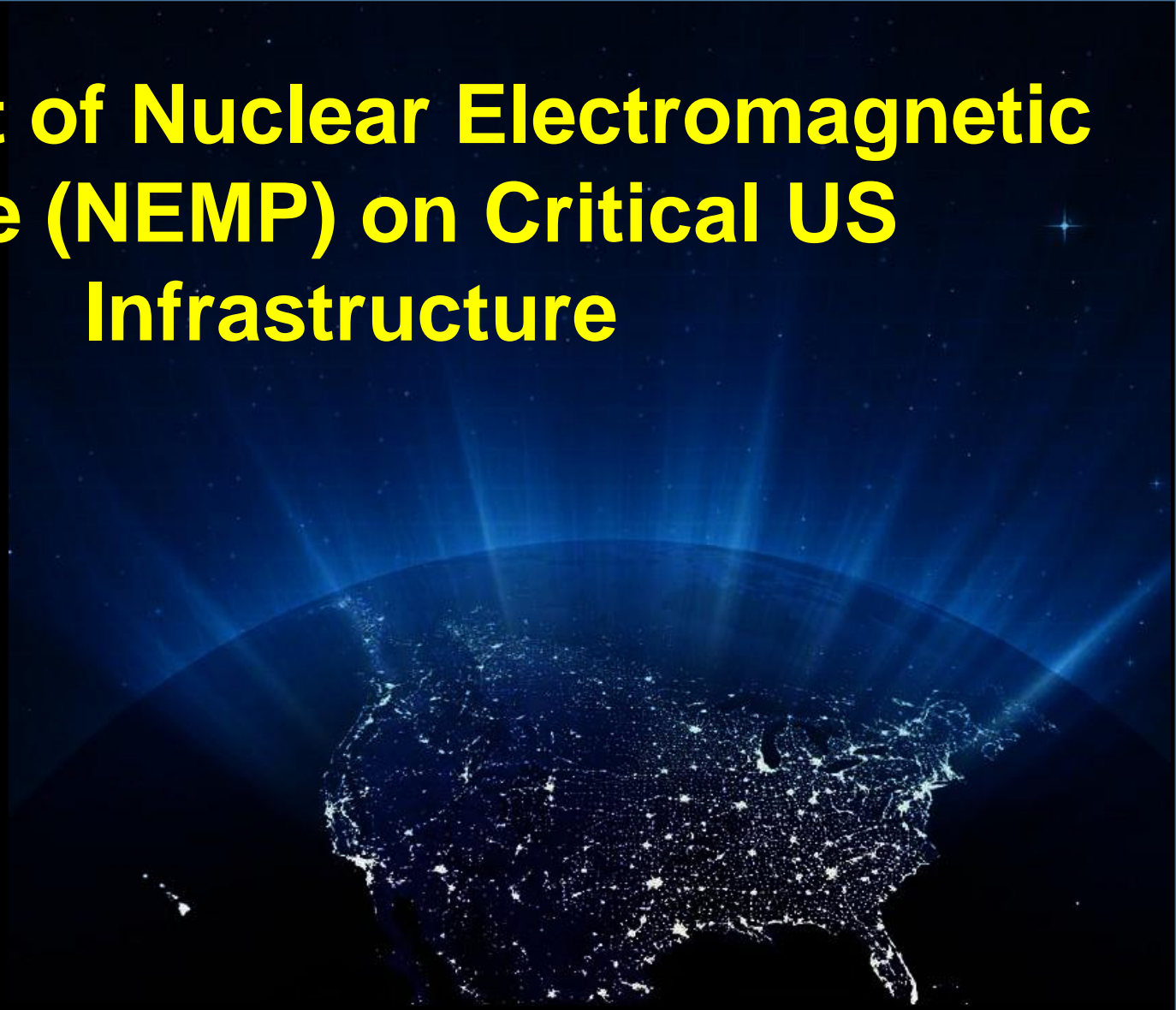


The Effect of Nuclear Electromagnetic Pulse (NEMP) on Critical US Infrastructure

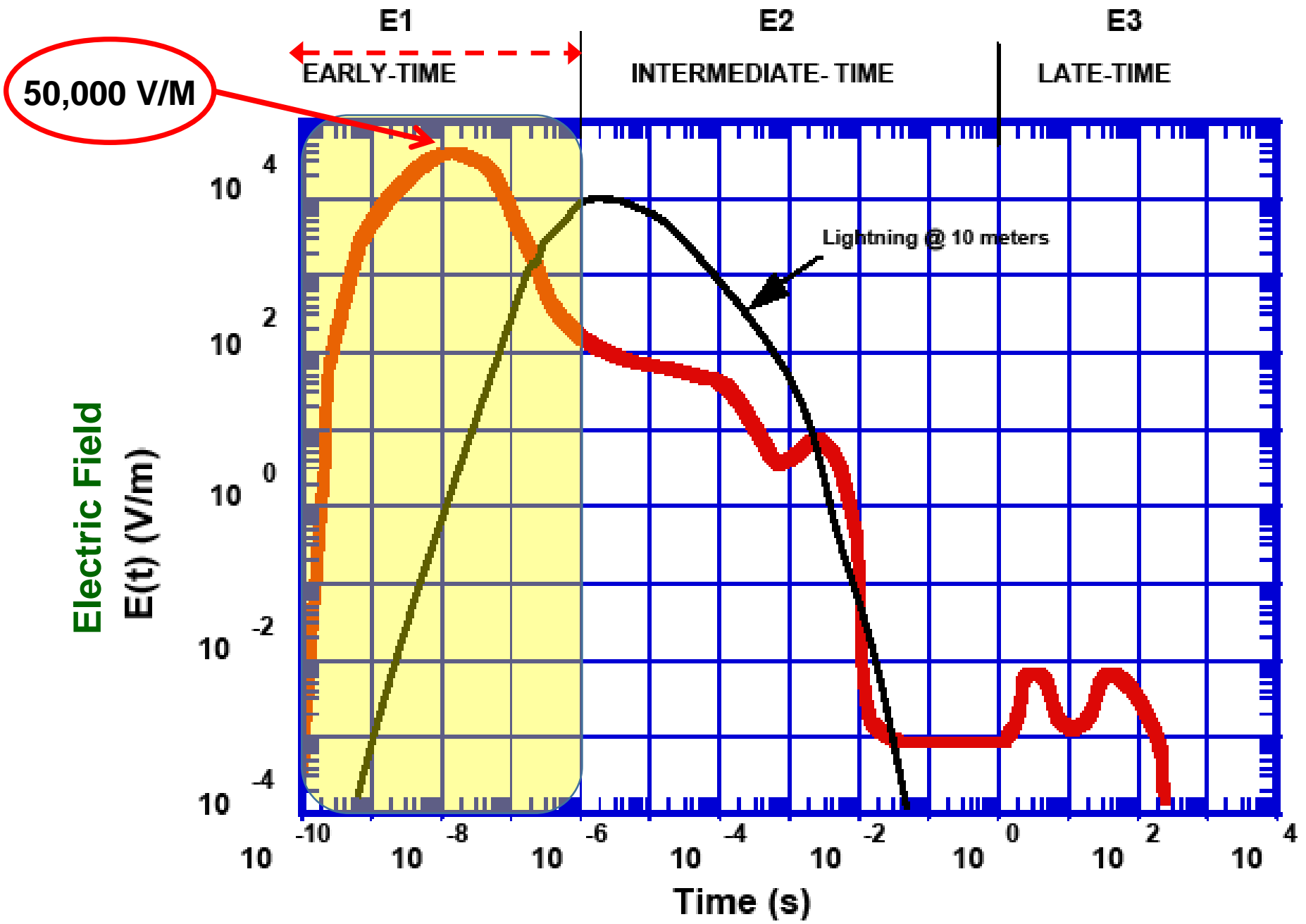


Todd Lovelace, K1KVA

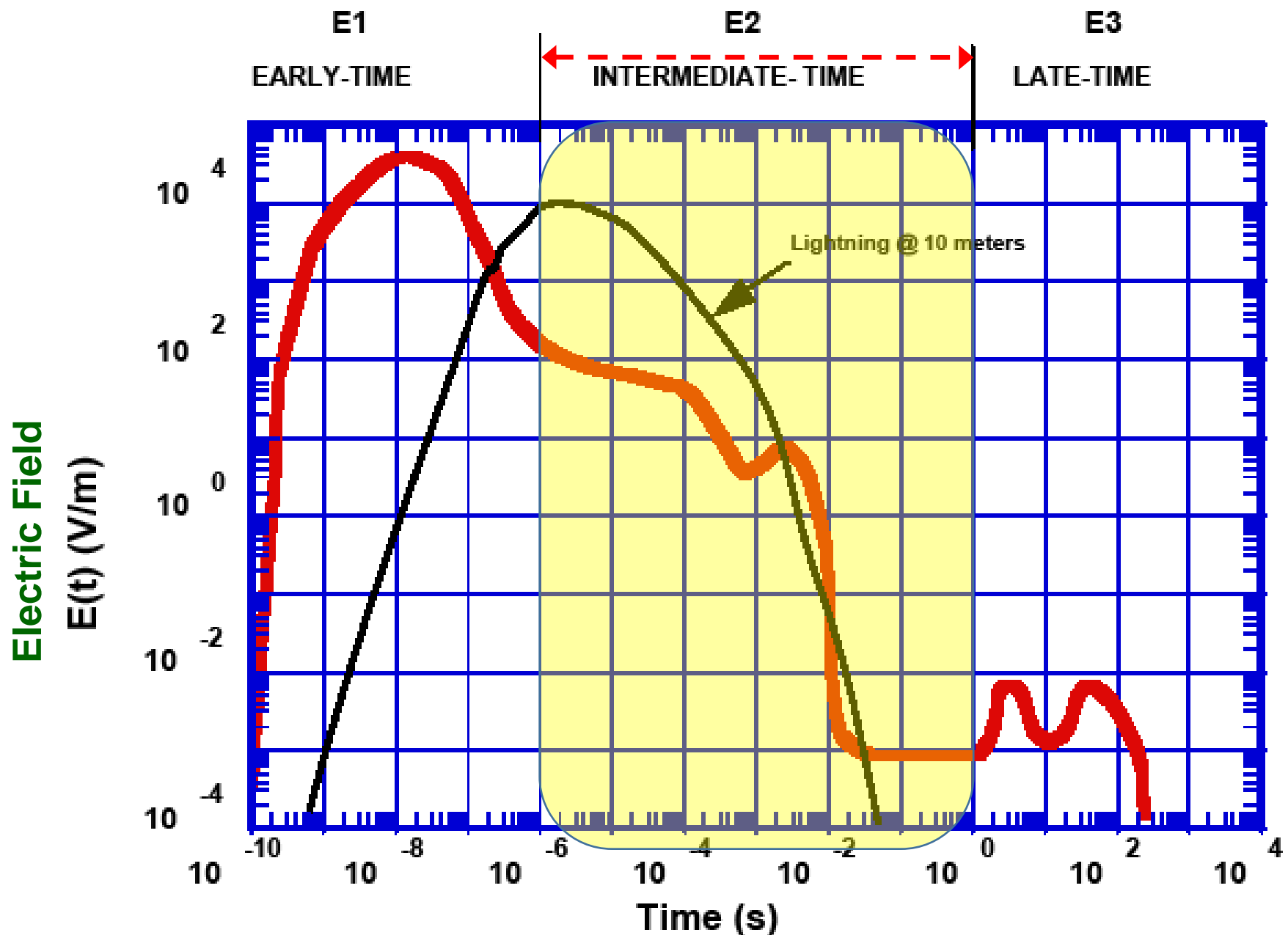
Utility Power Plant Engineer (Retired)

My apologies in advance...





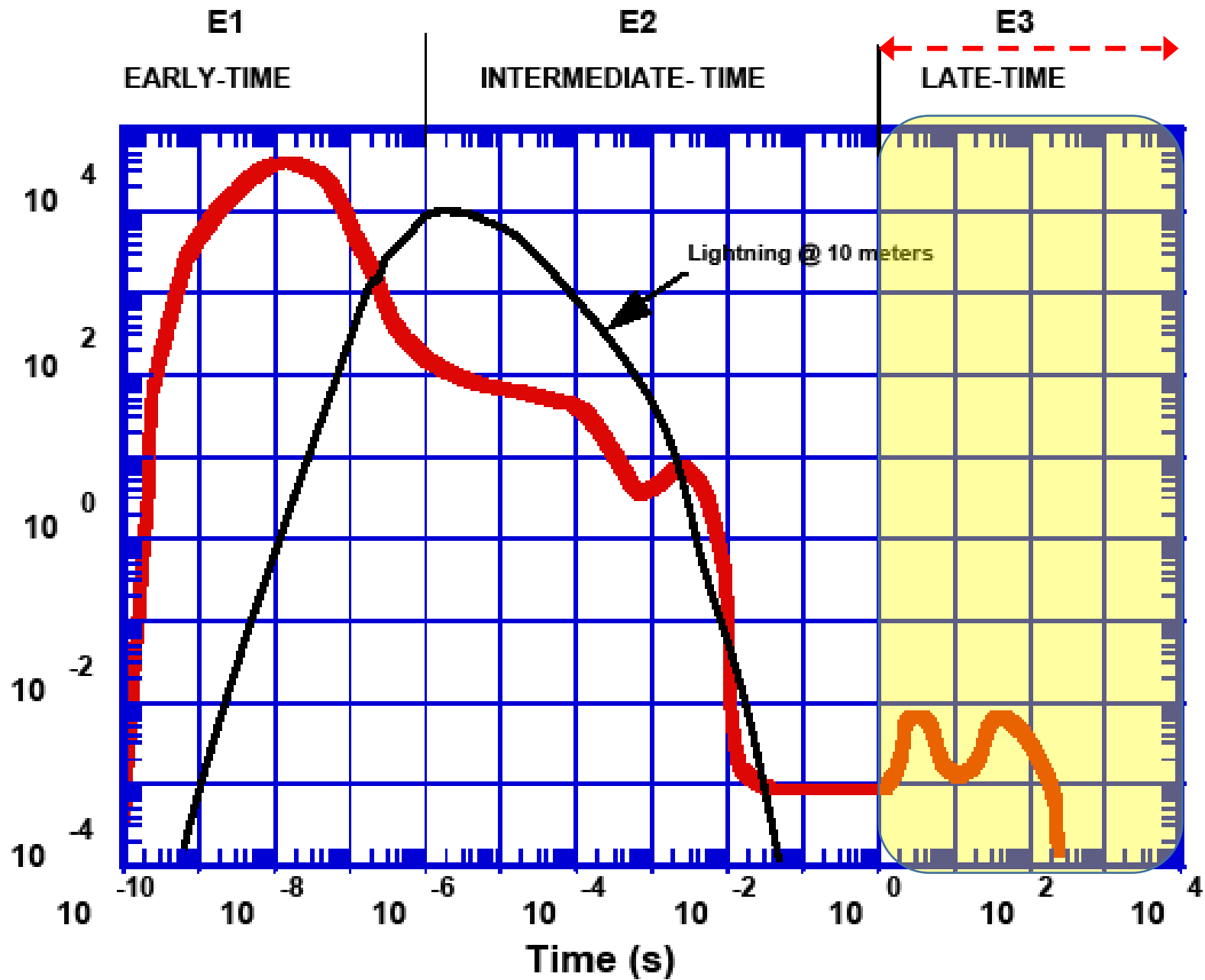
There are three distinct time domains of every NEMP pulse event.



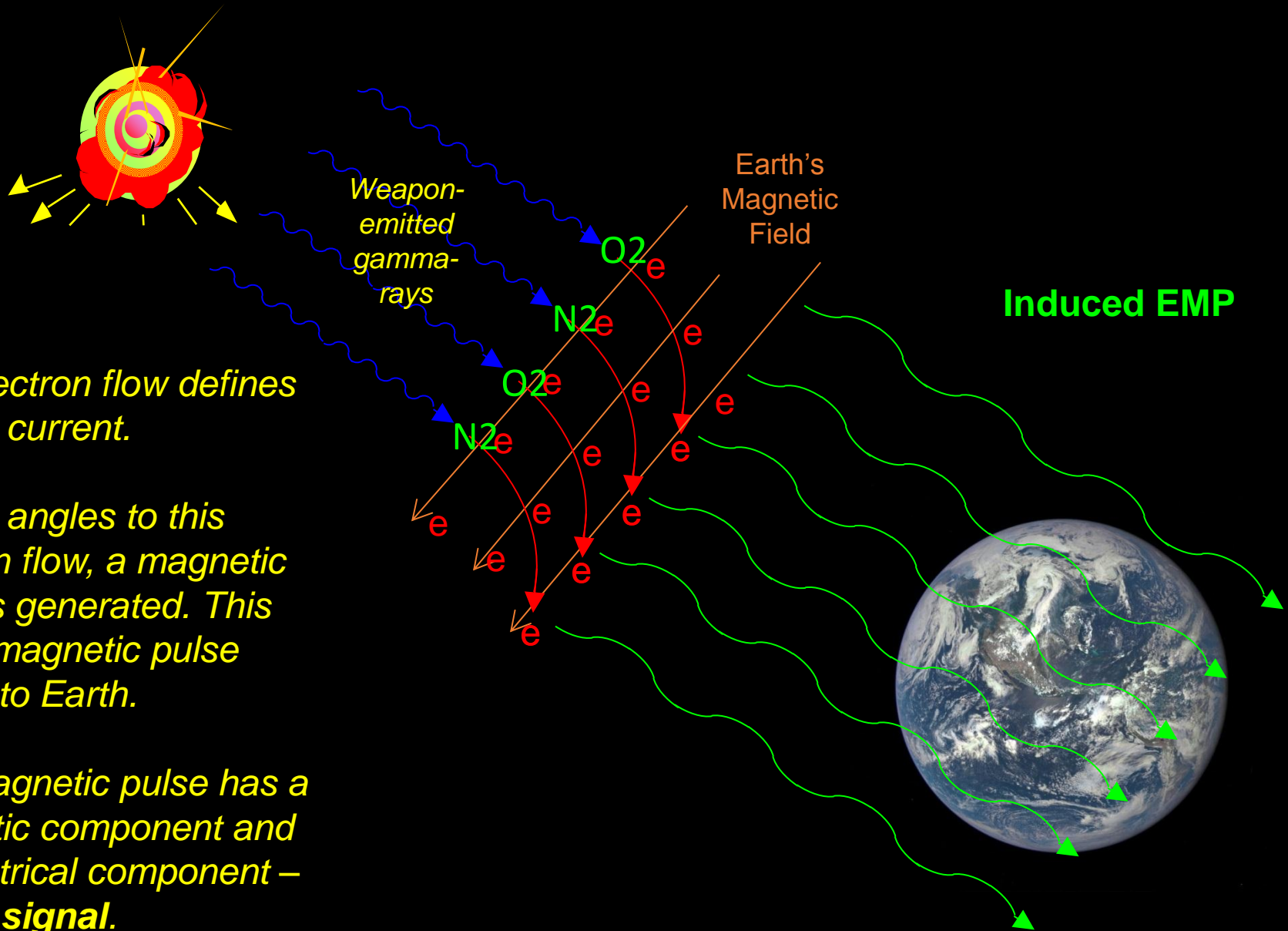
Each time domain has a distinctly different physical effect.

Electric Field

$E(t)$ (V/m)



Early-Time EMP Mechanism (E1)



This electron flow defines electric current.

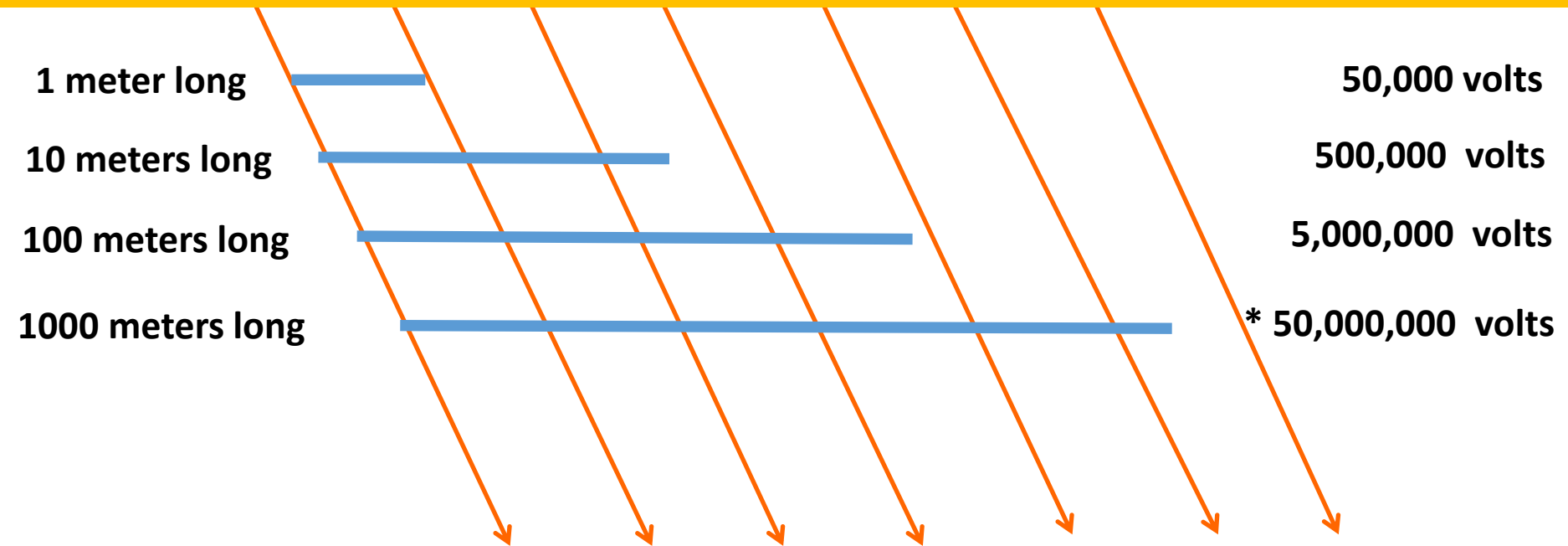
At right angles to this electron flow, a magnetic pulse is generated. This electromagnetic pulse travels to Earth.

*This magnetic pulse has a magnetic component and an electrical component – the **E1 signal**.*

Conductors Exposed to a NEMP (E1) Electric Field =

50,000 volts/meter

Frequency = ~1-100 MHz



*** NOTE: In nearly all practical installations, really high voltage on conductor usually causes corona or flashes over to the nearest ground before the peak voltage is achieved.....**

Typical Basic Insulation Breakdown Levels for Utility Insulators

Basic insulation level, kV
(standard 1.5- × 40-μs wave)

Voltage class, kV

Distribution

Transmission

1.2 

30

45

2.5 

45

60

5.0 

60

75

8.7 

75

95

15 

95

110

23

110

150

34.5

150

200

46

200

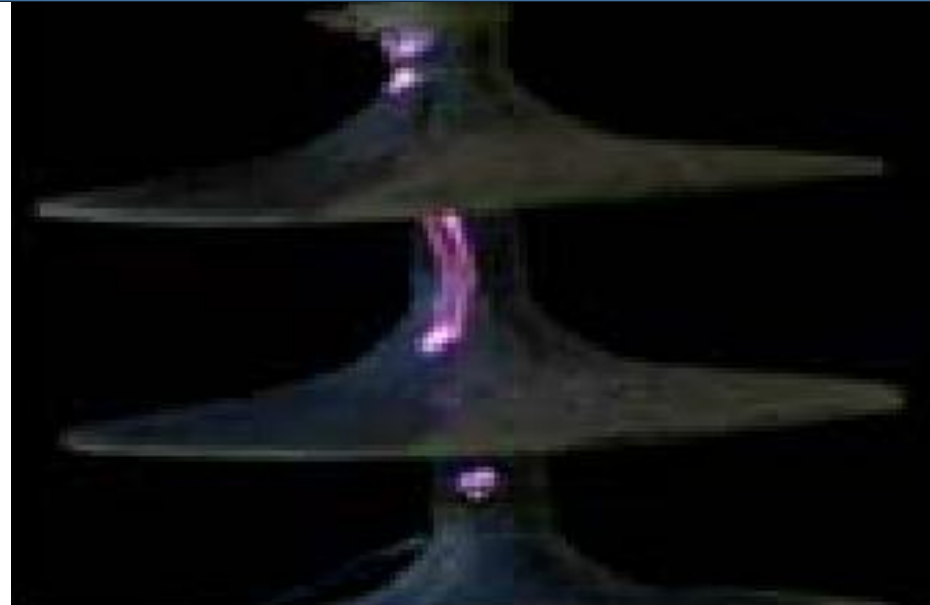
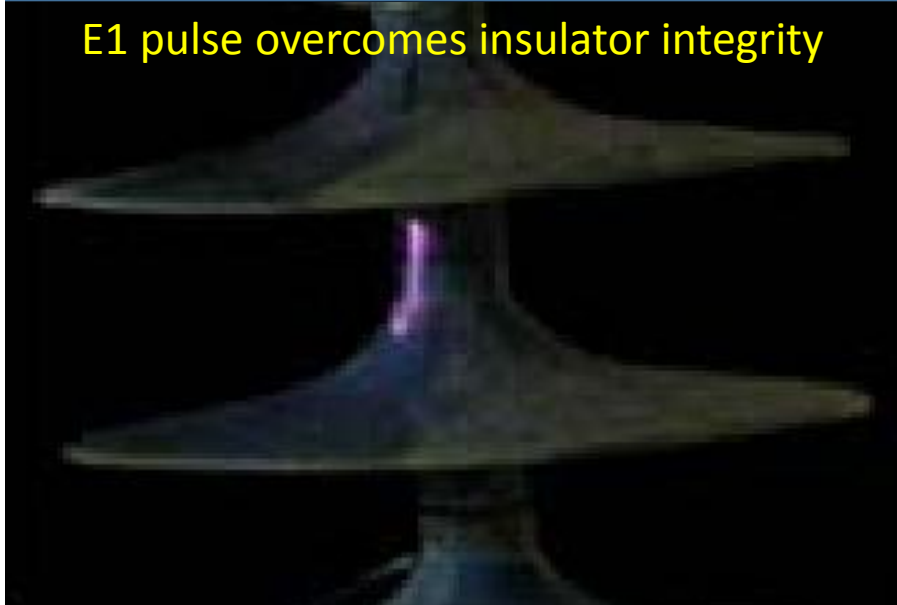
250

69

250

350

E1 pulse overcomes insulator integrity



Utility power follows E1 pulse



Illustration of high voltage breakdown of a utility insulator followed by current carry-over.



High temperatures for an insulator flash-over typically damages the insulator's porcelain (and in some cases, plastic composite) and greatly reduces its ability to withstand high voltage, necessitating replacement.



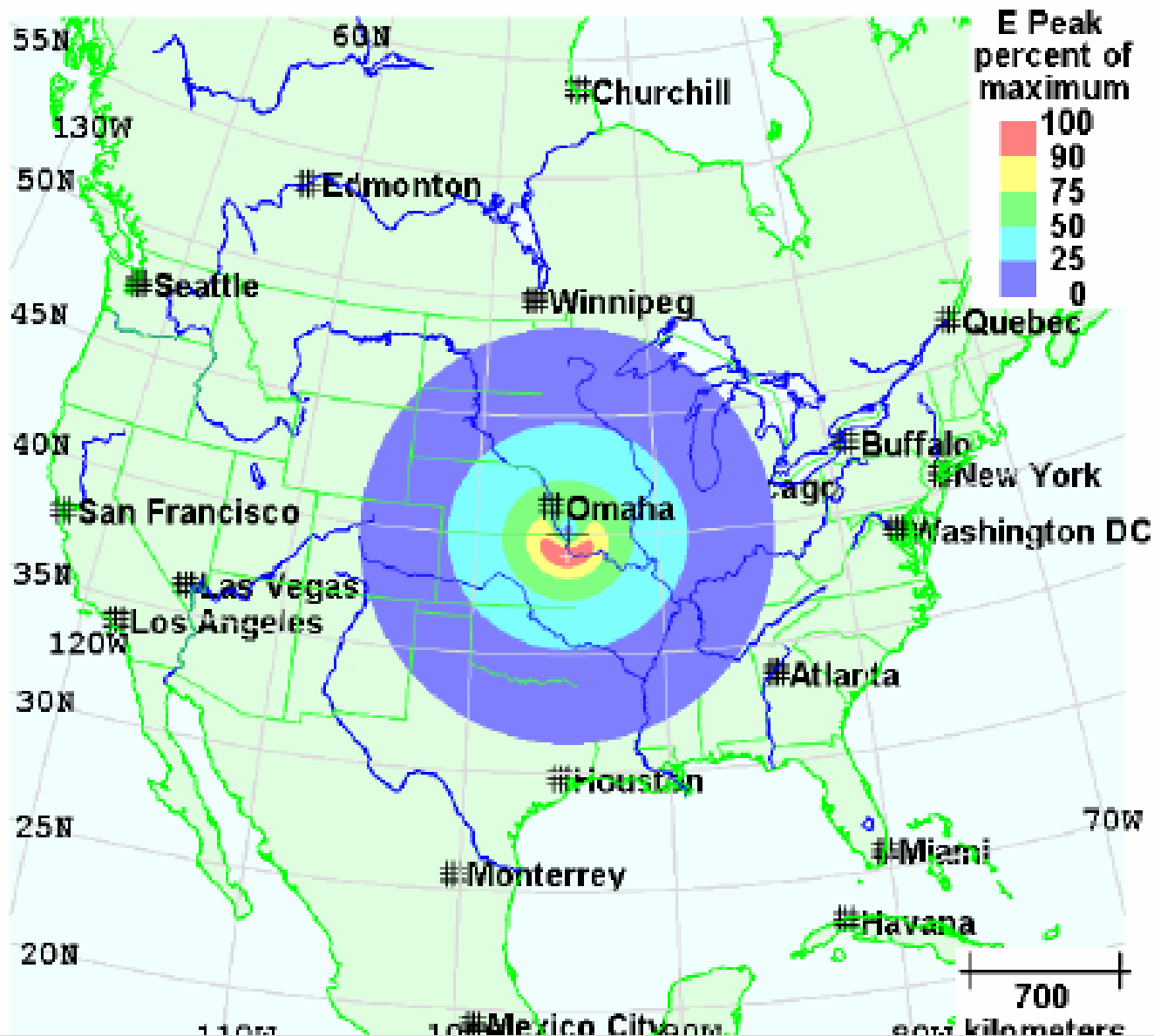
Failures of transformer bushings (insulators) will disable the transformer even if the internal core and windings are not affected.

It is anticipated that a considerable number of distribution level transformers would fail due to E1 flash-over and current follow-through. Bushings themselves are fairly long-lead time items available from a limited number of suppliers.

List of E1 Affected Devices and Systems

The E1 pulse will likely find its way into any device connected to:

- Electric Utility Service Entrance Cable
- Landline Telephone cable
- Radio/Television antenna cable
- Internet Services cable
- Antenna cables (public safety radio, cell tower, broadcast radio and TV, amateur radio.)
- Long cables connecting sensors to a central device.
- Oil and Natural Gas Pipelines
- Long fences and radio tower guy wires
- Railroad rails



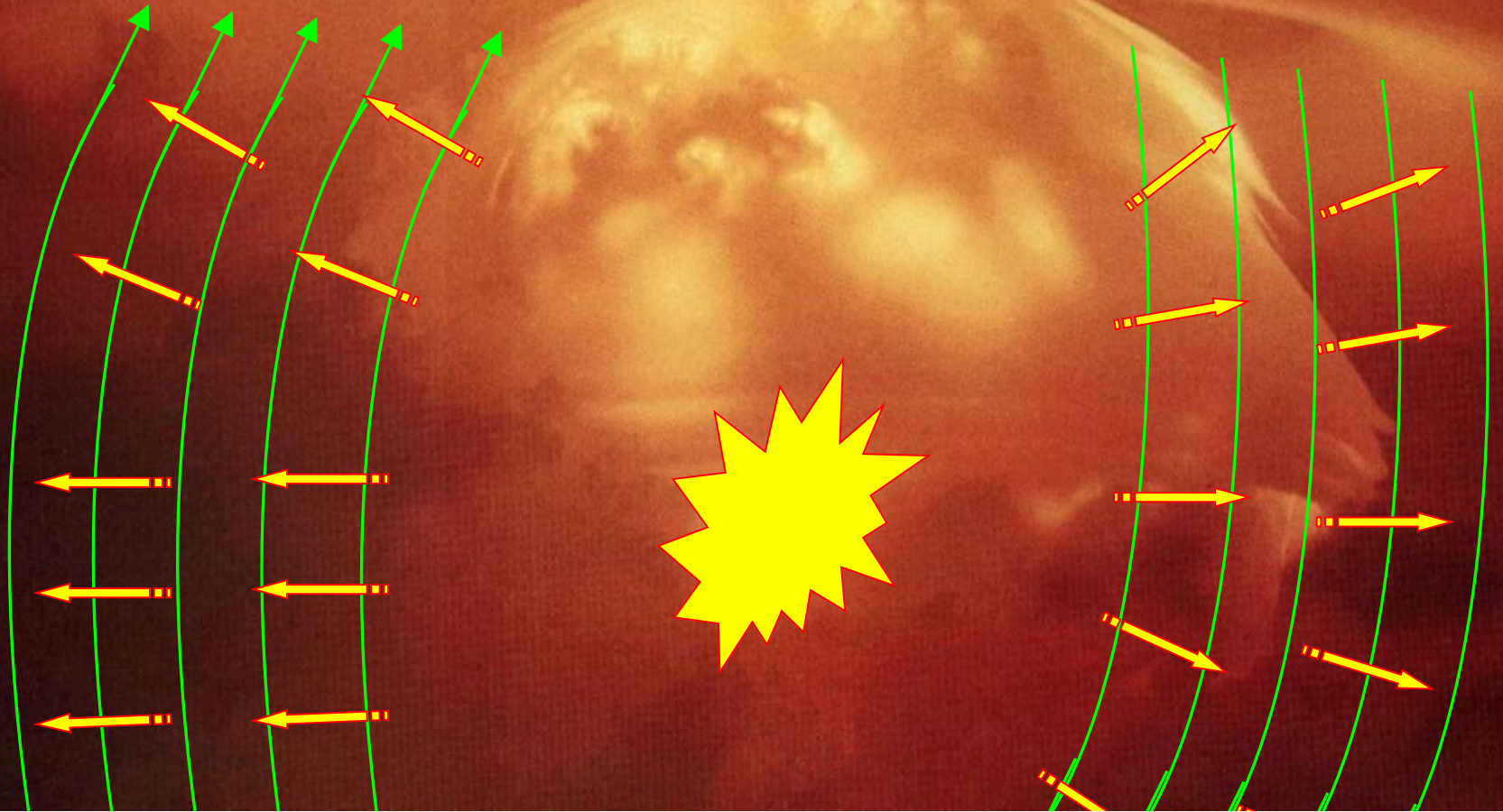
Classic “smile” diagram of E1 exposure area. The blue ring indicates area of exposure that will see 50% of peak E1 effect (~550 mile radius), the purple ring indicates 25% of peak E1 effect (~1000 mile radius).

Late-Time EMP Mechanism (E3)

How is the E-3 NEMP generated?

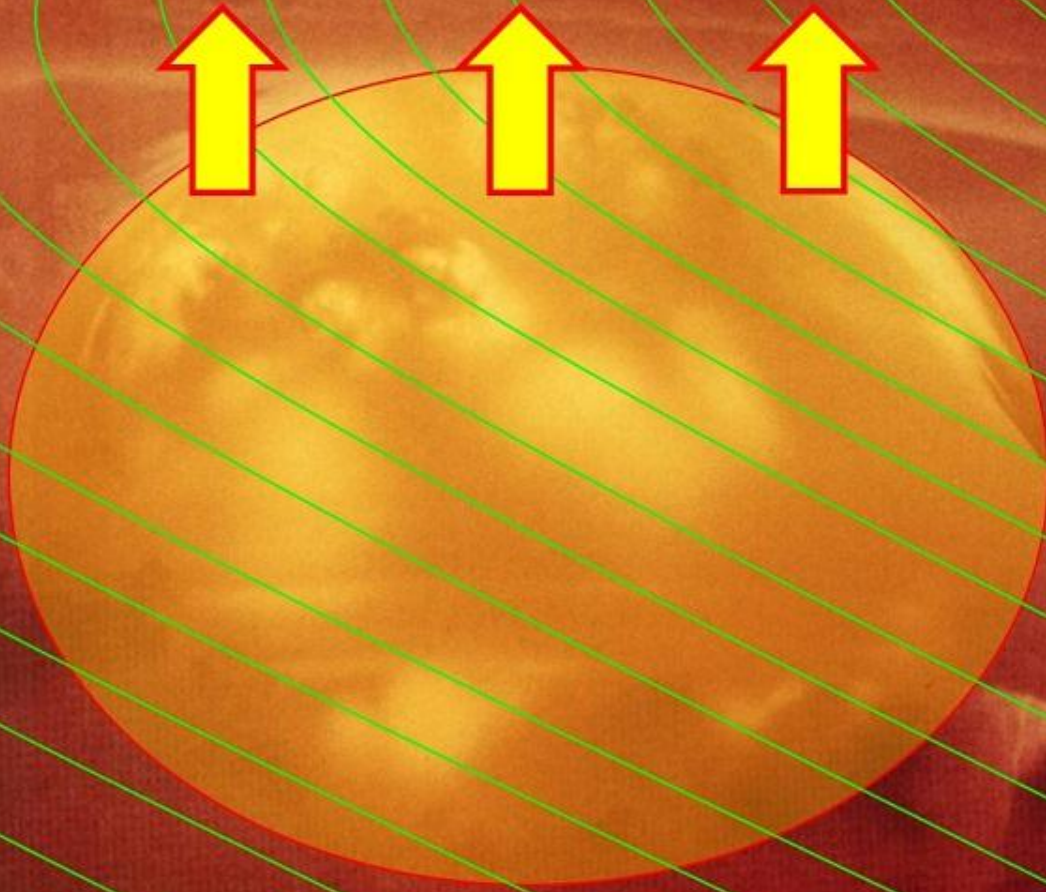


The Blast (E3A) period

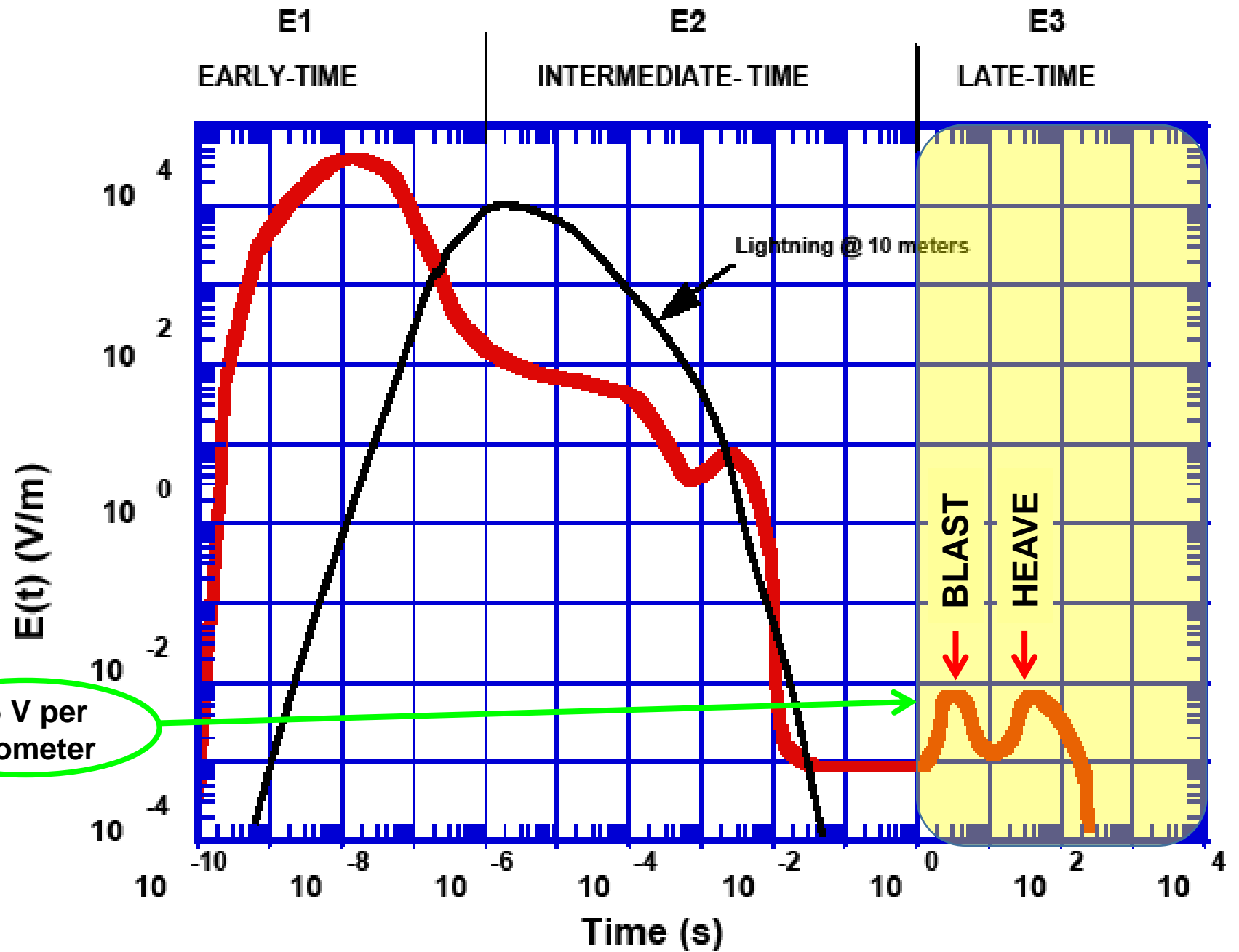


The 3A domain, or Blast Wave, is caused by the fast (1000 km/sec) radial flight of ionized metallic remains of the device. This moving, conductive mass expands into an ionized fireball, which displaces the earth's magnetic field and creates a magnetic "bubble".

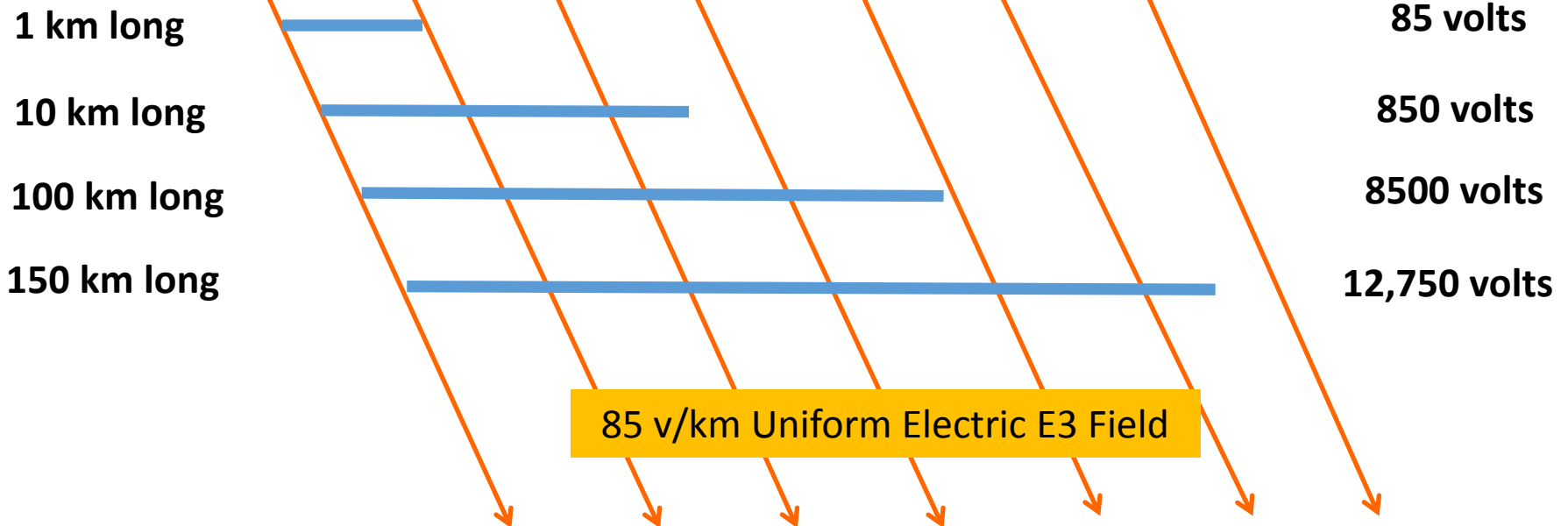
The Heave (3B) period



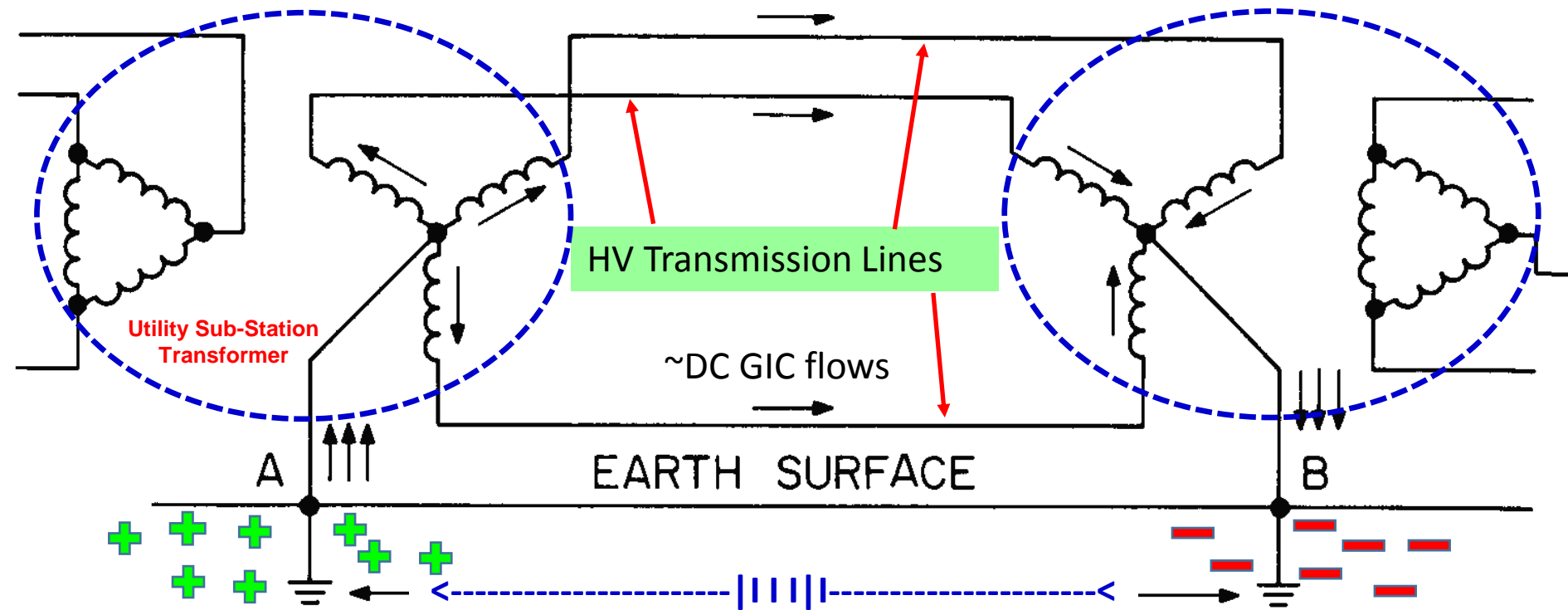
The 3B domain is designated as “Heave”. This heated cloud or bubble of ionized material slowly rises due to convection heating forces, crosses the magnetic lines of force, which cause an electric field to form.



**Electrical Conductors exposed to a Uniform NEMP
(E3) Pulse Electric Field = *85 volts/kilometer**

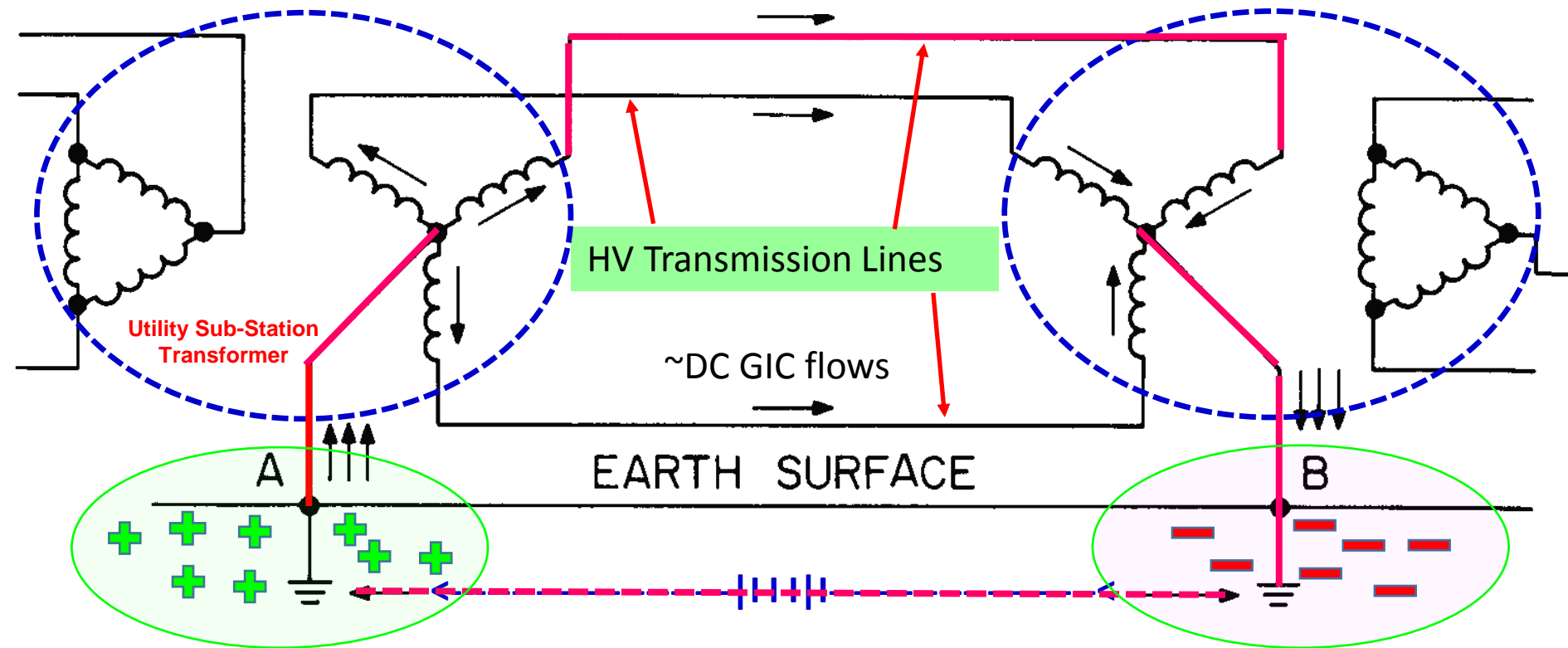


Any utility conductors exposed to the 85 v/km electrical field will have DC voltages induced on them for nearly 100 seconds after detonation.



The GIC acts like a battery and induces a relatively small pseudo- direct current into both transformer ground leads. Current travels from one transformer winding, through the three transmission line phase conductors, and through the winding of the second transformer.

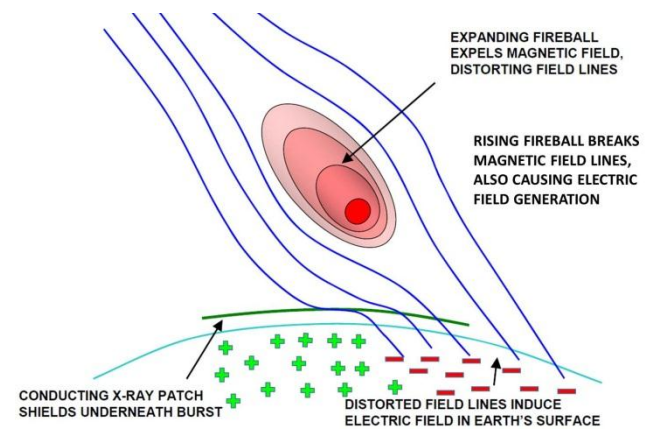
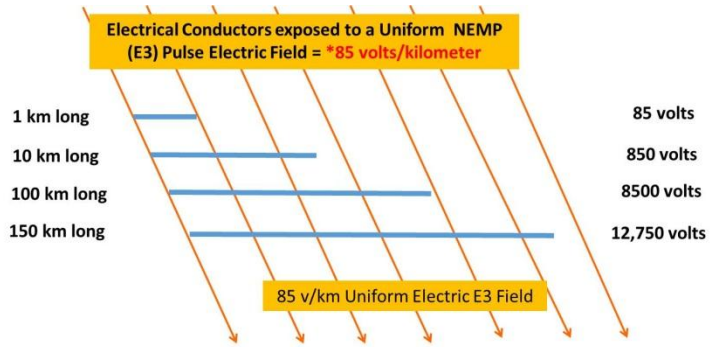
The E3 pulse will also induce uneven geomagnetic induced currents in the earth. Between areas of unequally charged ground, electric current will flow. These currents are picked up by utility grounds.



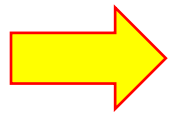
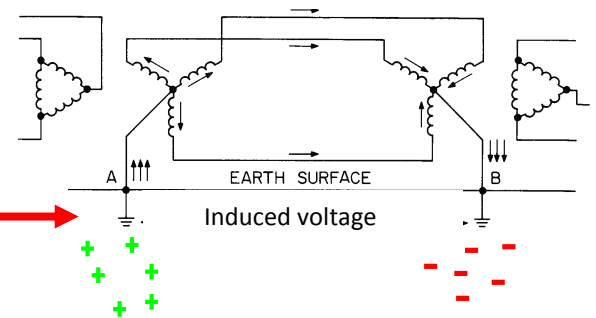
The GIC acts like a battery and induces a relatively small pseudo- direct current into both transformer ground leads. Current travels from one transformer winding, through the three transmission line phase conductors, and through the winding of the second transformer.

A small DC current flows from the ground, through the high voltage transmission line conductors, and back to ground.

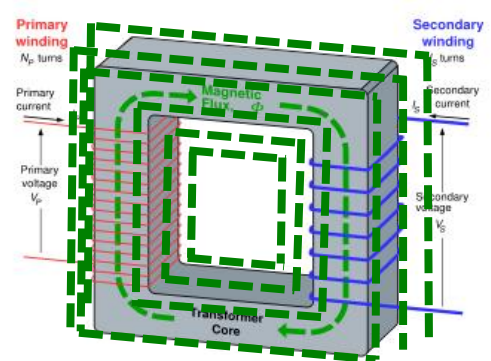
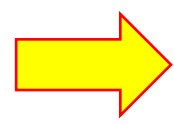
This “small” DC flow causes transformer core saturation which causes many electrical problems and results in transformer overheating.



Induced overhead conductor voltage



Induced ground path voltage



DC voltage causes core saturation, overheating



The 2017 EMP Commission Report, using new information - based on modeling and analysis of 1962 Russian nuclear EMP testing - concluded that the “the E3 threat is three times higher than originally thought”.



Photo of Starfish Prime EMP Test July 1962

At this time, US Electrical Utility Officials EPRI (Electric Power Research Institute) and FERC (Federal Energy Regulatory Commission) presently claim that the utilities need only protect to the 8 v/kilometer level.

Early-Time (E1) plus Late-Time (E3)

The most significant NEMP risk is that the E1 pulse and E3 pulse act together to create the Perfect Electrical Storm:

- 1.) The super-fast rise time E1 pulse avoids the standard lightning and surge arrestors, takes out electronic utility protective relays.
- 2.) The long, slow E3 pulse follows (after E1 kills the protective relays and sensors) and saturates the transformer core or other sensitive equipment.
- 3.) The transformer overheats and fails from E3 exposure (core saturation, overheating) because the sensors and protective relaying were damaged and couldn't remove the endangered transformer from the circuit.

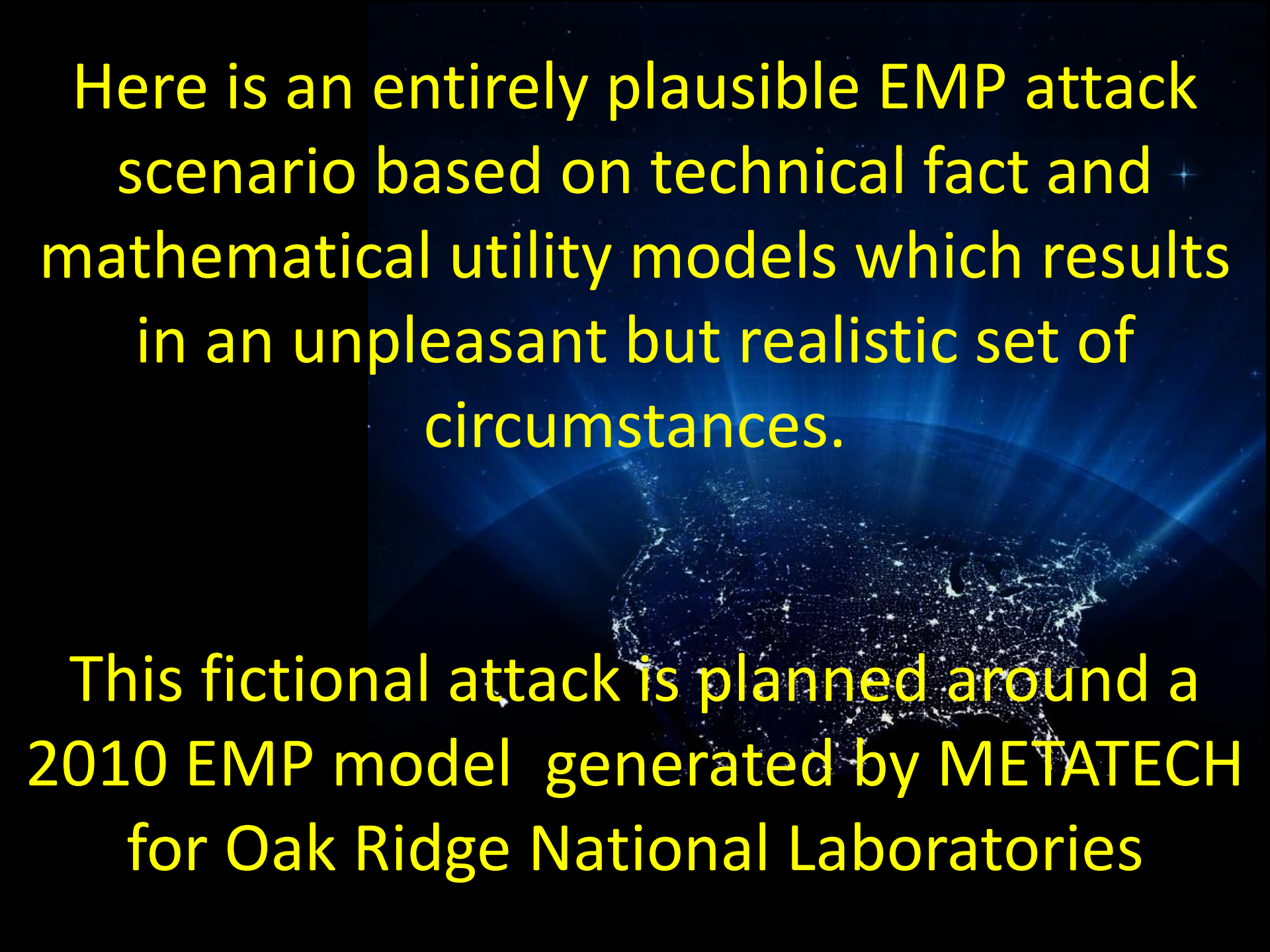
EMP Device Output and Effectiveness

All US EMP testing and data published in the 2008 EMP Commission Report was performed at the limits of the US EMP test facility – at 50 kV/m.

There is discussion that Russian EMP weapons might reach 200 kV/m.....no solid published confirmation or data.

Nuclear device size (in Kt or Mt yield) for nuclear devices is not proportional to the devices EMP output. *Smaller devices specifically designed to optimize gamma production will generate greater magnitude of EMP than much larger nuclear devices.*

Wise planners may wish to consider that “tactical” design features (ie, miniaturization) of Russian, Chinese, or Pakistani design might find their way into Iranian or North Korean EMP service.....



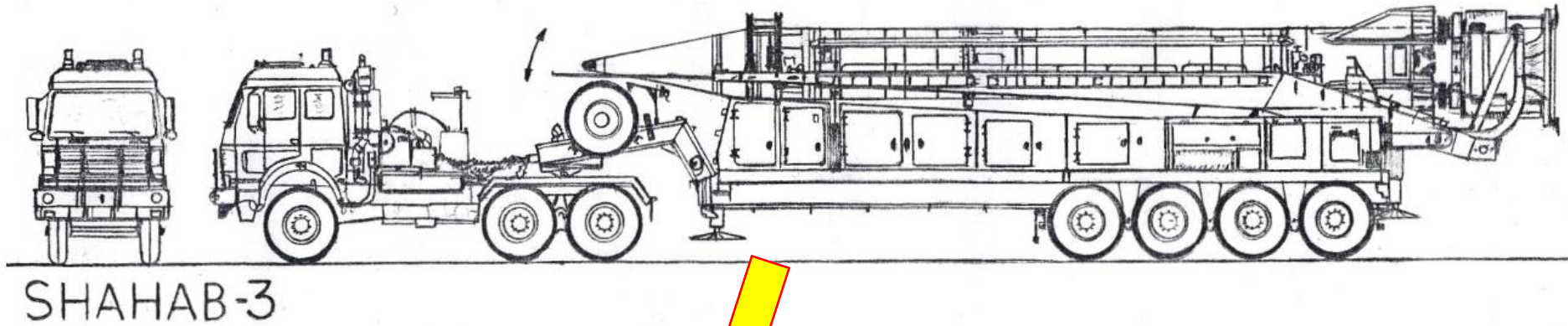
Here is an entirely plausible EMP attack scenario based on technical fact and mathematical utility models which results in an unpleasant but realistic set of circumstances.

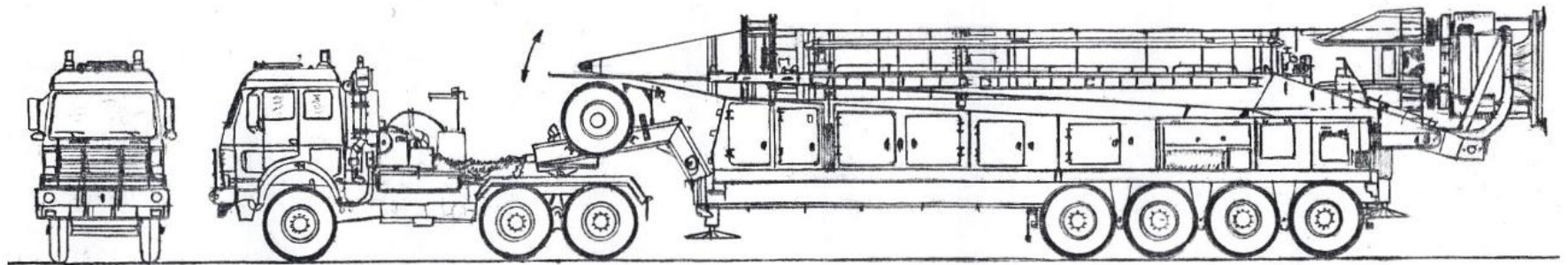
This fictional attack is planned around a 2010 EMP model generated by METATECH for Oak Ridge National Laboratories

The bad guys obtain a seagoing coal boat or ore boat capable of transiting from the Atlantic Ocean into the Great Lakes.



An Iranian *Shahab-3* or North Korean *Nodong* missile and launch system is installed inside one of the center cargo areas.





SHAHAB-3

The Shahab-3 is a medium-range, liquid-fueled, road-mobile ballistic missile. The Shahab-3 represents Iran's first successful acquisition and development of a medium-range ballistic missile that give it the capability to threaten targets (such as Israel) which lie beyond its immediate borders. **It has a range of about 1,300 km.**

Length: 16.58 m (55 feet)

Diameter: 1.25 or 1.38 m (4.5 feet)

Propulsion: Single-stage liquid propellant engine

Launch weight: 17,410 kg (38,302 #)

Payload: Single warhead, 1,200 kg (2,640 #)

Status: Operational

.....plenty of payload capacity for a small or tactical nuclear device.....



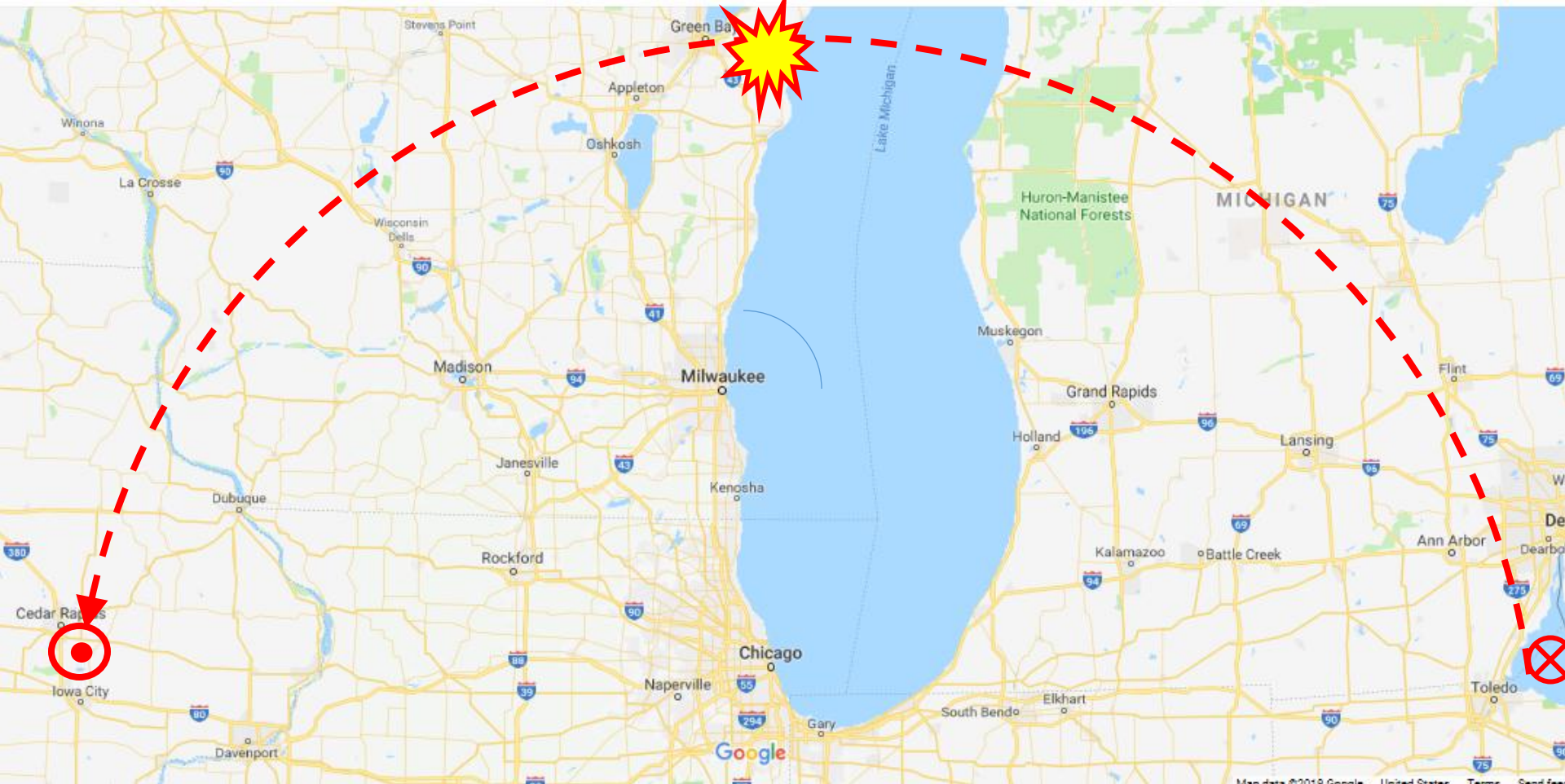
Plenty of room in here to build a structure to hold the launch trailer and missile together.....just open the hatch, tilt up the launch rail when ready to fire!



The missile-equipped freighter heads up the St Lawrence River, past Quebec City and Montreal, and into Lake Ontario. They pass through the Welland Canal lock system into Lake Erie and sail on to Toledo, Ohio.



The crew remotely opens the hatch doors, erect the launcher, and fire the missile. It's 05:00 AM local Chicago time..... Dark thirty so they can be sneaky without too many prying eyes.



From the Port of Toledo to Iowa City it's about 450 miles (750 Km).

This is well within the 1300 Km capability of the Shahab-3.

Our our pals have programmed the warhead to detonate mid-flight...
at the apogee or highest point. This method gets the warhead over the
Chicago city proper at maximum height to optimize the EMP field
strength and maximize the EMP damage area.

I intentionally
placed our
fictional attack in
Chicago because it
coincides with one
of the better
documented US
Government EMP
electric grid
damage model
scenarios.....
available on the
Internet!

Metatech

Meta-R-321

**The Late-Time (E3) High-Altitude
Electromagnetic Pulse (HEMP) and
Its Impact on the U.S. Power Grid**

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John Kappenman
William Radasky
Edward Savage

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January 2010

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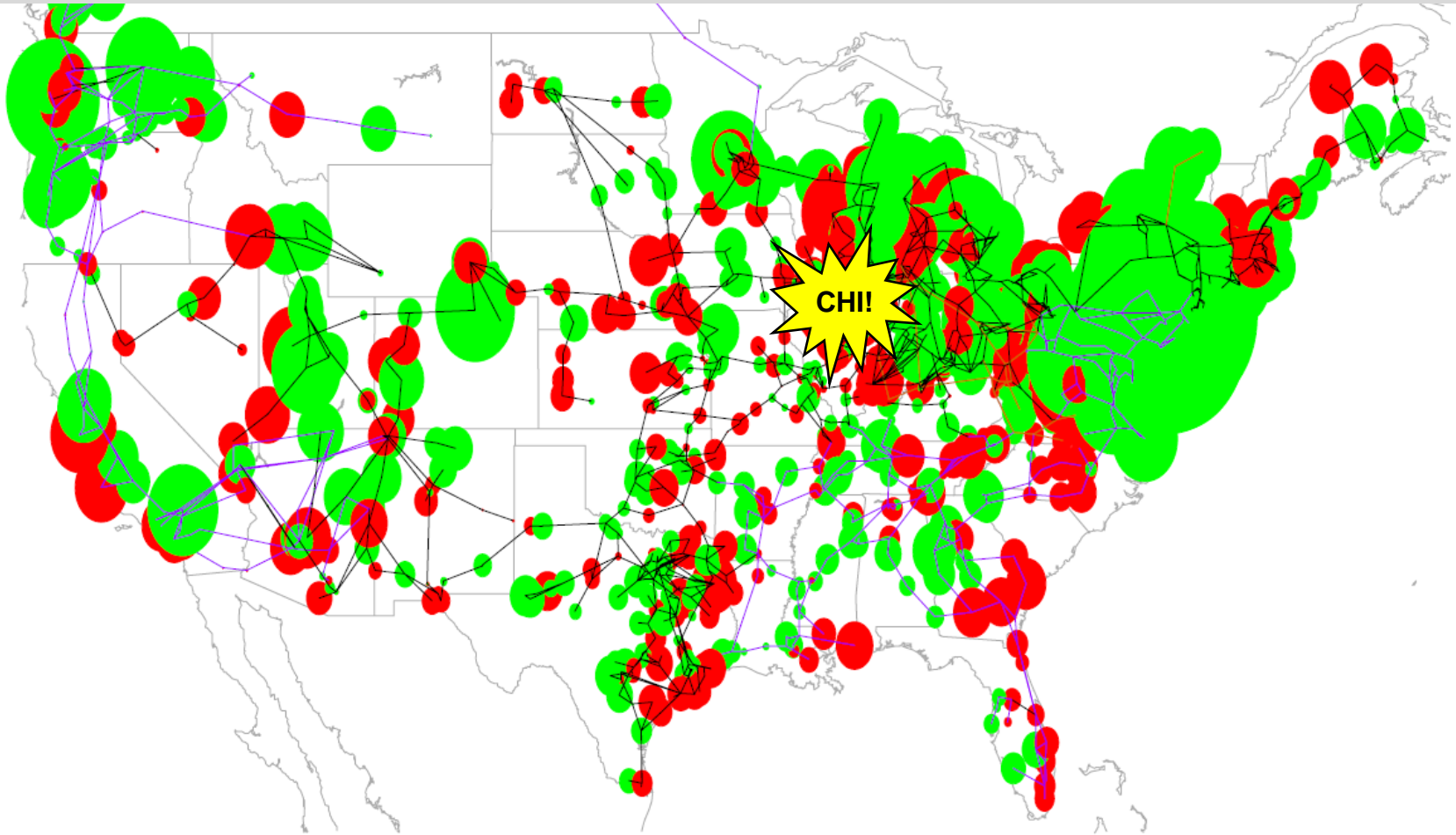


Figure 3-12. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B16b. The entire U.S. Power Grid is expected to collapse.

The perpetrators used the Metatech EMP modeling report (available online!) to determine where to best “invest” their efforts. This model shows that a device detonated over *Chicago* would bring down the entire US power grid.

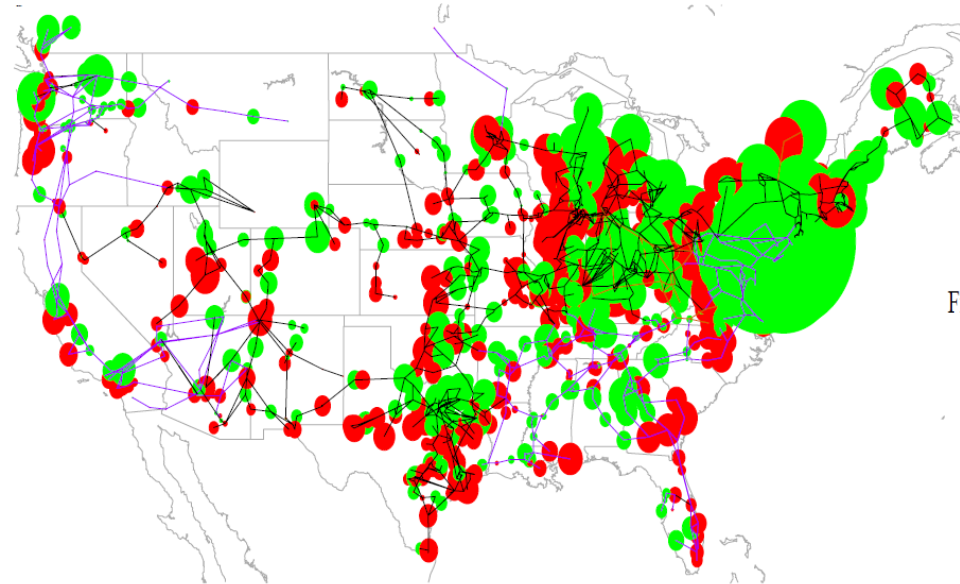


Figure 3-11. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B16a. The entire U.S. Power Grid is expected to collapse.

Every major state from the East Coast to the west coast states of Washington, Oregon and California, and from Maine to Florida and Texas, accumulated sufficient disturbance energy from this scenario to threaten collapse of the entire U.S. Power Grid (Figure 3-11). The disturbance also generated very high levels of GIC in the Pennsylvania/New York/New Jersey and neighboring regions. These levels could be large enough to exceed the normal AC current loads, and, as a result, could have consequential impacts that may lead to permanent damage to circuit breakers and other apparatus on the high voltage networks in these regions, due to attempts to operate under these unusual conditions. Possible widespread failures of this type could lead to significant delays in power system restoration in these regions.

The perpetrators carefully read the Metatech and picked the model scenario that would be most damaging to the grid: Chicago, Illinois.

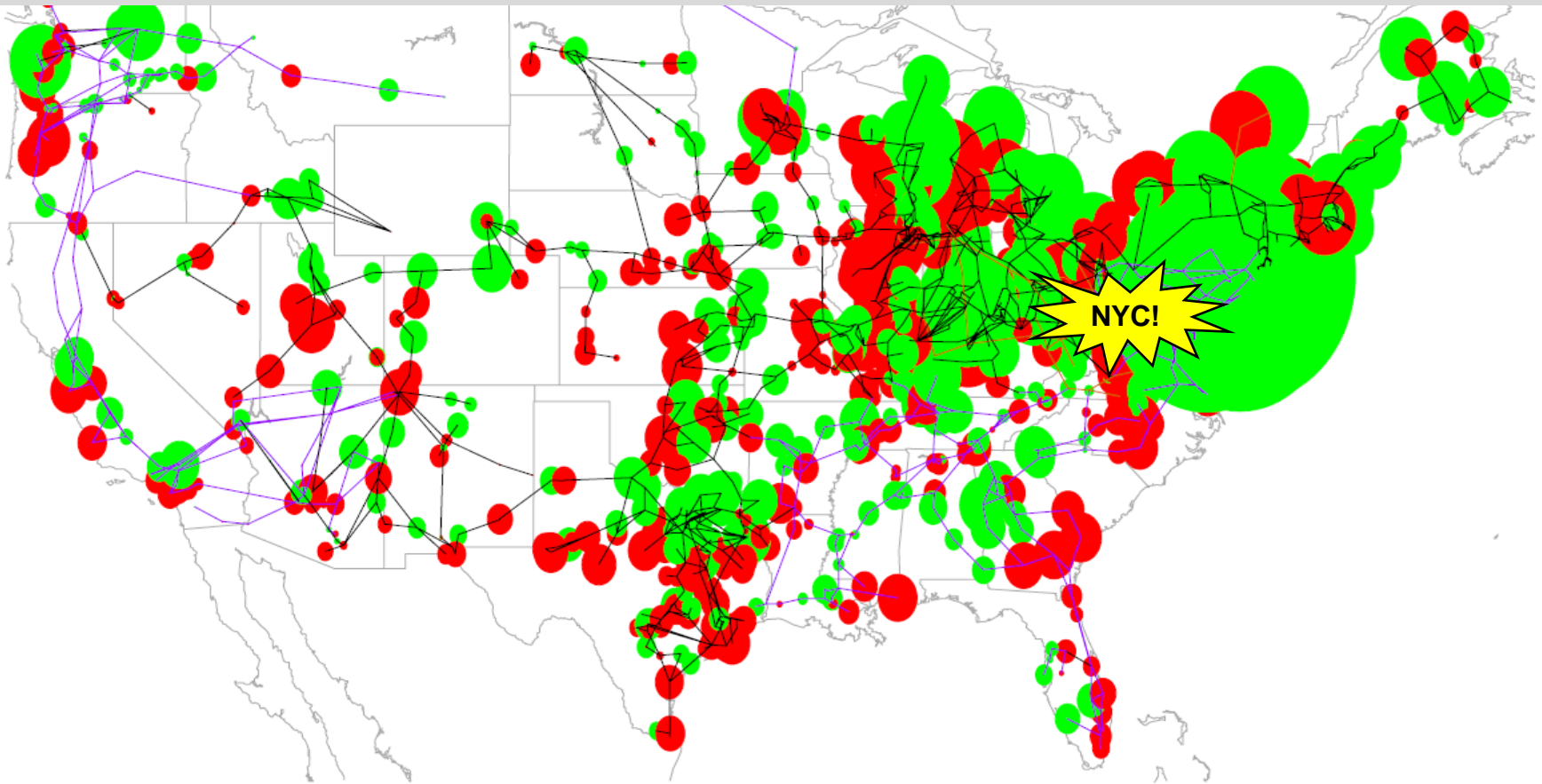
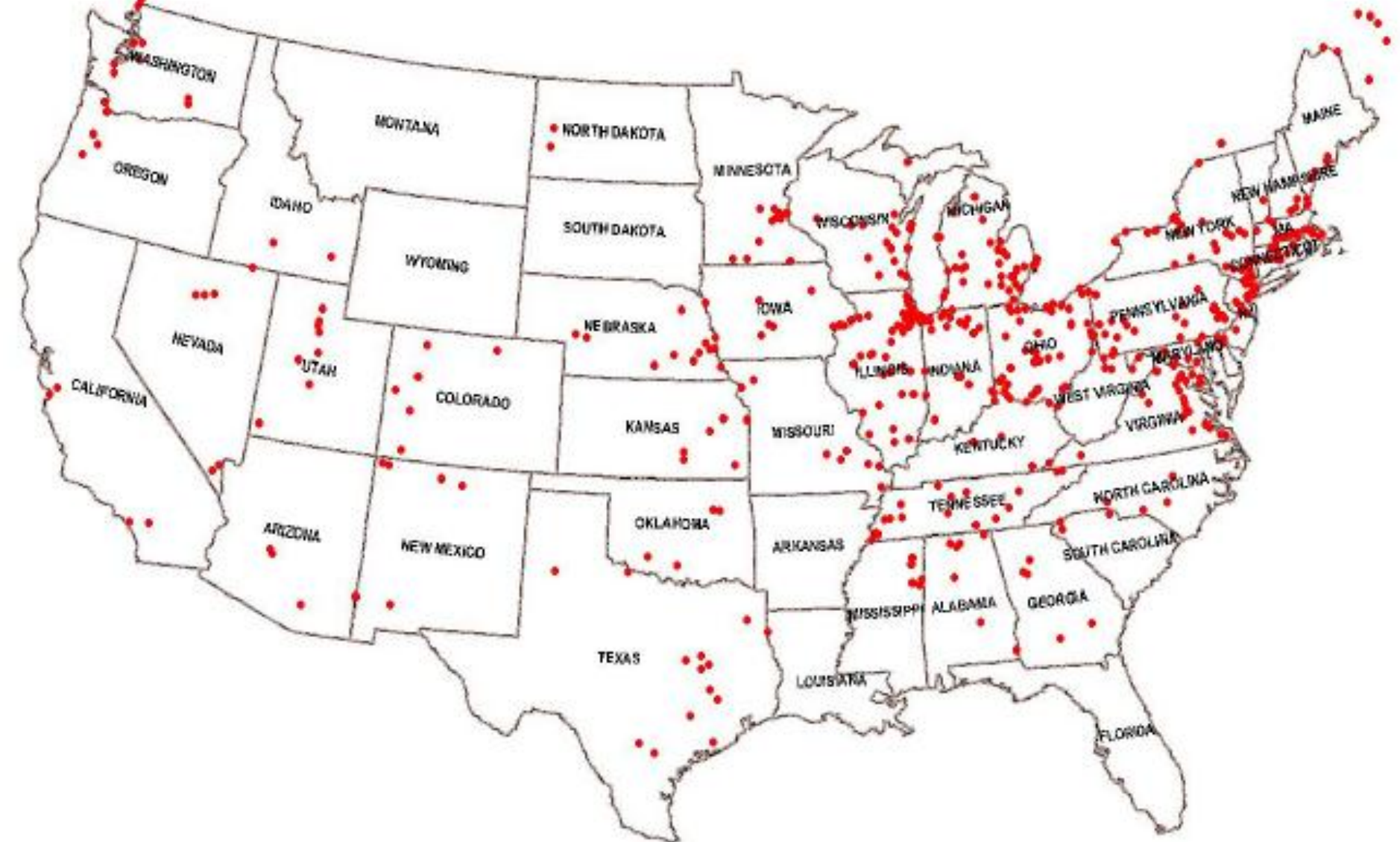


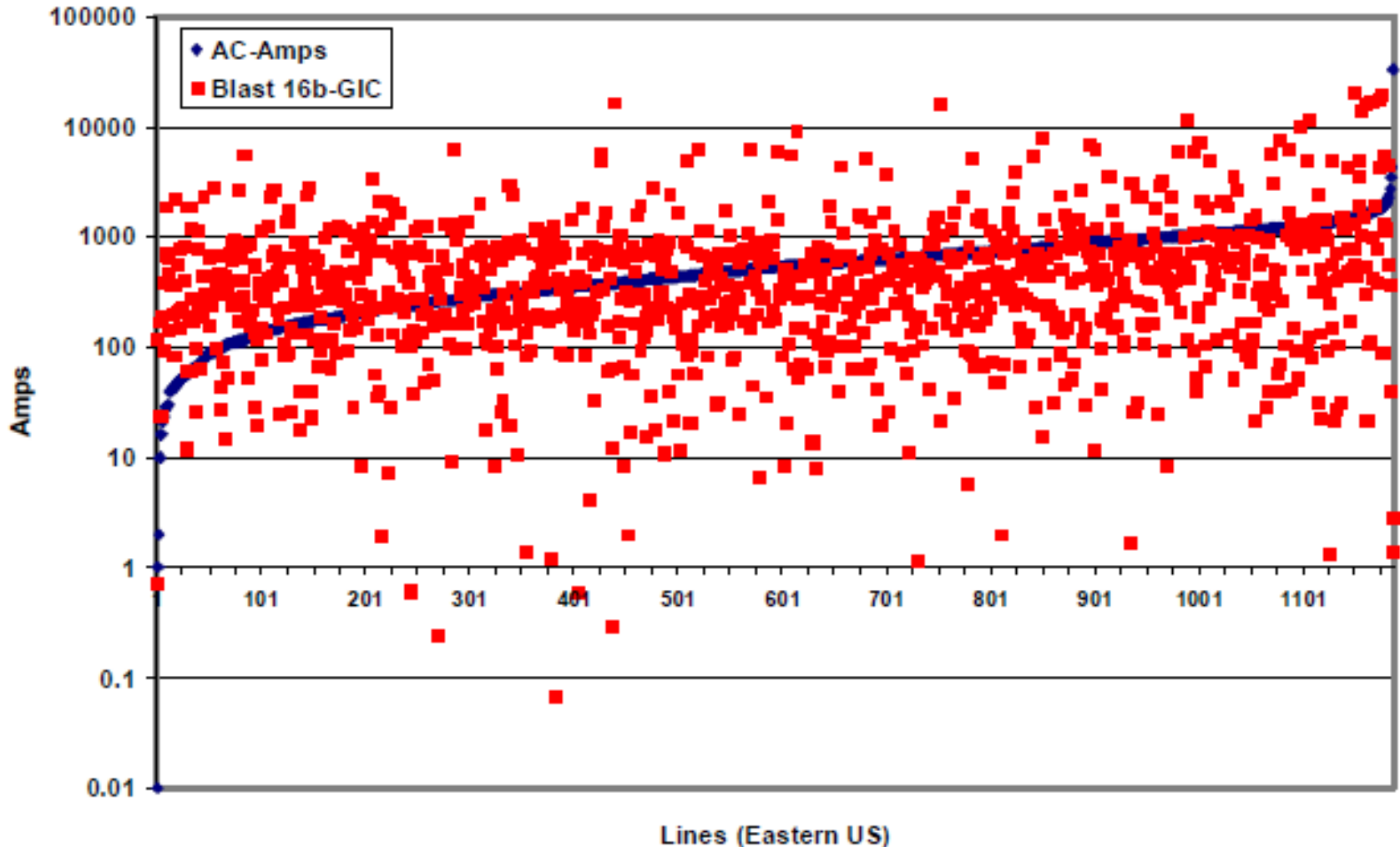
Figure 3-11. Summary of GIC flows in U.S. power grid for E3A Blast Wave Case B16a. The entire U.S. Power Grid is expected to collapse.

New York City was kept as back-up target in case of change in circumstances.
It is easily reachable from the coal boat from offshore in the Atlantic Ocean
or even while in the St. Lawrence River.



The same EMP model's graphical output shows where and how many **critical utility HV circuit breakers** are at risk for damage due to GLC generated by our scenario.

Transmission Line AC Loading & Blast Wave B16b GIC Flows Eastern US Grid Region



Again, the EMP model graphic showing how many utility transmission lines (and thus transformers and breakers!) have more E3 GIC current flowing on them than their normal AC load current.

Estimated Local (NE Florida) Effects
Resulting From the EMP Strike in
Chicago.
(1000 miles distant)



DAY 1



EMP Effect on Our Community (Day 1)

All generating plants in the Hometown Utility system tripped due to regional system voltage and frequency instability.

At several plants, E1 followed by E3 overheated the step up transformers. Several large substation transformers lost protective breakers (due to E1+E3) but crews haven't determined the damage yet.

Hometown U is presently on their own for restarting their generating plants. For a while, there will be no borrowing power from neighboring utilities to re-start our utility and to light customers homes and businesses

Our natural-gas fired combustion turbine units are off line until the natural gas pipeline company can get the inter-state pipeline compressor trains back up. They're controlled with PLCs and SCADA.....

EMP Effect on Our Community (Day 1)

The US Utility Grid has broken into many pieces called “islands”
.....not only from E1+E3 pulse damage, but from the cascading failure of the grid components and resulting system instability. Most near-burst “island” segments are totally without power.

Back here at Florida's Hometown Utilities, the Power Dispatcher is finding out that we're one of many utilities without power. At 1000 miles from ground zero the E1 pulse was weakened considerably by distance.....but we didn't escape entirely.

Just like us, neighboring utilities in all directions have damaged high voltage tie-line transformers and protective breakers.

Utilities closer to Ground Zero (Chicago) have much worse physical damage and a much harder recovery ahead of them.

EMP Effect on Our Community (Day 1)

Solid fuel (coal, coke) burning boilers are the most complicated and slowest to start on a good day.

We'll be weeks getting them back on line....after we have some start-up power and a thorough check-out.

The older fuel oil-fired steam generating units may save the day....if the control systems weren't cooked by E1. Hope we have some fuel oil inventory!



EMP Effect on Our Community (Day 1)

A few cell phones are presently up.... sporadicallyon towers where the E1 didn't kill the cell tower electronics. Any functional cell towers are on their backup generator again assuming E1 didn't kill the electronic controller on the emergency generator's power transfer switch.

On-site fuel for the generators will last for a day or three. Don't count on the cell company's fueling contractor to be able to keep the tanks full.....what fuel depot can fill his tank truck?

Cell providers have modified the system programming to prioritize Public Safety Employees. Your cell phone likely won't work.

The cell phone towers that are operating are overloaded due to the volume of priority traffic by emergency responders..

EMP Effect on Our Community (Day 1)

We can count on having ZERO help from mutual aid crews and equipment coming in from other companies and other states to get us get back to normal....they're up to their eyeballs in the same mess we're in!

Don't count on borrowing spare transformers, breakers, and insulators. Spare cards and boards for the turbine control systems and DCS computers? Most likely any request will be met with a polite "not until our system is restored"



EMP Effect on Our Community (Day 1)

At one power plant crews bypassed all of the fancy electronic controls on the modern Diesel engine powered Black Start Generator. They finally got the engine started, now they're praying that they can bypass all of the dead electronic "stuff" to manually route power from the Black Start Generator to a Gas Turbine (GT) generator running on Diesel fuel.

Once we have one GT on started and online we can (hopefully!) start three more GTs in this plant....if the E1 pulse didn't kill all of their modern control electronic system components.

From there we can manually (slowly, tediously!) line up pieces of the local grid to get some power to other Homeland U power plants for a re-start ...and that's assuming they're able to run.

EMP Effect on Our Community (Day 1)

It's chaos at Hometown U. Status of many substation relays is unknown - E1 has damaged many telemetry and control circuits.

Crews are trying troubleshoot these relays using the company's trunking radio system ...but there's more radio traffic than there is bandwidth. Hometown Police/Fire/Rescue has priority on this system so many attempts to communicate result in a "bonk"a busy signal. The cell phone system is even worse.

With many of the lineman's trucks working, operators are driving around and manually opening breakers in preparation for an eventual attempt at re-powering Hometown, USA.

The normal order of restoration is police-fire stations, hospitals, and other public safety and health entities. Today it's more like "get start-up power to the generating stations!"

EMP Effect on Our Community (Day 1)

If you think the Buckman Bridge, Dames Point Bridge, I-295, and I-95 are mess on a normal day, you're in for a real experience this morning.

Five percent of the usual traffic flow (thousands of cars!) stopped dead, some permanently. Many vehicles rolled to a stop but were able to be re-started. The really "dead" vehicles created a gauntlet on each roadway for traffic to creep around. Traffic is backed up in all directions for miles on every major road.

Most traffic signals are non-operational -the power is out.... and E1 may have cooked some of the PLCs that operate the traffic lights anyway. DOT will have some portable generator to power some critical intersections.

EMP Effect on Our Community (Day 1)

Your favorite convenience store can't dispense gasoline.

Most cash registers are dead...power and data lines are dead.

The regional fuel distributor won't be able to load fuel into tanker trucks to replenish the fuel tanks tonight.

Refrigeration is without power at many food retail stores....and their supply warehouses.

Cash registers and emergency lights are running on backup generators. Stores have no connectivity to suppliers due to internet and satellite communication issues.

Logistics to order, load, and bill grocery supply trucks are also inoperable.

DAY 8



EMP Effect on Our Community (Day 8)

You still can't get any cash from the ATM or your home bank.
No power, no data service, no money.

The AM radio in your car works fine. The local Emergency Services broadcast remind you continually of martial law and curfew before sunset. Get home, stay home. Lock the doors, It's not going to be pretty.

Water supply and wastewater collection service is "rationed". The water plant generators can only run when diesel fuel is available for the emergency generators....the original tanks of fuel lasted about two days after the event.

The entire region is literally depending on diesel generators.

EMP Effect on Our Community (Day 8)

Northeast Florida is competing with other regions that were far more damaged for Federal assistance resources (fuel, food, security, medicines, money, everything!)

Most people are hungry and occupy themselves looking for food.

Martial law is in full effect.

Curfew begins one hour before dark. Crime increased dramatically on the first night and continues to skyrocket.

There are no street lights in most areas, partial public safety radio service, minimal cell phone service for police and fire.

Most businesses closed after a few days of futility. People hang close to home.....no gas, no place to go.

EMP Effect on Our Community (Day 8)

Power is back on to about 25% of only critical circuitsthose being two hospitals and a few public safety headquarter buildings and a few remote facilities that (by luck) are near hospitals or water/sewer plants. Power to residences is still weeks out.

Natural gas pipelines feeding Hometown U plants are still out. Remote compressor stations, once operated remotely with SCADA and PLCs, are being furiously repaired and re-started with limited spare parts on hand. Some are powered by utility electricity, some run on the natural gas that they pump.

Starting up the coal-fired generators is not going to happen for a long time. These units had modern DCS controls with thousands of sensors connected via long cable runs. The DCS had many computer cards that received E-1 damage from both the signal cable end and the power supply end.

EMP Effect on Our Community (Day 8)

Technicians were finally able to get all four diesel-fired combustion turbines running at one plant. Some of this power will be wired to another local power plant to boot-strap another diesel-fired gas turbine in a nearby town. We have two weeks of diesel fuel left for our four combustion turbines. {4 CTs burn 100 GPM EACH!} We need a fuel ship or barge NOW just to replenish our diesel and our Bunker C fuel oil just to “hold what we got.”

Ingenious techs are scrambling to pirate control parts from the coal units to get the old Bunker-C-oil-burning unit on line. We have enough Bunker C fuel for ten days at about 400 MW, or three weeks at 200 MW.

Some of this power is to expand critical circuits locally (water and wastewater plants) and help boot-strap a utility neighbor to the south....if they can get their generators fixed.

EMP Effect on Our Community (Day 8)

Crime around Hometown has continued to increase daily – both at day and at night. Line crews are having to protect themselves from “citizens”. Homicide rate has rocketed from *one every three days* to five or six per day.

Enterprising retailers have set up generators to pump gas and power registers. Cash, gasoline, or diesel fuel are the only “legal” tender. Some retail stores were stripped bare by hot, hungry, and thirsty customers after two days before National Guard arrived.

Home-owners lucky enough to have a generator - are siphoning fuel from their (and other's!) - vehicles....at great risk from car owners and competitor fuel “customers”.

If you left your car where it stalled, it's history. Looters have cleaned out valuables and fuel.

CRITICAL INFRASTRUCTURES

There are sixteen infrastructures that are considered critical to the function of the US.

I was asked by INFRAGARD to address how an EMP attack would affect each one.

Day Eight after the EMP Attack

Possibilities of what you (a Critical Infrastructure Manager) will likely be facing.....

Some (~25%) of local **critical** electric circuits are restored.

Priority 1 nationally is restoring the natural gas pipelines and any liquid fuel pipelines that can be repaired and restarted. Some pump/compressor stations run directly off of their pumped fuel, some run on electric utility power. The plan is to restore the self-powered pumping stations and get partial capacity of fuel flow going, then begin re-starting of the electric power generation plants, oil refineries, and chemical manufacturing plants on line.

Local power restoration has two main priorities: 1.) Trouble shooting and repairing HV transmission breakers/transformers to restore connectivity inside our region. 2.) Getting generating stations running (getting fuels, fixing and starting generating units.

National gasoline and diesel fuel stored stocks are running low.

Water/Waste Water Sector (Day 8)

Priority 1 – Plant Security. Potable water and fuel are precious.

Priority 2 – Keeping emergency generators online and fuelled, then keeping the water and **sewer** plants running.

Priority 3 – Keeping the regional lift stations functional and their on-site generator sets running. Employees drive between local feeder lift stations with fuel bowzers, portable electric generators, and engine-driven pumps to keep the sewage flowing from houses to the plant.

Priority 4 – Fixing sanitary sewer overflows (SSOs).

Daytime only: Tanker trucks filled from the water plant to shopping centers to distribute potable water. Fuel tanker trucks go to nearby rail sidings to get diesel for dependent infrastructure.

The few cell phone system resources available are totally occupied by law enforcement, fire/rescue, and utility recovery.

COWS trailers (cell-on-wheels) trailers to help stretch local cell coverage are few and far between. Landline telephones (those still on them) is spotty.

Only the EMP-hardened FEMA AM Broadcast Station is providing community service and emergency announcements.

Many FM Broadcast stations and TV stations typically don't have emergency generators and are awaiting the return of utility power.

Need to provide power or emergency generator fuel to internet provider facilities and landline telephone facilities. Thousands of cable modems and are likely damaged from E1 and E3...we won't know until the power comes back up!

Emergency Services

(Day 8)

Approximately 50% of the Police-Fire/Rescue/Utility Trunking Radio System was damaged by E1 coming down the antenna tower cables and coming in on utility power connections.

Overflow public safety comms are being switched over to the cell phone system, continuing to displace civilian use of the cell phone system due to “prioritization”.

Fire/Rescue capabilities are severely handicapped by lack of reporting ability from citizens, curtailed dispatch ability, and from a shortage of suitable fire-fighting water and fuel.

Many citizens have already exercised their “Stand Your Ground” right as others have forcibly entered their homes to take food, water, and fuel.....adding to the Public Service personnel workload.

Emergency Services

(Day 8)

Public safety and utility personnel are avoiding some areas to avoid contact with aggressive gang members and other citizens engaging in looting stores and homes (collecting food, water, fuel, other goods).

Law Enforcement – The Governor mobilized Florida National Guard to try to help calm down the hot spots state-wide.

That wasn't nearly enough to keep the peace. **The US President was quickly asked to enact DSCA** – “Defense Support of Civil Authorities”..... So FEMA and numerous federal resources have joined the National Guard and local authorities to maintain order.

It's a tall order for the Feds..... Most of the continental US needs help due to the wide-spread failures caused by the EMP. The situation is far worse as you get closer to Ground Zero - Chicago.

Food and Agriculture Sector (Day 8)

There is immediate critical need for electric power and diesel fuel for warehousing, refrigeration, food re-supply ordering, loading, and shipping logistics.

Response from Federal sources (FEMA, Homeland Security, US military Reserves) is diluted due to this nation-wide emergency.

A renewed coordination between railroads and over-the-road trucks is necessary to move enough finished food to prevent the citizens from starving.

Need civilian communication volunteers (**HAMS**) to help organize and execute food transport and delivery logistics.

Need civilian volunteers to provide manpower for POD (Points of Distribution) for food, water, and medical supplies.

Food and Agriculture Sector (Day 8)

The need to ensure continuity and restoration services to food production facilities nationwide is becoming critical as the food warehouses are being emptied.

This diminishing of warehouse stores is slowed by the problem of re-supply logistics: no information highway backbone for ordering, shipping, and distribution.

Restoring supply of transportation, raw materials, electricity, and fuel to food manufacturing materials is immediately critical.

Food grains are stored in commercial facilities and on farms. According to the June 2018 Grain Stocks Report, on-farm storage of food grains is down considerably from last year.

Harvesting of this years crops will need lots of diesel fuel.

Healthcare/Public Health Sector (Day 8)

All facilities are racing against time and fuel consumption curves.

One hospital is dependent on natural gas for on-site generation and is therefore without power. Moving some of those patients to other hospitals in “better” conditions is extremely difficult. There were many fatalities in the weaker patients.

Only one major hospital is back on 100% utility power to date.

Inability to get sufficient fuel to power some of these facilities has caused or facilitated hundreds of elderly deaths of those dependent on medical devices.

Hometown U is trying to expedite power up circuits carrying elder care, rehab, and hospice facilities before there are further patient deaths from heat issues and lack of power for medical devices.

Transportation Sector (Railroads) (Day 8)

Most (95%) of locomotives south of the Missouri-Kentucky-Virginia state lines remain functional. Priority is being given to rail shipments of food, medicines, diesel fuel, and utility fuels.

Efficient railroad operations depend on centralized control using track signals and radio communications with trains. Within minutes of the EMP burst, several locomotive crews, unaware of the EMP situation, fell victim to track signals providing incorrect indications, resulting in serious collisions and many near misses.

Railroads immediately defaulted to “loss of track control” protocol, which greatly slowed train speeds and freight tonnage throughput. Officials are trying to re-introduce old-days “paper train order” dispatching to speed things up.

Transportation Sector (Railroads) (Day 8)

There's still a lot of mess on several mainlines to clear before getting back to un-interrupted hauling of tonnage anywhere.

Most locomotive-mounted VHF radio systems survived the burst (short whip antennas) but many track-side repeaters and more than a few switchyard "base stations" were lost from the E1 pulse following coax cables and power cables into radios.

Freight trains on mainline tracks and sidings waiting for loading, unloading, dispatch instructions, waiting for fuel delivery, or motive power repair are inviting targets of opportunity for hungry citizens, not to mention entrepreneurial gangs of thieves.

Railroads are requesting federal assistance for fuel, manpower, and security for each train.

Transportation Sector (OTR Trucks) (Day 8)

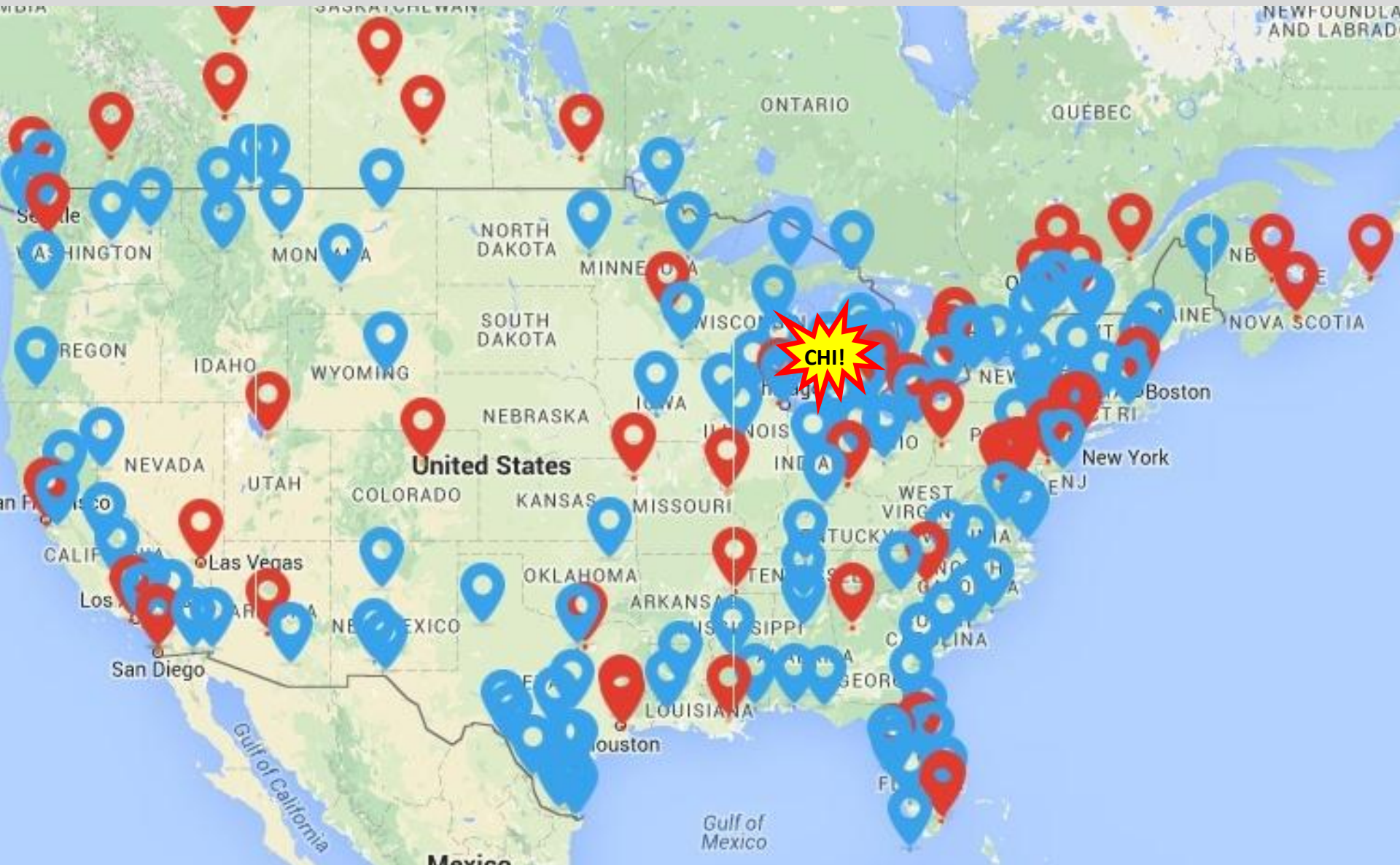
Most over-the-road trucks that were south of the Missouri-Kentucky-Virginia state lines at the time of the burst survived (400 miles away from ground zero). Others – 10-15% - had engine failures – modern diesel truck engines are electronically controlled.

Fuel supply and truck dispatch are problematic.....lack of cell phone, internet, and satellite data systems prevent efficient logisticspriority is being give to shipments of food, medicines, and diesel fuel.

Driving on the cluttered roads and avoiding groups of people wanting to hijack your truck for its valuables is dangerous business. More injuries for the Public Safety folks to deal with.

Trucks are traveling in convoys – safety and security in numbers.

Transportation Sector (Aircraft) (Day 8)



Many airports were close to the EMP Burst Location

Transportation Sector (Aircraft) (Day 8)

Much of the on-board aircraft electronics survived - they're designed to deal with near- or direct- lightning strikes on aircraft.

That being said, the E1 pulse near to the burst location was extreme. Some on-board electronics closer to the burst failed.

With sporadic ground power, damaged air traffic control equipment, and the FAA order for all craft to return immediately to ground. The resulting mayhem resulted in several mid-air collisions, many aircraft fuel emergencies, and runway mishaps.

Aircraft and airports further from the burst received some E1 damage to controls and communication. Ground facilities were left without mains power due to the E1+E3 combined pulse and are dependent on their emergency generators.

Transportation Sector (Aircraft) (Day 8)

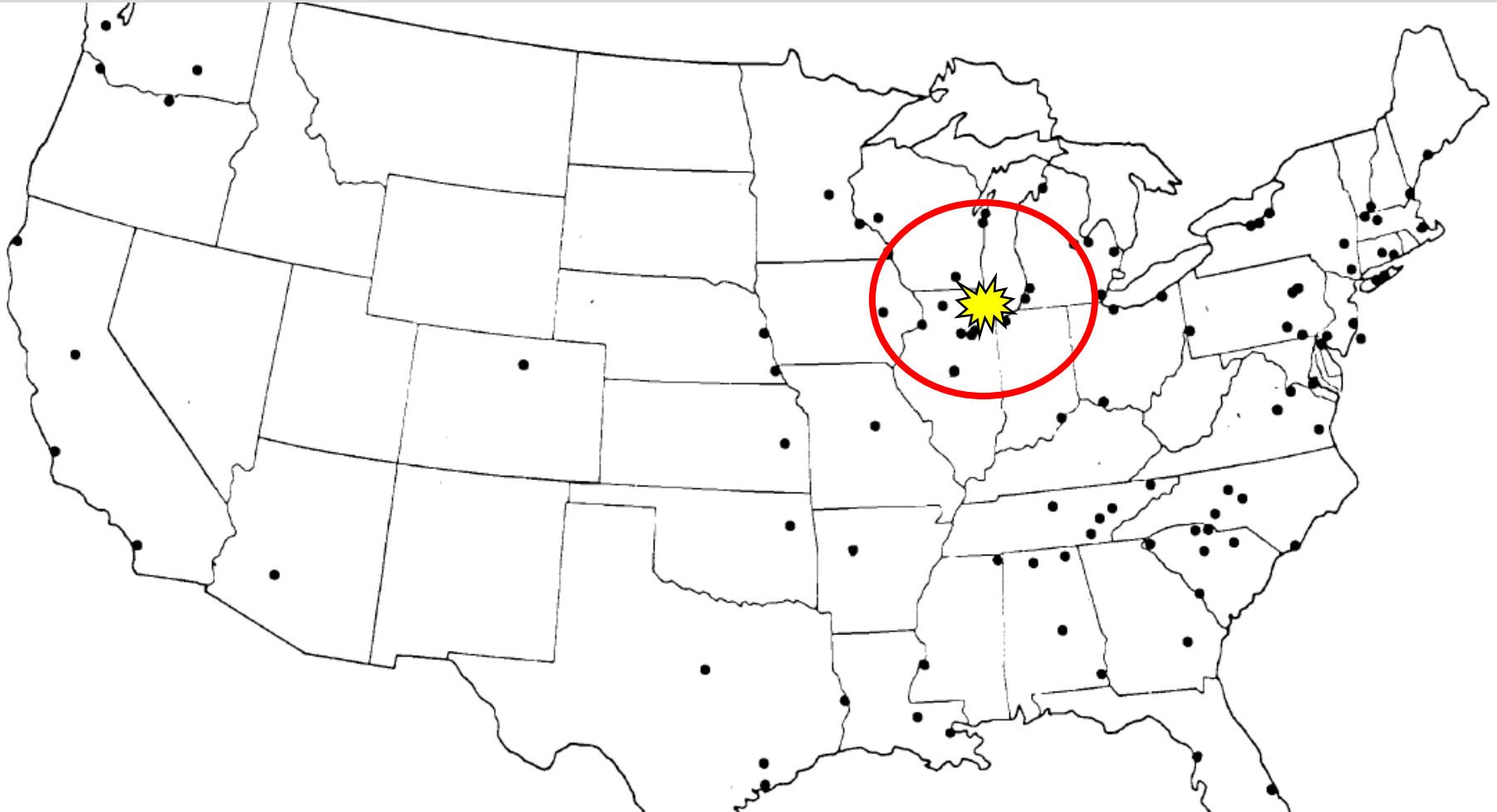
All civilian flights are cancelled until all ground and aircraft electronics are tested, repaired, and re-certified.

Before the EMP, there were about 42,000 US passenger and freight air flights per day, which means up to 5000 aircraft in the air at any time. Peak traffic hours on the east coast are 06:00 to 10:00 local time....right after the EMP burst.

In the minutes immediately after the EMP attack, power went out at many airports. E1 damaged the emergency generator controllers at some facilities. Within a 500 mile radius of the blast, E1 caused major failures in air traffic control centers and the sophisticated computer and radar systems. E1+E3 damaged the ground power, anything running is now on diesel backup power.

The Jet-A and JP-8 aviation fuels are being eyed for generator use...

Nuclear Reactors, Materials, and Waste (Day 8)



Map of US Nuclear Power Plant Sites. An EMP strike over Chicago ensured that 10 nuclear plants are within close proximity to the E1 and E3 effects, maximizing the potential for control system failure, permanent transformer damage and maybe even a nuclear mess.

Nuclear Reactors, Materials, and Waste (Day 8)

Priority 0 – Reactor Plant Physical Security

Priority 1 – Reactor Safety – cooling system backups.

Priority 2 – Inspection of Generator Step-up and Station Service Transformers.

Priority 3 – Test and repair reactor plant controls - DCS and PLCs.

Priority 0 – Waste Storage Facility Physical Security

Priority 1 – Waste Storage Facility Safety – integrity of cooling system backups and power supplies.

There is a critical need for diesel fuel for emergency generators to keep cooling systems operational. On-site fuel supply were good for two weeks.

FEMA will need to add manpower and security resources to protect reactor and waste storage facilities .

Dam Sector

Hydro-electric power – even small hydroelectric power sources – is critically important at this time because:

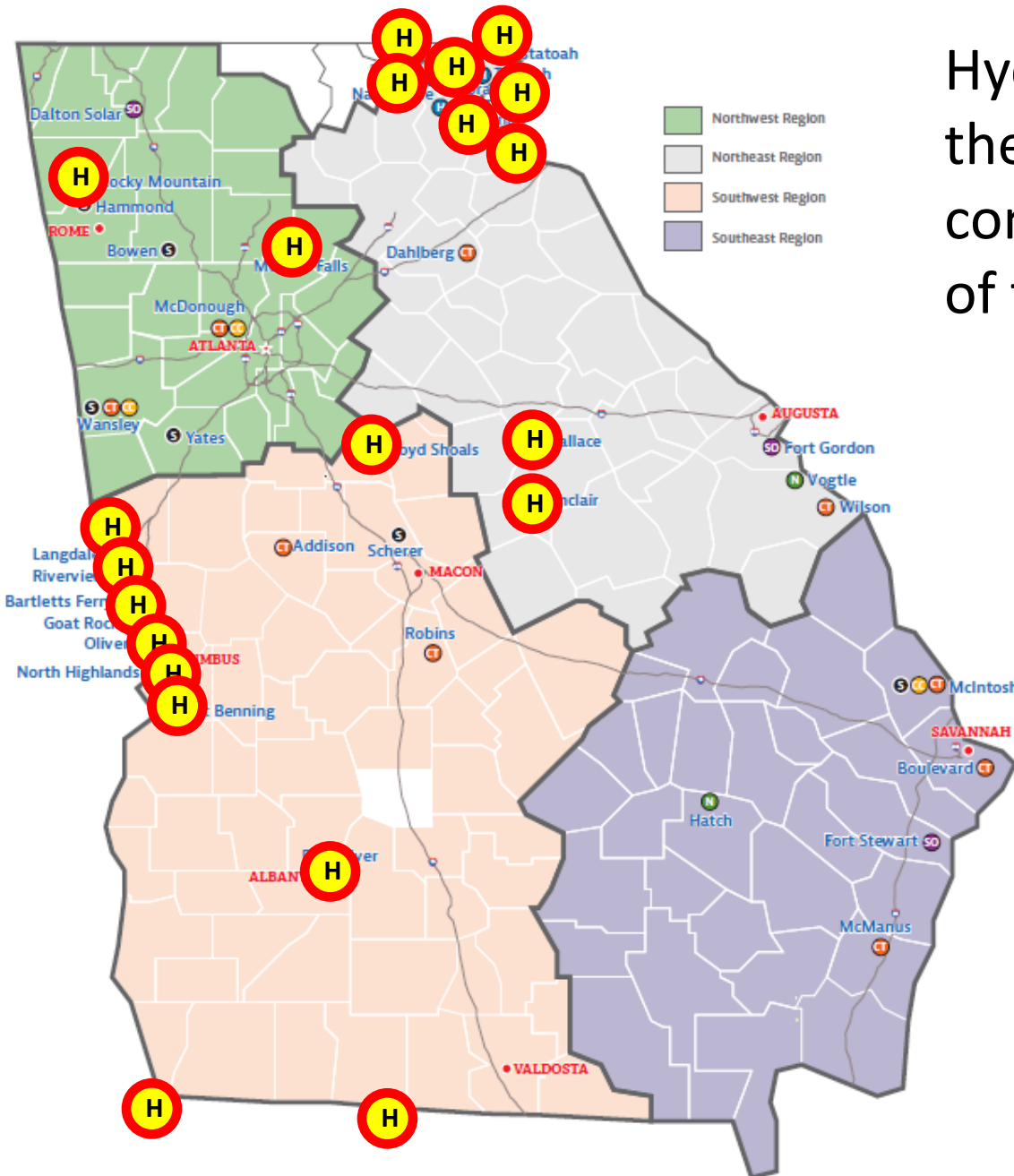
- 1.) **Hydro typically has simple electro-hydraulic controls** that can be operated without fancy, vulnerable electronics.
- 2.) **Most hydro power should be available immediately.**
- 3.) It requires no fuel, minimal personnel and supervision.
- 4.) It can quickly be brought online and can feed power into the grid for black-starting other fossil-fuel generating stations.

Dam Sector

Hydroelectric power may be the saving grace when it comes to black-starting parts of the US Grid.

Georgia has nineteen hydro plants...hopefully this will minimize Hometown's need to support utility black start efforts north of us.

**Florida also has two hydro units.... Corn (Tallahassee, 12 MW) and the Jim Woodruff - (43.5 MW, Chattahoochee)
Ditto: not having to help those to the west!**



Information Technologies Sector (Day 8)

Based on my recent research, **EMP shielding for commercial computer infrastructure buildings and their power and signal conductors is just now starting to be considered seriously.**

Most information available is “popular” or low-tech “professional” literature repeating the typical hearsay and non-science.

I have to assume that some percentage (30%? 40%? 50%?) of computer hardware related to IT infrastructure would at least be interrupted (requiring re-start), or damaged....even at a thousand miles from ground zero.

With adequate technical manpower and electricity available, the surviving internet backbone hardware can be “pirated” and re-combined to get the system up at reduced level of functionality.

Pervasive Digital Infrastructure == Vulnerability

Over the last two decades we have observed unprecedented global expansion of the digital infrastructure:

- Spanning the civil, military and “dual use” domains;
- Spanning industry, commerce, administration, education;
- Spanning fixed and wireless infrastructure domains;
- Personal devices like cellphones, pads, notebooks pervasive.
- The digital infrastructure has become deeply embedded across all facets of our social, economic and military systems.
- Increasingly we observe integrated and distributed applications, where the system comprises a large number of globally distributed components, which are mutually dependent on fixed and mobile components, and networks.
- The digital infrastructure is now a “single point of failure”.

“The Digital Infrastructure is a Single Point of Failure”

Larger banking institutions are trying to figure how to get power, data, and communications up so they can re-open.

A great portion of “conventional telephone service” is now VOIP, which also depends on the internet.

The “Big Money” is going to be mostly paralyzed until the Information Technologies Sector is back up.

Wall Street and all other forms of investment businesses are also stuck “waiting for cell phones and the internet to come back”.

It takes movement of cash/value to make things run again.

Some local banks and credit unions have cobbled together emergency power and a local intranet inside their facilities and are reviving their internal accounting systems.

Gasoline or diesel are being bought here for cash....gotta keep the banks lights on!

If you're a member/customer, you may be in luck. Small amounts of cash can be had.....these banks are being very careful and have only limited cash in hand until the Brinks truck can bring more.

Citizens are admonished to keep this money in circulation.

Qualified security guards and ex-military are in great demand.....

Homeland Security has supplied technical and security personnel to work with local facilities to ensure they have security measures in place to reduce the risks associated with certain hazardous chemicals, and prevent them from being exploited in a terrorist attack.

There are numerous local businesses which deal with “DHS Chemicals of Interest” including compressed gas suppliers and chemical manufacturers.

DHS has also added security personnel to the eight local railyards which contain many hundreds of tank cars and containers of miscellaneous chemicals.

Government Facilities Sector (Day 8)

Many facilities are secured and being used for distribution of food basics, water, and critical medications if you have proof of need.

Able-bodied persons that show up are being offered the opportunity to be paid in food for assisting in bodily clearing streets, roads, and highways in order to restore free-flowing traffic to enhance our transportation.

Commercial Facilities Sector (Day 8)

Commercial facilities including arenas, shopping malls, and are being secured by FEMA and National Guard personnel.

They are being used for storage and distribution of food basics, water, critical medications, and provision of medical services.

Normal use of these venues has been terminated until critical support infrastructures (electric power, water/wastewater, communication, etc.) can be returned.

Critical Manufacturing Sector (Day 8)

Most local critical manufacturing facilities are completely shut down due to the lack of electric power and the ability of many personnel to be able to get to work. These facilities require FEMA to provide substantial security to prevent looting/sabotage. These facilities must remain intact in order to provide product to re-establish normal service and supply chain materials.

Local Critical Manufacturing includes but is not limited to:

- Electric generating system components (turbine, motor repairs)
- Rail car and locomotive repairs
- Airframe repair and manufacturing facilities
- Storage battery manufacturing
- Critical medical device manufacturing
- Ocean-going ship maintenance/repair

Defense Industrial Base Sector

Most manufacturing facilities are completely shut down due to the lack of electric power and the ability of most personnel to be able to get to work.

There is still a need for facility security which requires FEMA to provide manpower, vehicle, communication, and electric power resources to each site.

Think Ahead!

(All of the following bullet points are appropriate for all of us citizens!)

What personal actions could you take now to help be prepared for a widespread, multi-month outage?

As a responsible member of an infrastructure business, you'll find that you may have considerable new and "previously unconsidered" responsibilities.

Do you have an extended family emergency plan? Can they shelter in place or with another family? How will your spouse and family deal with your extended absences?

Is your household prepared for a long-term disaster? Possess 2-3 weeks of non-perishable food, water, shelter, medications, cash, fuel, means of protection?

Does your family have an independent means of communicating? (CB-GMRS-FRS-Ham Radio). FORGET CELL/LANDLINE PHONES!

Is your personal vehicle prepared to deal with possible scenarios?

What actions could your business/infrastructure take now to help be prepared for a multi-month outage?

Does your business have a continuity plan? Will it cover an EMP scenario?

Does it include back-up power and means to keep that power running for 3-4 weeks? Reliable, independent communication?

Does your business have sufficient business supplies to keep going for 3-4 weeks?

Does the business have the means to keep food, water, and personal needs to keep employees coming to work for 3-4 weeks?

Do you know how to protect electronic gear? Is critical business info updated to LOCAL storage drives so you can work off-internet?

Could your company be prepared to pay your employees salary in cash or other valuta to keep them working for you?

EMP Effects on Critical Infrastructures

One of the best single sources of information on EMP is the 2008 EMP Commission Report.

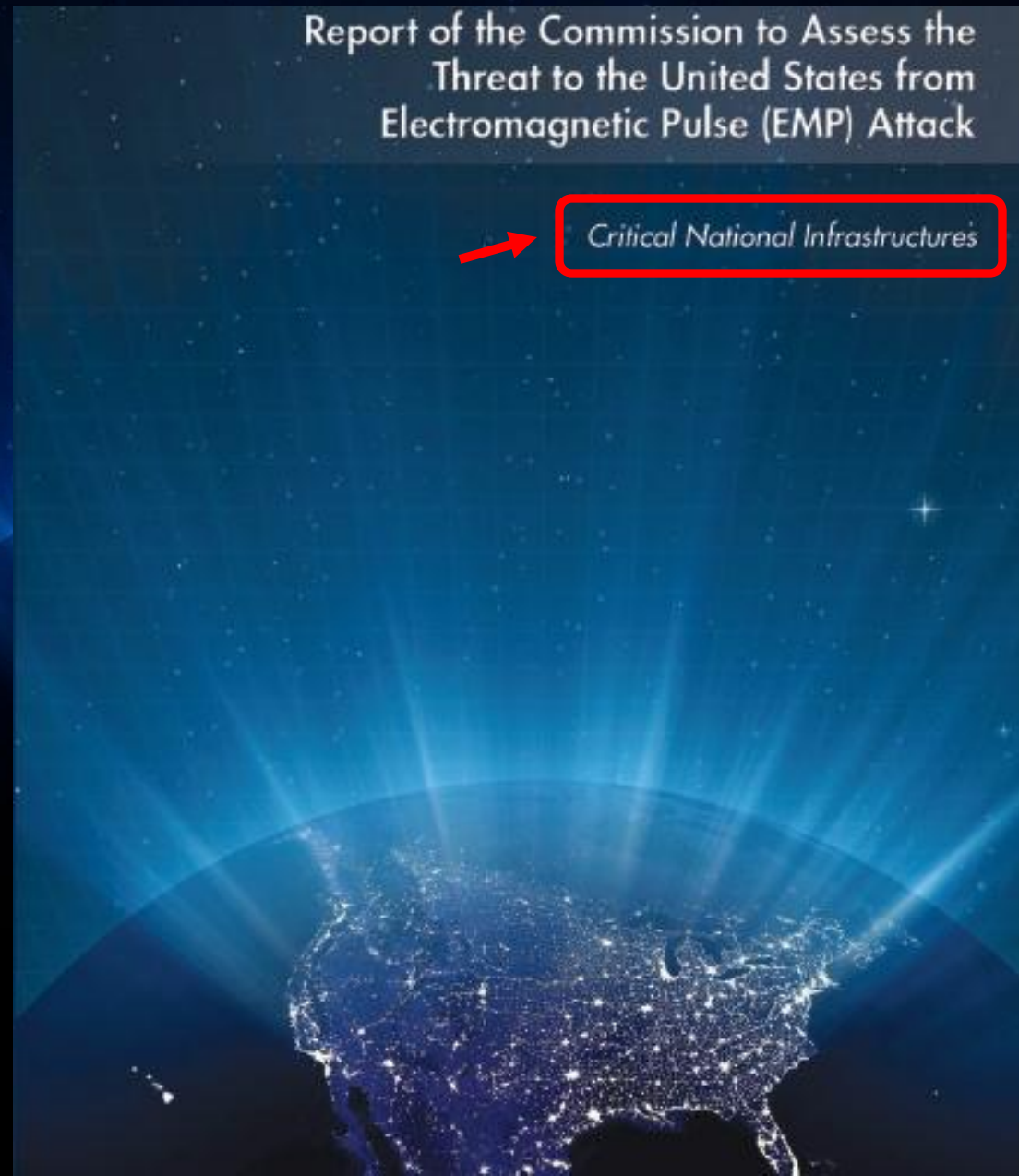
Note the sub-title.....

“Critical National Infrastructures”

208 pages of information about EMP, effects on infrastructure.

Available at

http://www.empcommission.org/docs/A2473-EMP_Commission-7MB.pdf



EMP Effects on Critical Infrastructures

A new source of
credible information:

Written by THE experts
on EMP of all types:

- George Baker
- William Radasky
- James Gilbert

Available at

<https://info.publicintelligence.net/DHS-FacilitiesGuidelinesEMP.pdf>

UNCLASSIFIED

Electromagnetic Pulse (EMP) Protection and Restoration Guidelines for Equipment and Facilities

With Appendices A - C



December 22th, 2016
Version 1.0

Developed by the
National Coordinating Center for Communications (NCC)
National Cybersecurity & Communications Integration Center (NCCIC)
Arlington, Virginia

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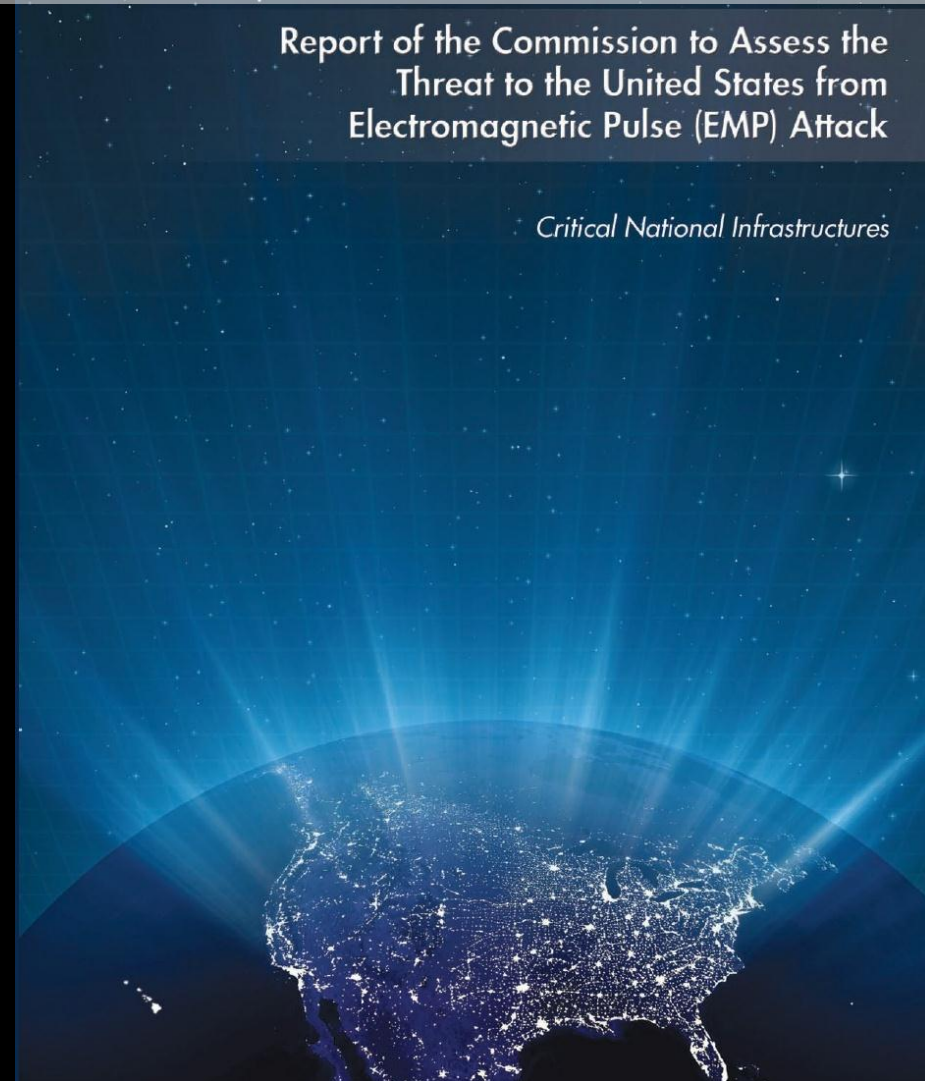
Recommended Reading!



A Novel Which Helps One
Understand the Seriousness of the
EMP Issue

Report of the Commission to Assess the
Threat to the United States from
Electromagnetic Pulse (EMP) Attack

Critical National Infrastructures



The Official Report to the US
House of Representatives –
Easy to Understand

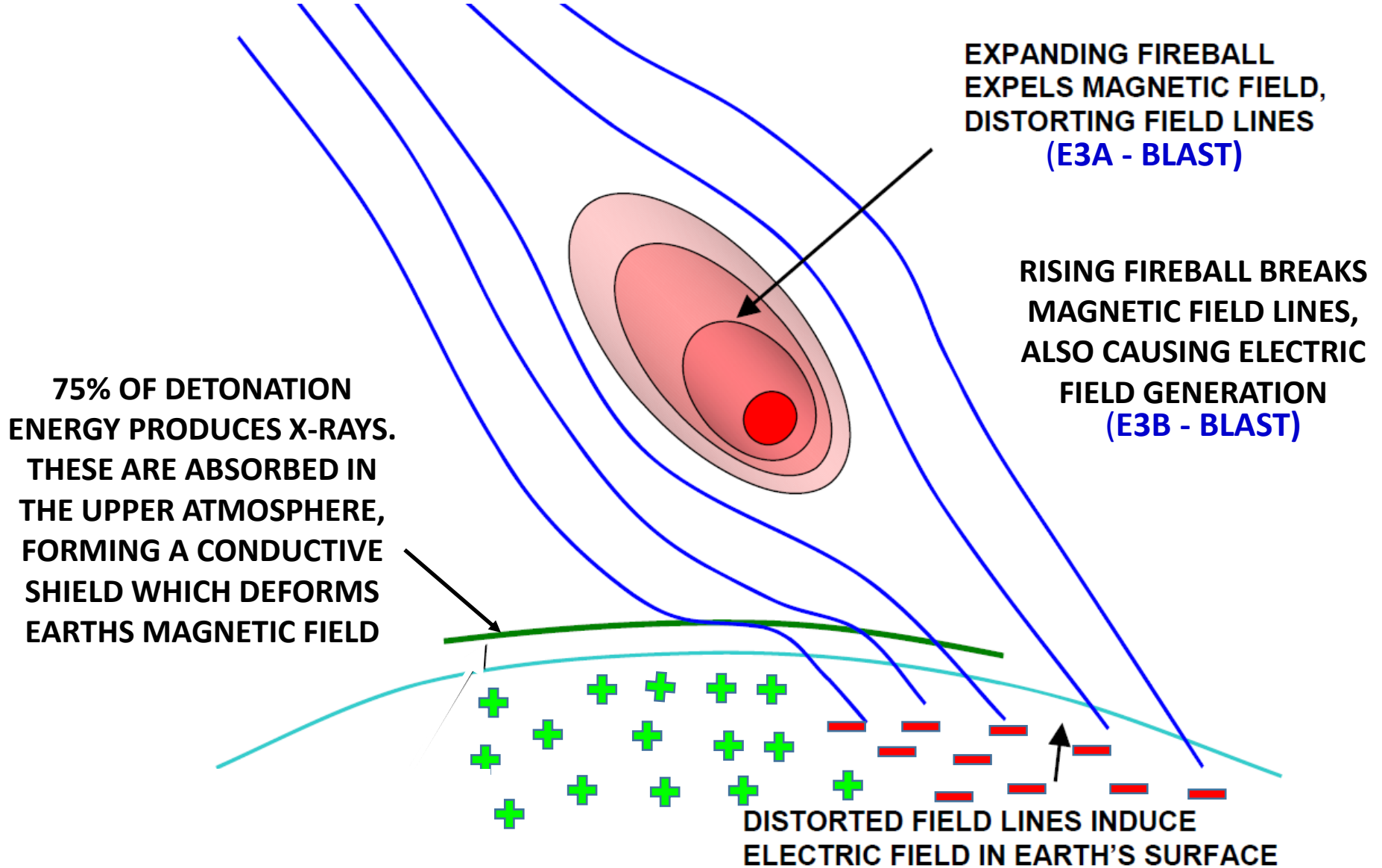
Pdf file at <http://www.empcomission.org>

QUESTIONS?



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Just as in CME, atmospheric electric fields cause charges to be induced in the ground. Since there is a charge differential between the ground under the shield compared to the ground not shielded, there is spatial voltage

List of E1 Affected Devices and Systems

Depending on local field strength, the E1 pulse will disrupt operation of some percentage of the following:

Stationary computing devices (PCs).

Control systems operated with a Programmable Logic Controller (PLC).

Control systems operated with a Distributed Control System (DCS).

Stationary Point of Sale device (cash registers, ATM machines).

Radio, TV, computer, appliance, or machine containing a microprocessor.

{including HVAC systems, Refrigeration Systems, Process Equipment, Life Safety equipment}

Think about everything that:

1.) Has a microprocessorand

2.) Has an exposed power, signal or interconnect cable that can act as an antenna for E1.....and

3.) Is not protected by effective Faraday shielding

Injection of even a few volts of direct current electricity into the transformer winding causes the following problems:

- 1.) Saturation of the transformer core, which forces magnetic flux lines to escape their intended path through the core, promoting localized heating of the tank and other structure.
- 2.) Distortion of the voltage and current waveforms that further impair efficiency and promote heating.
- 3.) Generation of excessive (un-expected) reactive power. Transformer efficiency drops, resulting in substantial copper and iron heating, followed by winding material and insulation oil temperature increases.

If protection relay circuits and breakers do not take the transformer out of service the transformer will soon fail.

Todd's Rules of Thumb:

- E1 weakens with distance.... Double the distance, quarter the intensity.
- E1 will likely get into everything electronic that has a 1-2 foot long conductor attached.
- E1 will cause some level of utility line insulator flashover, potentially damaging the insulator and dropping the conductor.
- E1 will likely damage relaying and control circuits on utility transformers, the E3 pulse then damages the transformer.
- E1 will likely damage anything using SCADA, DCS, and PLCs.
- E1 will likely damage Public Service Radio Systems unless the antenna AND utility power conductors are protected AND the radio rooms are inside Faraday shielding.

Subjects to think about, discuss among yourselves....

What if the power goes off for three days, what would you do? What would you anticipate?

Now it is one month later and the power is still not on (could also think about three months). What are your actions/ thoughts/concerns?

What actions could you take now to be prepared for a widespread multi-month outage? For your community? For your business?

Todd's Rules of Thumb:

Some percentage (5%? 10%?) of automobiles will be affected by a 50 kV/meter NEMP E1 electrical field. Automobiles with advanced electronics are more likely to have issues.

Luckily for us:

OEM vehicle electronics are well-shielded to keep computer-generated electrical noise from affecting entertainment radios and passenger-carried computer devices. This will likely help to keep a lot of E1 pulse out and keep the damages lower.

Most vehicles – especially those with steel body panels – have additional protection for attenuating the E1 pulse energy.

Many vehicle cables (computer, brake and tail lights, etc.) are typically run through the chassis rails which will aid shielding.

Todd's Rules of Thumb:

- E3 will only affect equipment with very long wires or is connected to earth ground – **utility transformers and breakers**, cable TV/Internet systems, railroad tracks (and thus rail signal systems), gas and oil pipelines, etc.
- CME effects and E3 pulse effects will be very similarexcept that the E3 pulse damage will likely be many times more severe but somewhat less global.
- Neither E3 nor CME events should affect the stand-alone operation of cell phones, laptops, tablets, hand-held radios....but these devices are likely to be ineffective without the support of cell towers and internet.

Todd's Rules of Thumb:

**Automobiles should not be affected
by CME or E3 pulse.**

**There is no connection to Earth or to a long wire (hundreds
of meters long) necessary to pick up the E3 pulse.**



The sky over Chicago and Lake Michigan would look like this at the instant that the device detonated. There would be no direct health effects to the citizens.