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HIGH-ALTITUDE ELECTROMAGNETIC PULSE THREATS AND HAZARDS

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Agenda

- History of High-Altitude Electromagnetic Pulse (HEMP) Research
- HEMP Waveform Characteristics
- HEMP Threats
- Electric Grid Characteristics
- Potential HEMP Effects on Grid Infrastructure
- Reasons for Scientific Uncertainty

The History of HEMP Research

- Early atomic scientists aware of electromagnetic emissions of bombs as a threat to electronics
- Electromagnetic effects of low-altitude or surface bursts are largely confined to area of heat and blast damage
- U.S. and Soviet high-altitude tests in the upper atmosphere in the early 1960s affected electrical grids and electronics hundreds or even thousands of miles away
- The Partial Test Ban Treaty of 1963 precluded further scientific observations of HEMP effects on infrastructure *in situ*
- Military and civilian scientists have continued theoretical work and laboratory testing on grid components and other electronics

Existing Research

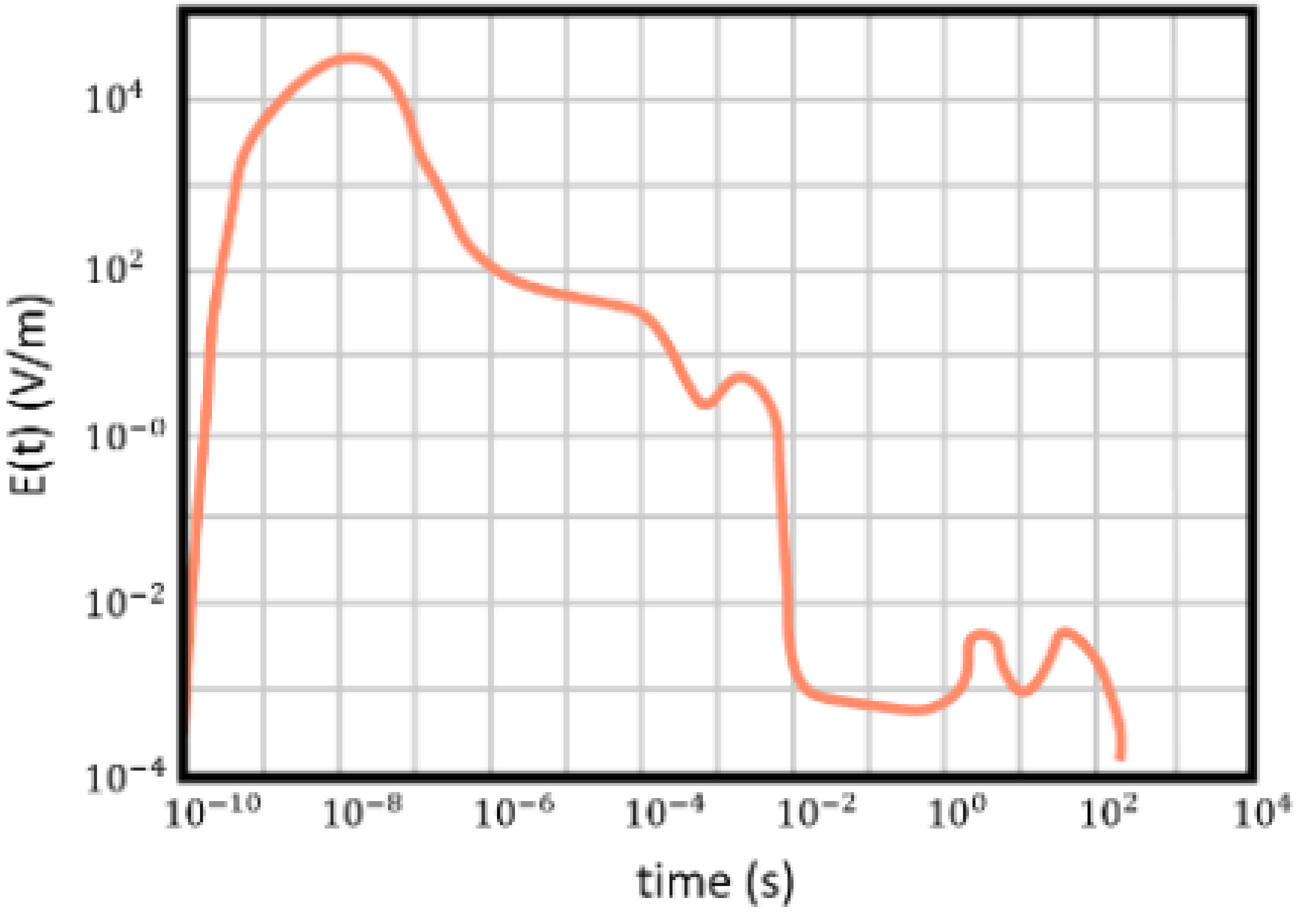
- During Cold War, research was heavily focused on ensuring survivability of weapons systems and military infrastructure, but interest in EMP effects on civil infrastructure has increased in recent decades
- Electric Infrastructure Security Council (EIS)
- U.S. National Laboratories (Department of Energy)
- U.S. Geological Survey (USGS)
- Electric Power Research Institute (EPRI)
- Defense Threat Reduction Agency (DTRA)
- EMP Commission Reports

HEMP Waveform Characteristics

- E1: (Early Time) Occurs within first milliseconds of detonation
  - Intense brief burst of electromagnetic energy
- E2: (Intermediate Time) Occurs within a few hundredths of a second
  - Similar to lightning but occurs simultaneously over broad area
- E3: (Late Time) Longer duration “blast” and “heave” effects for several minutes after detonation
  - Similar in some key characteristics to geomagnetic disturbances (GMD) caused by extreme space weather events

HEMP Waveform

(V/m=volts per meter)



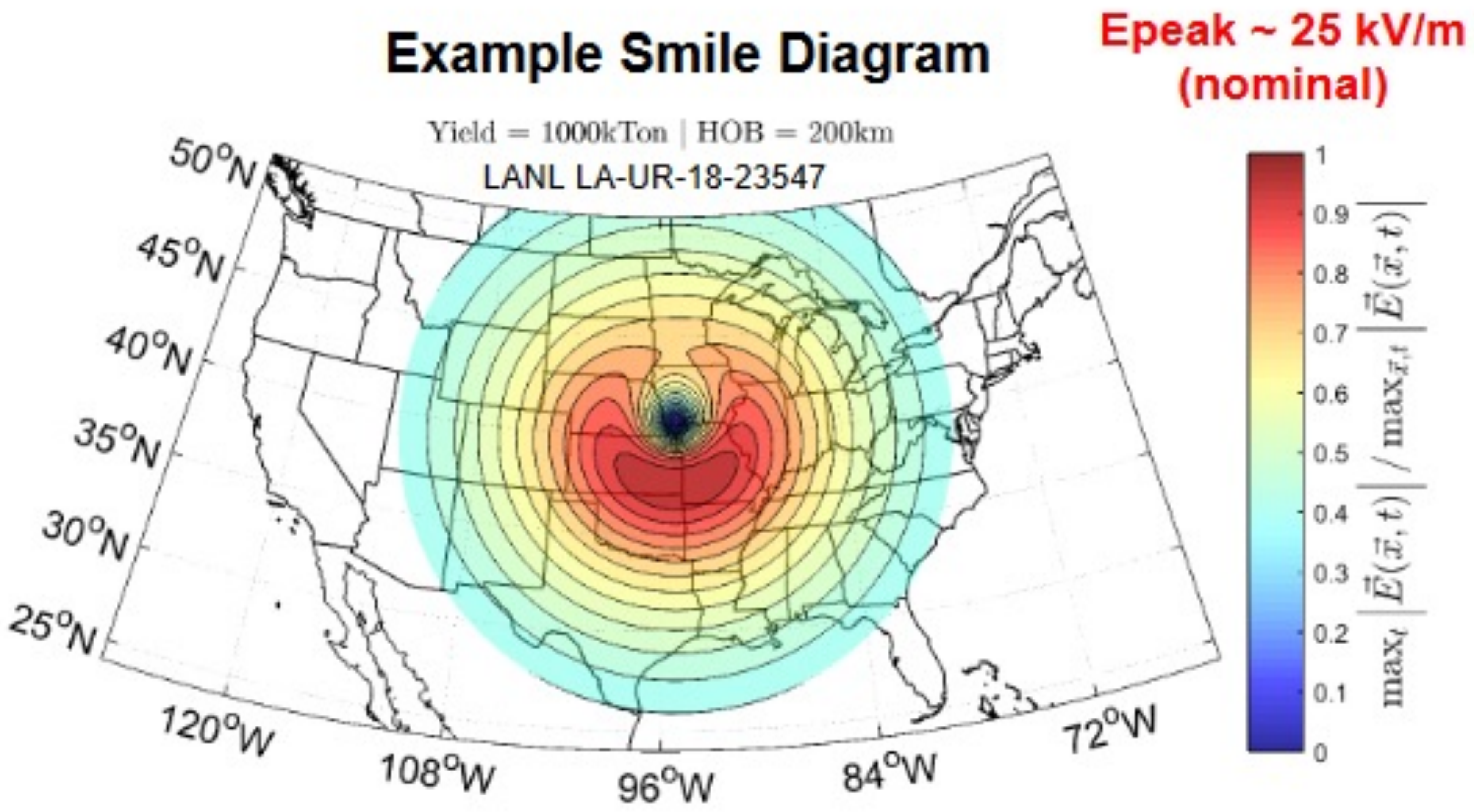
Source: Los Alamos National Laboratory (LANL)

HEMP Radiated and Conducted Threats

- E1: Early-time pulse
  - May cause upset or damage to digital protective relays, and supervisory control and data acquisitions (SCADA) systems
  - May couple with power lines and damage connected equipment
  - May damage communications equipment by coupling with conductive copper lines
- E2: Intermediate-time pulse
  - Lower amplitude pulse over wide area
  - Most studies assume existing measures to prevent lightning damage are sufficient
- E3: Late-time pulse
  - May couple with power lines and cause overheating and damage to large power transformers
  - May cause bias in large power transformers leading to grid voltage collapse

Sources: LANL, EPRI, EIS

EMP E1 Effects: 1000 kiloton weapon at 200km altitude



Source: LANL (HOB=height of burst)

The U.S. Electricity Grid: Key Characteristics and Considerations

- Three main interconnections (Eastern; Western; Texas) operating largely independently of one another, cover nearly the entirety of the continental United States
- Generation and consumption must be continually balanced on massive scale to maintain grid operations and avoid worst-case outcomes
- Electric utilities within each interconnection operate at 60Hz synchronized frequency
- Risks are managed by grid operators using highly digitized monitoring and control systems
- Adding additional power or taking large segments of the grid offline involves highly complex and synchronized operations that cannot be completed instantaneously

Predicted HEMP Effects on Grid

- Scientific uncertainty allows for a wide range of plausible predictions, ranging from catastrophic to moderate
  - HIGH
    - Nationwide or interconnection level grid collapse and widespread permanent damage to large power transformers. Recovery period measured in months and years over continental scale.
  - MIDDLE
    - Widespread disruption to grid in affected areas, with rolling cascading failures. Most serious effects are limited to local and regional areas in proximity to HEMP burst. Recovery period measured in days and weeks in most areas.
  - LOW
    - Shorter term disruptions at local and regional level. Most damage to critical systems, assets, and networks is quickly repaired or otherwise bypassed without risk to overall system. Recovery period measured in hours and days in most areas.

CRS synthesis of LANL, EPRI, EIS, EMP Commission sources

Reasons for scientific uncertainty

- Practical limits on experimentation on interconnection scale grids
- Grid and communications infrastructure constantly evolving
- Sensitive weapons testing data is classified, complicating development of widely-accepted HEMP waveform
- Many hypothesized variables are difficult to test or are inadequately theorized
- Stakeholder perspectives vary, affecting research design and interpretation of experimental results

QUESTIONS