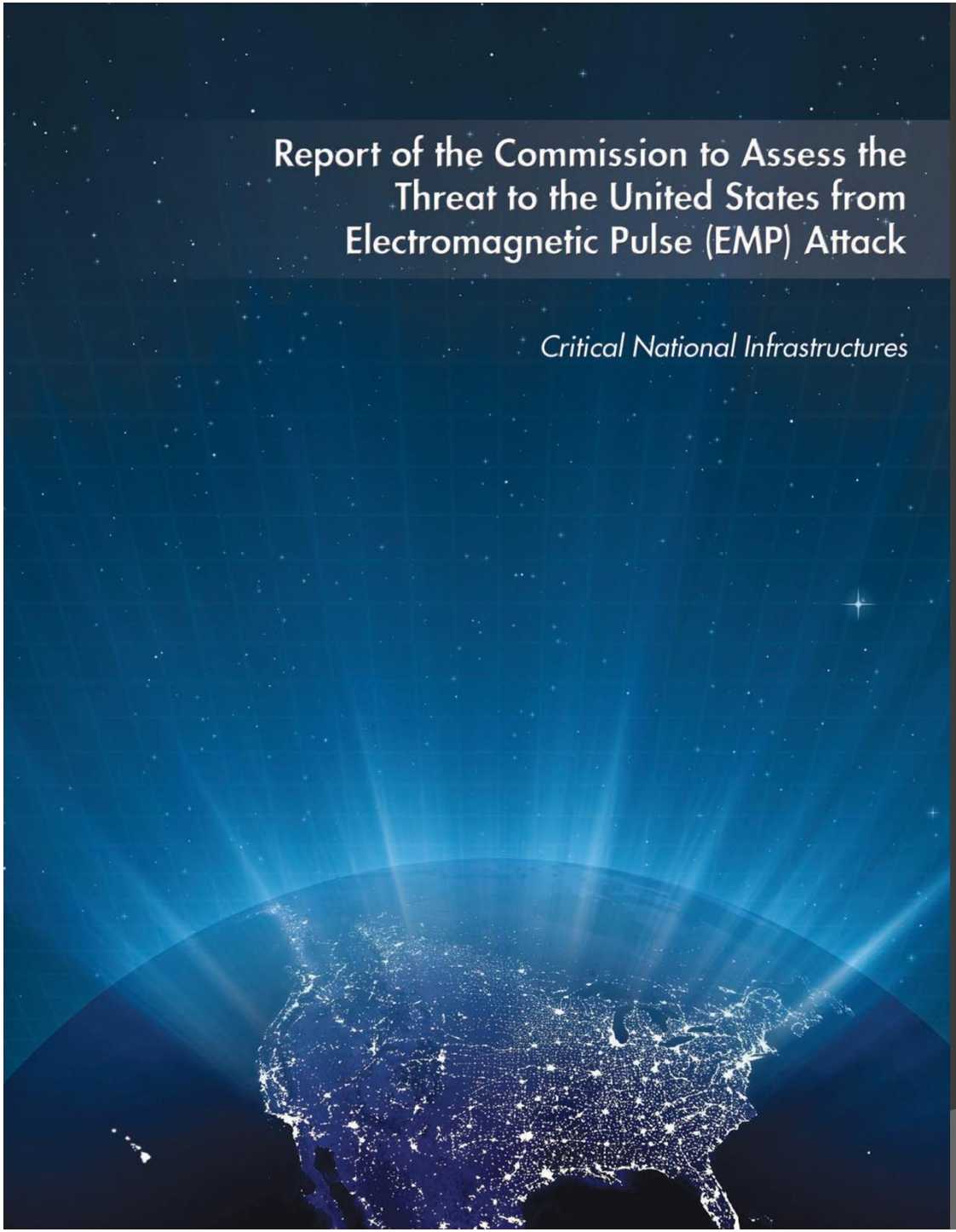
EMP
ELECTRO MAGNETIC PULSE

Dennis Conklin, AI8P



The EMP Commission was established pursuant to title XIV of the Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001 (as enacted into law by Public Law 106-398; 114 Stat. 1654A-345).

The EMP Commission was reestablished via the National Defense Authorization Act for Fiscal Year 2006

References

- Federal EMP Commission
  - www.empcommission.org/reports.php
- North American Electric Reliability Corporation
  - High Impact Low Frequency Threat Assessment
    - http://www.nerc.com/files/HILF.pdf
  - Spare Equipment Database System
    - http://www.nerc.com/docs/pc/sedtf/SEDTF_Special_Report_October_2011.pdf
- Energy Sector-Specific Plan. An Annex to the National Infrastructure Protection Plan 2010
  - http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/Energy_SSP_2010.pdf
- Oak Ridge National Laboratory and Meta Tech Reports
  - *The Early-Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid (Meta-R-320)*
  - *The Late-Time (E3) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid (Meta-R-321)*
  - http://www.ornl.gov/sci/ees/etsd/pes/ferc_emp_gic.shtml
- "Lights Out" by Ted Koppel
- "Disaster Preparedness for EMP Attacks and Solar Storms", By Arthur T. Bradley
- "EMP, the Prepping for Tomorrow Series", by Bobby Akart

Meta-R-320

The Early-Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid

Edward Savage
James Gilbert
William Radasky

Metatech Corporation
358 S. Fairview Ave., Suite E
Goleta, CA 93117

January 2010

168 pages

Prepared for

Oak Ridge National Laboratory
Attn: Dr. Ben McConnell
1 Bethel Valley Road
P.O. Box 2008
Oak Ridge, Tennessee 37831
Subcontract 6400009137

Meta-R-321

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

James Gilbert
John Kappenman
William Radasky
Edward Savage

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Topics

1. EMP Components
2. EMP Experience
3. Infrastructure Interdependencies
4. Electric Power
5. Telecommunications
6. Petroleum and Natural Gas
7. Transportation
8. Food
9. Water
10. Faraday Smaraday
11. References

Electro-Magnetic Pulse Components

Philosophy of this Presentation

BIG SUBJECT
MULTIPLE REPORTS
HUNDREDS OF PAGES
SHOW WHAT INTERESTED ME

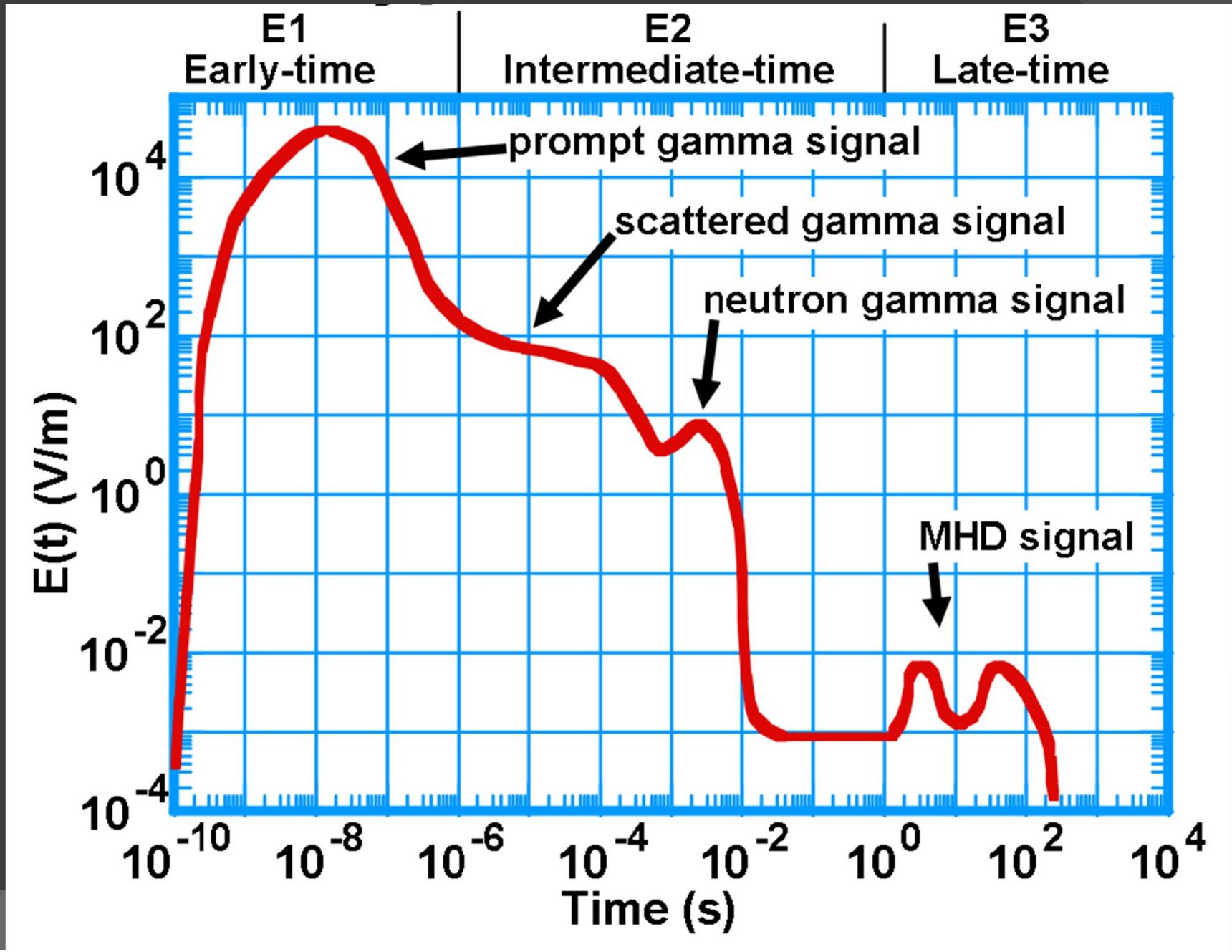
High Altitude Nuclear Explosion - EMP

- Broad band, high amplitude
- Affects large area (line of sight)
- Unsophisticated technology – known for decades
- Extreme asymmetry vs adversaries
  - Current vulnerability invites and would reward attack

STATEMENT FOR THE RECORD
DR. WILLIAM R. GRAHAM, CHAIRMAN
DR. PETER VINCENT PRY, CHIEF OF STAFF
COMMISSION TO ASSESS THE THREAT TO THE UNITED STATES
FROM
ELECTROMAGNETIC PULSE (EMP) ATTACK
TO
U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON HOMELAND SECURITY
SUBCOMMITTEE ON OVERSIGHT AND MANAGEMENT
EFFICIENCY HEARING
"EMPTY THREAT OR SERIOUS DANGER:
ASSESSING NORTH KOREA'S RISK TO THE HOMELAND"
October 12, 2017

North Korea Nuclear EMP Attack: An Existential Threat

Three Strikes and You're Out!



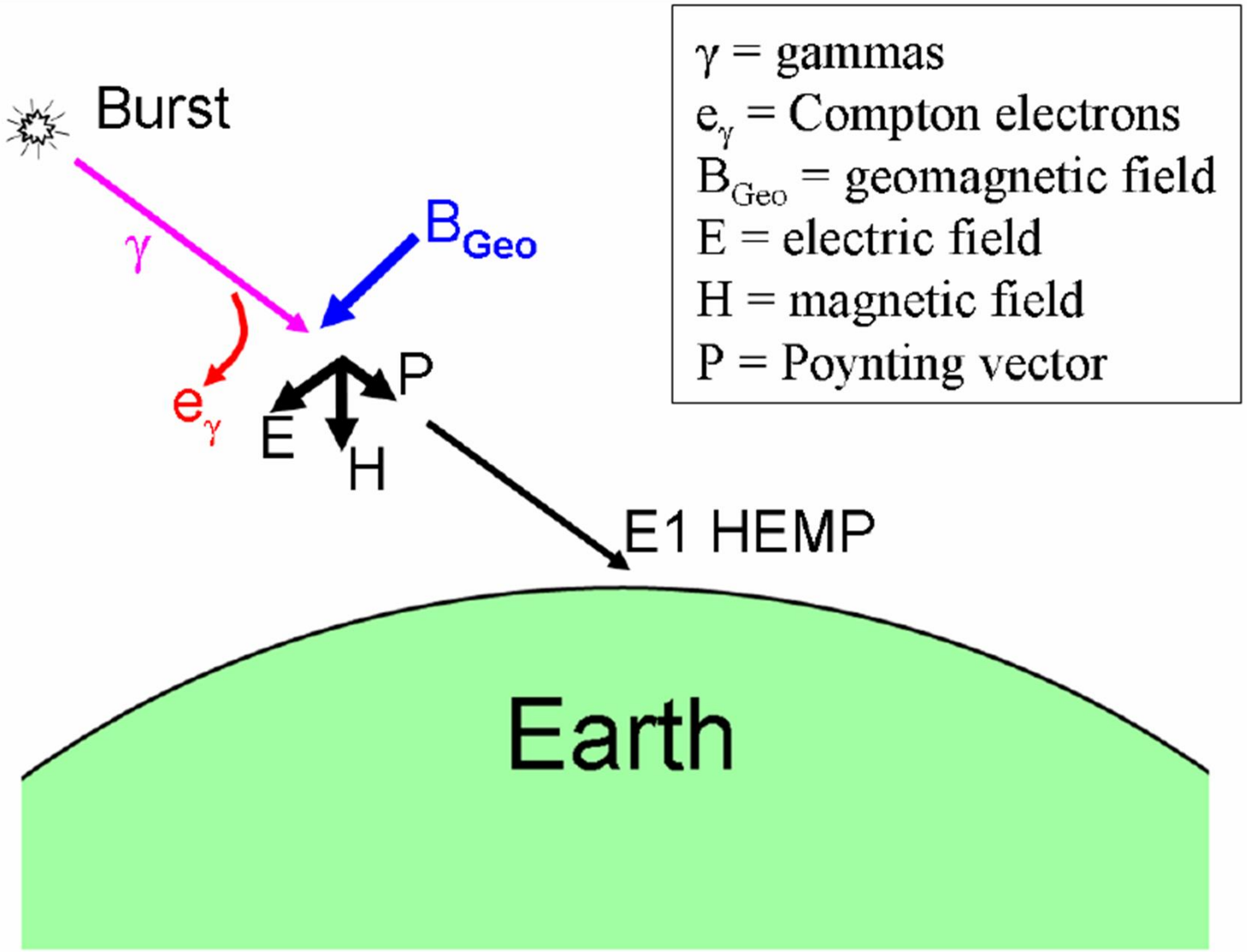
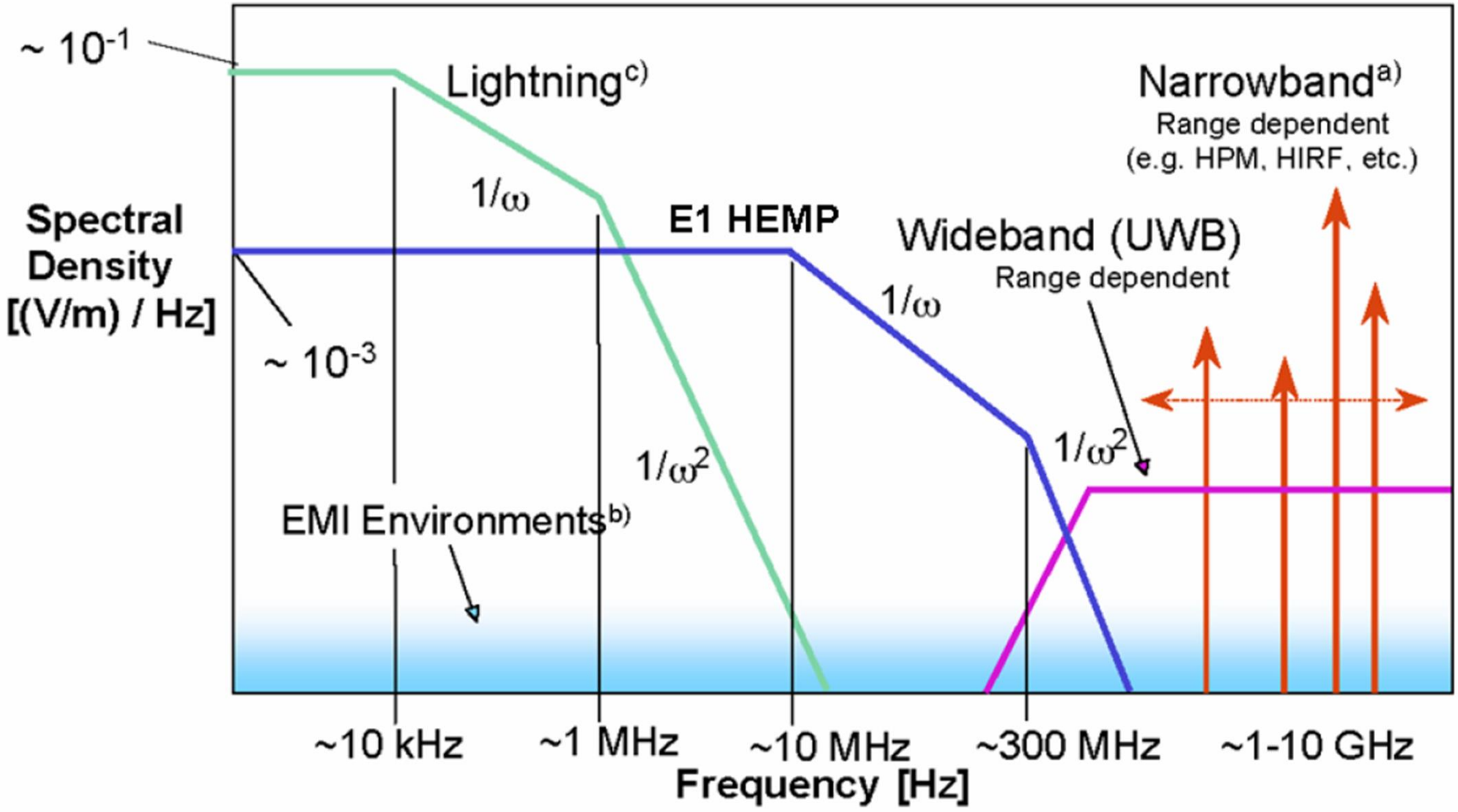


Figure 2-2. General basis of the E1 HEMP generation process. Gammas from the nuclear burst interact with the upper atmosphere – generating Compton electrons, which are turned in the Earth's geomagnetic field, and produce a transverse current that radiates an EM pulse towards the Earth.



a) narrow band extending from ~0,5 to ~ 5 GHz
b) not necessarily HPEM
c) significant spectral components up to ~10 MHz depending on range and application

Ref: IEC Standard 61000-2-13

Figure 2-5. Approximate EM spectrums for various EM disturbances. E1 HEMP dominates in the range of about 1 MHz to several hundred MHz. IEMI is represented by the "Wideband" and "Narrowband" signals on the upper frequency (right) side.

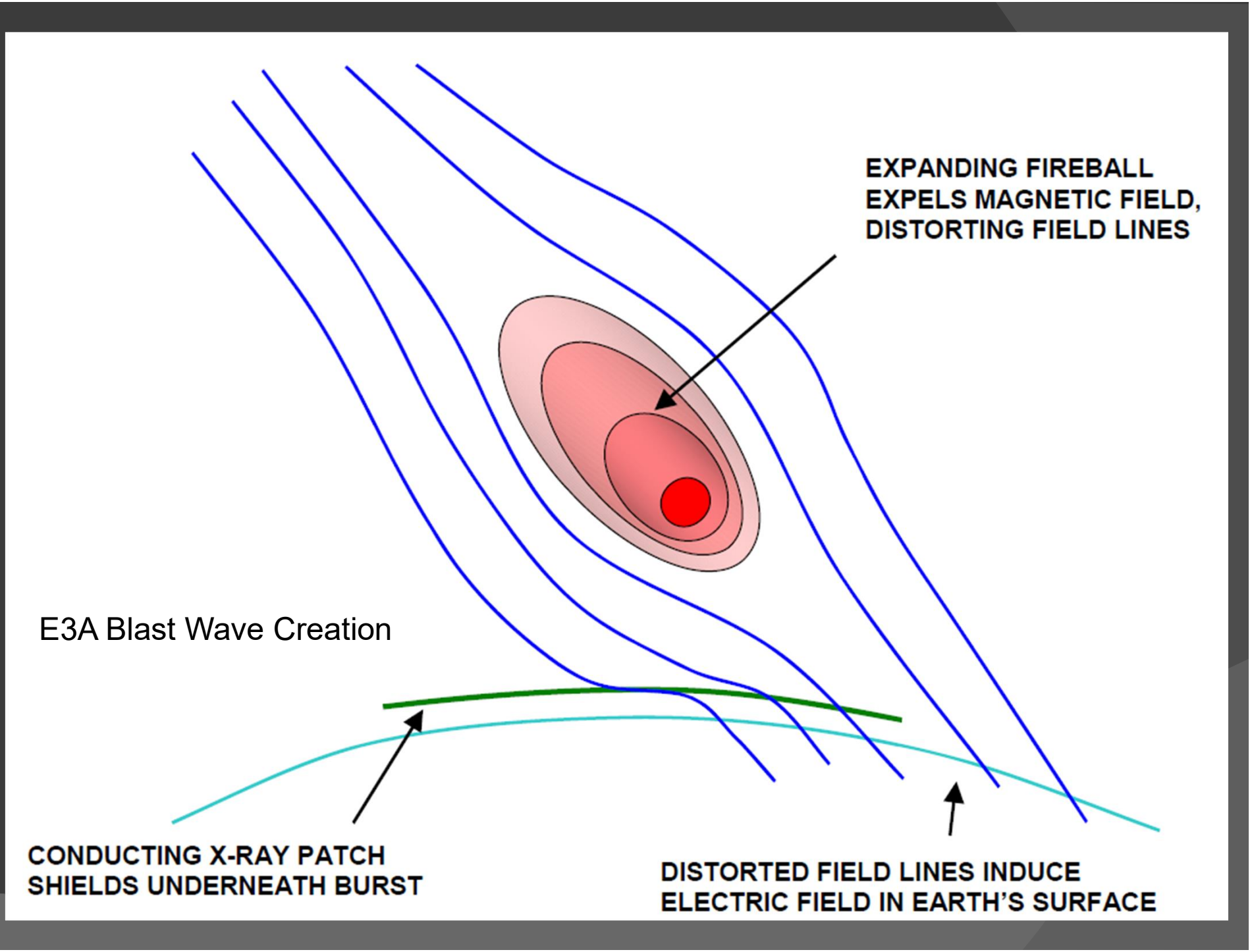
First EMP Component (E1)

- Free-field energy pulse
- 50,000 V/m pulse – 1 inch = 5000 V
  - High power, low energy
- 1MHz to 1 GHz
- Rise time fraction of billionth of second
  - Much faster rise time than lightning
  - Traditional lightning protections don't work
    - Ground lines which are low impedance at Lightning frequencies are high impedance at E1 frequencies
- Disrupts or damages:
  - Control systems
  - Sensors
  - Communications
  - Protective systems
  - Computers
  - Sensitive Electronics

EMP Effects – E1 Fast Pulse

Second EMP Component (E2)

- 1 kHz to 1 MHz
- Millions of simultaneous lightning strikes
- Rise time comparable to Lightning
- Lower amplitude than lightning
- Lightning protection should shield BUT
  - Multiple simultaneous strikes
  - Arrives fraction of second after E1
    - E1 can disrupt or destroy many protective and control features
    - Synergy between E1/E2 can let energy of E2 enter and disrupt systems


EXPANDING FIREBALL
EXPELS MAGNETIC FIELD,
DISTORTING FIELD LINES
E3A Blast Wave Creation
CONDUCTING X-RAY PATCH
SHIELDS UNDERNEATH BURST
DISTORTED FIELD LINES INDUCE
ELECTRIC FIELD IN EARTH'S SURFACE

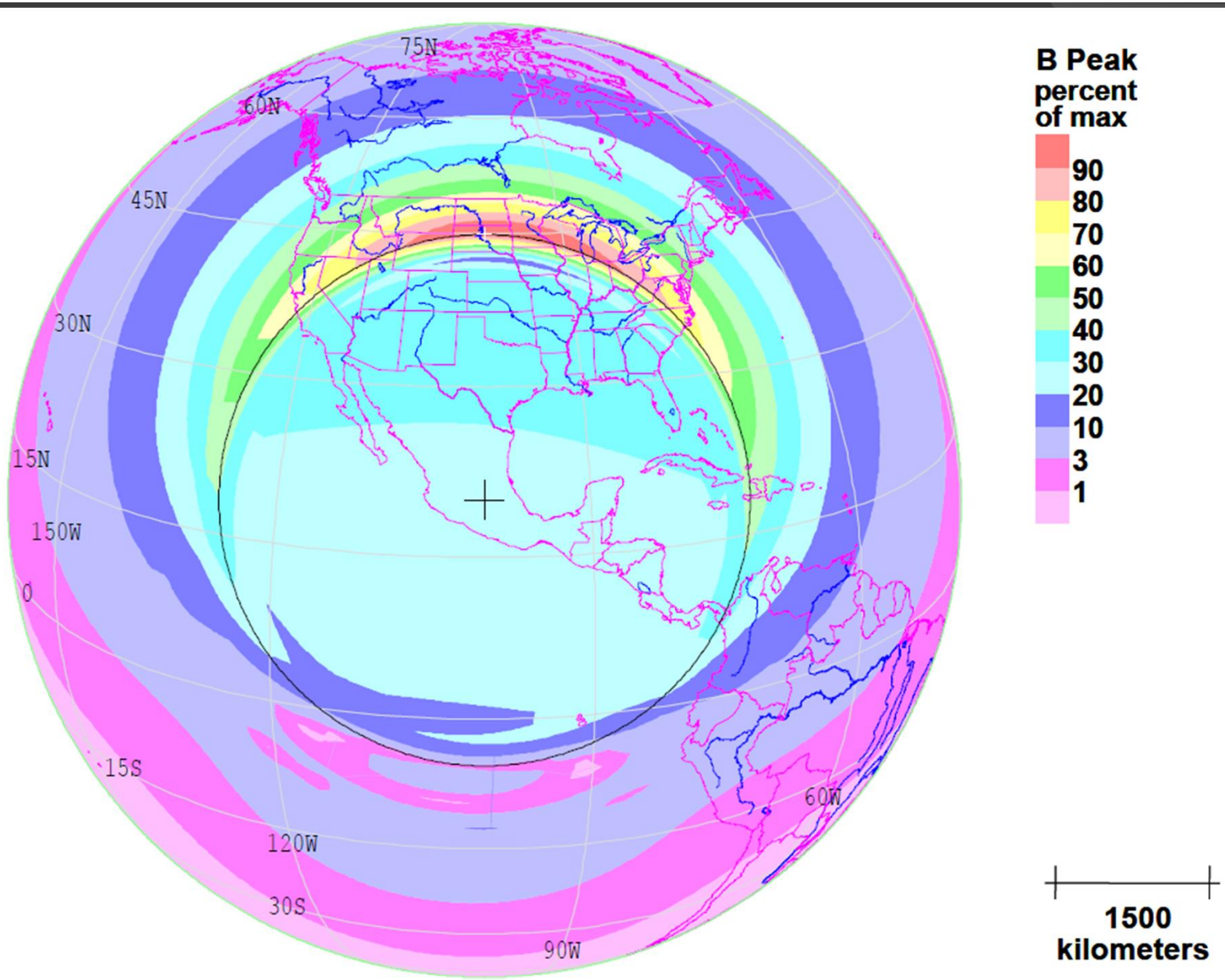


Figure 2-2. Spatial distribution of the perturbed magnetic field for E3A Blast Wave, showing the effect of the shielding by the x-ray patch.

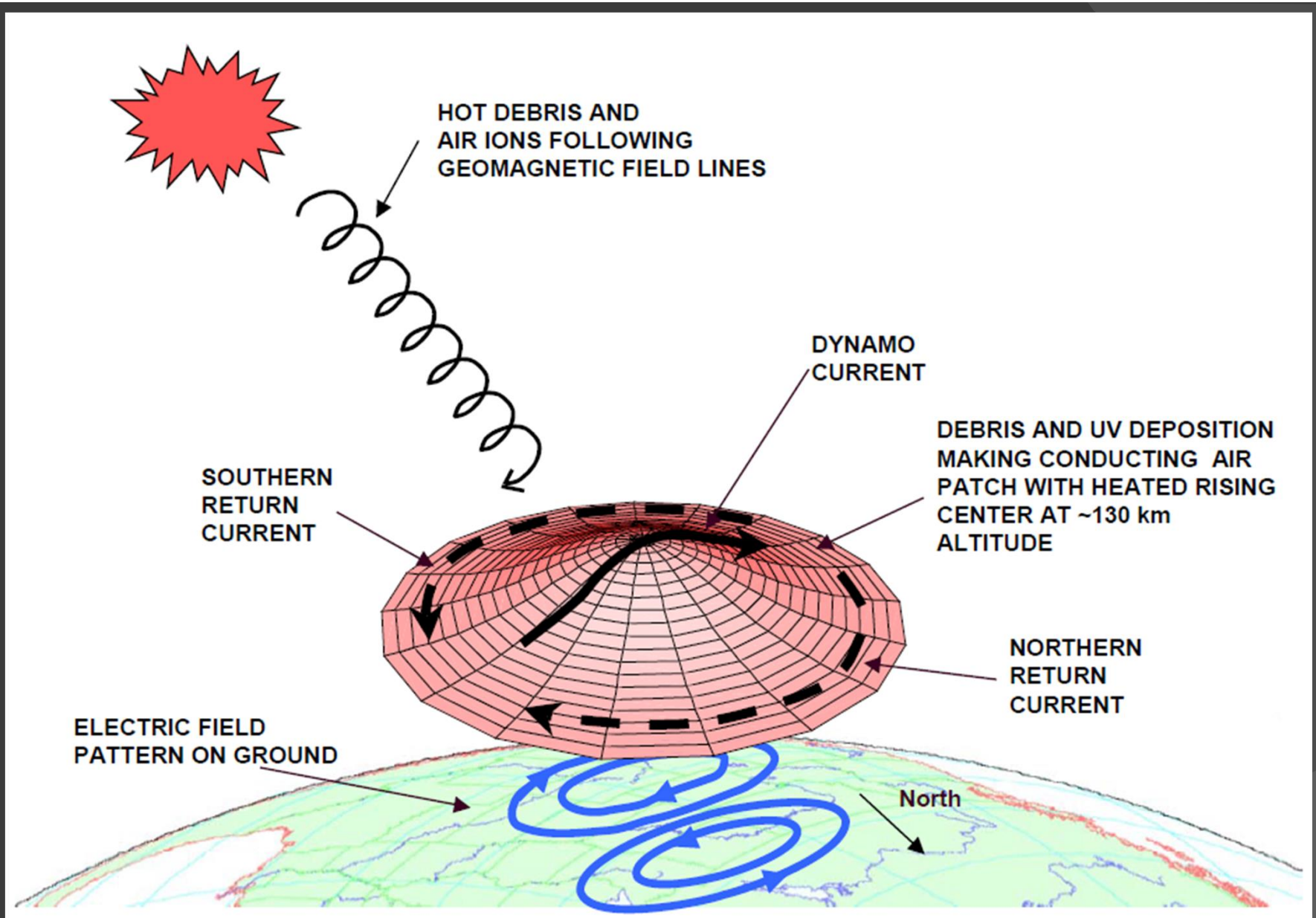


Figure 2-7. Schematic of E3B Heave phenomenology.

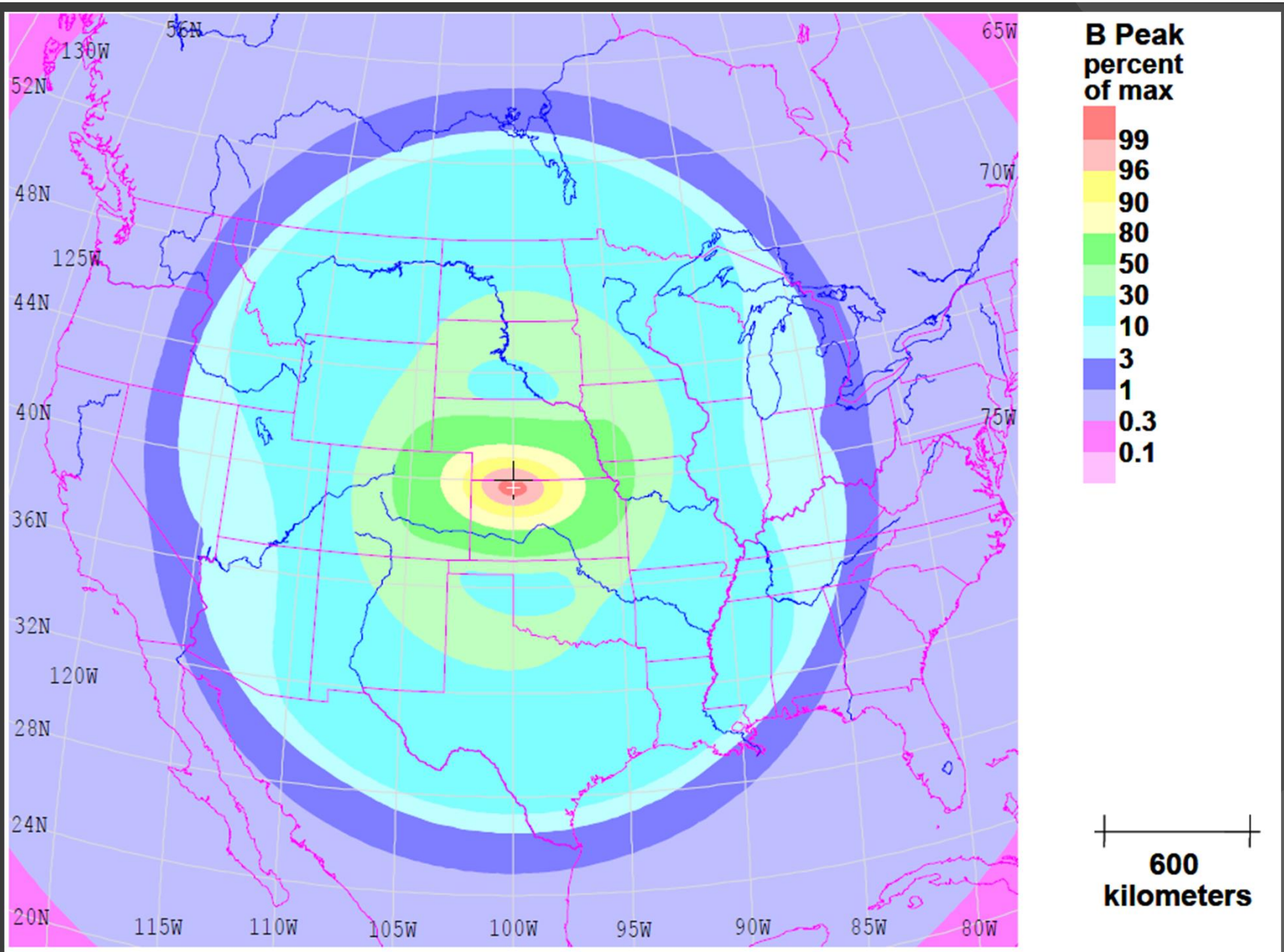
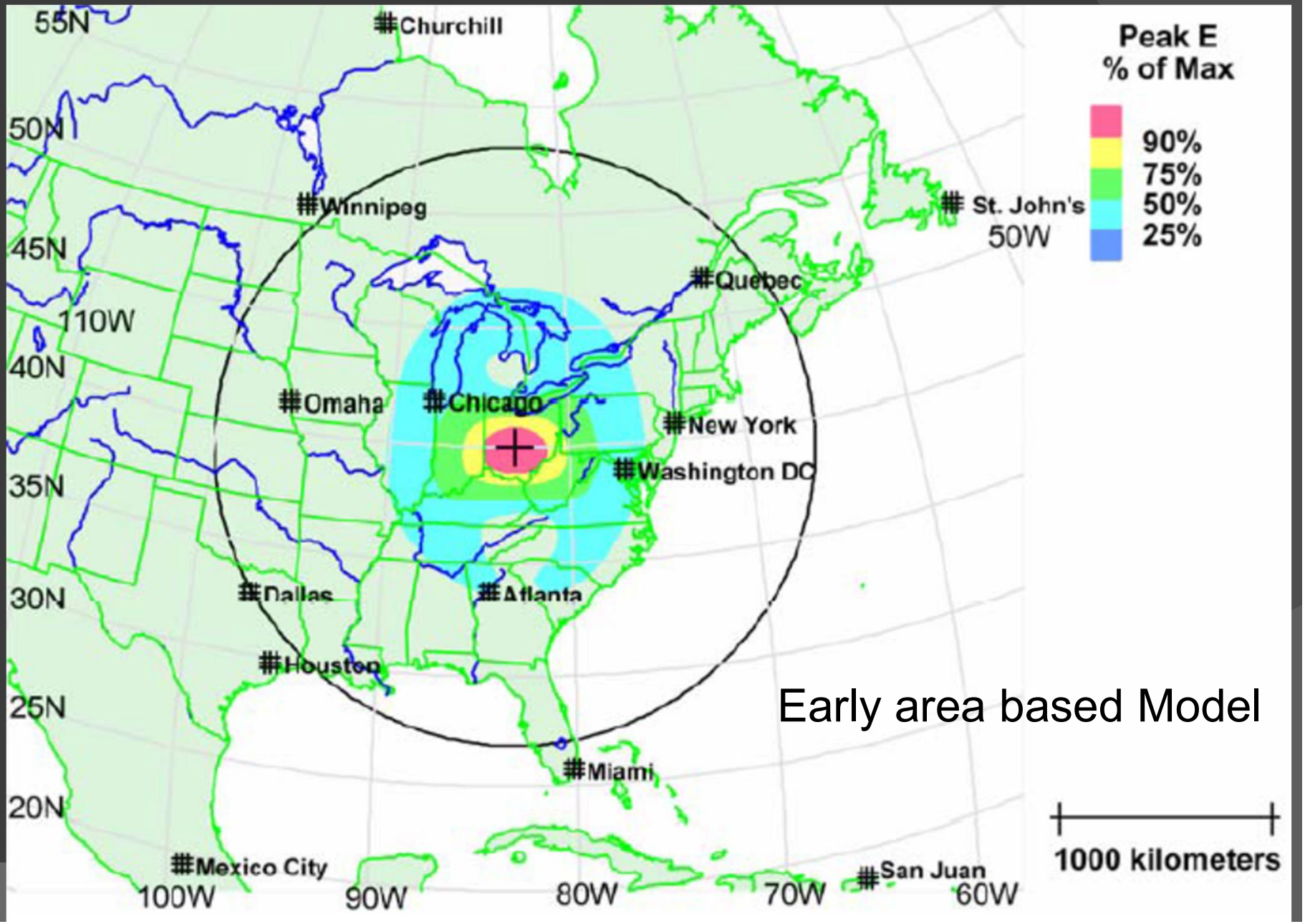


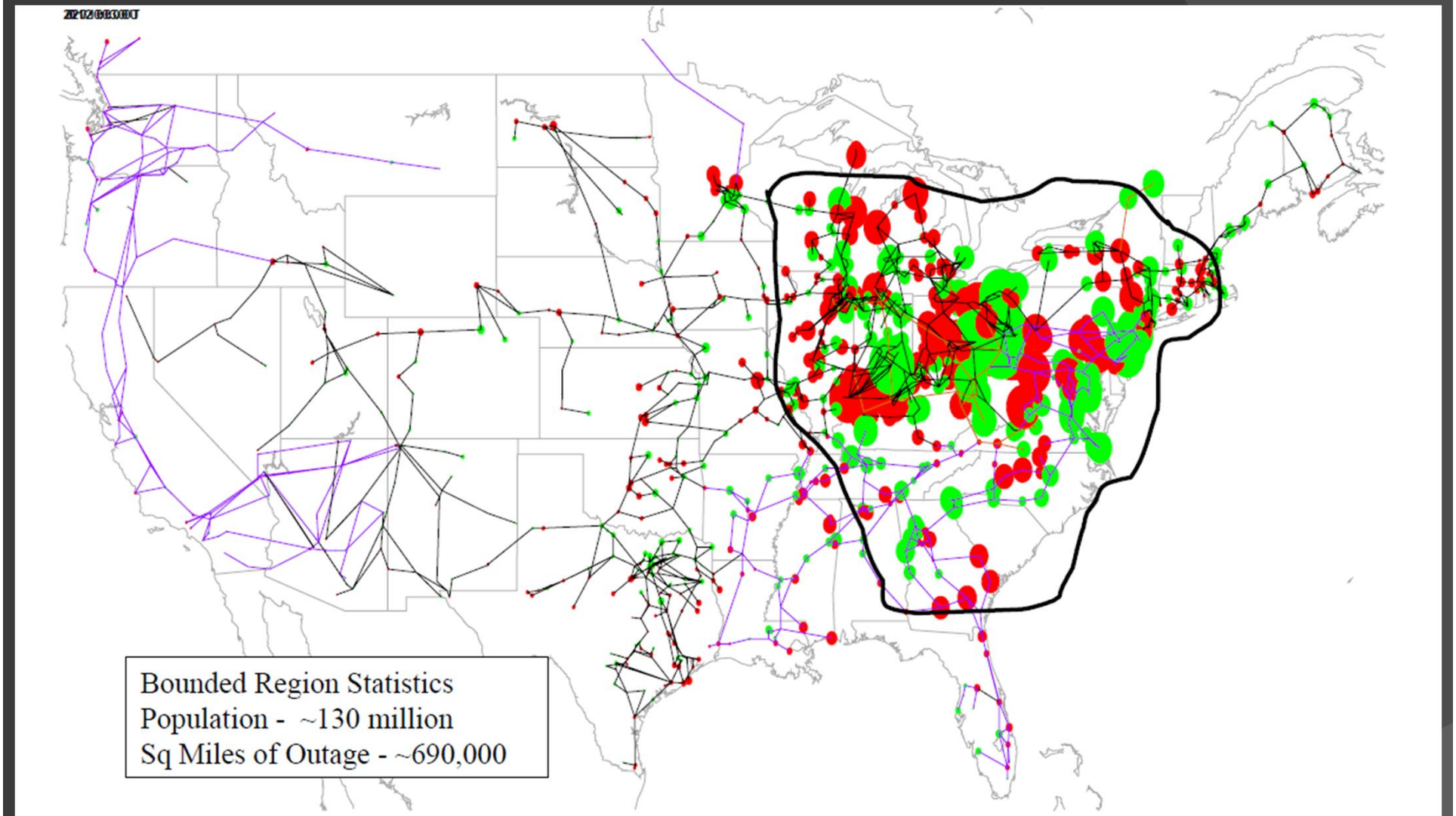
Figure 2-9. Spatial distribution of the perturbed magnetic field for E3B Heave.

Third EMP Component (E3)

- Geomagnetically Induced Current (GIC)
- 1Hz to 100 Hz
- Result of distortions of Earth's magnetic field
- Slower rising, longer duration pulse
- Like Solar Storm but STRONGER
- Induces large quasi-direct currents in long electrical transmission lines
- Duration in minutes
- Currents in thousands of amps
- Damaging to electrical system
- Anything with a long wire attached to it

Slow Pulse – E3





Later complex model explicitly including Grid details

Figure 3-2. Summary of GIC flows in U.S. power grid for E3B from burst centered on Columbus, Ohio.

Sensitivity

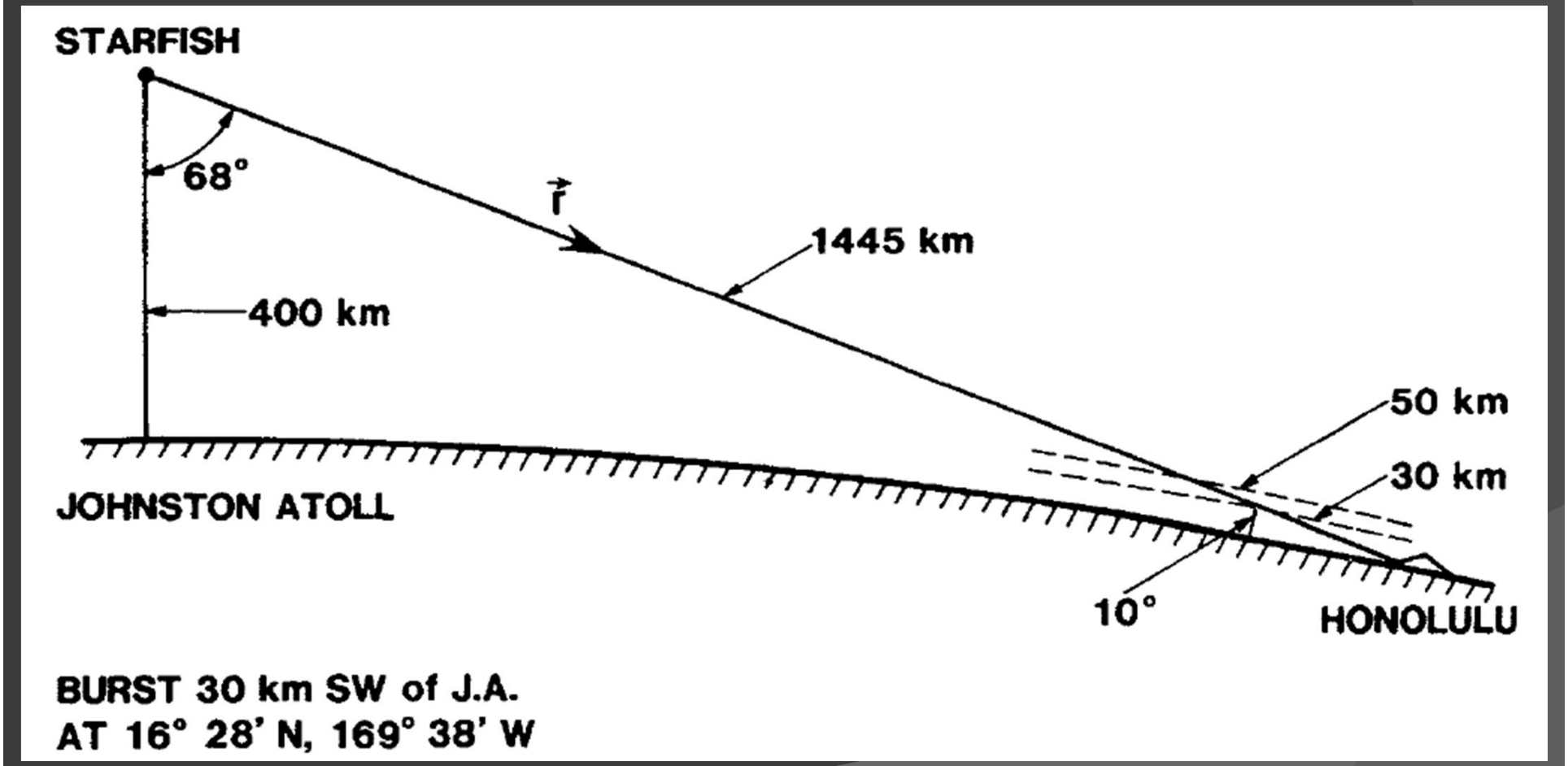
- Worse when ionosphere is least ionized
  - Night-time
  - Solar minimum
    - Least likely to get solar storm though
- Dueling weather conditions
  - Hot summer – grid highly loaded, easily damaged
  - Winter extreme cold – some equipment and protective mechanisms don’t operate as well

EMP Experience

US Starfish Test 1962

- Johnson Atoll
  - Detonation at 400 KM
  - 1.4 megatons yield
- 900 miles West-SouthWest of Hawaii
  - Burgler alarms, air raid sirens came on
  - Street lights toggled
  - Microwave telecom went down
  - HF ionosound transmitter damaged
- Scientists surprised at range of effect

1962 Starfish Test



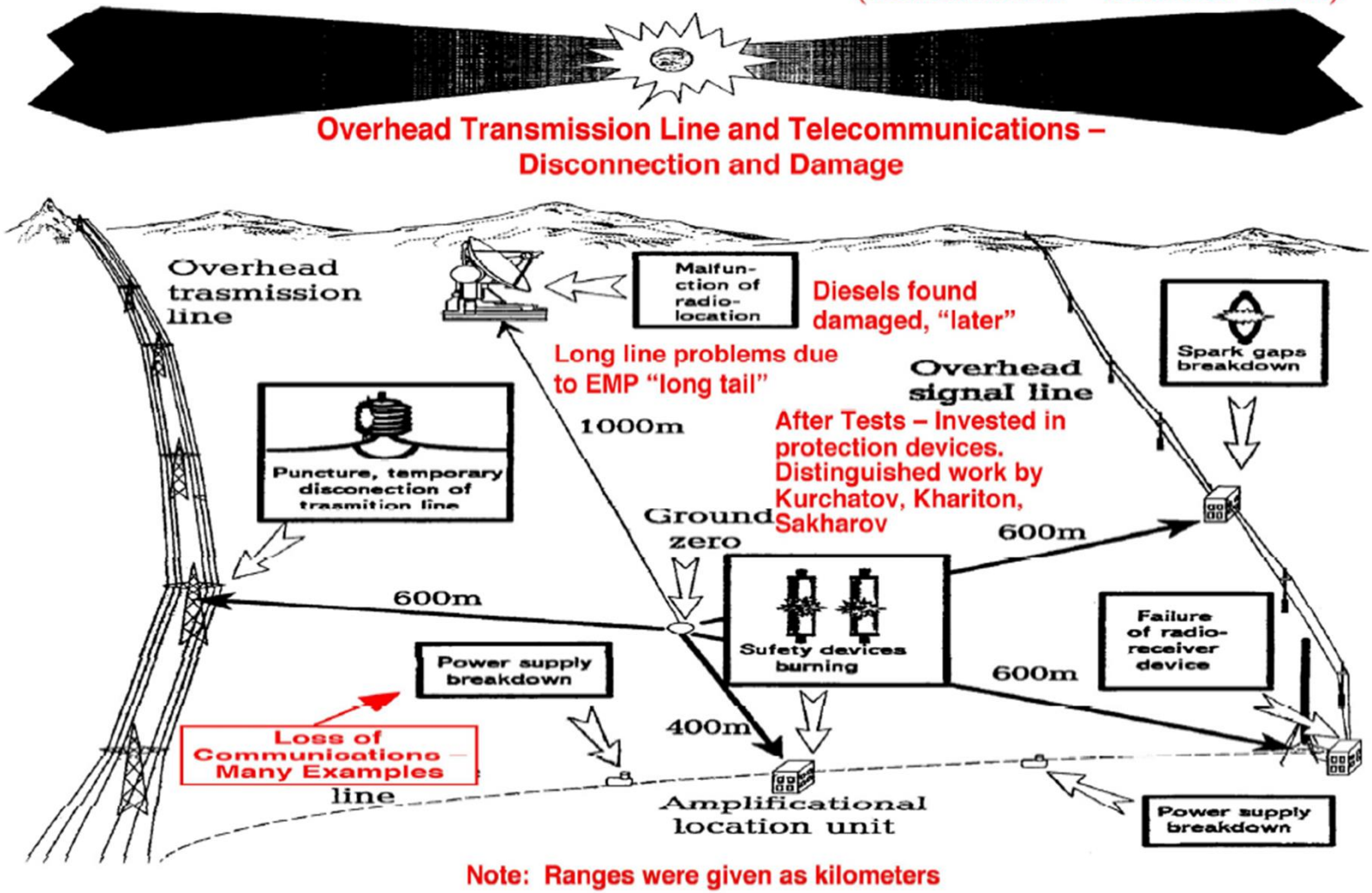
Russia Kazakhstan Test 1962

In 1994, Prof. Vladimir Loborev presented results on failures from the Soviet Union's 1962 high altitude tests. Figure 3-3 shows a slide from that presentation (annotated by William Radasky, based on the oral presentation itself) indicating failures. These included:

1. A long, radially oriented, aboveground communication line failed.
2. A buried communication line more than 600 km away from ground zero failed.
3. Power line insulators were damaged, resulting in a short circuit on the line and some lines detaching from the poles and falling to the ground.
4. Diesel generators failed.
5. Antenna systems were affected.

It was thought that later time HEMP contributed to the failures identified in numbers 1 and 2. The other effects are thought to be caused by E1 HEMP.

HIGH ALTITUDE ELECTROMAGNETIC PULSE EFFECT (Kazakhstan - October 1962)



Note: Red text based on Loborev's spoken words in June 1994 as documented by Radasky

Figure 3-3. Soviet HEMP test experience. This presentation slide summarizes effects from the Soviet high altitude test bursts in 1962, as reported by the Russians. (From: "Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack," Vol. 1, Executive Report, 2004.)

EMP Weapons

- Directed energy weapons
  - High Power Microwaves (HPM)
  - E-bombs
  - Coaxial Flux Compression Generator (CFG)
  - Virtual Cathode Oscillator (vircator)
- Used during invasion of Iraq
- Russia & China have resistant military and significant offensive capability
- North Korea & Iran have significant capability
- ISIS has published Radio Frequency Weapon assembly instructions online

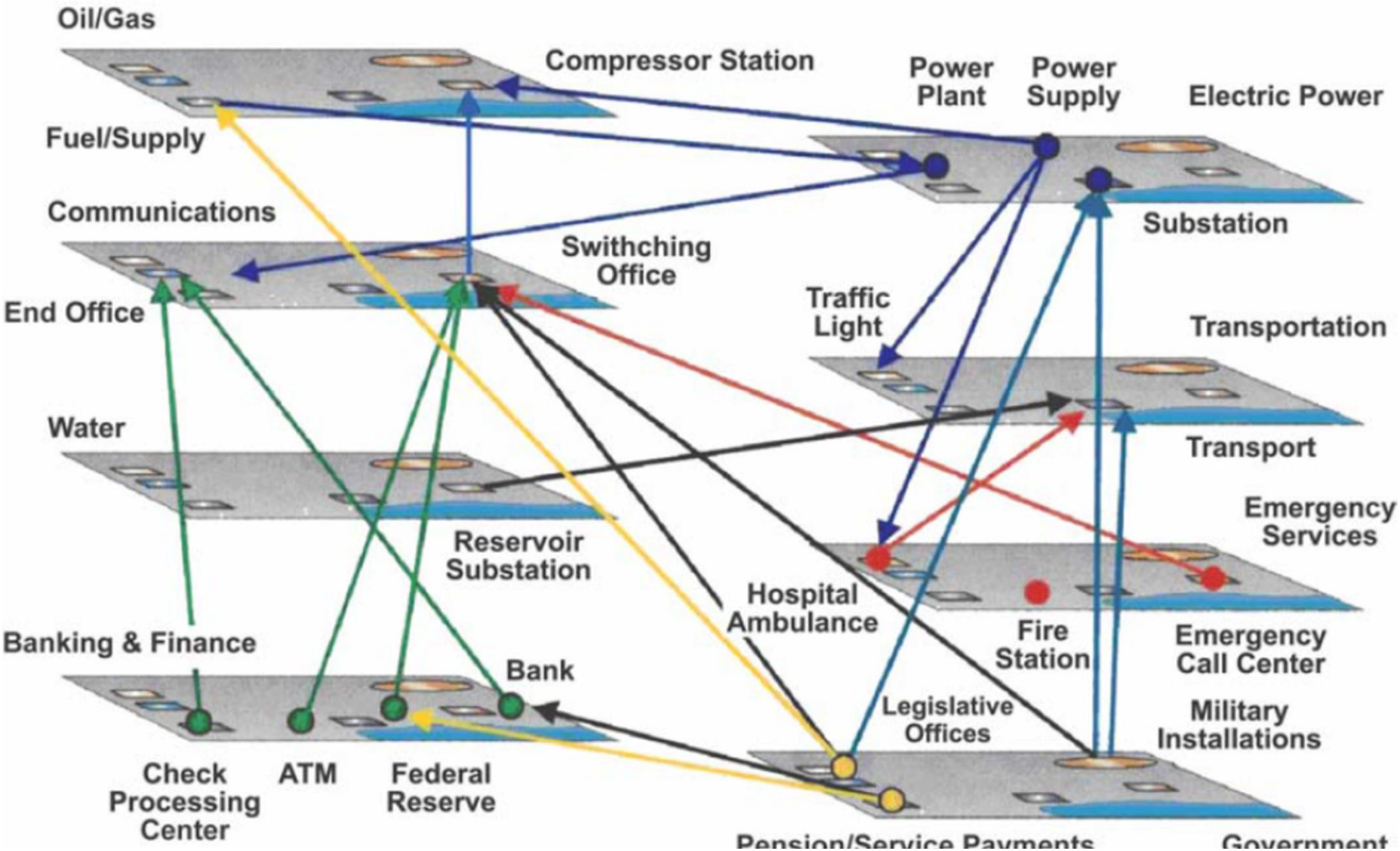
Chapter 1

Infrastructure Dependencies

Critical Infrastructure

- USA sustained by system of systems
  - Complex
  - Dynamic
  - Interlocking
  - Interdependent
  - Electronics Pervasive in all Systems
  - Just in Time Inventory increases fragility
- Electronics susceptible to EMP
- Few qualified operators for manual ops
- No large undamaged area to supply goods and workers to damaged area (disaster model)

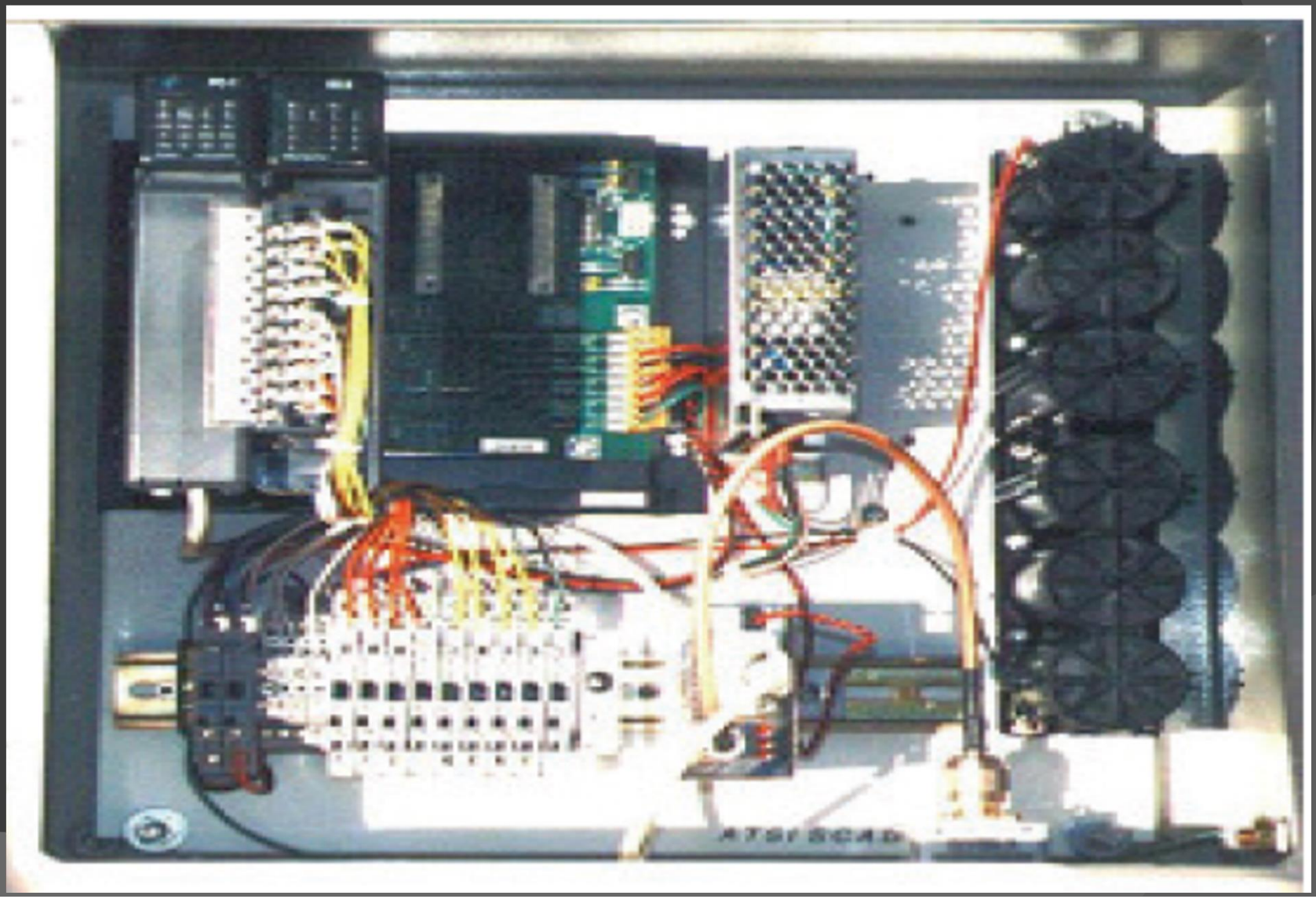
Interdependent Infrastructure



SCADA Systems (weak link)

- Supervisory Control And Data Acquisition
  - Ubiquitous Robots of the Infrastructure
  - Electronic control system - wide geographical area
    - Electric transmission and distribution
    - Water management
    - Gas and oil pipelines
    - Railroad control
    - Telecommunications networks
    - Boiler control
    - Turbine lubrication, speed control, etc
    - Everywhere!
  - Computer controller for system
  - Often in unmanned location
  - Can be disrupted or damaged by EMP
    - Switch wrong pump/valve etc
    - Give false indication – lead operator astray

Typical SCADA



Government EMP Simulator

Electronic Controls in EMP Simulator

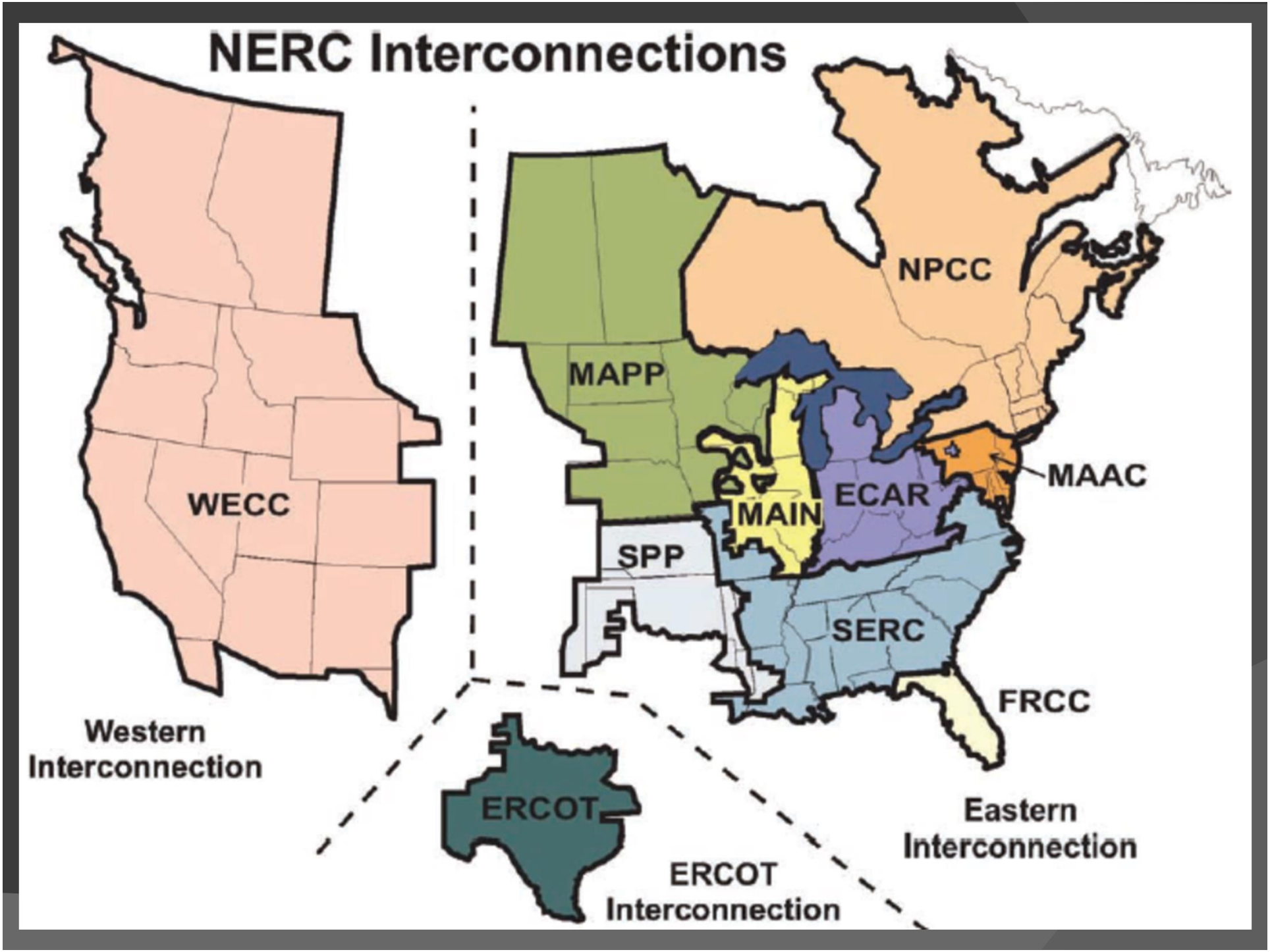
- SCADAs
- Protective Relays
- DCS (Digital Control System – local)
- RTU (Remote Terminal Unit)
- PCs with Ethernet cables of 25/50/100/200 ft
- ALL FAILED!
  - Individual port failures
  - Multiple port failures
  - Loss of system control
  - Incorrect readings
  - Disruption requiring reboot
  - Permanent damage

Chapter 2

Electric Power

Electrical System

- US Critically dependent on electricity
  - Continuous reliable supply at controlled freq
- Most of life's activities stop without it
- Loss for significant period of time is catastrophic
  - Cannot support US Population without it
    - Food, water, transportation, communications, etc
- Enormously complex
  - No storage – turn on light, generator revs up
- Operates near peak capacity
- Highly dependent on other infrastructures
- Most critical & most vulnerable system
- E1 may disable system thru cascading failures
- E3 can physically damage critical components


NERC Interconnections
NPCC
MAPP
MAAC
ECAR
MAIN
SPP
SERC
FRCC
WECC
ERCOT
Western
Interconnection
Eastern
Interconnection
ERCOT
Interconnection

2008 Electric Infrastructure Data

- 3,273 traditional electric utilities
- 1,738 nonutility power producers
- 6,413 power plants
- 30,320 substations
- Transmission lines
  - 203,930 miles of high-voltage AC
  - 6,222 miles of high-voltage DC

Power Plants (6,413)

- Highly complex, electronic controls
- Control system malfunction (E1) is main danger
- Nuke and Natural gas plants probably can't blackstart
- Some plants probably damaged
  - Boiler, turbine, gearing repair has long lead times
  - Loss of generation capacity further complicates system recovery
  - "black-start' required
    - hydroelectric, diesel, small gas plants
- Large Transformers at each plant

Power Transmission System

- Substations (30,320)
  - Substation control systems
    - Complex, electronic (E1)
    - Dependent on comms systems, etc
  - Transformers
    - Protective relays – failed EMP simulator test
  - HV AC Circuit Breakers
    - Only work at natural zero current condition
    - E3 GIC (DC) can exceed AC current – breakers fail
- Line insulators have been destroyed in past
  - Widespread transmission line loss

"The limited availability of [spare] extra-high-voltage transformers in crisis situations presents potential supply chain vulnerability."

- *A Framework for Establishing Critical Infrastructure Resilience Goals, National Infrastructure Advisory Council, 2010*

Table 1: Spare Transformer Magnitude			
HV-LV (Phase to Phase) Voltage Rating	**Capability MVA Rating**	**Approximate Price ($)**	**Approximate Weight & Dimensions**
Transmission Transformer			
Three Phase:			
230-115kV	300	$2,000,000	340,000 lbs 21ft W-27ft L- 25ft H
345-138kV	500	$4,000,000	670,000 lbs 45ft W-25ft L- 30ft H
765-138kV	750	$7,500,000	820,000 lbs 56ft W-40ft L- 45ft H
Single Phase:			
765-345kV	500	$4,500.000	470,000 lbs 40ft W-30 ft L-40ft H
Generator Step-Up Transformer (GSU)			
Three Phase:			
115-13.8kV	75	$1,000,000	220,000 lbs 16ft W-25ft L-20ft H
345-13.8kV	300	$2,500,000	370,000 lbs 21ft W-40ft L-27ft H
Single Phase:			
345-22kV	300	$3,000,000	450,000 lbs 35ft W-20ft L-30ft H
765-26kV	500	$5,000,000	650,000 lbs 33ft W-25ft L-40ft H

GSU Transformer
Transmission Transformer
Transmission Transformer
GSU Transformer
Transmission Transformer

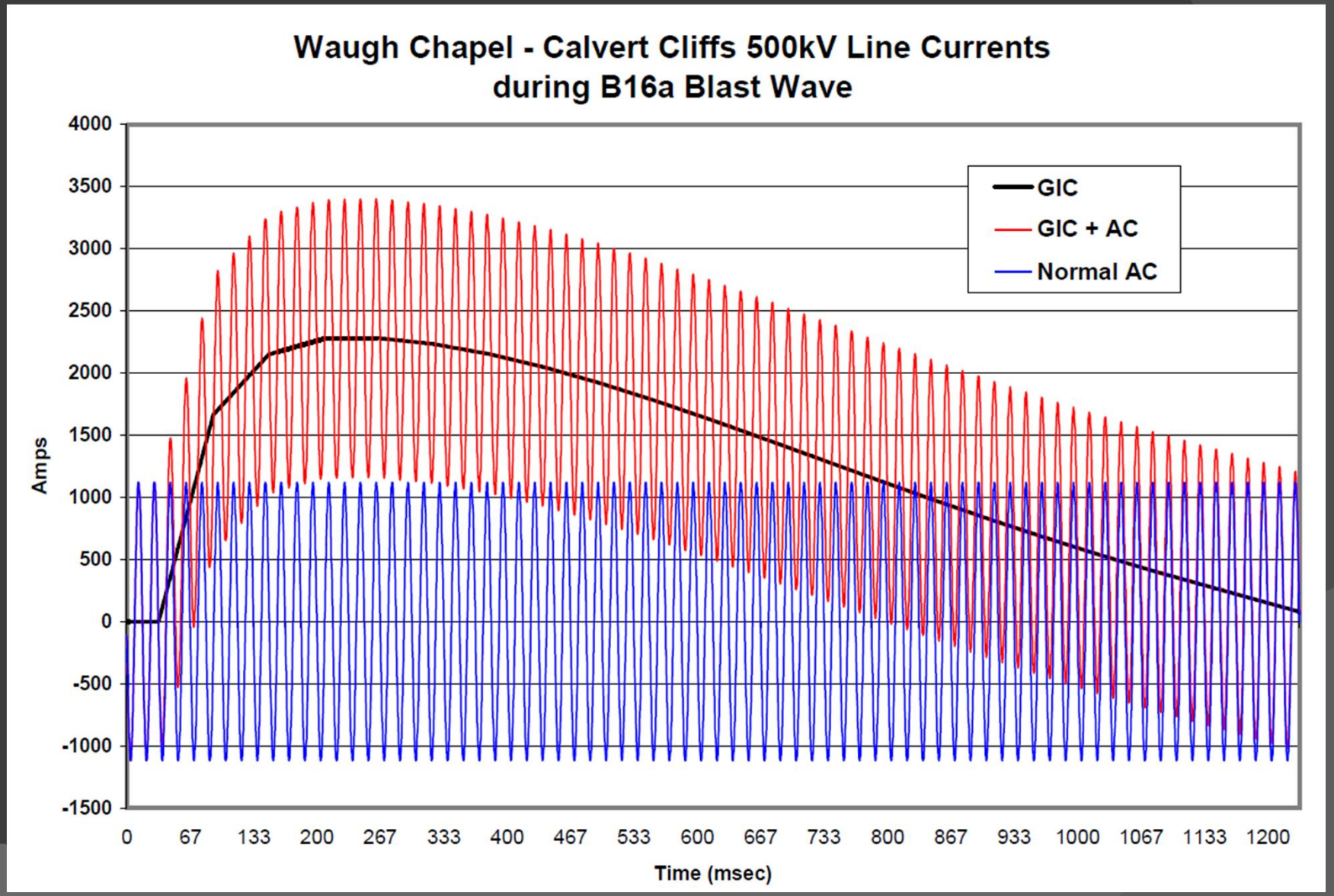
Large Power Transformers (LPT)

- High-value assets
- Average age in USA is 40 years old
- Custom designs - $millions
  - Very limited replacement units
  - Replacement time for single unit – 1-2 years
- Stressed by E3 currents
  - Operating close to capacity – easier to damage
  - Saturated by large quasi-direct current flow
  - Overheating & fires & shorts
  - Solar events with smaller currents have damaged
  - New 3 single phase transformers more susceptible
- LPT failure is catastrophic – cooling oil fire
- Each LPT has HV Circuit Breakers
  - Not designed to interrupt large DC voltages
  - Many are predicted to fail during EMP

HV AC Circuit Breakers

- Safely Operate during natural zero current
- Large GIC DC Currents from E3 may exceed AC Current
  - No zero current state
  - Opening with current is outside design
  - Ceramic breaker failure may provide shrapnel

Example of Non-zero current



Recovery

- Key is speed of Recovery
  - Backup power < 72 hours w/o refueling
  - Cascade of other systems begin to fail
- Historical Outages – speedy Recovery
  - Mostly non-destructive protective shutdowns
    - Highly effective Protective systems (SCADA)
      - Protect Generation and Transmission assets
    - Good communications to coordinate repairs
    - Transportation to unmanned stations available
    - Replacement parts & technicians from unaffected areas
  - Hurricane Sandy
    - Physical damage to small area
    - Long recovery time

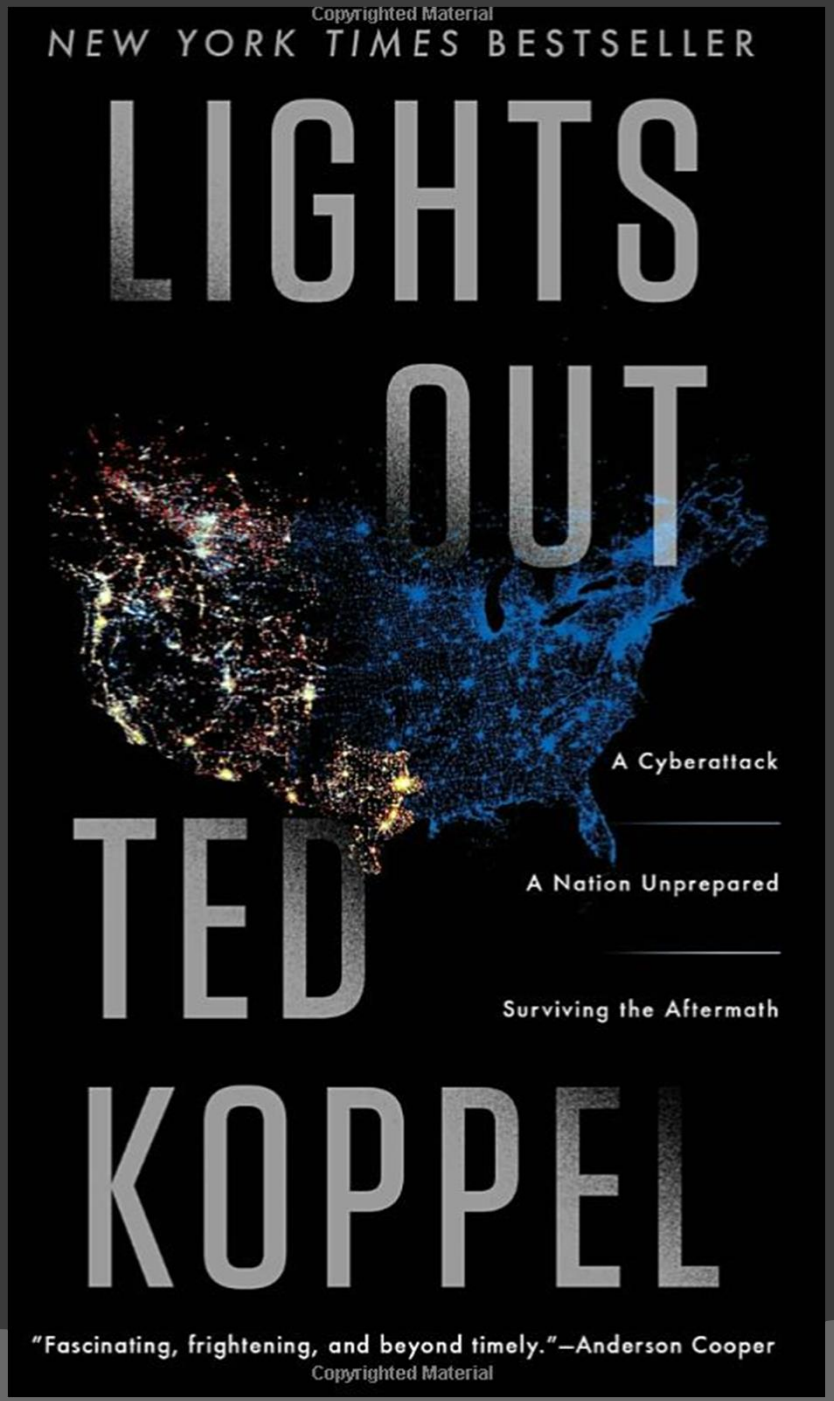
Recovery (cont)

- Recovery from EMP
  - Must avoid damage to high-value assets
    - Transformers & Circuit Breakers
  - More damage due to widespread SCADA malfunctions
  - Electronics reset/replacement required
  - Communications and transportation limited
  - Replacement parts & technicians limited
- Point of No Return
  - Cascading physical/electronic damage to components
    - Long lead time for replacements
    - Infrastructure to support repairs deteriorates
  - Society collapses
    - Massive fatalities (200-300 million)
    - Break-down of law and order
    - TEOTWAWKI - Cue the Zombies!

Commission Conclusions

- At least one NERC region will go down
  - East and/or West +/- Texas
- Very different from past Outages
  - Will exceed 72 hours for power restoration
    - Emergency backups depleted – additional systems down
  - Solar events lower than E3 have damaged system
    - Intact protective and control systems
  - E1 and E2 will damage/disrupt prior to E3
  - E3 larger than previous solar events
  - EMP Simulation showed failure of ethernet connected electronics (PCs)
  - Distribution line insulators found more susceptible than previously thought – widespread physical repairs (P.R.)
  - Electronic Emergency Generators may be damaged
  - Possibly Months of Outage – maybe more than a year
  - TEOTWAWKI - Cue the Zombies!

- Prepare for loss of power grid (solar, etc)



- Cyberattack scenario
- Discusses electric grid weaknesses
- Concludes grid is very vulnerable

Chapter 3

Telecommunications

Telecommunications

- Voice, data, video
- Landlines, cell phones, PC, Internet
- National Communications System (NCS)
  - Government Emergency Telephone System (GETS)
    - National Security/Emergency Preparedness (NS/EP)
    - Priority phone card – pre-authorized
  - Telecommunications Service Priority (TSP)
    - NS/EP priority for new or restored services
  - Wireless Priority Service (WPS)
    - NS/EP priority for cellular service
  - SHARES – Government HF Radio Program

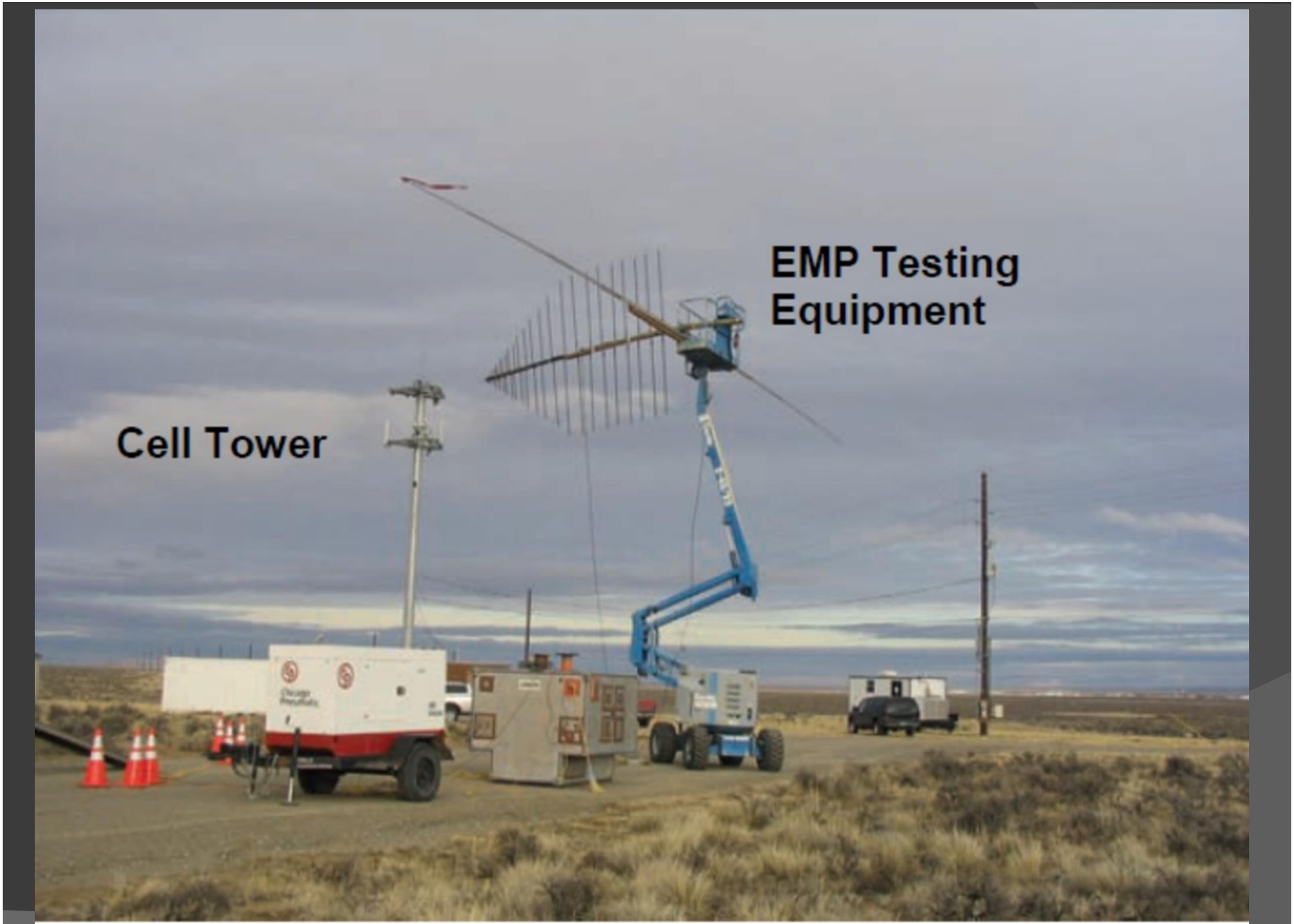


Figure 3-6. Cellular Network Testing at INL

Telecommunications

- Backbone – fiber optic – immune to EMP
- RF/EM Hardening currently in place
- Significant fraction of system disrupted
  - Low E1 amplitude
    - Landlines – minutes or hours to restore
    - Cellphones - hours or days to restore
  - High E1 Amplitude – days to weeks to restore
- Simultaneous Power Outage
  - 72 hours Backup power
  - Additional time would degrade system

Immediate Effect

- Some cellphones functional
  - Cellphones operating at EMP may fail
  - Cellphone towers are not manned
- Most Landlines functional
  - Landline centers are manned – immediate reboot
- High level of call attempts
  - Despite reduced available functioning phones
  - At least 4X normal traffic
  - Network overloaded
  - GETS/WPS are critical

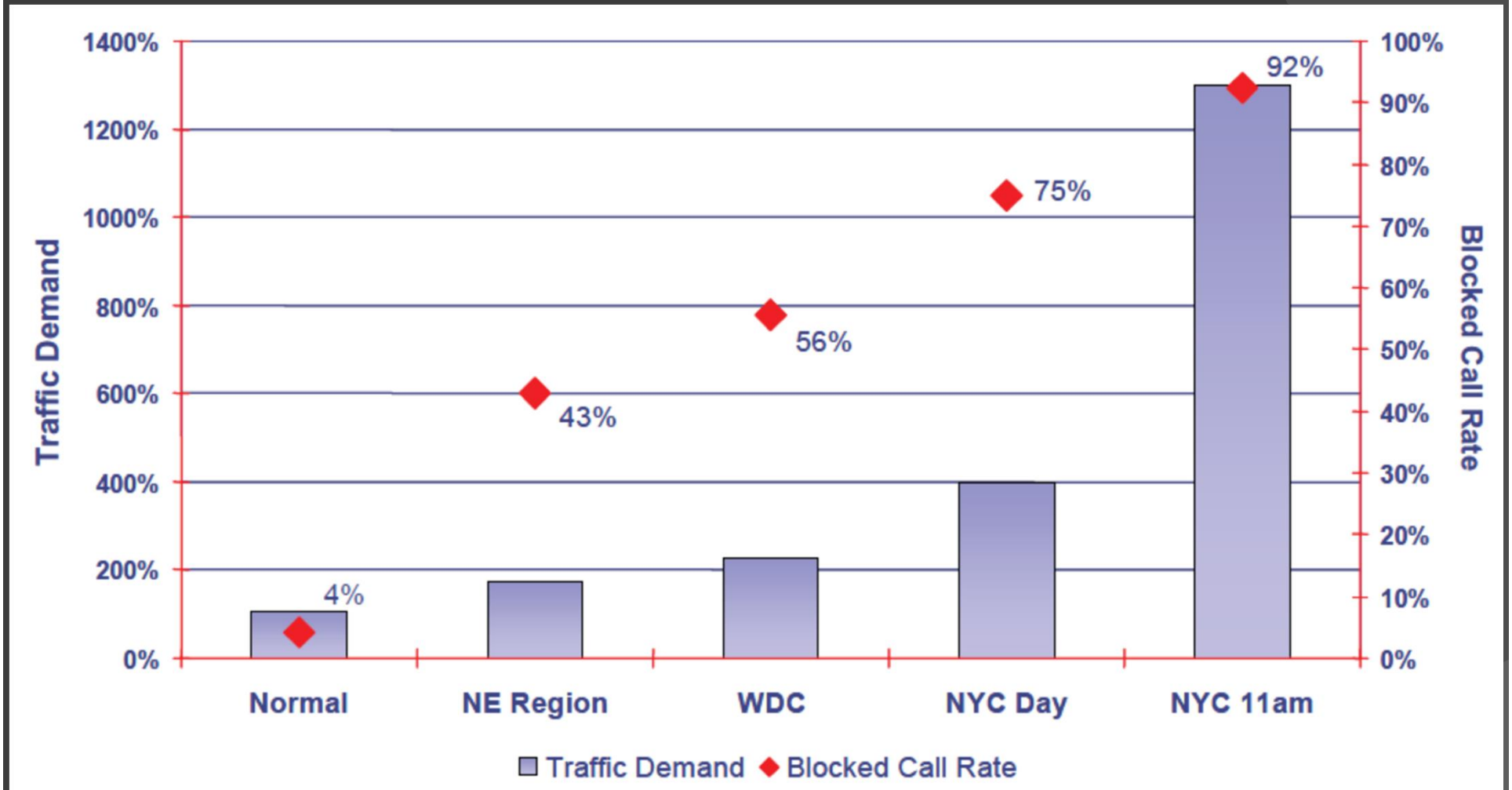


Figure 3-2. September 11, 2001, Blocked Call Rate—Cellular Networks

Reduced Number Of Phones Making Calls

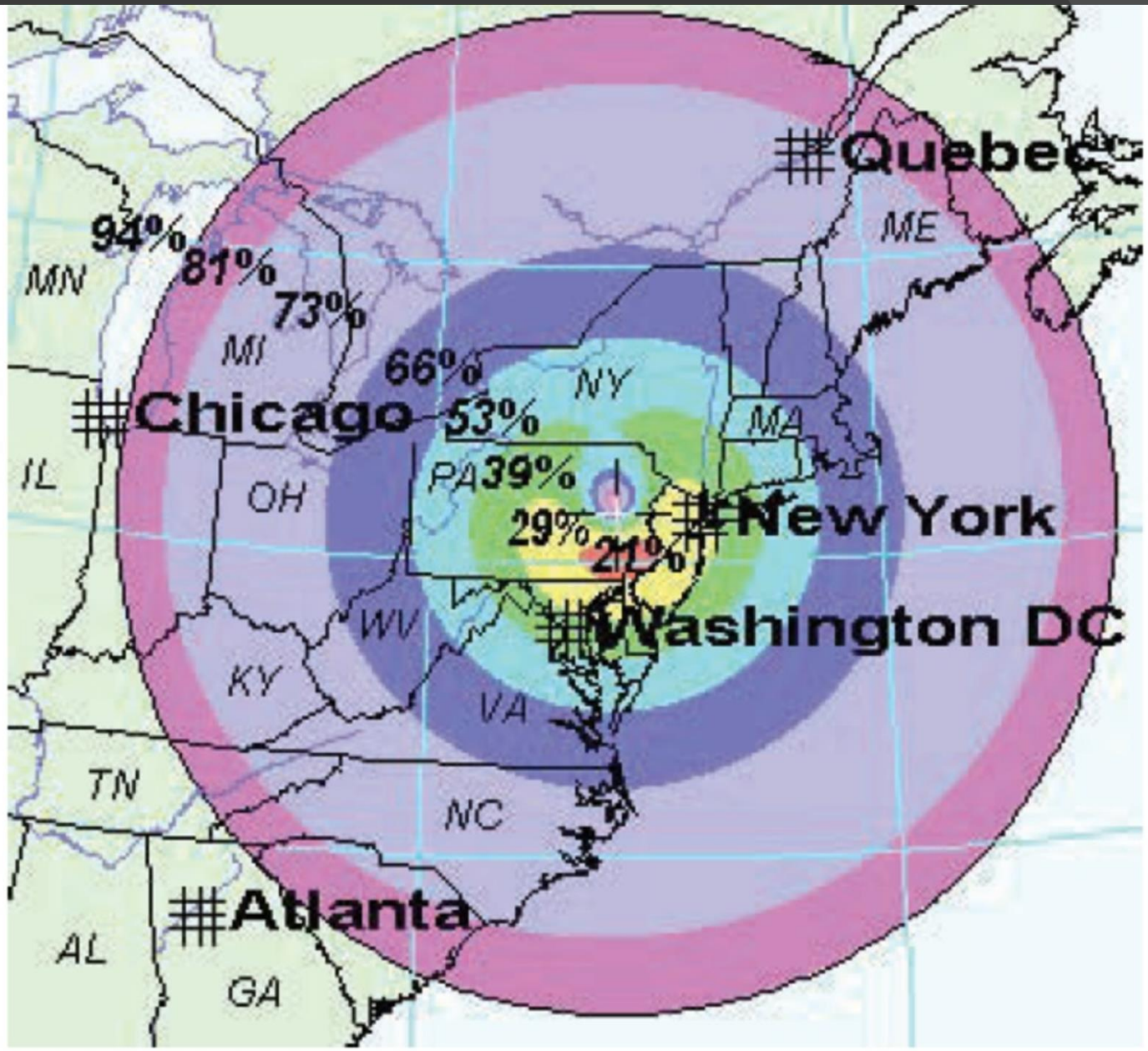


Figure 3-11. Percentage of Calls Completed 2 Days After EMP Event

Conclusions - Telecommunications

- Significant fraction of system disrupted
- Landlines more robust than cell service
  - Can operate off telecom power
- Phones more robust than Electric Power System
- Power outage beyond 72 hours will degrade system

- Keep an active landline

Chapter 5

Petroleum and Natural Gas

Non-Electrical Energy

- 40% of Energy from Petroleum
- 20% of Energy from Natural Gas
- Delivered by National Pipeline System
  - SCADAs throughout system
  - Good communications capability required
  - Many electrical pumps, valves, etc

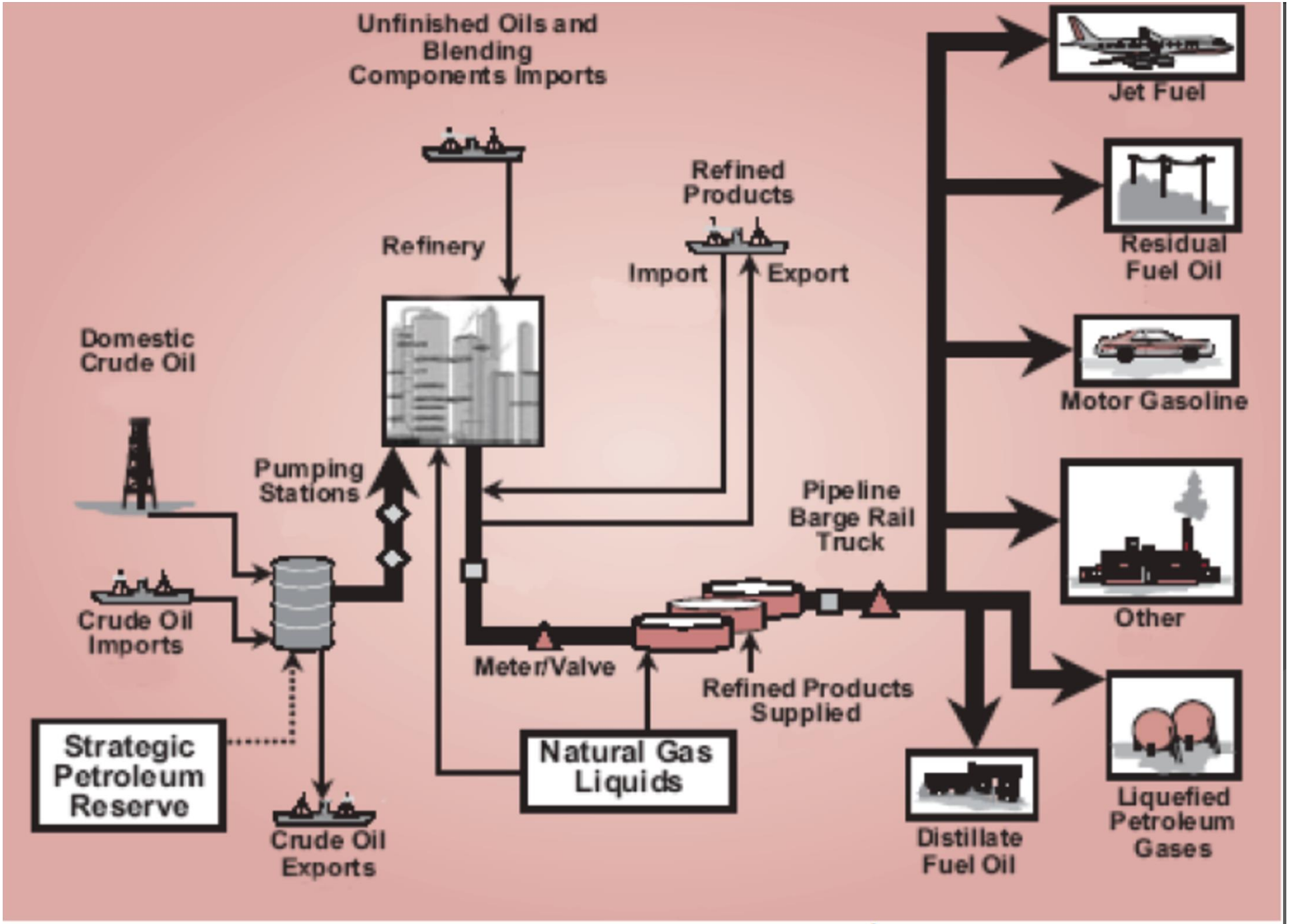


Figure 5-1. Petroleum Infrastructure[3]

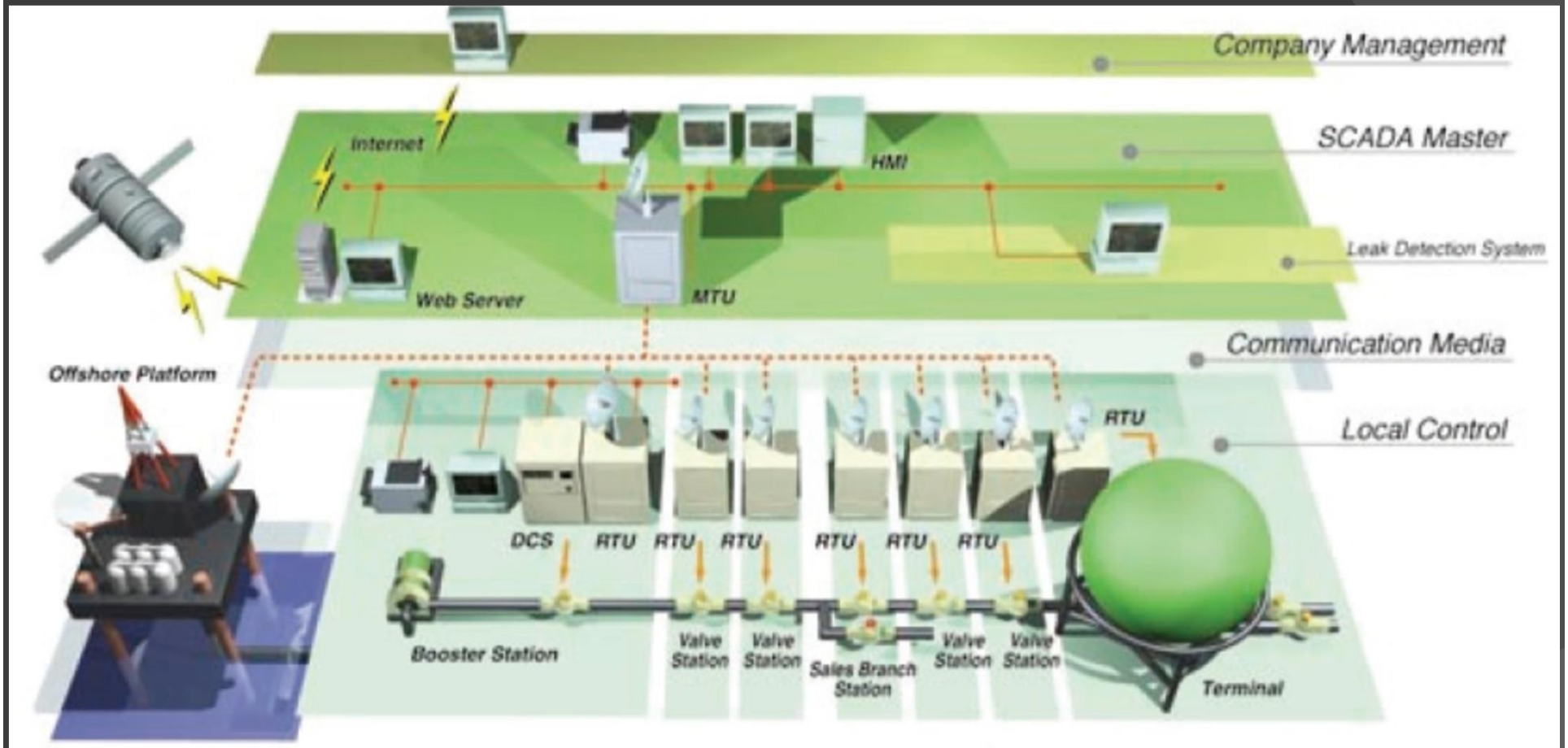


Figure 5-3. Typical SCADA Arrangement for Oil Operations

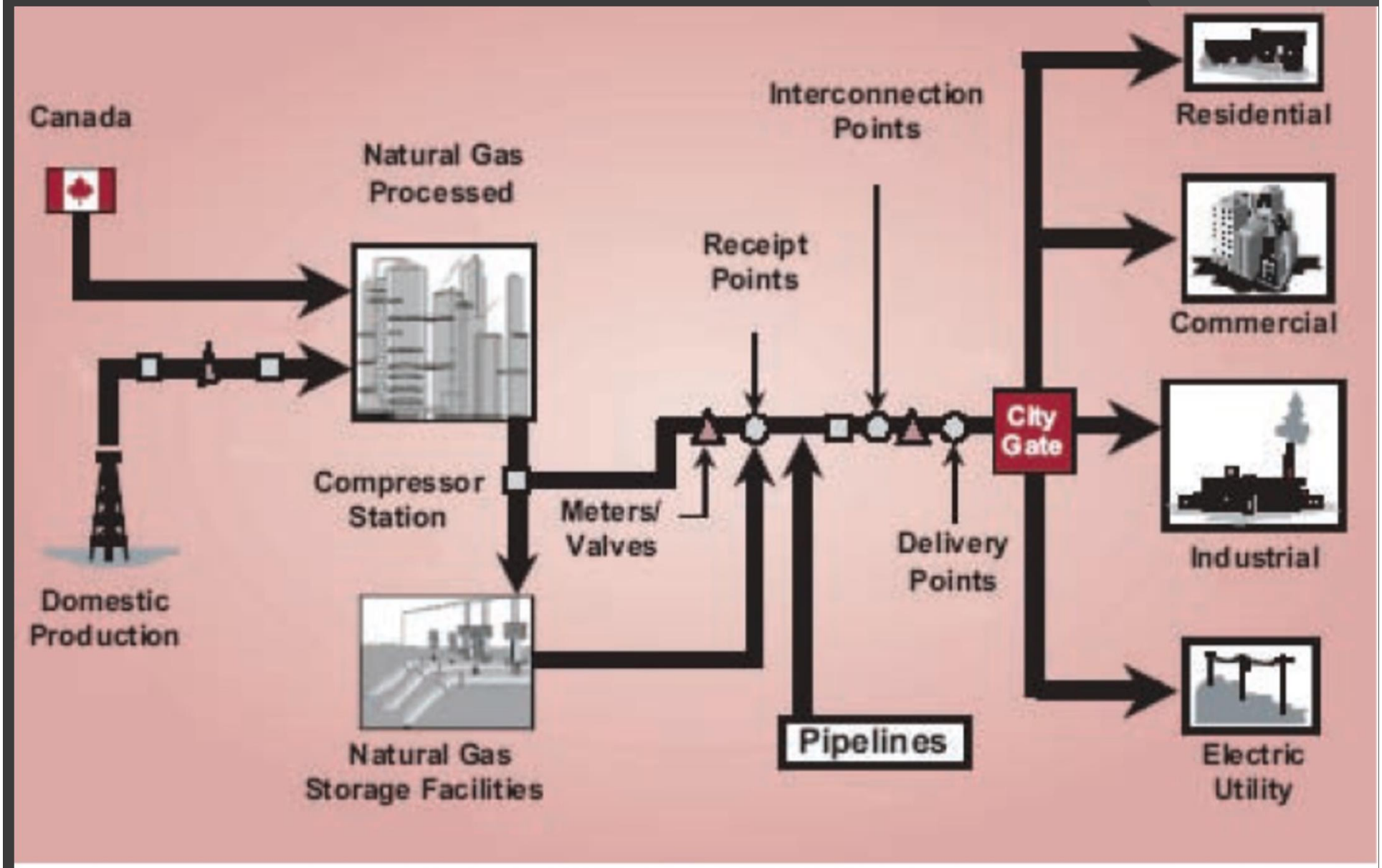


Figure 5-2. Natural Gas Infrastructure

EMP Effects

- Natural Gas Pipeline
  - Reasonably high tolerance to EMP
  - Can be operated manually
  - Underground Storage + Line Pack
  - Would be slow to react to changing demand
- Petroleum Pipeline
  - If control circuits lost, pipeline must be shut down
  - History of catastrophic pipeline disasters
- Both have limited Emergency Power
  - Power Outage more than a few days will severely affect all operations

Chapter 6

Transportation

Transportation

- Road – Passenger & Trucking
  - Personal transportation critical
  - 80% of goods transported by truck
- Rail – Longhaul ~~& Commuter~~
  - Coal is major Freight
  - Power Plants fuel (>1/3 of Electric Power)
  - Plant reserve few days to a month
- ~~Water – Maritime Shipping & Inland Waterways~~
- ~~Air – Commercial and General Aviation~~

Automobile Testing

- 37 Autos – 1986-2002 Model Years
- EMP Simulator – varying intensity
- Cars OFF during exposure – no effect
- Cars ON during exposure
  - 3 cars stalled at high intensity
    - 2 re-started
    - 1 permanently damaged
  - 25 exhibited nuisance (blinking dashboard light)
  - 8 were not affected

Truck Testing

- 18 Trucks – Gas pickups to Diesel 18-wheelers
- 1991 to 2003 Model Years
- Trucks OFF during exposure – no effect
- Trucks ON during exposure
  - 3 trucks stalled at high intensity
    - 2 re-started
    - 1 permanently damaged
  - 10 trucks had minor responses not requiring driver intervention
  - 5 trucks were not affected

Road Transportation Conclusions

- Vehicles not running at EMP are not affected
- Vehicles running at time of EMP
  - 10% of cars/15% of trucks may be seriously affected by EMP – stall, but most will re-start
  - 2/3 of cars/70% of trucks will exhibit nuisance behavior which will distract the drivers
  - Crashes triggered by these factors will:
    - Damage many more vehicles than the EMP
    - Produce multiple injuries and deaths
- Major traffic congestion in urban areas
  - Traffic lights will be disrupted
  - High effect of disabled and crashed vehicles
- Fuel and Power will be critical factors

LongHaul Rail

- Railroad Control Centers
  - Centralized Control Centers
  - Highly Computerized
  - High susceptability to EMP
  - Highly dependent on landline communications
  - Some satellite backup capability
  - Substantial hardening for Terrorist scenario
    - Standby Diesel generators
    - Food and fuel for 30 days
    - Beds for 50 people
    - Onsite wells
  - Backup locations geographically dispersed
  - Loss of all sites would revert to manual control
    - Substantial capability degradation

Locomotives

- No direct test data
- Older generation (20% in 2004)
  - Immune to EMP
  - Loss of comms will force train to stop
- Modern, electronic units
  - Malfunctions will bring train to stop
  - Manual emergency brake system
  - Potential permanent damage

Railroad Signal Control

- Block Controls
  - Assure next section (block) of track is clear
  - Radio and phone connects to Control Center
  - 24 hour Emergency Power
- Local Controls
  - Gate controls
  - Autonomous operation
- Both types of controls:
  - Malfunctions at very low EMP levels
  - Permanent damage at moderate levels

Longhaul Rail Conclusions

- Short term all traffic will stop safely
- Degraded manual operation may be possible
- Coal delivery to power plants is priority

Chapter 7

Food

Food

- Relies critically on Electric Power
  - Agriculture requires large amounts of water
  - Egg/poultry farms high density with climate control
  - Clean, pack, canning of produce using electricity
  - Butchering, cleaning, processing meat is automated
  - Refrigerated storage
  - Farm machinery is electronically controlled
  - Dependence on communications, transport, etc

Food Supply

- Supermarkets – 1-3 days of food for area
- Regional Warehouses
  - Large amounts of food – 1 month
  - Trend towards more “just in time” inventory
  - Perishable food in power outage
  - Distribution is chokepoint

Effects of Food Deprivation

- A few days
  - Greatly reduced capacity
- 4-5 days
  - Impaired judgment
  - Difficulty with simple intellectual tasks
- 2 weeks
  - Virtually incapacitated
- 1-2 months
  - Death
- In home food storage is vital

Food Conclusions

- Food shortages as soon as 24 hours
- Government may not supply sufficient food for a protracted period of time
- Local famines due to distribution bottlenecks

Store Food!

Chapter 8

Water

Water

- Water requires Electricity
  - Gravity fed systems are negligible
  - Purification and delivery of water
  - Removal and treatment of wastewater
- Death in 3-4 days without water
- Local water supplies rapidly exhausted
- Drinking surface water – serious illness
- Government cannot supply enough water to population to sustain life

- Store water and water purification

Chapter 9

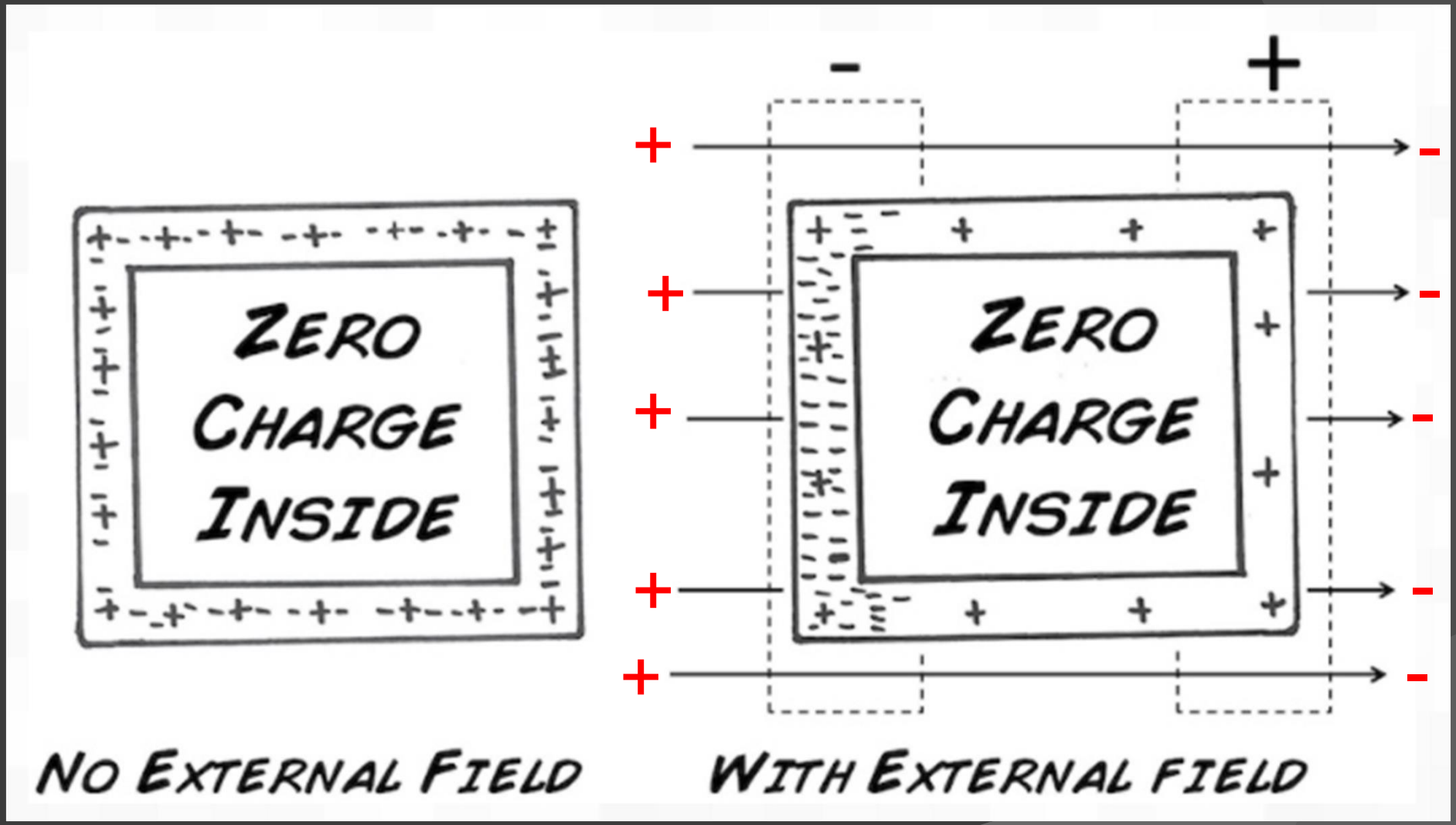
Emergency Services

Commercial Radios

- A variety of mobile radios were tested in the stored, dormant, and operating states, in both handheld and vehicle-mounted configurations.
- Consistent with older test data, none of the radios showed any damage
- While many of the operating radios experienced latching upsets, these were correctable by turning power off and then on

Prevention
or
Faraday, Smaraday

Faraday Cage

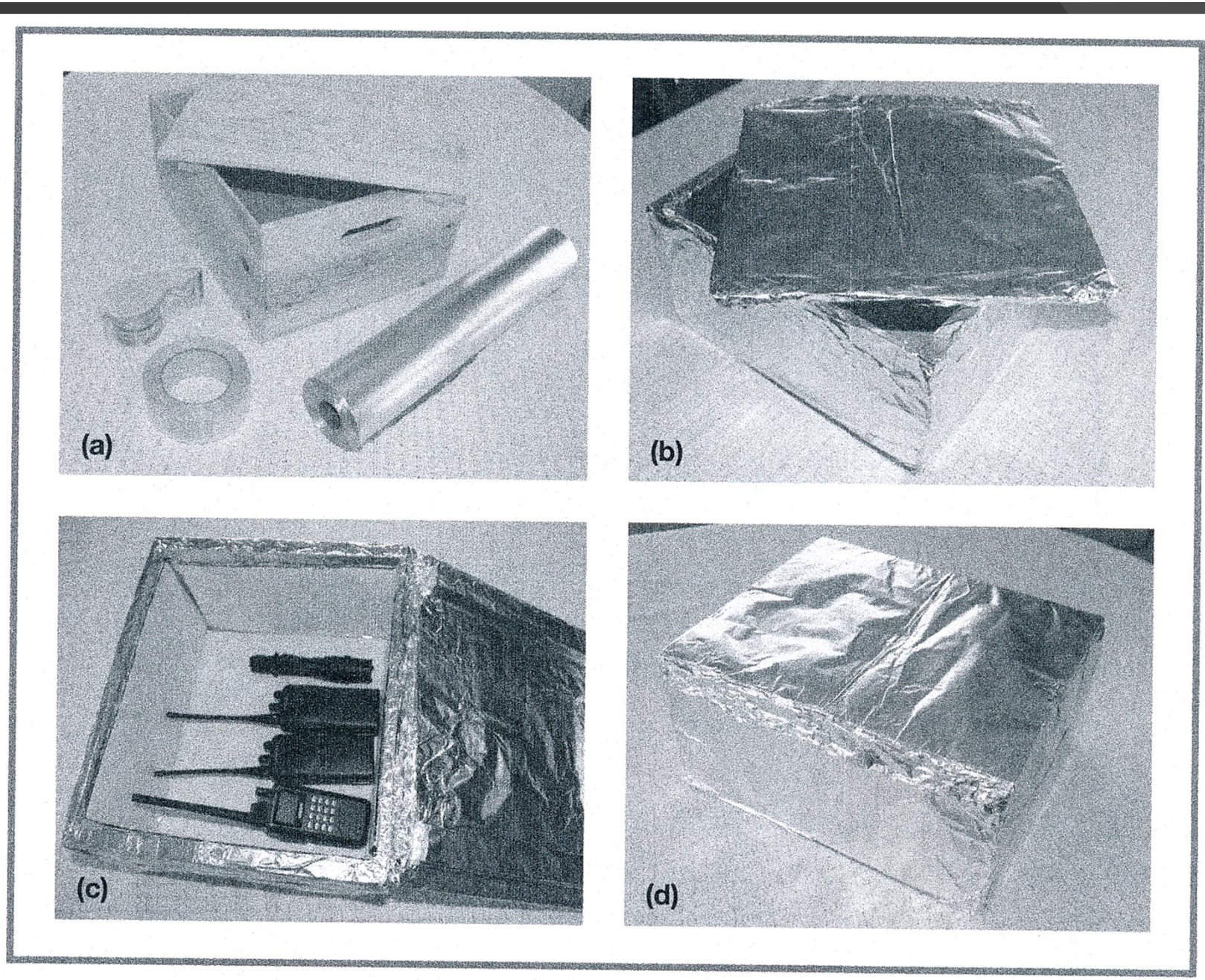


Faraday Testing

Arthur T. Bradley, Ph.D.

- Aim for 50 db Attenuation 100 Hz to 1 GHz
  - 50 kV/m to 150 V/m - survivable
- Items Tested:
  1. Fire Safe
  2. Electrostatic Bag
  3. Large Military Ammo Bag
  4. Microwave Oven
  5. Foil-wrapped box
  6. Metal compost can (garbage can with ½” holes)
  7. Metal garbage can (no holes)

First Alert



Building a homemade Faraday cage: (a) gather tape, box, and aluminum foil, (b) cover box and lid completely with foil, (c) line box with cardboard and store items, and (d) close Faraday cage

Level 50 Shield??

Table 4-9: Shielding Effectiveness of Various Enclosures (dB)

Frequency	Fire Safe	Static Bag*	Ammo Can	Microwave Oven	Foil Box	Compost Can	Garbage Can	Taped Garbage Can	Taped Garbage Can with Static Bag
100 kHz	35	40	>50	>50	>50	>50	>50	>50	>50
500 kHz	39	37	>50	>50	>50	>50	>50	>50	>50
1 MHz	37	41	>50	>50	>50	>50	>50	>50	>50
5 MHz	32	22	>50	>50	>50	>50	>50	>50	>50
10 MHz	22	19	>50	>50	>50	>50	>50	>50	>50
50 MHz	23	22	41	48	>50	>50	>50	>50	>50
100 MHz	23	15	26	34	>50	>50	>50	>50	>50
250 MHz	16	17	21	24	>50	>50	>50	>50	>50
500 MHz	15	18	38	45	21	40	20	41	>50
1 GHz	6	18	28	9	19	13	21	33	>50

Note: Additional static bags tested and compared later.

A Bag By Any Other Name!

Table 4-10: Details of Static Bags Tested

Specifications	Bag #1	Bag #2	Bag #3
Vendor	ULINE	3M	3M
Closure Method	ZipTop	Fold and Tape	Fold and Tape
Part Number	S-7654	Dri-Shield 2000	Dri-shield 3400
Compliance	ANSI/ESD EIA S541 MIL-STD-3010 4046 ANSI/ESD S20.20 EIA 625	MIL-PRF-81705D Type 1 MIL-B-81705C Type 1 MIL-PRF-131	MIL-PRF-81705D Type 1 MIL-B-81705C Type 1 MIL-PRF-131

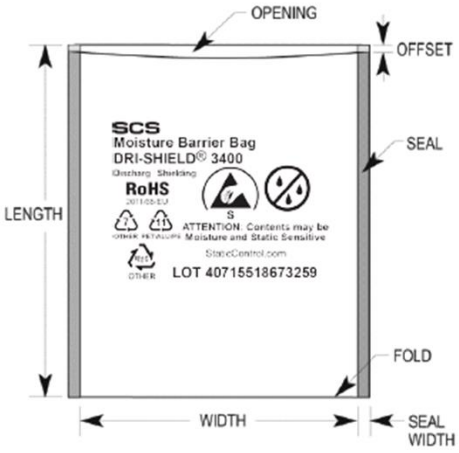
Table 4-11: Comparison of Shielding Effectiveness of Static Bags

Frequency	Bag #1	Bag #2	Bag #3
100 kHz	40	>50	>50
500 kHz	37	>50	>50
1 MHz	41	>50	>50
5 MHz	22	>50	>50
10 MHz	19	>50	>50
50 MHz	22	32	>50
100 MHz	15	41	>50
250 MHz	17	40	>50
500 MHz	18	32	49
1 GHz	18	44	48

Moisture Barrier Bag Dri-Shield® 3400

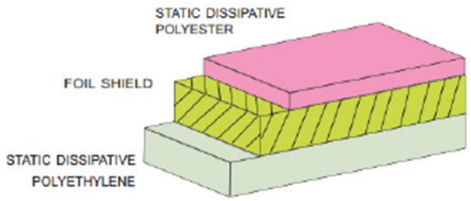
This foil moisture barrier bag is designed to provide protection for ESD sensitive and moisture sensitive electronics, typically SMT (Surface Mount Technology) items. Best practice is to use with Desiccant and a Humidity Indicator Card. The bags are heat sealable and suitable for vacuum packaging. Bags are printed with ESD protective and moisture sensitive warning symbols, and a lot code for traceability.

SCS Moisture Barrier Bags Dri-Shield® 3400 are manufactured from a laminate of polyester, foil, and polyethylene. The metal layer is intended to provide discharge shielding and to minimize the penetration of electric fields and electrostatic discharges.



Tolerance: Width -0, +1/4"
Length +/- 1/8" Offset 0 to 1/4"
Seal width 3/8" with a tolerance of +/- 1/8"

Note: Standard bag markings shown above are not to scale.



SCS Moisture Barrier Bags are packaged in a polyethylene bag.

RoHS 3, REACH, and Conflict Minerals Statement
None of the RoHS 3 restricted materials or REACH substances of very high concern as of 2017/07/07, or Conflict Minerals are intentionally added in manufacturing this product. Ref: European Union Directive 2011/65/EU and Regulation (EC) No. 1907/2006/CE.
See SCS Warranty, Limitation of Liability and Remedies

Meets ANSI/ESD S20.20, Packaging standard ANSI/ESD S541, Static Control Bag ANSI/ESD S11.4 Level 1, and IPC/JEDEC J-STD-033.

Physical	Typical Value	Testing Method
Moisture Vapor Transmission Rate (MVTR)	≤ 0.0003 grams/100 sq. in./24 hrs ≤ 0.002 grams/100 sq. in./24 hrs	ASTM F1249 ASTM F392 condition E and ASTM F2149
Tensile Strength	6000 PSI, 41 MPa	ASTM D882
Puncture Resistance	20 lbs, 88 N	MIL-STD-3010 Method 2065
Seal Strength	15 lbs, 66 N	ASTM D882
Thickness	4 mils, 0.1016 mm +/-10%	MIL-STD-3010 Method 1003
Marking Adhesion	Pass	IPC-TM-650 2.4.1
Electrical	**Typical Value**	**Testing Method**
ESD Shielding	<10 nJ	ANSI/ESD STM11.31
Surface Resistance - Interior	1×10^4 to $< 1 \times 10^{11}$ ohms	ANSI/ESD STM11.11
Surface Resistance - Exterior	1×10^4 to $< 1 \times 10^{11}$ ohms	ANSI/ESD STM11.11
EMI Attenuation	45 dB	1 to 10 GHz
Cleanliness	**Typical Value**	**Testing Method**
Silicone	Not Detected	FTIR
Heat Sealing Conditions	**Typical Value**	
Temperature	400°F, 204°C	
Time	0.6 – 4.5 seconds	
Pressure	30 – 70 PSI, 206 – 482 KPa	

Bag is free of amines, silicones and heavy metals.

This product is intended for commercial use only. This product is not on the Qualified Product Listing under the Defense Standardization Program.

NOTE: The complete dry package concept of packaging for electronics requires three elements:

Moisture Barrier Bags - To Protect

Desiccants - To Absorb Moisture

Humidity Indicator Cards - To Monitor Performance

Made in the United States of America with Globally Sourced Materials.

Specifications and procedures subject to change without notice.

DRI-SHIELD® 3400 MOISTURE BARRIER BAG

926 JR Industrial Drive, Sanford, NC 27332
WEB SITE: StaticControl.com
PHONE (919) 718-0000

DRAWING NUMBER	DATE
Dri-Shield® 3400	October 2017

CONCLUSIONS

EMP
EVERYONE MOSTLY PHUCKED

Dennis Conklin, AI8P

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