

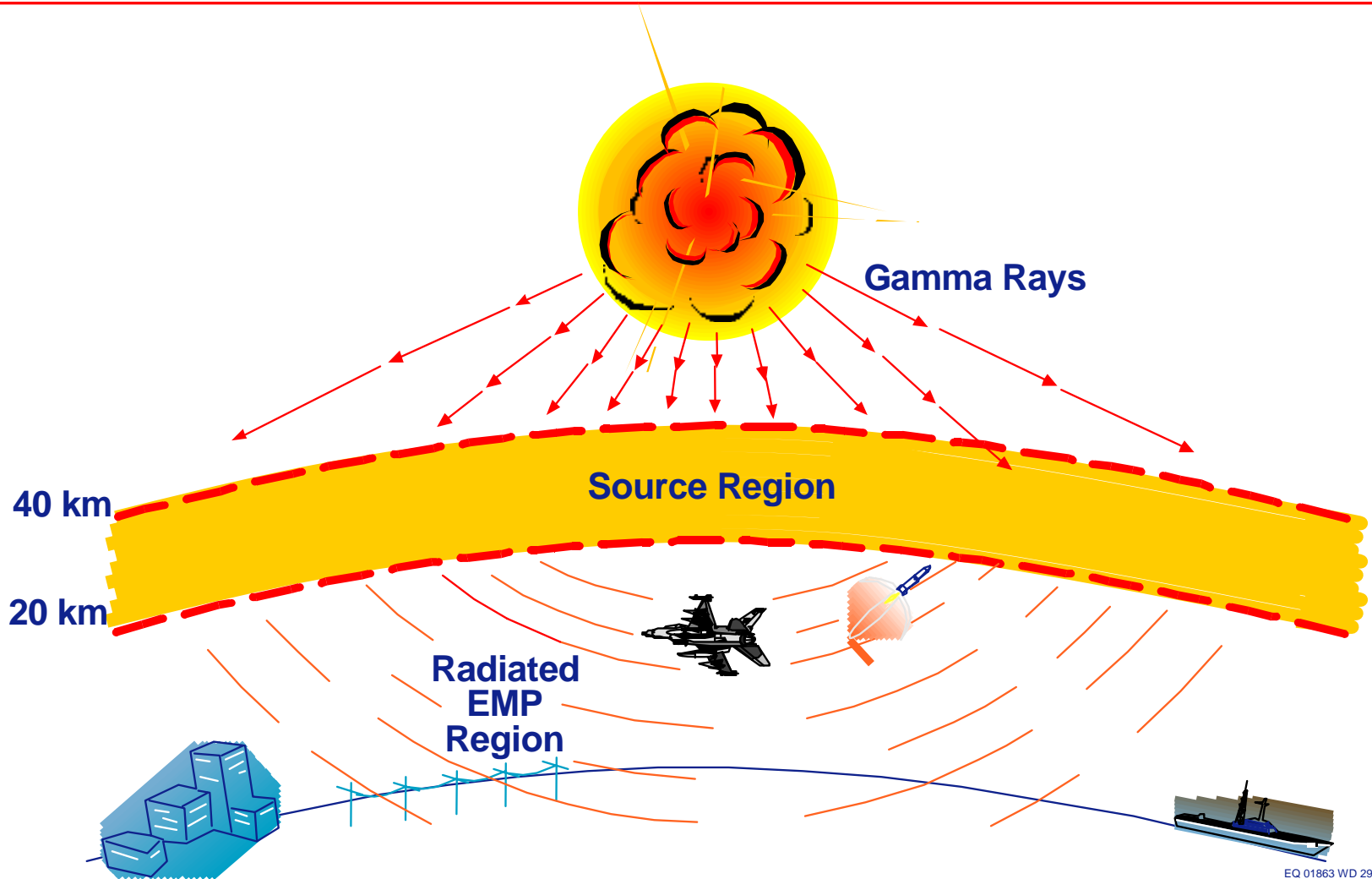
Addressing the Possibility of a National-Scale Disruption of Critical Infrastructure

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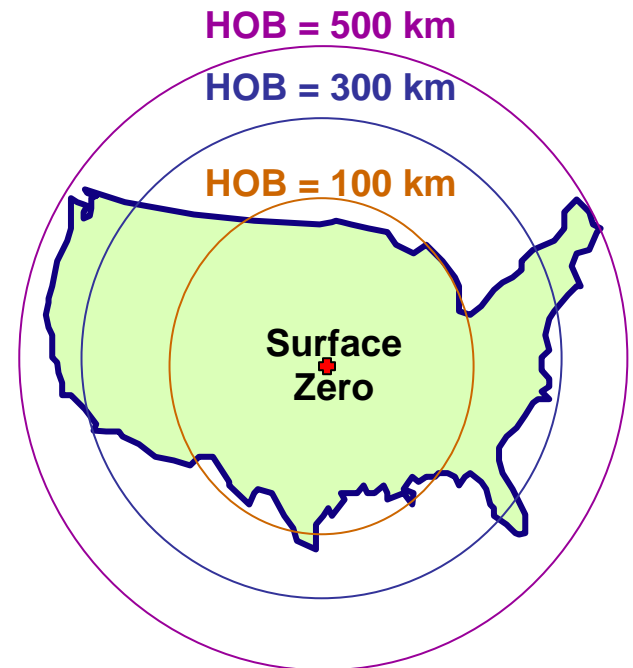
High-Altitude EMP Production



Nature and Magnitude of EMP Threats

- EMP is one of a small number of threats that may
 - Hold at risk the continued existence of today's US civil society
 - Disrupt our military forces and our ability to project military power
- The number of US adversaries capable of EMP attack is greater than during the Cold War
- Potential adversaries are aware of the EMP strategic attack option
- The likelihood of attack depends on the actions we take to be prepared

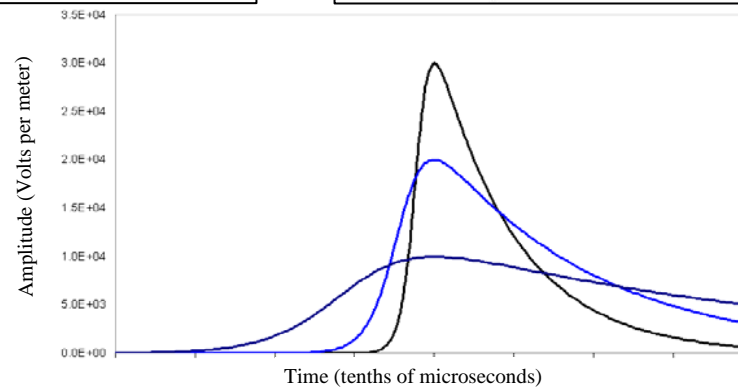
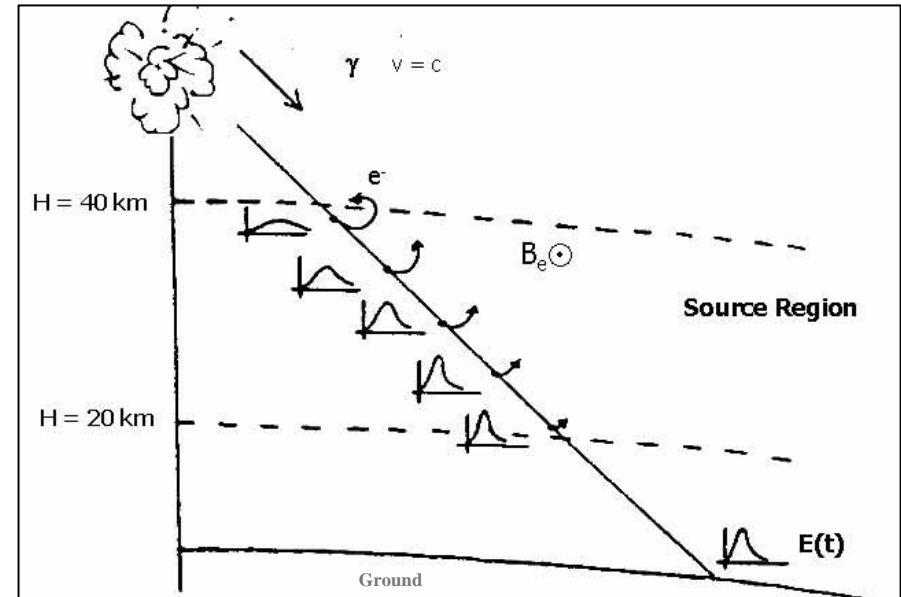
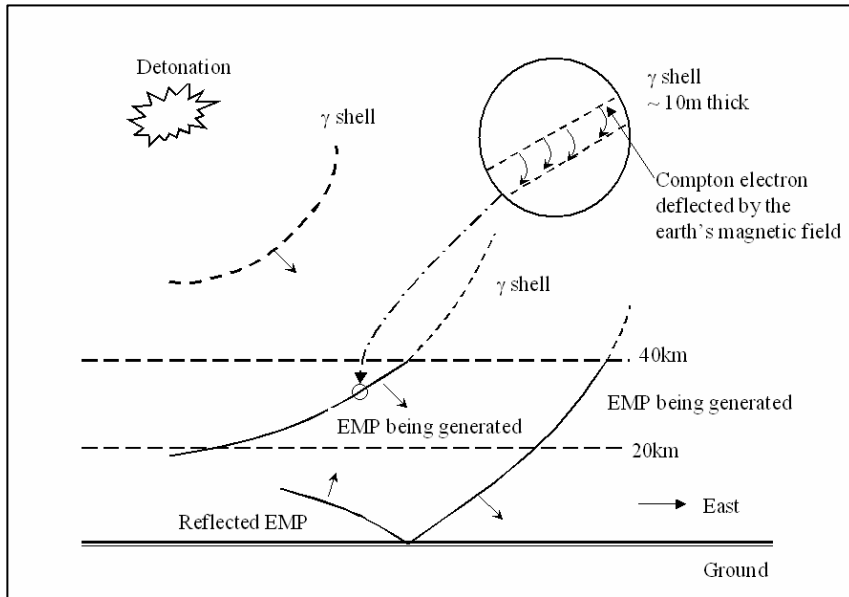
EMP Coverage for Bursts of Various Heights



- **Wide area coverage**
 - A million square miles
- **Intensity depends on:**
 - Weapon design
 - Height of burst
 - Location of burst
- **Broad frequency range**
- **Threat to all exposed electronics**

Vulnerability may be an invitation to attack

Generation Process and Sample Waveform



$$E(t) = \left(1 + \frac{\alpha}{\beta}\right) \frac{Ae^{\alpha t}}{1 + \frac{\alpha}{\beta} e^{(\alpha + \beta)t}}$$

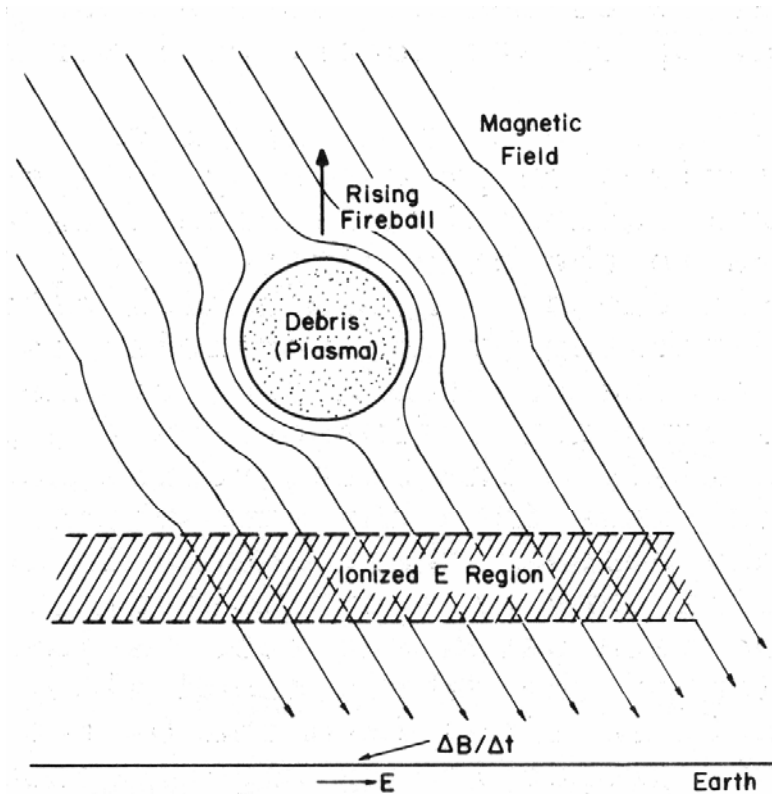
where A = peak amplitude

α = rise rate

β = decay rate

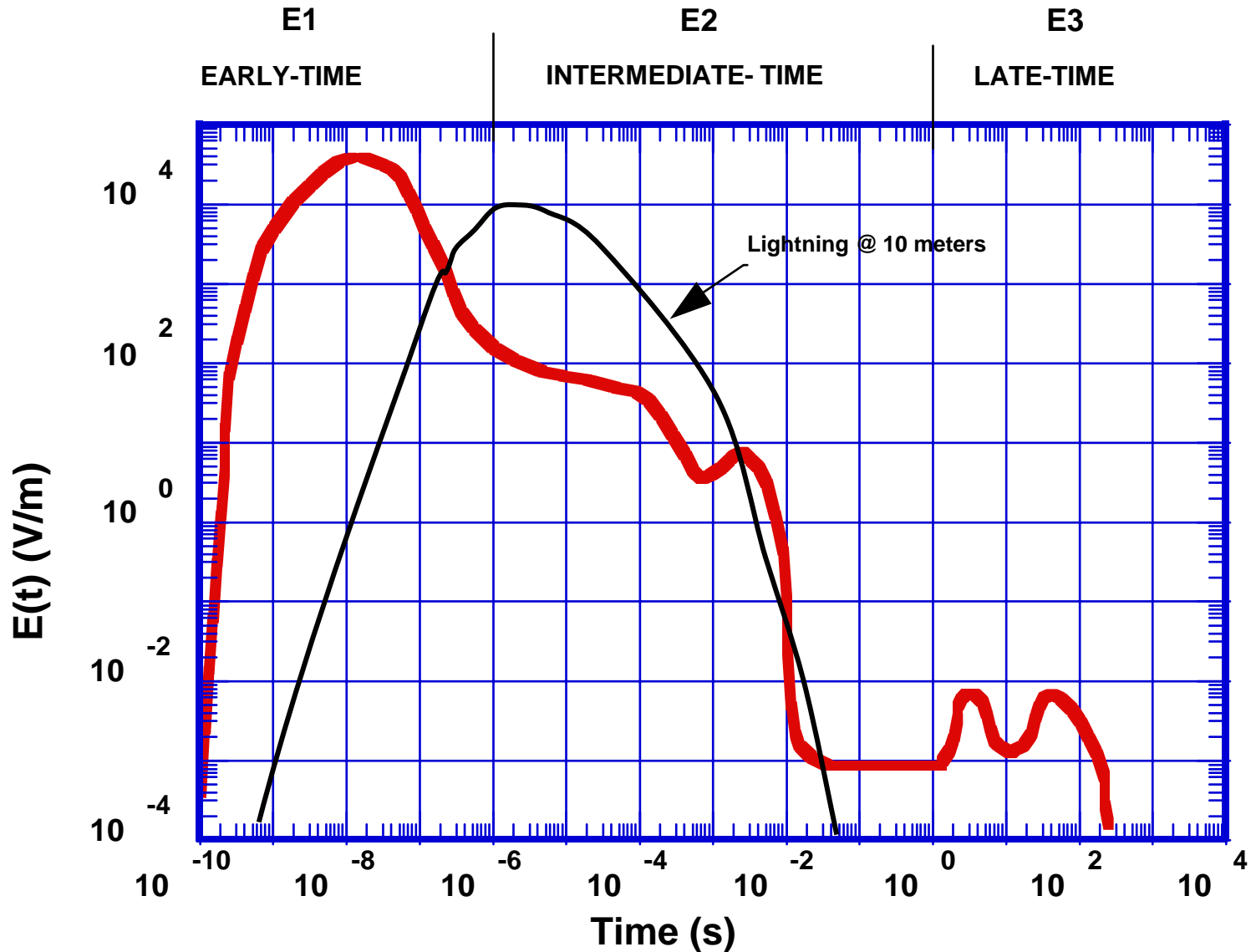
Typical values are $A = 3 \times 10^4 \text{ V/m}$; $\alpha = 10^8 \text{ sec}^{-1}$; and $\beta = 10^7 \text{ sec}^{-1}$

MHD EMP (E3) Simplified Generation Model

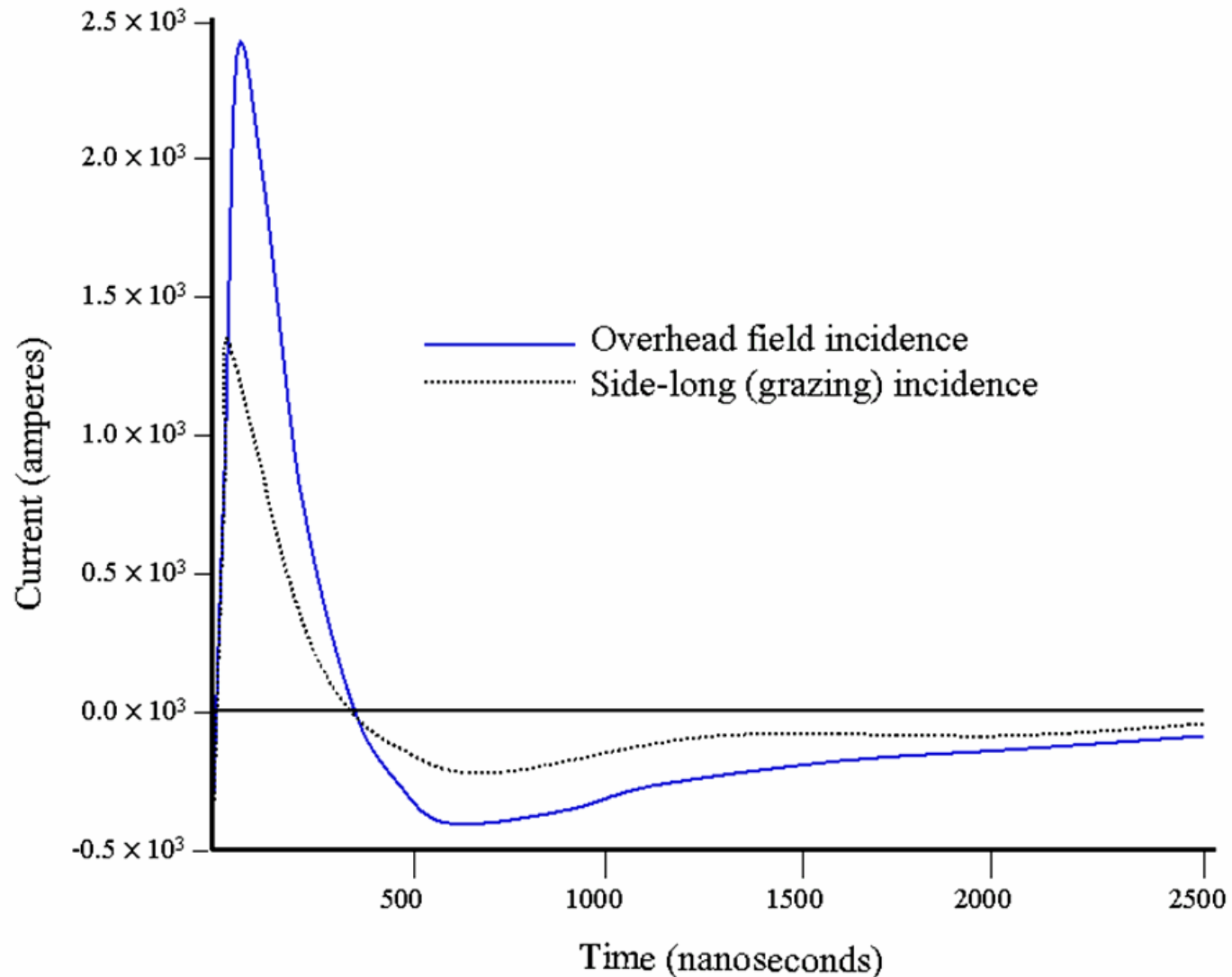


EXPANDING AND RISING FIREBALL
OF THE MAGNETIC "BUBBLE" MODEL

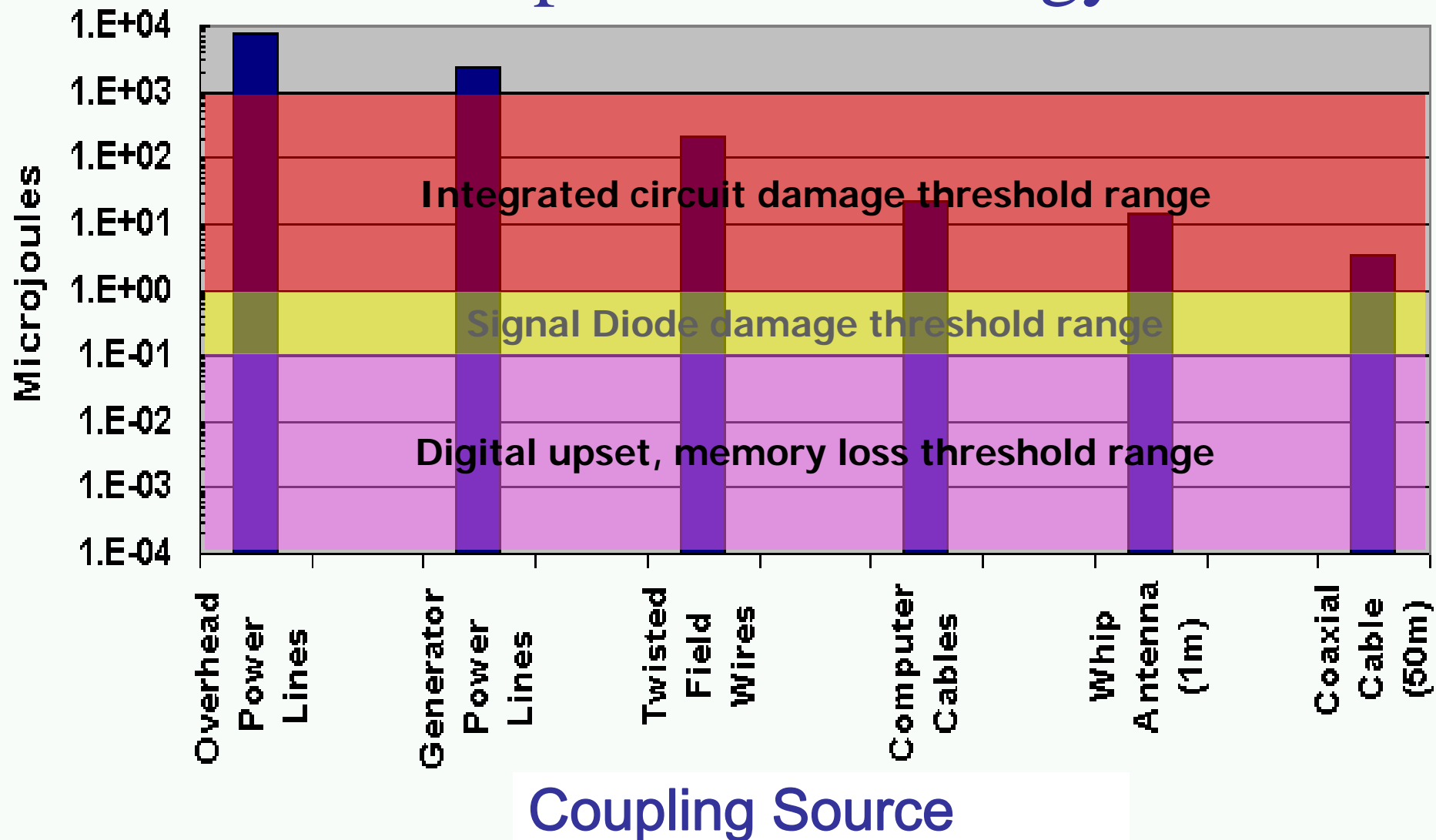
Full Time-Domain Waveform



Currents Coupled to Long Lines by E1



Component thresholds vs Coupled EMP Energy



Observed System Effects

- Systems not connected to wire penetrations tend to be immune to EMP
- Systems connected to wire penetrations tend to be vulnerable. Long line/ networked systems are the most vulnerable
- Both upset and damage have been observed in a high proportion of objects tested
- Wide variation in thresholds ($< \text{few kV/m}$ to $> \text{few hundred kV/m}$)
- Effects most pronounced for late technology electronics
- Damage and upset effects are highly repeatable

Potential Adversaries Know About EMP

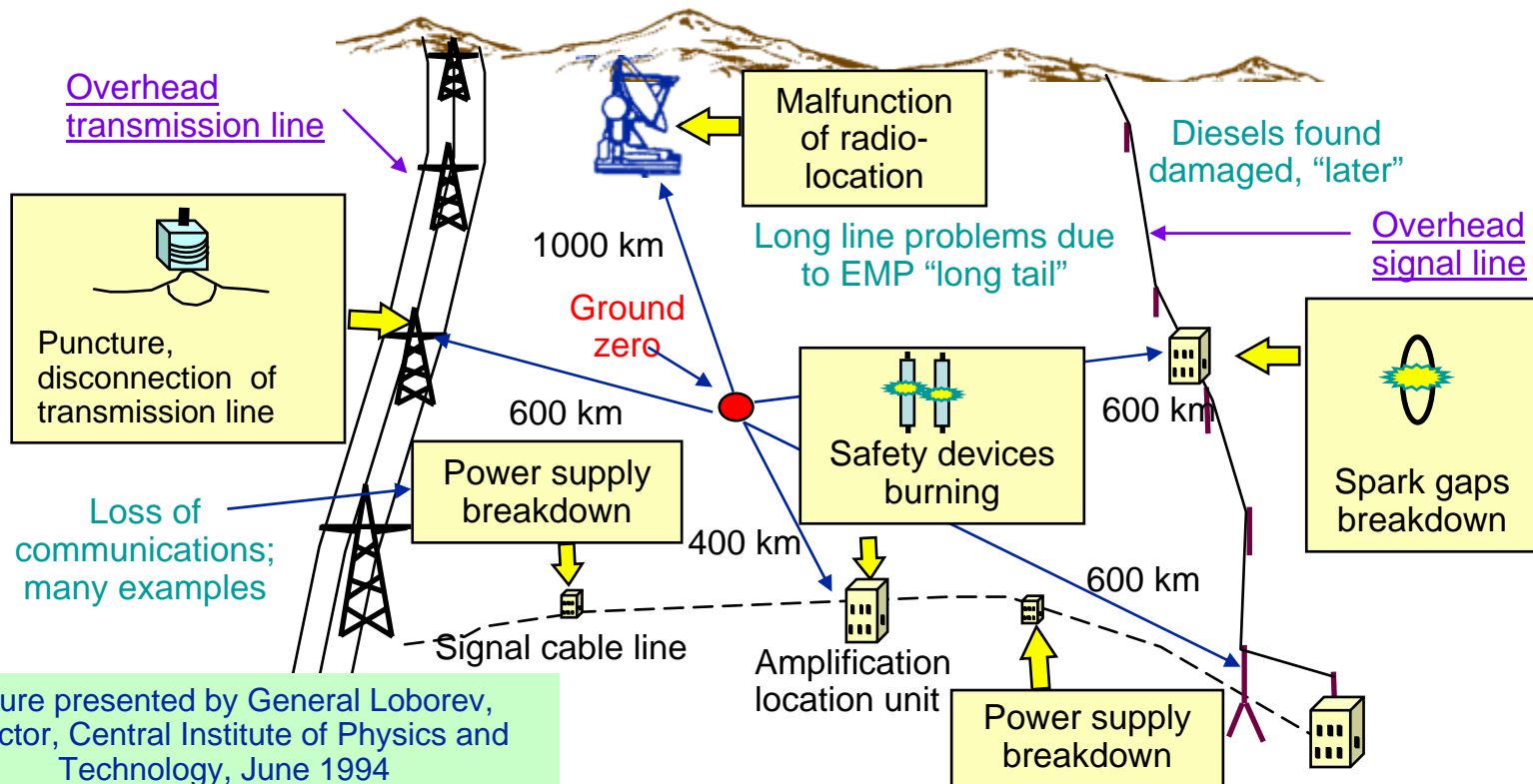
- “Hypothetically, if Russia really wanted to hurt the United States in retaliation for NATO’s bombing of Yugoslavia, Russia could fire an SLBM and detonate a single nuclear warhead at high-altitude over the United States. The resulting EMP would massively disrupt U.S. communications and computer systems, shutting down everything.” – Russian Duma Leaders to U.S. Congressional Delegation (May 2, 1999)
- Chinese military writings describe EMP as the key to victory, and describe scenarios where EMP is used against U.S. aircraft carriers in a conflict over Taiwan
- A survey of worldwide military and scientific literature sponsored by the Commission found widespread knowledge about EMP and its potential military utility, including in Taiwan, Israel, Egypt, India, Pakistan, Iran, and North Korea

Threat – Russian Experience

- EMP observed during Russian atmospheric test programs

Observed EMP Anomalies During USSR Atmospheric Testing (circa 1960)

Overhead Transmission Line and Telecommunications Disconnection and Damage



Iran May Exploit EMP

- Iranian Journal Quotes:

“Terrorist information warfare [includes] using the technology of directed energy weapons (DEW) or electromagnetic pulse (EMP).

“If the world’s industrial countries fail to devise effective ways to defend themselves against dangerous electronic assaults, then they will disintegrate within a few years...150,000 computers [belong] to the U.S. Army...if the enemy forces succeeded In infiltrating the information network of the U.S. Army, then the whole organization would collapse...the American soldiers could not find food to eat nor would they be able to fire a single shot.”
- Iran has tested launching a Scud missile from a surface vessel, a launch mode that could support a national or trans-national terrorist EMP attack against the United States.

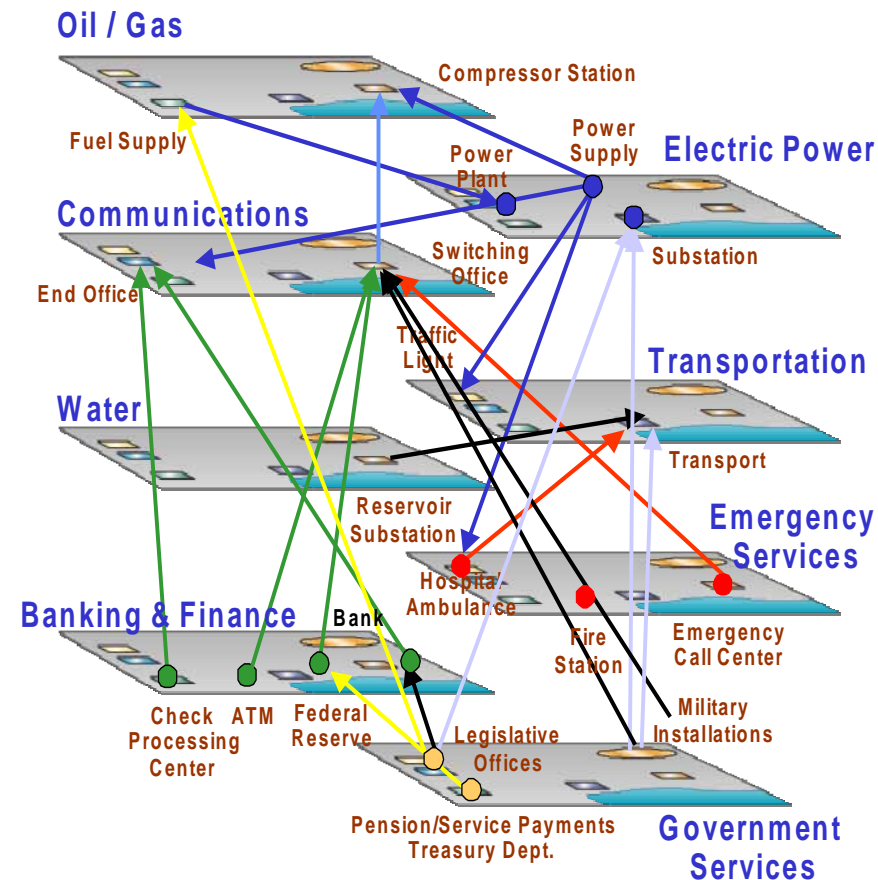
The Threat: Why EMP?

States or terrorists may well calculate that using a nuclear weapon for EMP attack offers the greatest utility

- EMP offers a “bigger bang for the buck” against US military forces in a regional conflict; or a means of damaging the US homeland
- EMP may be less provocative of US massive retaliation, compared to a nuclear attack on a US city that inflicts many prompt casualties
- Infrastructure Warfare: Strategically and politically, EMP attack can threaten entire regional or national infrastructures that are vital to US military strength and societal survival; challenge the integrity of allied regional coalitions; and pose an asymmetrical threat more dangerous to the high-tech West than to rogue states
- Technically and operationally, EMP attack can compensate for deficiencies in missile accuracy, fusing, range, reentry vehicle design, target location intelligence, and missile defense penetration

Vulnerability of US National Infrastructure

- One or a few high-altitude nuclear detonations can produce EMP, simultaneously, over wide geographical areas
- Unprecedented cascading failure of our electronics-dependent infrastructures could result
 - **Power, energy transport, telecom, and financial systems are particularly vulnerable and interdependent**
 - **EMP disruption of these sectors could cause large scale infrastructure failures for all aspects of the Nation's life**
- Both civilian and military capabilities depend on these infrastructures
- Without adequate protection recovery could be prolonged—months to years



Large Scale Outage from EMP

- September 10, 2007 News Release Headline:
New Report Projects \$34 - \$770 Billion Blow to the Baltimore-Washington, DC – Richmond Economy from EMP Attack; Local Governments Could Protect Critical Infrastructure
 - WASHINGTON, D.C. – Congressman Roscoe Bartlett (R-6-MD) participated in a Washington, DC news conference today to release a study that projected the economy in the Baltimore-Washington, DC-Richmond corridor would suffer a blow of between \$34 to \$770 billion from an electromagnetic pulse (EMP) attack, *not including the cost of any infrastructure repairs.*
 - “EMP is a low risk, but asymmetrical form of devastating attack that would dwarf the scale of the damage from the 9/11 terrorist attack,” said Congressman Bartlett.
 - Also participating in the news conference were Chuck Manto, President of Instant Access Networks (IAN), a Frostburg, MD company that commissioned the study...
- Findings
 - The intentional use of electromagnetic pulse, particularly in a high-altitude burst, is one of the least expensive ways to cause the most amount of economic and infrastructure damage to a technology-based society such as the US, Europe or Japan.
 - Loss of economic output in a regional EMP event would range from \$34B to \$770B in lost revenue – before infrastructure damage repair and secondary effects are considered
 - Extrapolating to the entire regional exposed, the total economic loss in such an event would scale by 10X.
 - Protecting as little as ten percent of critical infrastructure in a community could drastically reduce the near term financial effects and speed overall economic recovery.
 - Protection has deterrent value.

Congressional EMP Commission Charter

Duties of the Commission:

- Assess the EMP Threat to the US:
 - Nature and magnitude of EMP threats within the next 15 years
 - From all potentially hostile states or non-state actors
 - Vulnerability of US military and especially civilian systems
 - Capability of the US to repair and recover from damage to military and civilian systems
 - Feasibility and cost of EMP hardening select military and civilian systems
- Recommend protection steps the US should take

Commission considered:

- Only EMP threats produced by high-altitude detonation of a nuclear weapon
- Threat assessment based on present and possible future capabilities of potential adversaries because of 15-year outlook

EMP Commission Infrastructure Test Activities

- Power

Electromechanical and electronic relays, generator controls, RTU/MTU/DSC/PLC control devices, ...



- Telecommunications

wireless cell tower, E911 switch equipment, routers, frame relay switch, modems, corded/cordless phones, IP Data Network elements, NOC equipment,...

- Transportation

cars, trucks, traffic control systems, railroad switches,.

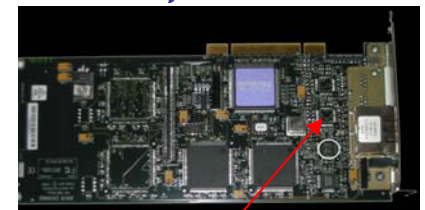


- Emergency Services

police/fire civilian communications devices, mobile command centers, medical equipment/pacemakers, radio/TV,...

- Energy Distribution (Gas/Oil)

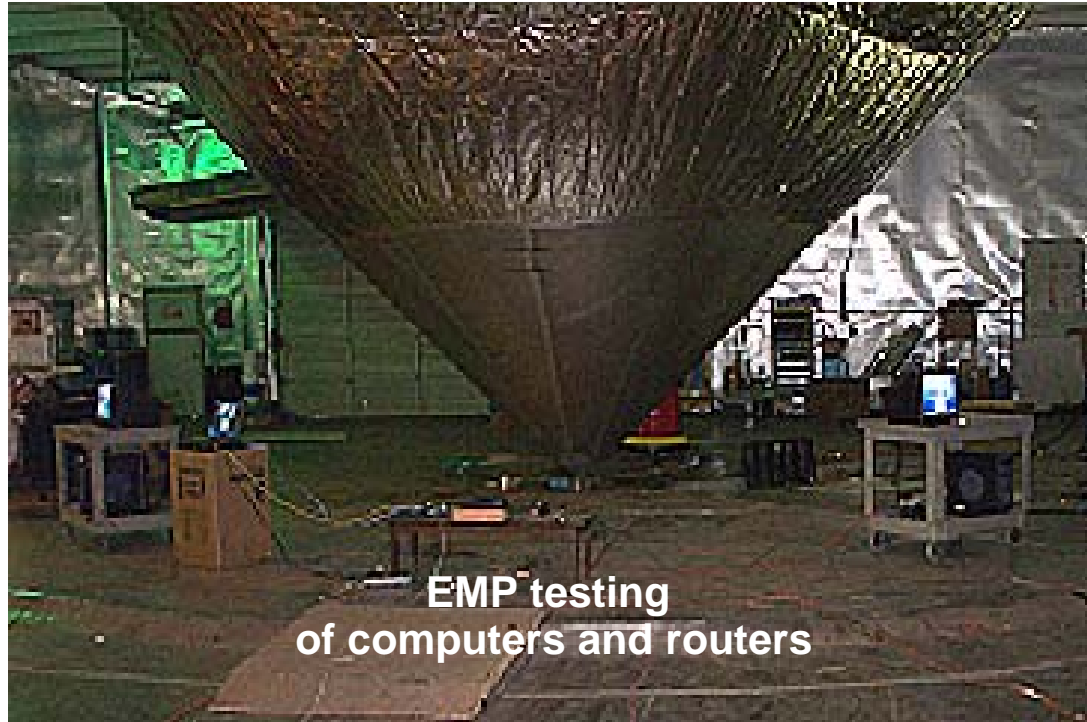
SCADA systems, pipeline/pump/valve control systems,...



Damaged Component

- Food/Water *water distribution system controls, refrigerator/freezers...*

EMP Test Facility

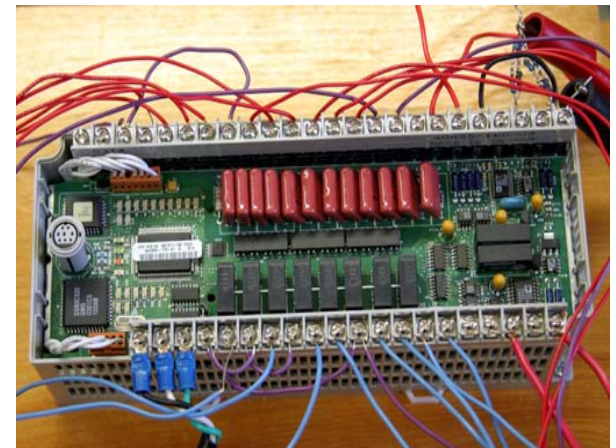


SCADA/Remote Controls

- **Supervisory Control Systems (SCADA)**
are the ubiquitous robots of modern civilization
 - Process control
 - Environmental monitoring and control
 - Safety of operation
 - Rapid problem diagnosis
 - Real time data acquisition
and remote control
- **Generic SCADA may share many
component commonalities with PCs**
 - Circuit boards, I/O ports,...



Pipeline SCADA components



PLC switch activator

Vulnerability of US Electric Power Infrastructure

- EMP induced functional collapse of the electrical power grid risks the continued existence of US civil society
 - Immediate EM transients likely to exceed capabilities of protective safety relays
 - Late time EMP could induce currents that create significant damage throughout the grid
- National electrical grid not designed to withstand near simultaneous functional collapse
- Procedures do not exist to perform “black start”
 - Restart would depend on telecom and energy transport which depend on power
- Restoration of the National power grid could take months to years
 - Typical 500kV transformer is custom tailored to application
 - Spares are seldom available
 - Manufacturing performed offshore
 - Normal delivery time months to more than a year



Substation Transformer



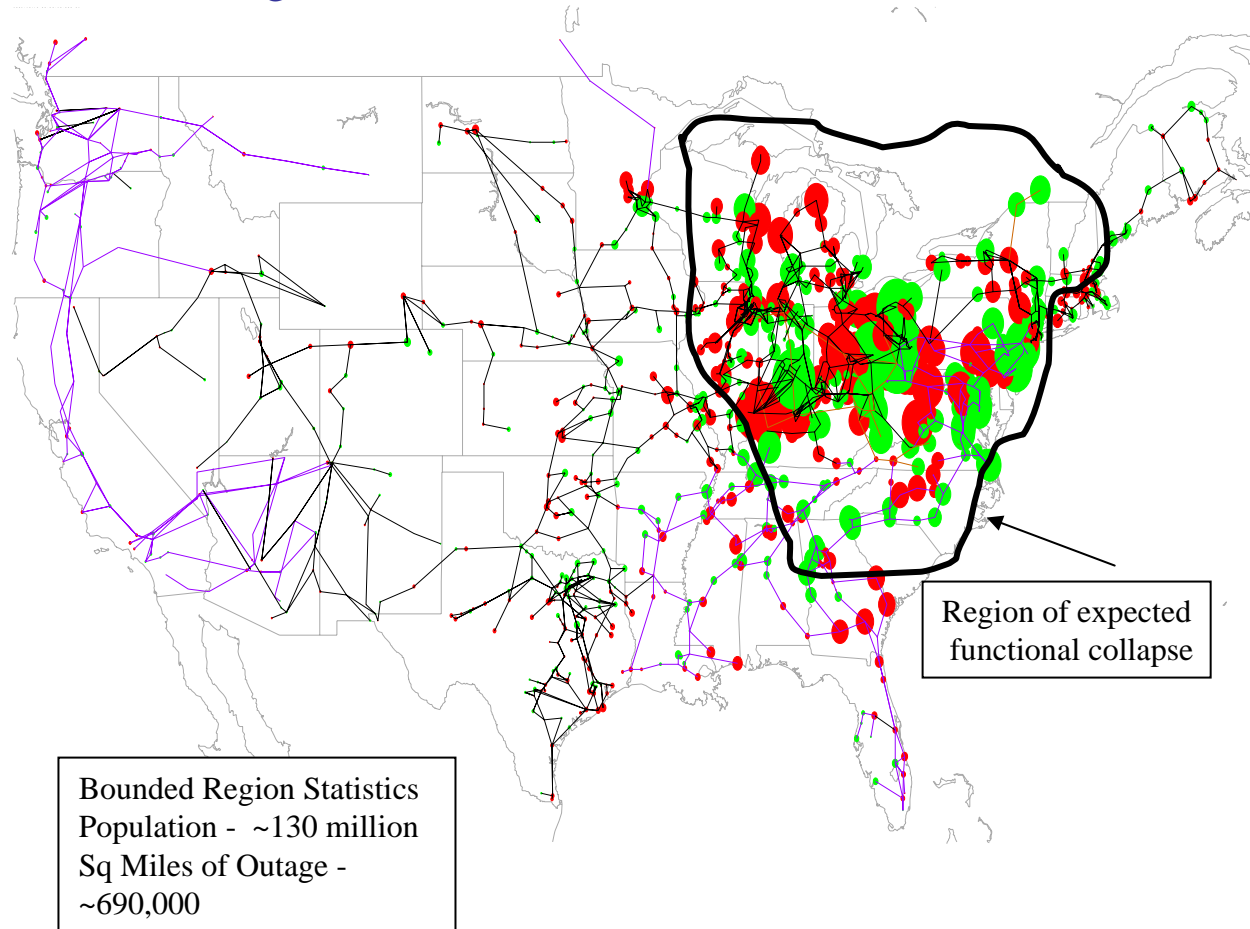
Melted 500kV transformer coil from EM induced flux creating a hot spot

Electric power is key to a functioning society and military. EMP induced destruction of power grid components could substantially delay recovery.

E3: Power Grid Response Modeling

Summary of Induced Current Flows in US Power Grid for a Multi-Megaton Threat

- Collapse of power grid likely for large E3 event
- Large E3 associated with “big” bombs
- Geomagnetic storms provide “natural” simulation of E3 response
 - 1989 collapse of Quebec Hydro
 - But, geomagnetic storms may be much smaller than EMP from large nuclear explosions



Capability of the US to Repair and Recover from Damage to Civilian Systems

Other Civilian Infrastructures Dependent Upon Availability of Electric Power:

- **Telecommunications:**

- May be significantly affected, at least at the outset
- Recovery will be dependent on prompt restoration of power

- **Financial system:**

- Vulnerable to an EMP induced disruption of telecommunications and computers

- **Remote controls** in infrastructures are at risk of disruption and damage

- **Transportation** infrastructure is vulnerable to disruption.
- **Oil and gas supplies** likely disrupted due to failures of pump and valve controls
- **Potable water** likely disrupted in the region affected by the EMP
- **Distribution of food** may be degraded

- US scientific and technical capability to address EMP and other nuclear weapon effects has diminished to the point where continued viability is questionable



No credible capability exists to predict the full response of a single system (e.g., national power grid), let alone the highly interdependent US infrastructure

Danger of EMP Attack Can Be Mitigated

- Our free, modern society has inherent vulnerabilities that cannot be completely eliminated
- Catastrophe can be averted by practical and affordable steps to
 - *Prevent* attacks,
 - *Prepare* to recognize and respond to an EMP attack
 - *Protect* critical infrastructure elements and strategic military capabilities, and
 - *Recover* following attack
- Scope of problem requires strong government involvement - because of the continental scale of effects, EMP preparedness is a Federal responsibility

In just a few years we can make significant, affordable improvements to protect society even if an EMP attack is carried out against us

Feasibility and Cost of EMP Protection of Select Civilian and Military Systems

- EMP protection methods are understood and feasible

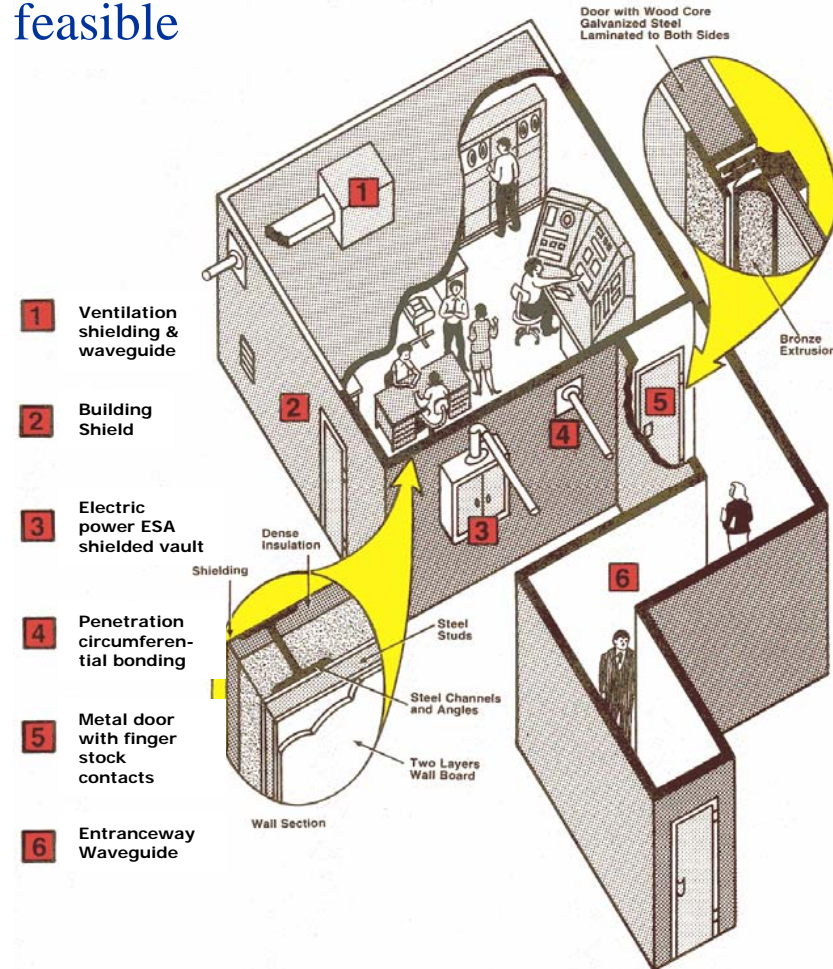
- Several engineering approaches ensure survivability

- Shielded enclosures
- Good grounding techniques
- Current limiting line filters
- Terminal protection devices
- Cable management

- Successful hardening requires testing

- Cost examples for Military Systems:

- Commission estimates a few percentage points of total system cost
- For strategic Comm. systems: about 5% or less for life cycle cost
- To retrofit existing equipment, cost is 15% or even greater

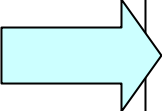


EMP hardening is most cost effective when started in the design phase

We Can Do Something About it: Strategy and Recommendations

- Pursue Intelligence, Interdiction, and Deterrence to Discourage EMP Attack
 - *highest priority is to prevent attack*
 - *shape global environment to reduce incentives to create EMP weapons*
 - *make it difficult and dangerous to try*
- Protect Critical Components of Key Infrastructures
 - *especially “long lead” replacement components*
- Maintain Ability to Monitor/Evaluate Condition of Critical Infrastructures
 - *absence of information can make things worse either through inaction*
 - *or inappropriate action. Salutory example ~ Blackout of August 13, 2003*
- Recognize EMP Attack and Understand How Effects Differ from Other Disruptions
- Plan to Carry Out Systematic Recovery of Key Infrastructures
 - *demonstrate will and capacity to recover from any attack*

Proposed Way Forward

- Public Awareness/Education
 - DHS
 - Regional Hazards Consortia
 - Public-Private Partnerships
 - SCC
 - Industry Consortia
 - Demonstrate principles on selected infrastructure
 - Emergency Management facilities are a prime candidate
- 
- Include EMP protection guidance in fire code standards
 - NFPA 1221 - National Fire Protection Association (NFPA) Standard for Public Emergency Services Communications Systems
 - NFPA 1600- Disaster Emergency Management & Business Continuity of Operations (COOP)

Conclusions

- The EMP threat is one of a few potentially catastrophic threats to the United States
- Military has developed standard protection techniques that may be used for critical civil infrastructure
- By taking action, the EMP effects can be reduced to manageable levels. Used balanced approach of
 - Prevention
 - Preparation
 - Protection
 - Recovery
- Reasonable to start risk management programs focusing on electric power and emergency services

Abstract

Since the nuclear weapon atmospheric test days of the 1950s, it has been known that a single nuclear weapon detonated at altitudes between 30 and 500 kilometers generates a strong electromagnetic pulse (EMP) that can disrupt electronic systems on the ground at large distances from the burst. Our vulnerability continues to increase due to our growing dependence upon electronics. Because a national-scale disruption may result from the detonation of a single weapon, EMP is arguably the most serious threat to US infrastructure. Recognizing our crucial dependence on advanced electronic systems, Congress has established a special Commission to examine the threat from such an explosion. The Commission recognizes EMP as one of a very small number of threats that can hold the entire nation at risk in terms of significant damage to critical infrastructures. This paper will describe the effects of EMP and discuss some key issues associated with national preparedness.