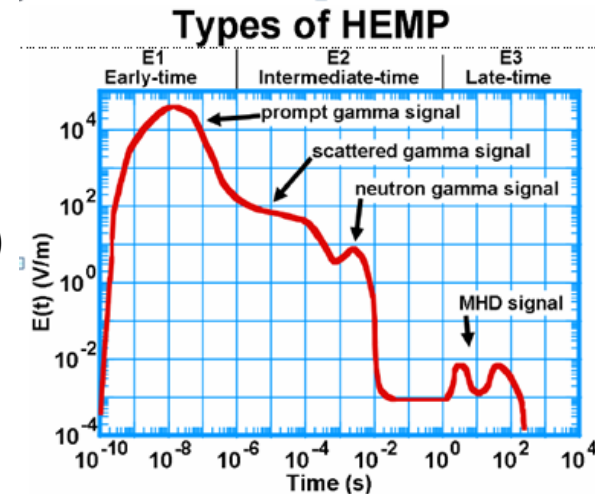
IEC E3 Horizontal Electric Field



- The High Altitude Nuclear Blast Distorts Earth's Magnetic Field
 - Remember the Electric Field is Produced by the Rate of Change in the Magnetic Field
 - This is a Very Rapid Change (Duh, It's a Nuclear Blast)
- The Effect is Wide Spread.
 - The Change is in the Earth's Magnetic Field
 - The Effect is Almost Global, Not Localized
- The Electric Pulse Produced is the Late Time Effect (E3)
 - Long Power Lines Act Like an Antenna (5-40 V/km)
 - This is a Very Low Frequency, Long Wave Length Pulse
 - To The Power Grid (60Hz) This Looks Like DC (0 Hz)
 - Transformers Hate DC. (Core Saturation & High Current)
 - They Heat Up, Catch Fire and Die (Destructively)
 - The Damage is Permanent and Could Spread
 - » Fire Damage
 - » Cascading Electrical Effect Across the Grid

The Impacts on Mankind

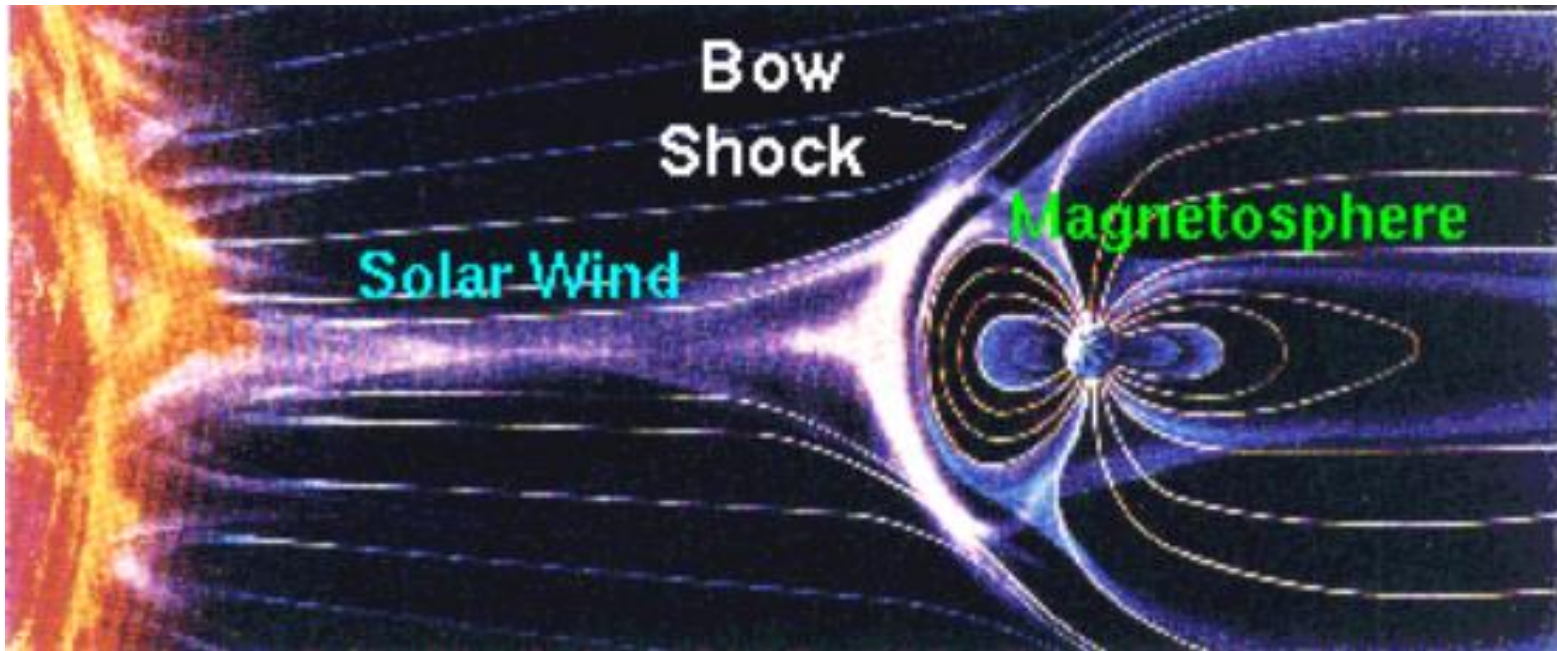
- Local Impacts Including Regional Level Effects Can Be Managed.
 - We Have Proven Ourselves With Incidents Such as
 - Katrina
 - Sandy
 - Can Be Costly But Not Civilization Threatening
- A Carrington Level Solar Event or High Altitude Atomic Detonation **Could Be A Threat to Civilization Itself**
 - Infrastructure Failure
 - No Power (SCADA & HV Transformers)
 - No Transportation (Including the Supply Chain)
 - No Communications (No Cell/Radio/TV Broadcasts/etc.)
 - Lack of Public Information
 - Lack of Public Safety/Defense
 - Breakdown of Our Civil Structure



These Impacts Will Likely be Long Term Effects (Months to Decades)

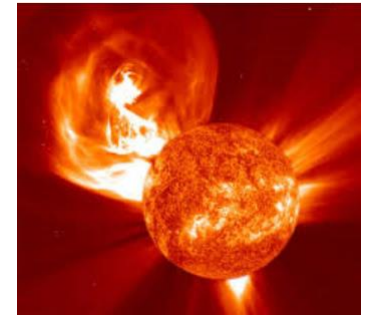
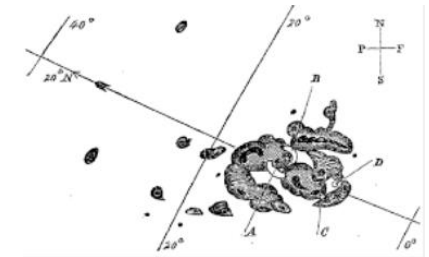
BACKUP

Earth's Protective Magnetosphere



Solar Weather Events

- Carrington Event Sept 1, 1859 at 11:18am Visual Observation
 - Dawn the Next Day
 - Auroras in Hawaii, Cuba, Jamaica, El Salvador and the Bahamas
 - Telegraph Incidents Around the World
 - This was the Advanced Technology of the Time
 - Messages Transmitted with Batteries Disconnected
 - Papers in Telegraph Offices Caught Fire
 - It Was a 500 Year Event (or Was It?)
- Significant Events Also Occurred on
 - Nov 18,1882: All telegraph transactions east of the Mississippi & North of Washington came to a halt
 - May 1921
 - Aug 4, 1972: Knocked out Telephone Communications in Illinois
 - Bastille Day Event, July 14, 2000:
 - March 13,1989: Hydro Quebec (6 million people for 9 hours in blackout)
 - Melted power transformers in NJ
 - Halloween 2003: Power outage in Sweden, Aurorae seen in the Med and Texas, Satellites Damaged
 - Dec 5,2006: Damages GOES 13. Disrupted Satellite com for 10 minutes including GPS
 - July 23, 2012 CME Near Miss of Earth (May Have Exceeded the Carrington Event)
- Satellite Systems Are Typically Designed to the 1989 Event
 - If Events Closer to the Carrington Event Were to Occur..... (Scientifically Speaking: "WOW!")



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