Lightning Protection for Radio Operators

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Myth: Object must be grounded to be hit by lightning

Myth: Lightning always goes from cloud to ground

Myth: Lightning always hits tallest object

Myth: Lightning rods always collect the strike

Myth: Lightning seeks center of earth

(Note radial distribution of current and step/touch dangers)

Myth: Lightning never strikes same place twice

Lightning Facts*

- Globally over 2,000 thunderstorms in progress at any given moment
- Globally over 100 cloud to ground flashes every second
- In U.S. lightning property losses exceed $5 Billion / year
- 5% of all insurance claims (over $1 Billion / year) are caused by lightning
- Over 30% of all lightning insurance claims are fraudulent
- 30% of all power outages (over $1 Billion / year) are caused by lightning
- Over 100,000 PC's a year are destroyed by lightning

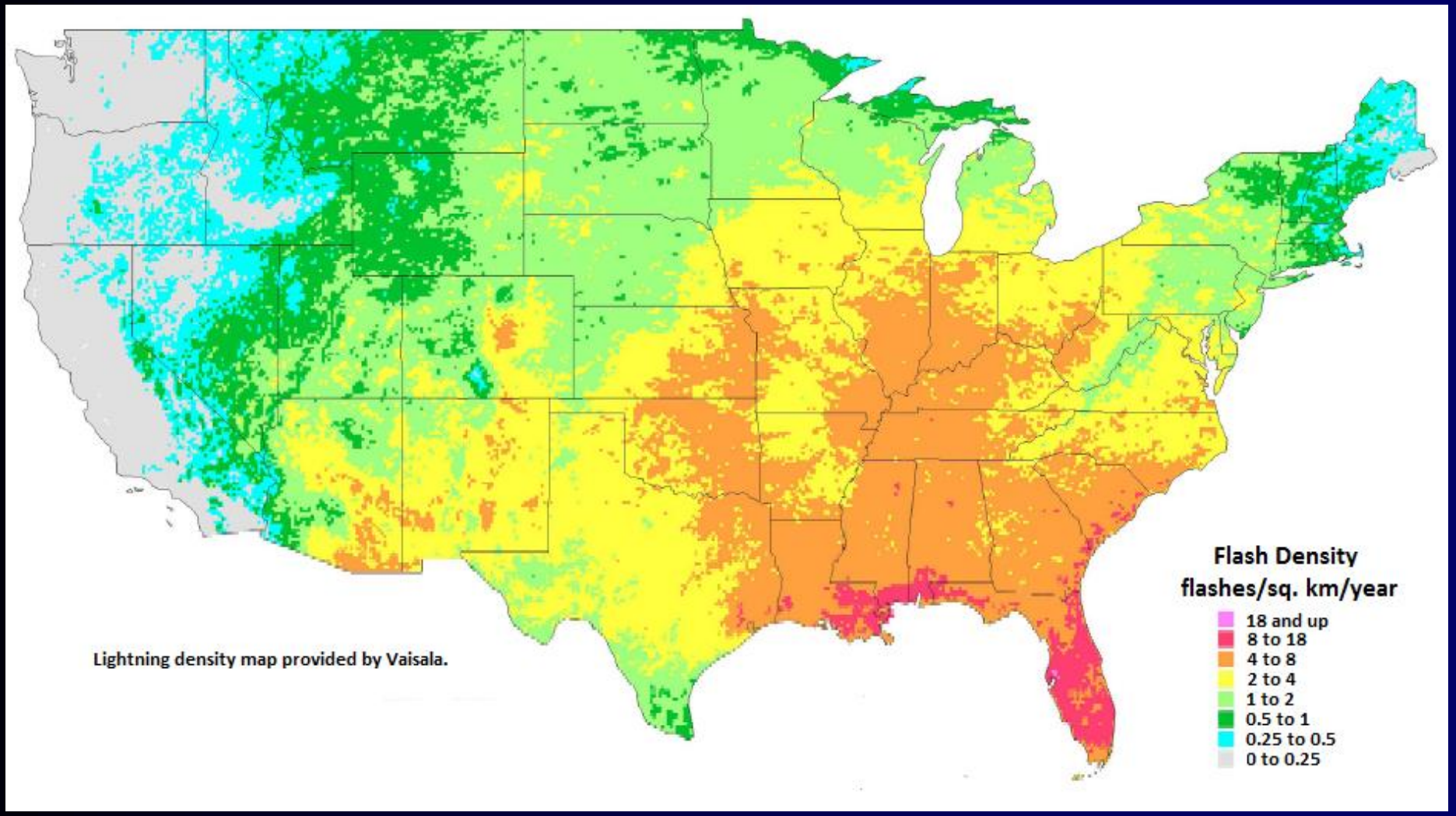
* Source: National Oceanic & Atmospheric Administration (NOAA)

• The Lightning Threat

- **15% increase in lightning-related losses from 2009 to 2010 – Lloyds & Insurance Information Institute, 2011**
- **In 2008 the cost of lightning damage and related losses exceeded $5 billion - National Lightning Safety Institute, 2009**
- **By 2040s-2060s, weather damage in the UK during a "normal" year, is likely to be double that of current years - *Association of British Insurers, 2007***

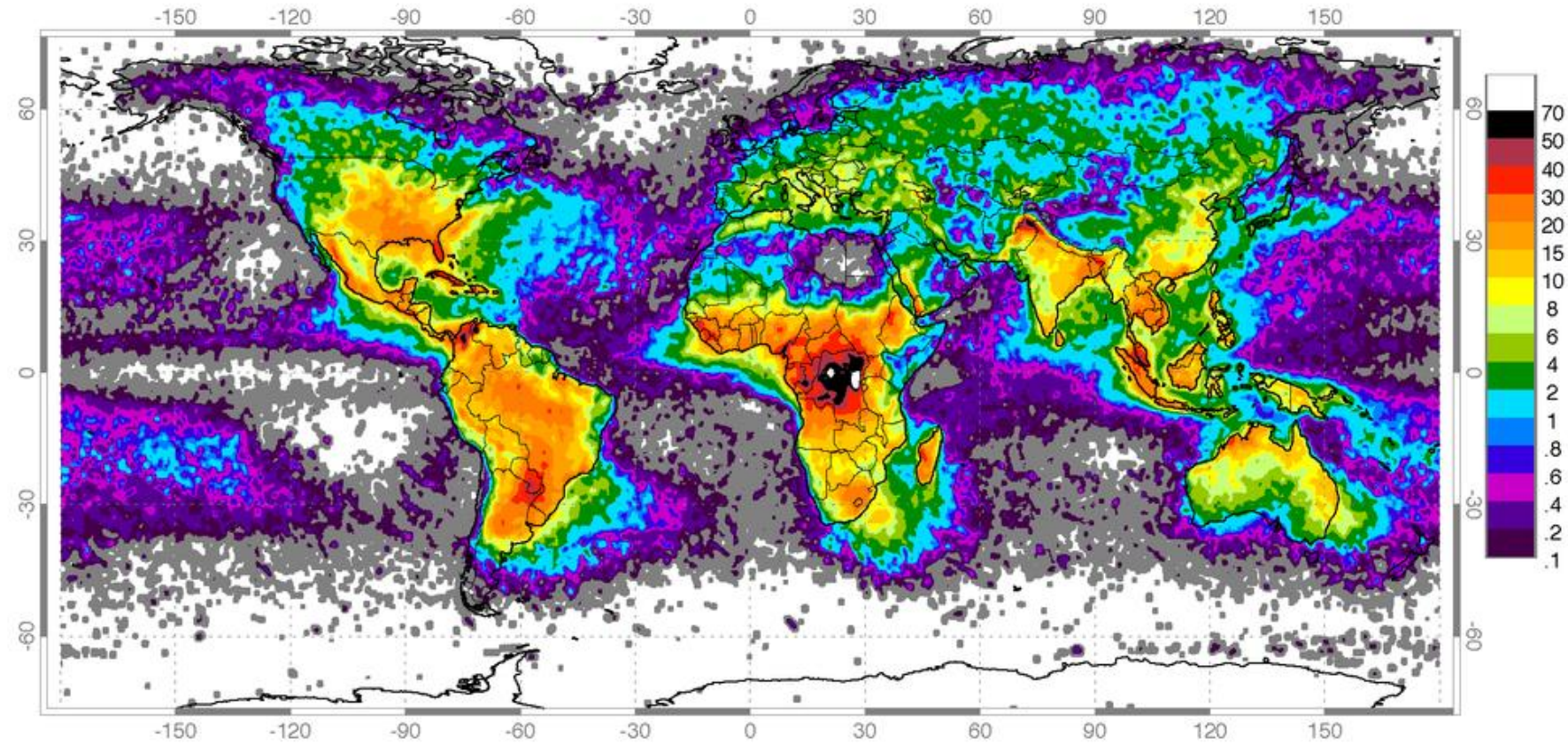
• Lightning Risk

- **Lightning strikes can not be predicted exactly but risk can be calculated broadly**
  - **Geographic location**
  - **Height of structure**
  - **Geometry of structure**



* Notes

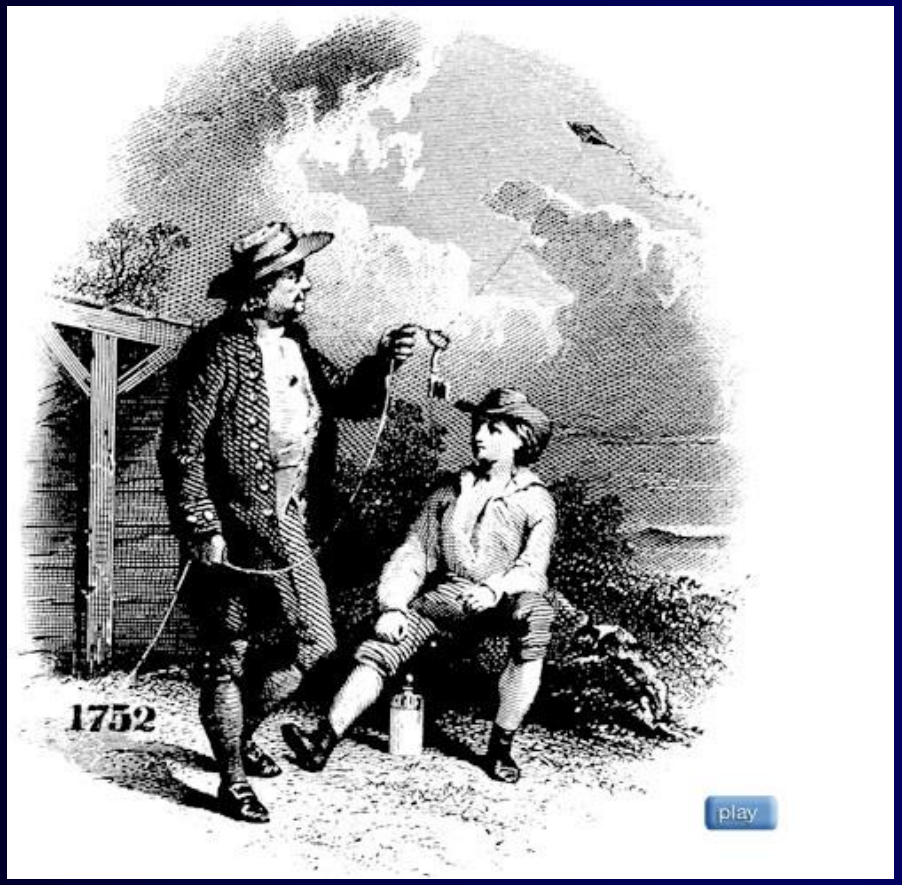
To convert flashes per square kilometer to flashes per square mile, multiply by 2.59.
A lightning flash is defined as a complete lightning discharge.
A lightning flash may contain up to 30 individual lightning strikes, with the average being 4.
To convert flashes per square kilometer to strikes per square mile, multiply by 10.4.



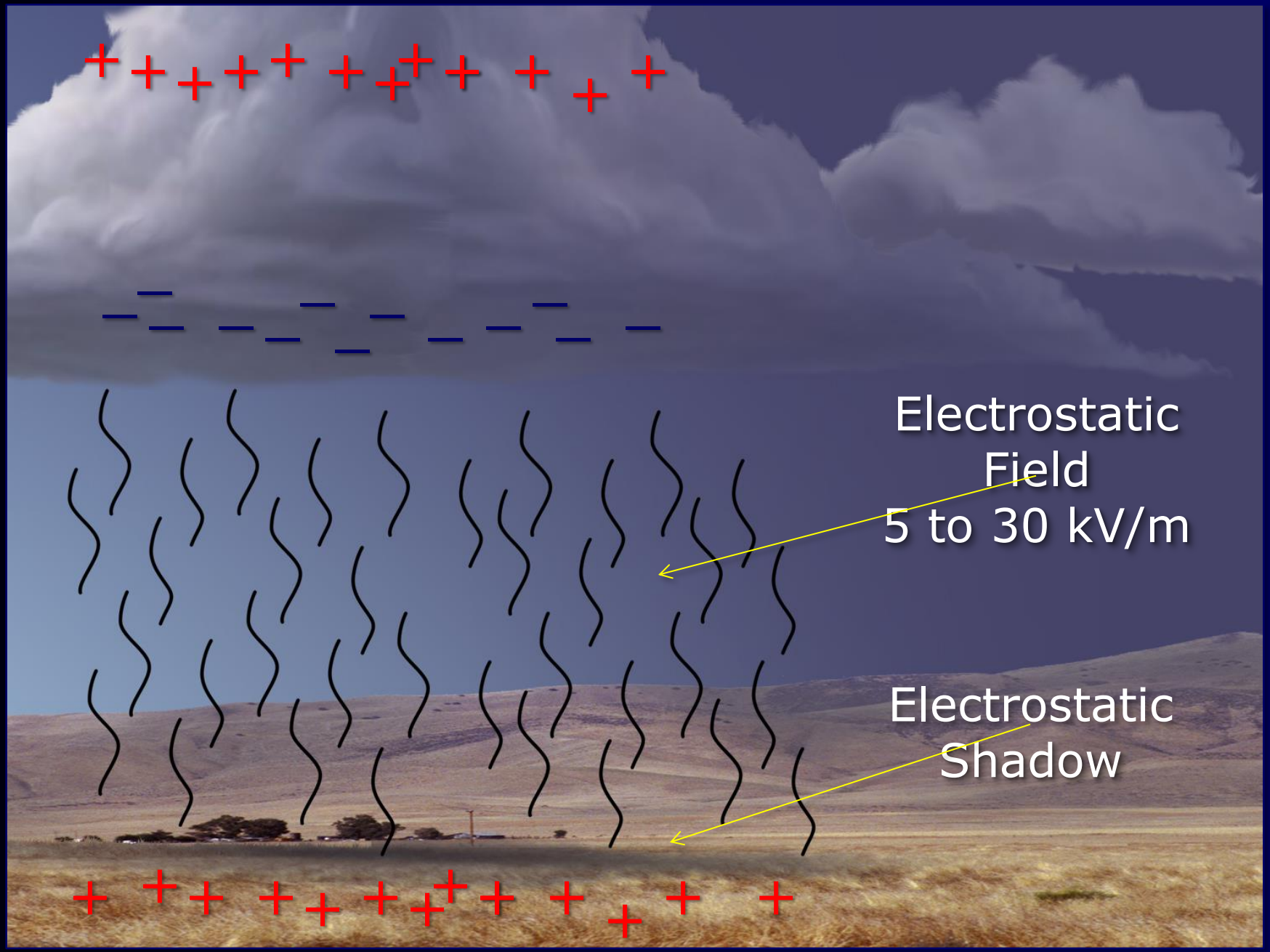
Units are flashes/sq km/year

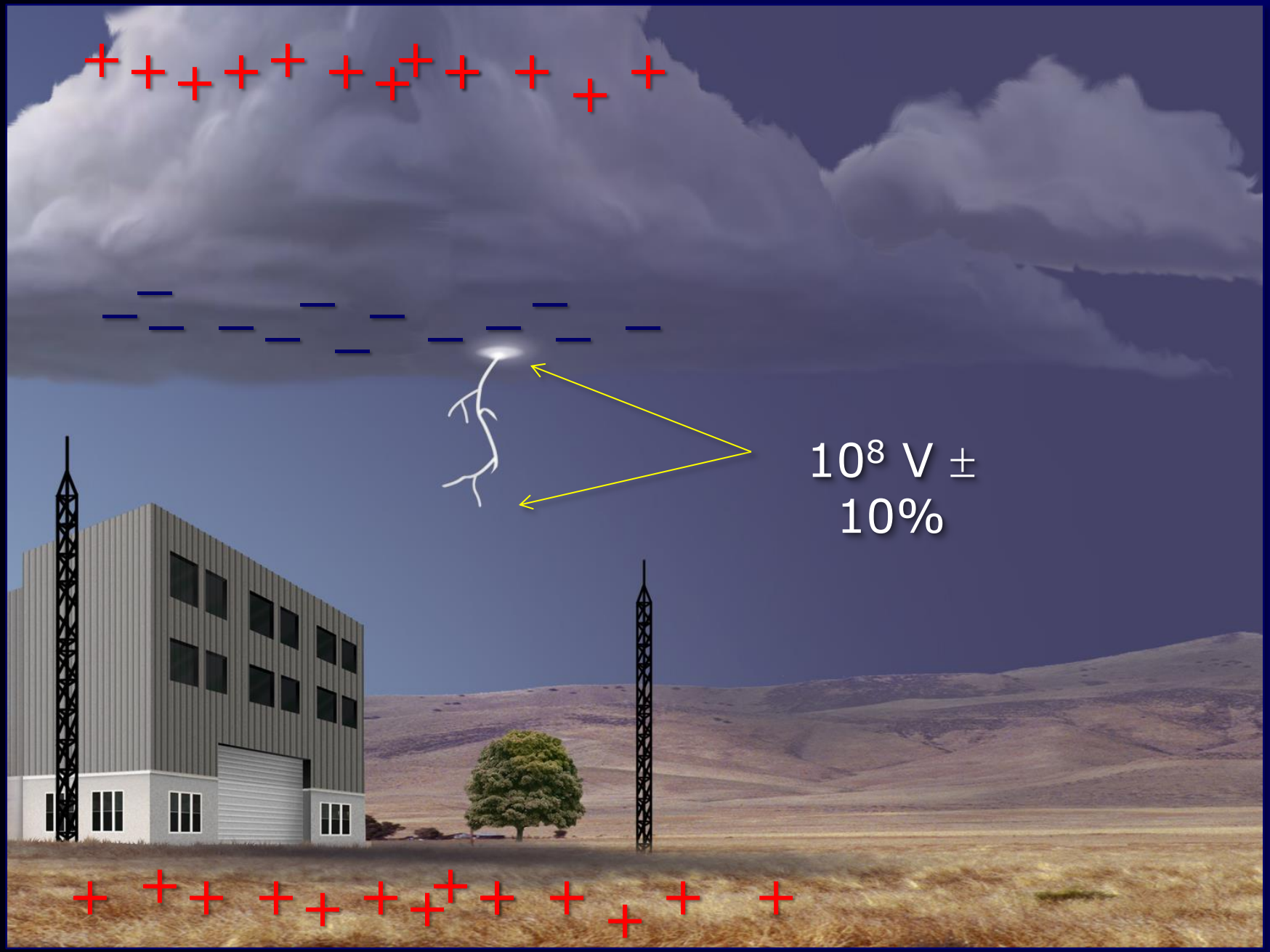
The Lightning Discharge

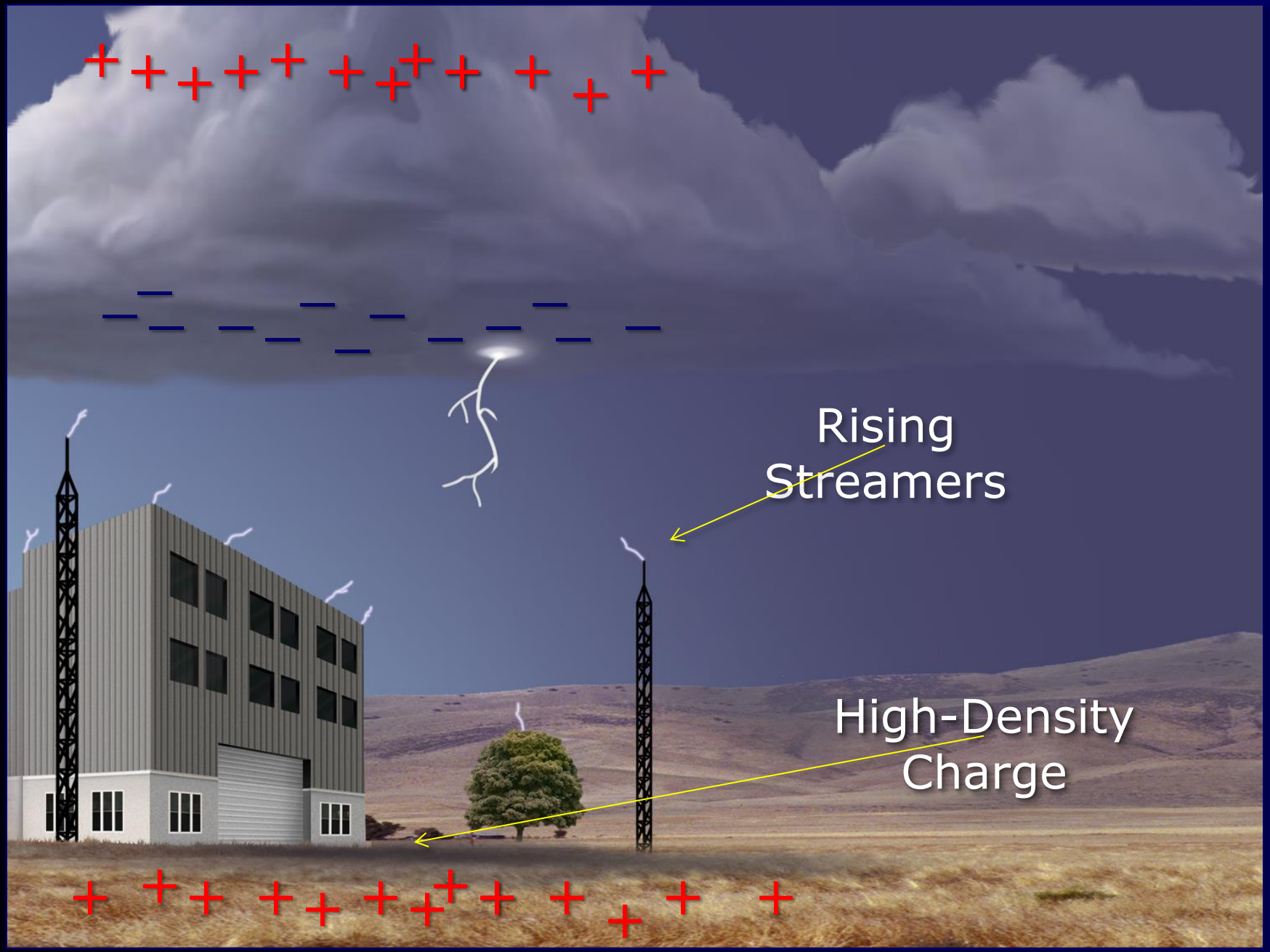
Ben Franklin, June 1752

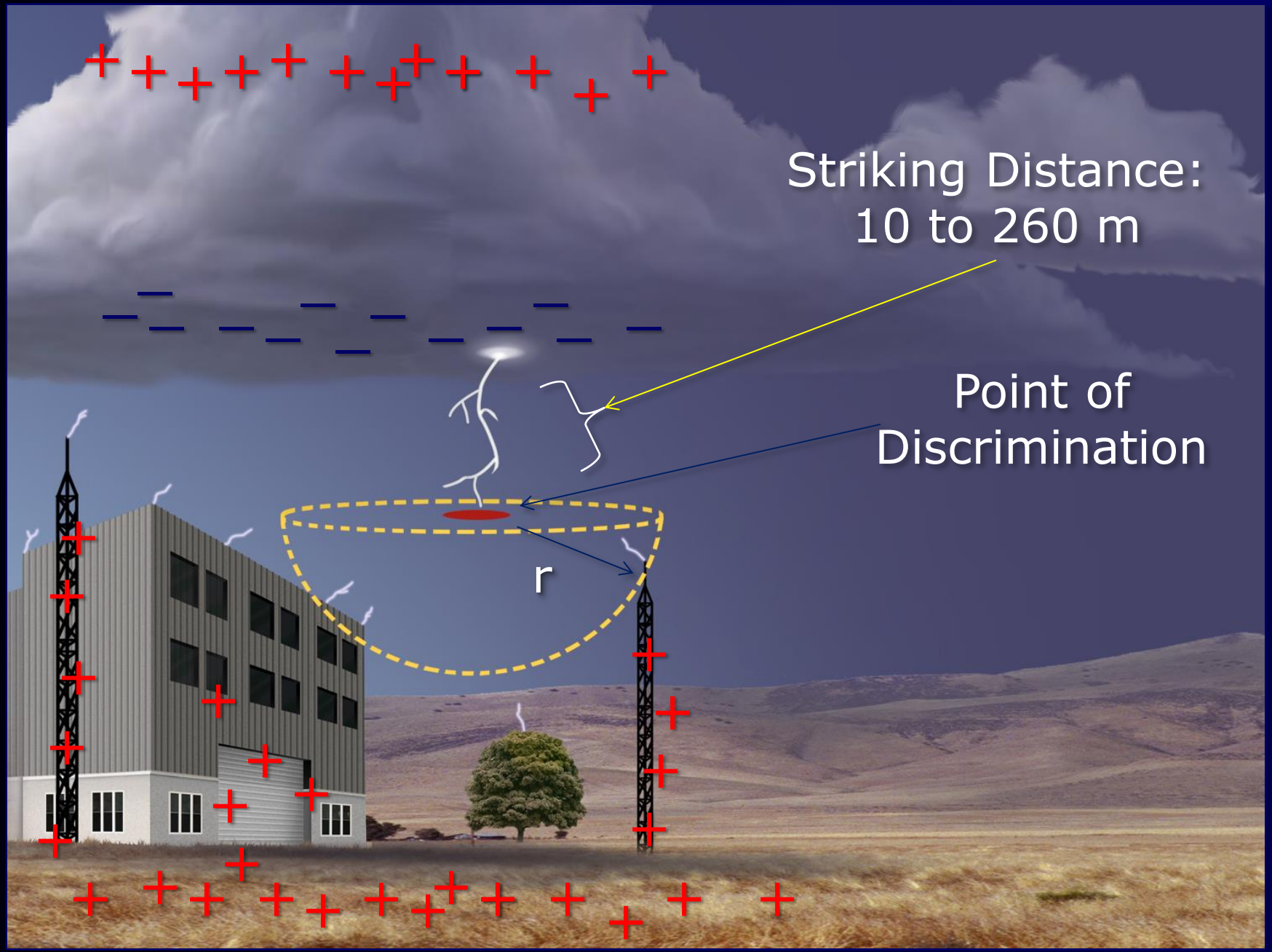


- Proved lightning was electricity and not fire
- Several others were killed by this experiment
- Went on to invent the grounded lightning rod for “lightning protection”

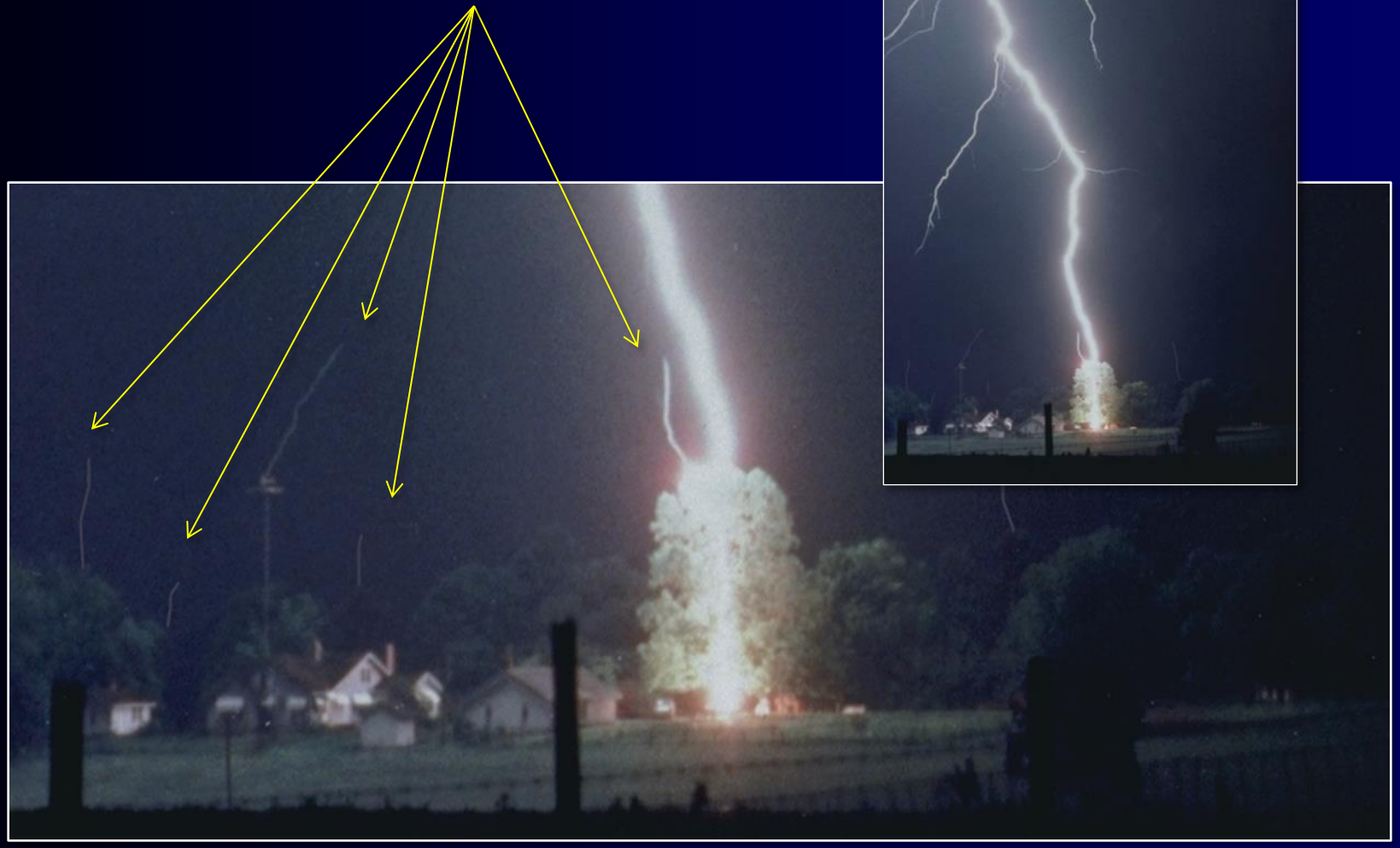

Electrostatic
Field
5 to 30 kV/m
Electrostatic
Shadow


10^8 V ± 10%


Rising
Streamers
High-Density
Charge


Striking Distance:
10 to 260 m
Point of
Discrimination
r

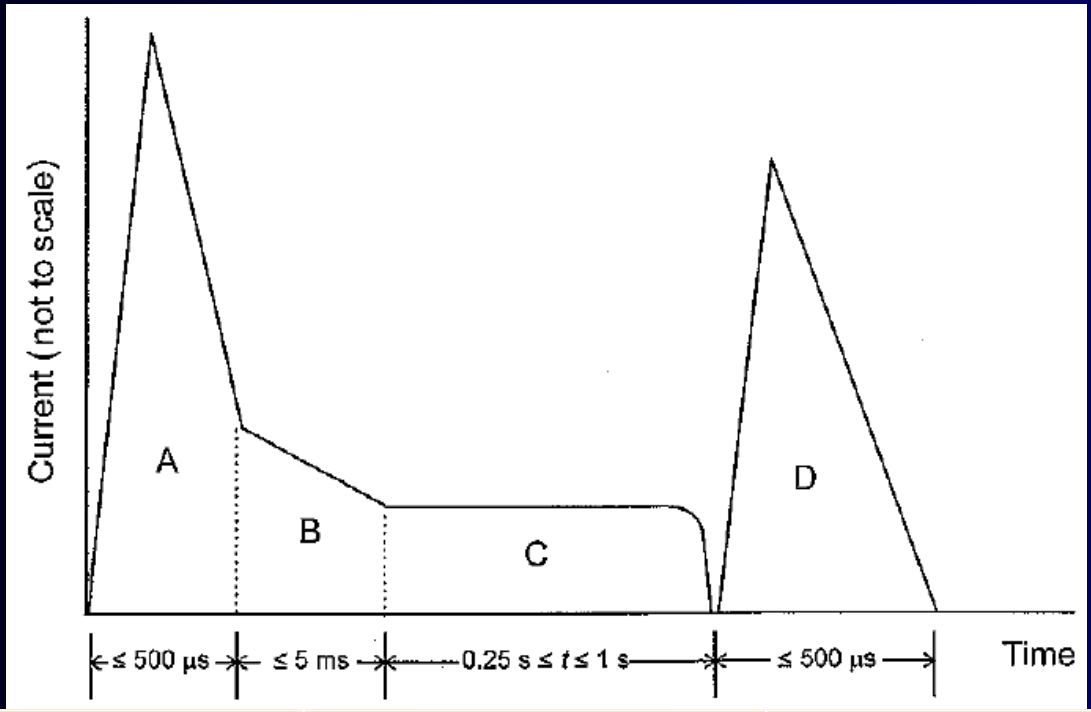
Storm Generated Upward Streamers



Stroke Data

Peak Current	2 – 510 kA
99%	≅ 200 kA
50%	≅ 30 kA
Negative Polarity	> 90%
Time Between	> 10 Seconds
Temperature	55,000 F
RFI Range (95%)	200 kHz – 20 MHz
Strokes/Flash: range (avg)	1 to 30 (4)
Diameter of strike channel	6 to 8 inches
Avg diameter of strike	3/4 inch

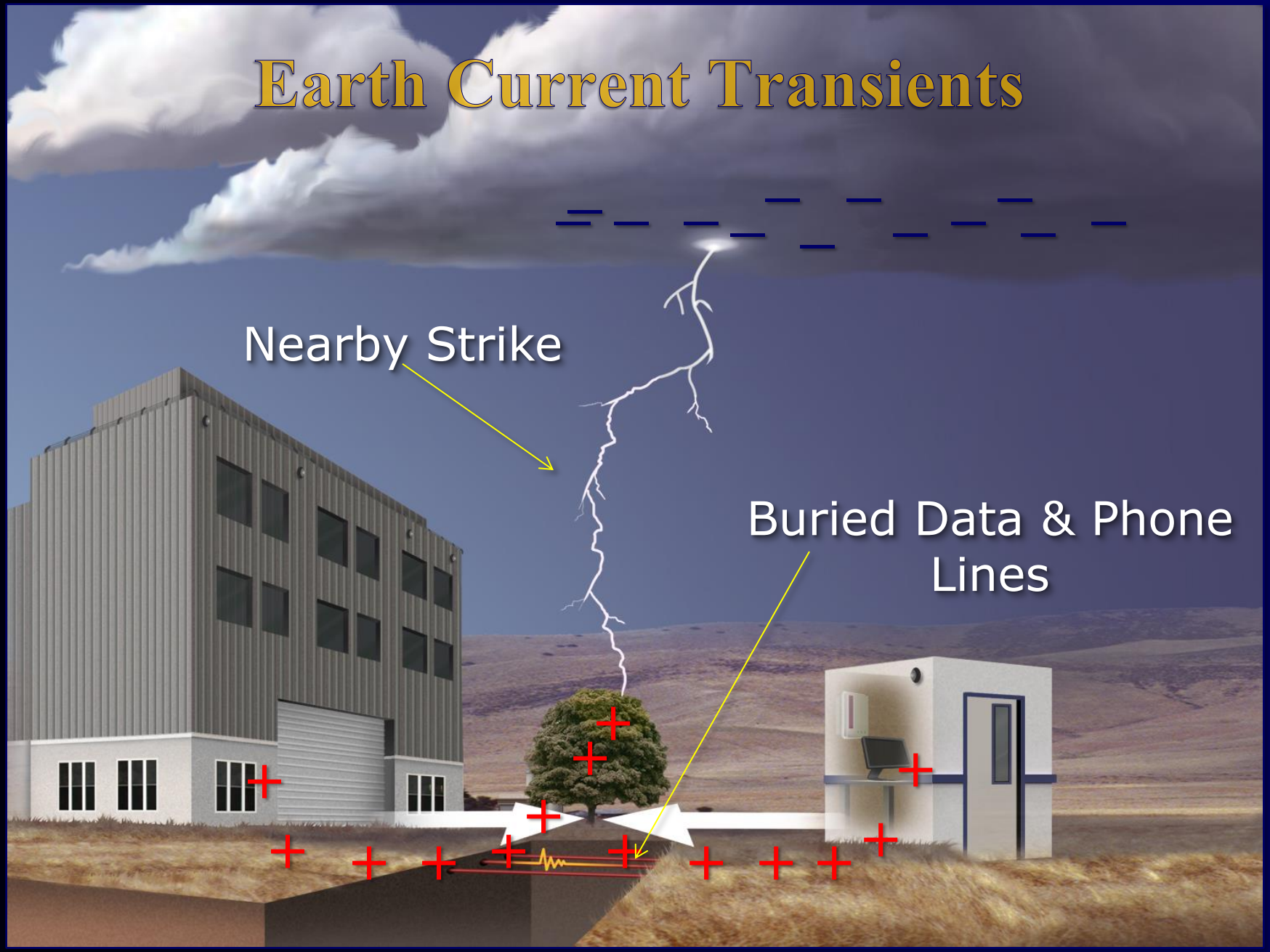
The Lightning Discharge

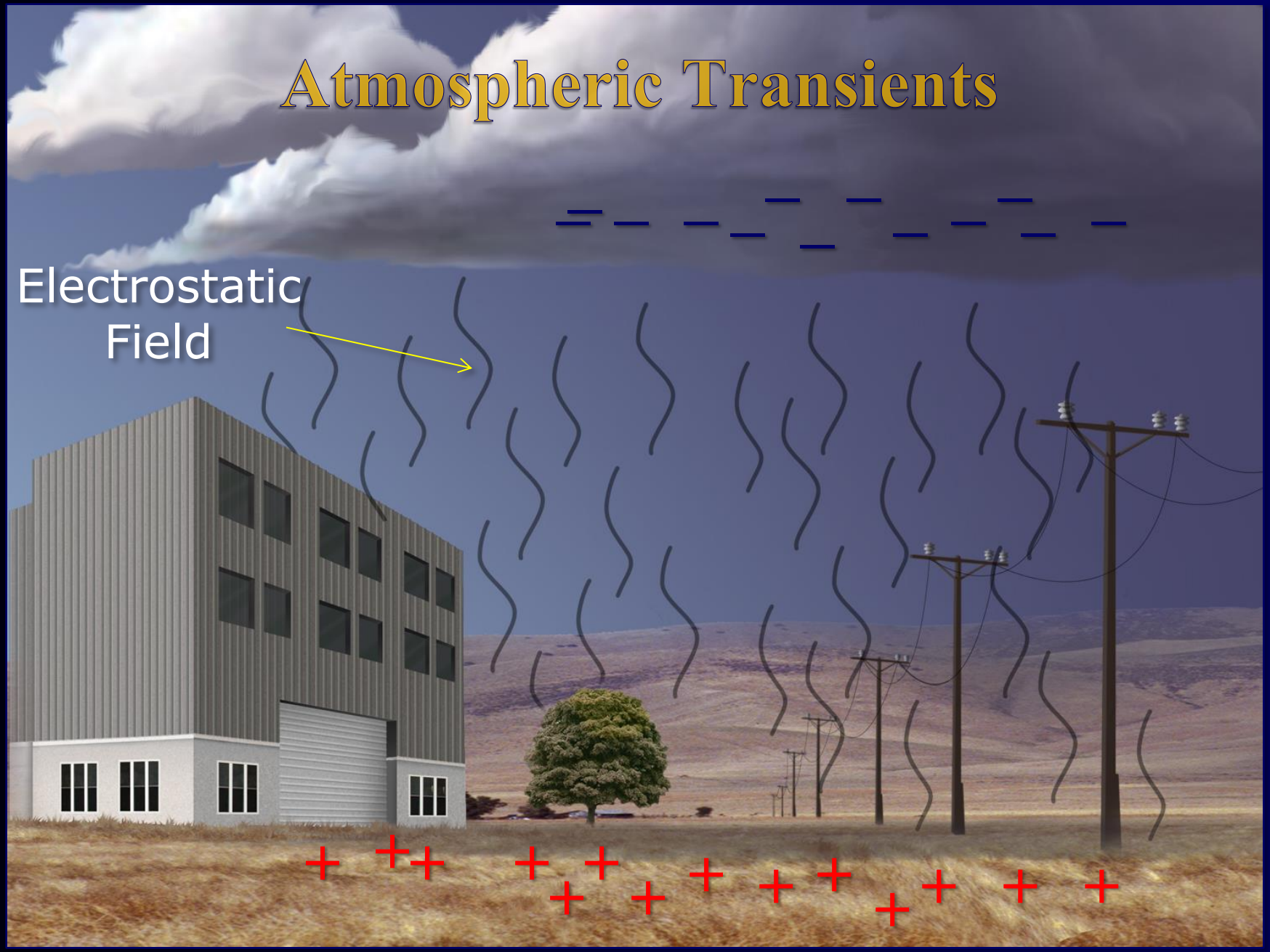


Component	Amplitude, kiloamperes	Charge Transfer, coulombs	Duration, milliseconds
A (first return stroke)	200 (+10%) peak	NA	≤ 0.5
B (intermediate current)	2 (± 20%) average	10 (± 20%) max	≤ 5
C (continuing current)	0.2 to 0.8	200 (± 20%)	250 to 1000
D (subsequent return stroke)	100 (± 10%) peak	NA	≤ 0.5

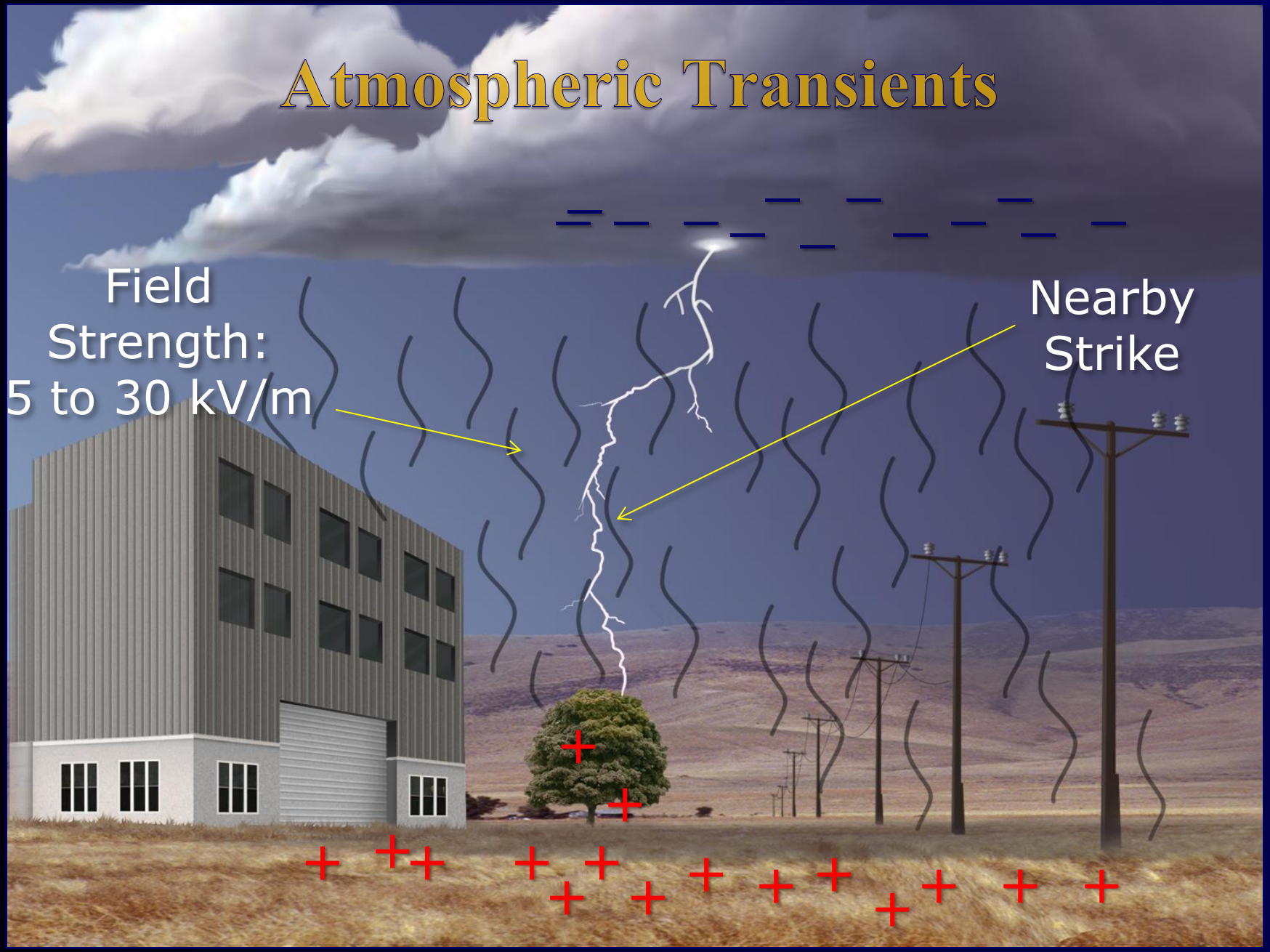
Duration of component C >> A and contains most energy

The Secondary, Indirect Effects of Lightning

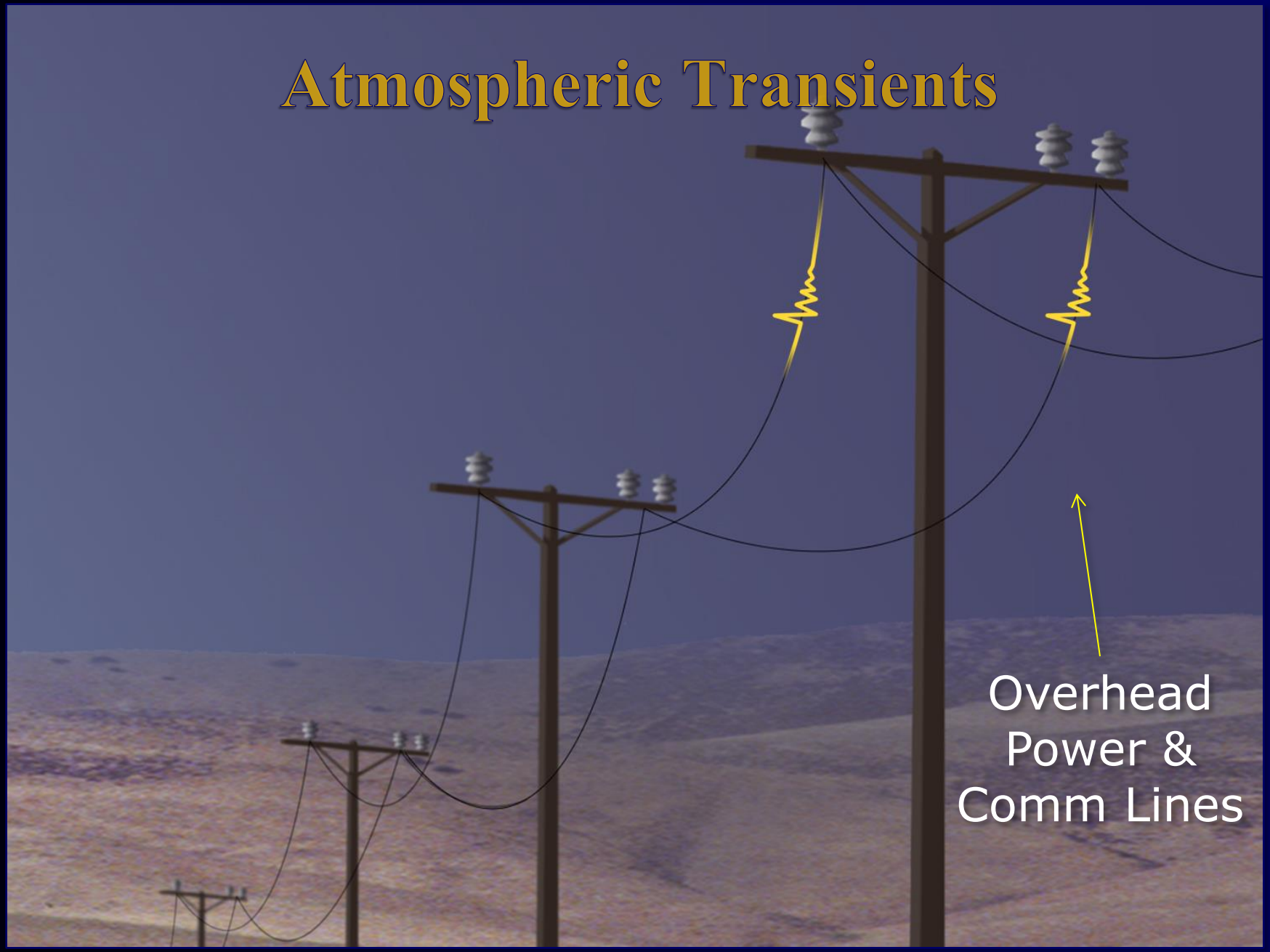

Earth Current Transients
Nearby Strike
Buried Data & Phone Lines

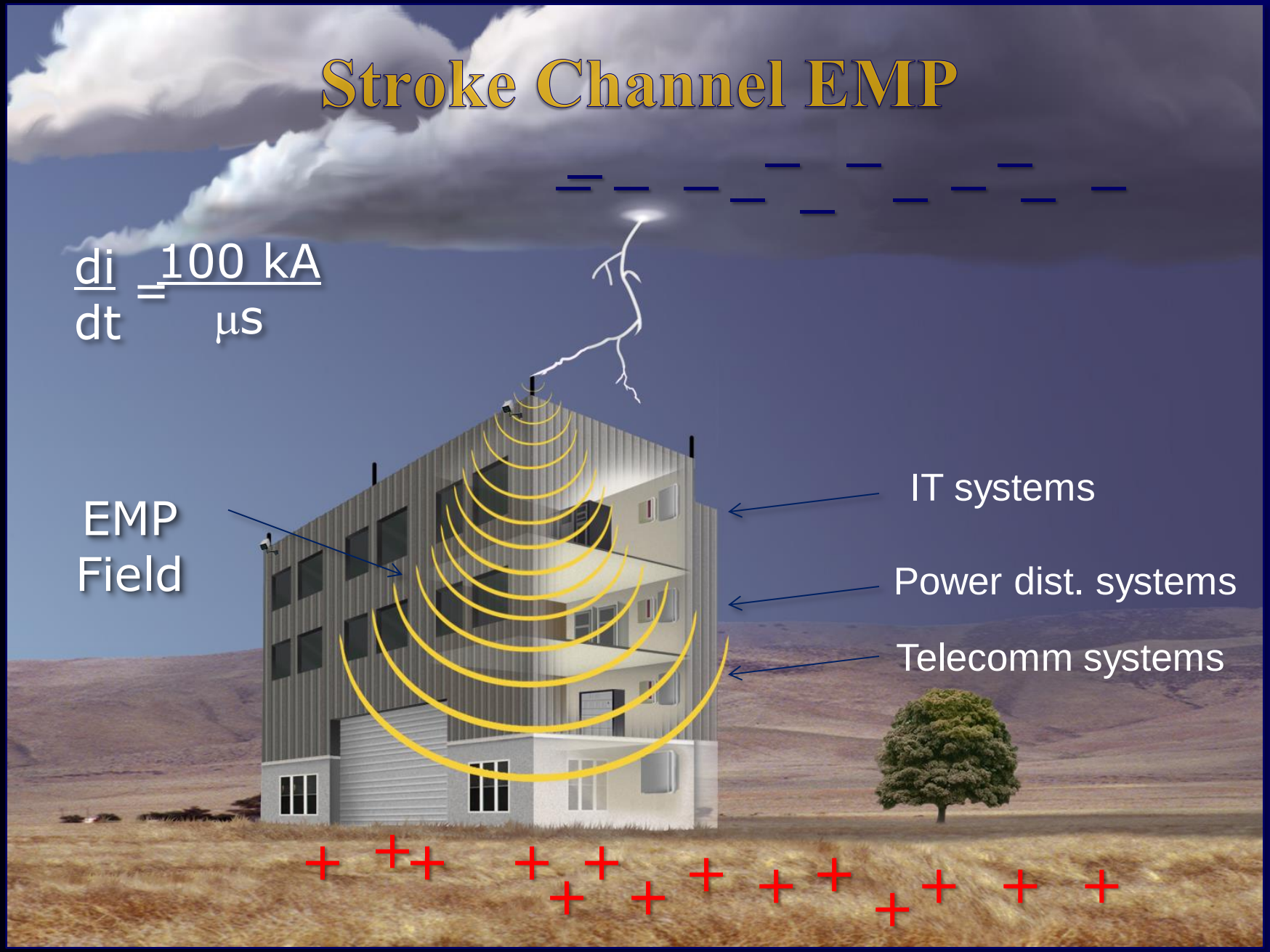

Atmospheric Transients
Electrostatic Field

Atmospheric Transients

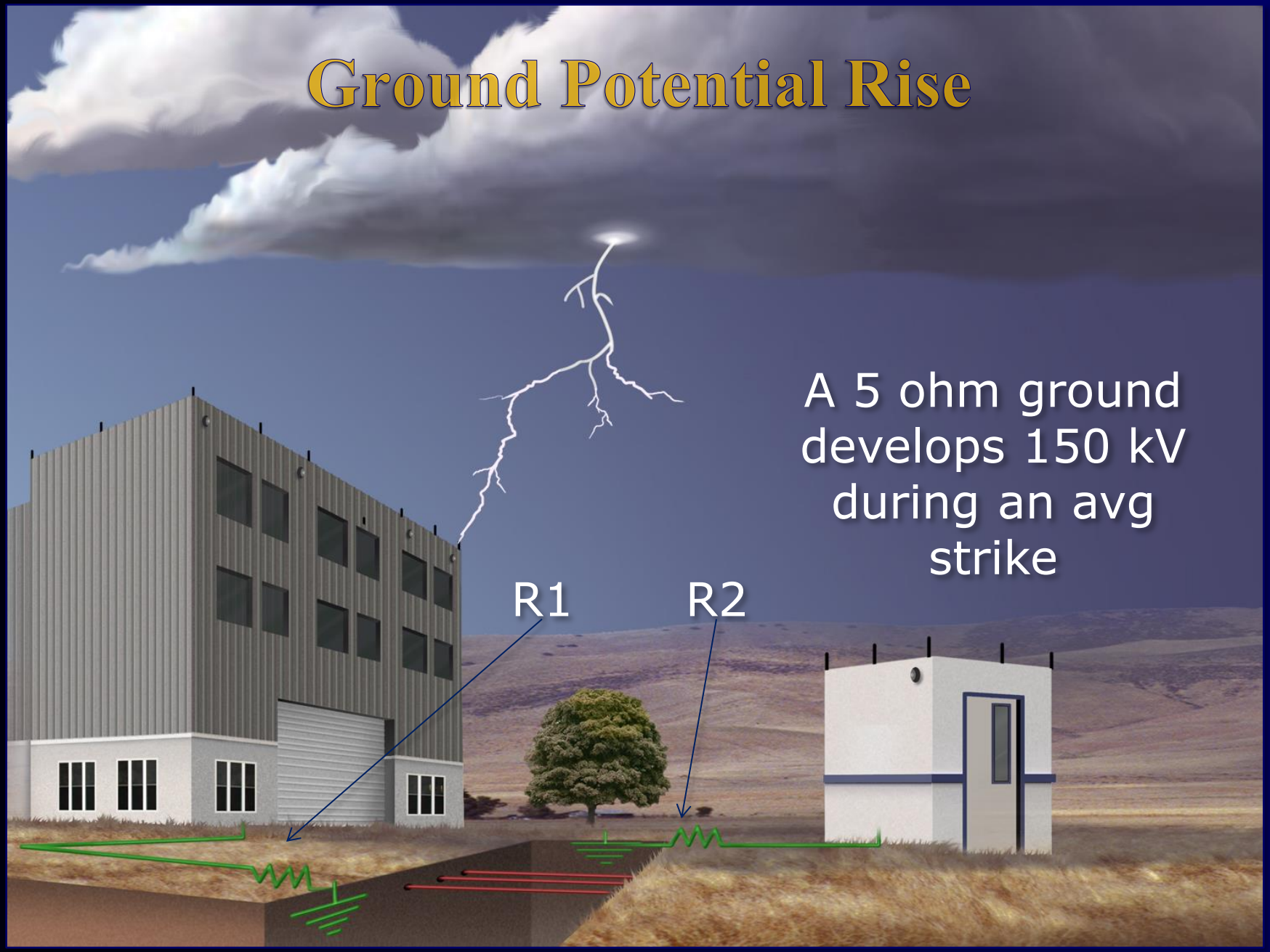


Atmospheric Transients




Stroke Channel EMP
di = 100 kA
dt μs
EMP Field
IT systems
Power dist. systems
Telecomm systems

Ground Potential Rise



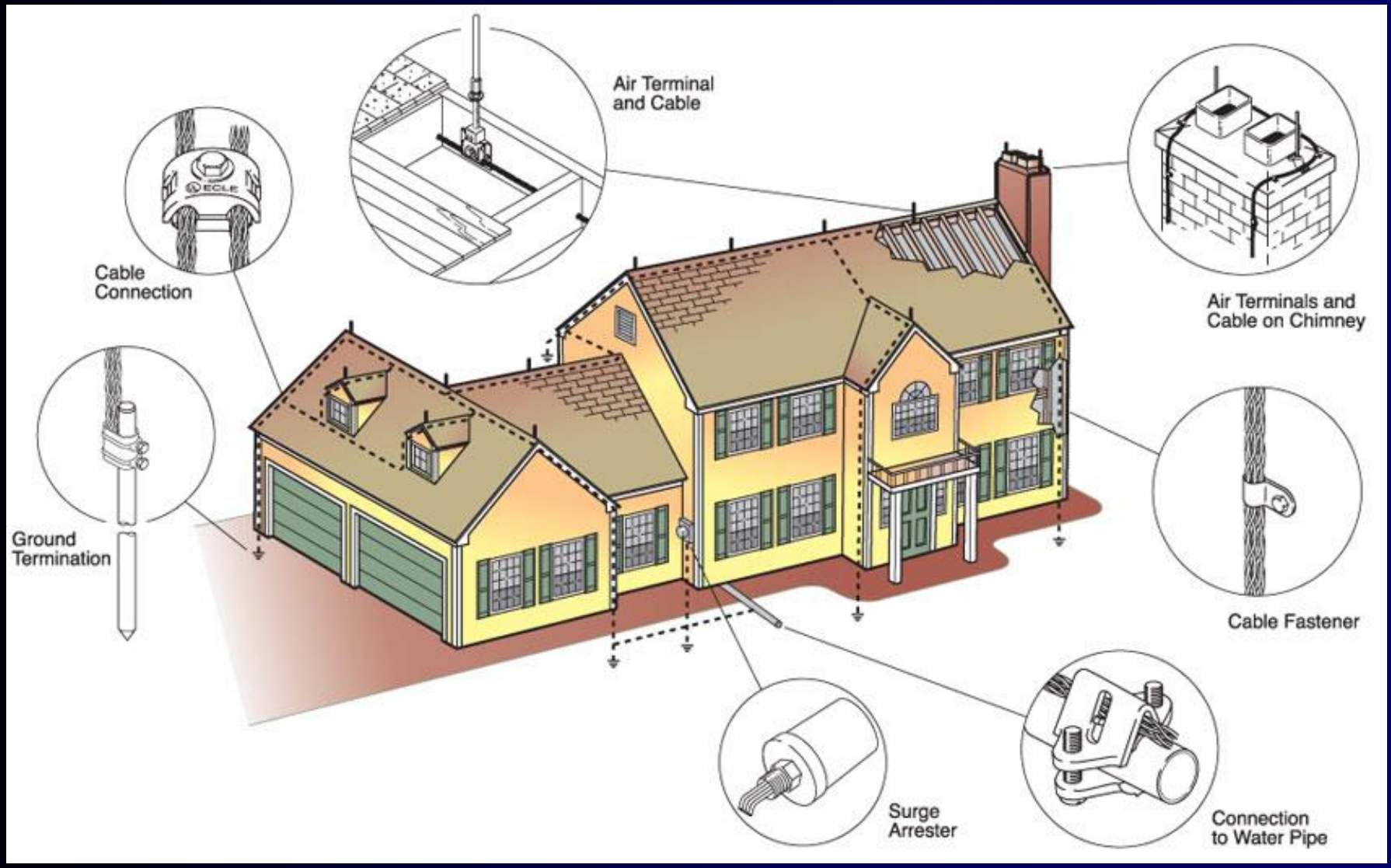
Summary of Secondary Effects

- Earth Current Transients
- Atmospheric Transients
- Electromagnetic Pulse
- Ground Potential Rise

Components of Lightning Protection System (LPS)

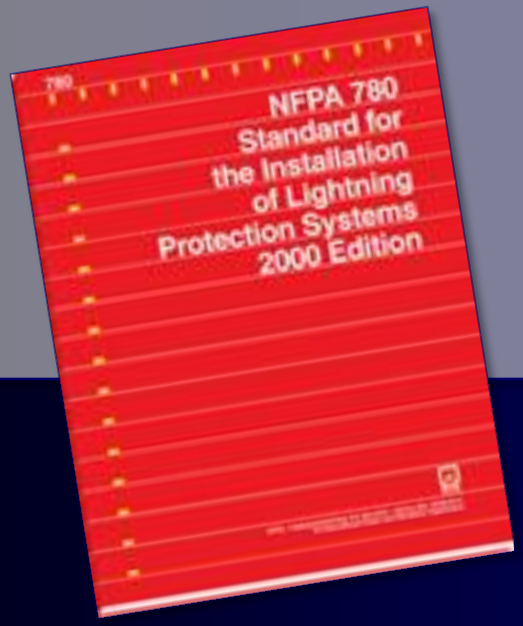
1. Direct Strike protection equipment on roof
2. Surge protection devices (all wires)
    i. AC power
    ii. Telephone
    iii. Coax
    iv. Datacomm, etc.
3. Grounding electrode system

Components of LPS



Industry Standards

- NFPA 780 and UL 96A
- Based on historical precedent
- Intended to collect strike and divert energy to ground

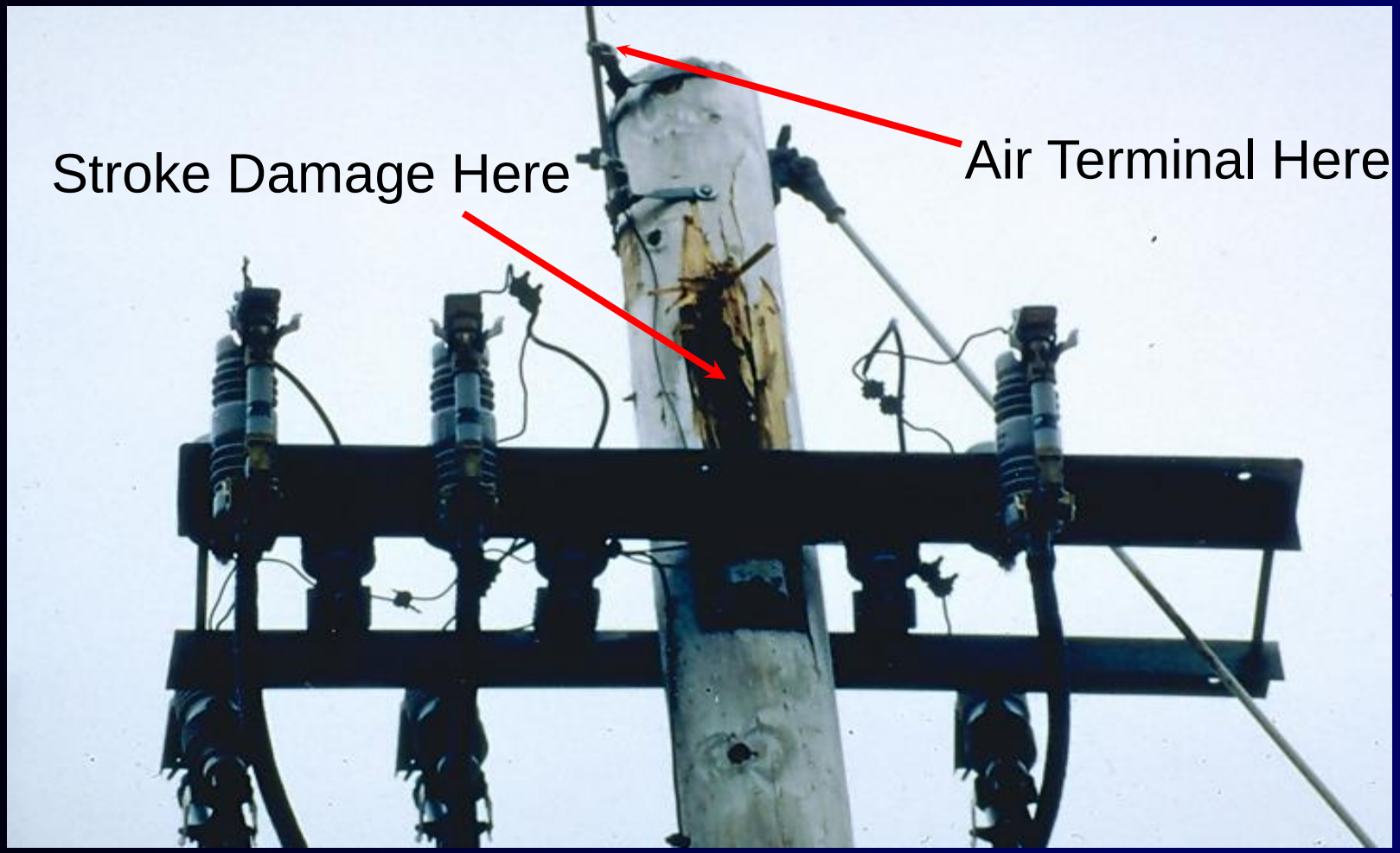


Conventional air terminals (lightning rods) on roof

Conventional overhead shield (ground) wire

Strike Physical Damage

Stroke Physical Damage



Damage to ESE

Strike Protection Options

- Collectors
  - Air terminals (lightning rods)
  - Shield wires
  - Early streamer emitters (ESE's)
  - Masts
- Ionizers
  - Multi-point air terminals
  - Dissipators

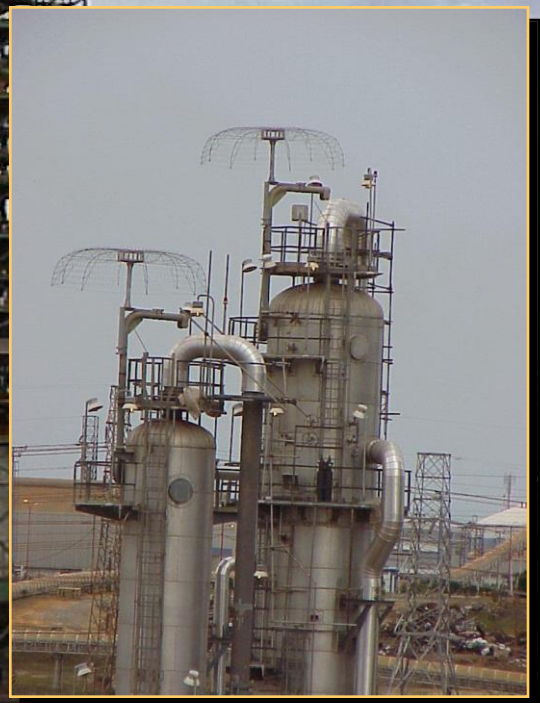
Strike Collectors

LEC Ionizers

- Spline Ball Ionizers & Terminals
  - UL listed air terminals
  - Can be installed per NFPA-780
  - Can obtain UL Master Label
  - Lightning rod replacements and alternatives
- Dissipation Array System
  - Beyond scope of NFPA-780
  - Custom designed to fit site requirements
  - No-strike guarantee

CIG – Douglas, WY
DAS and SBIs

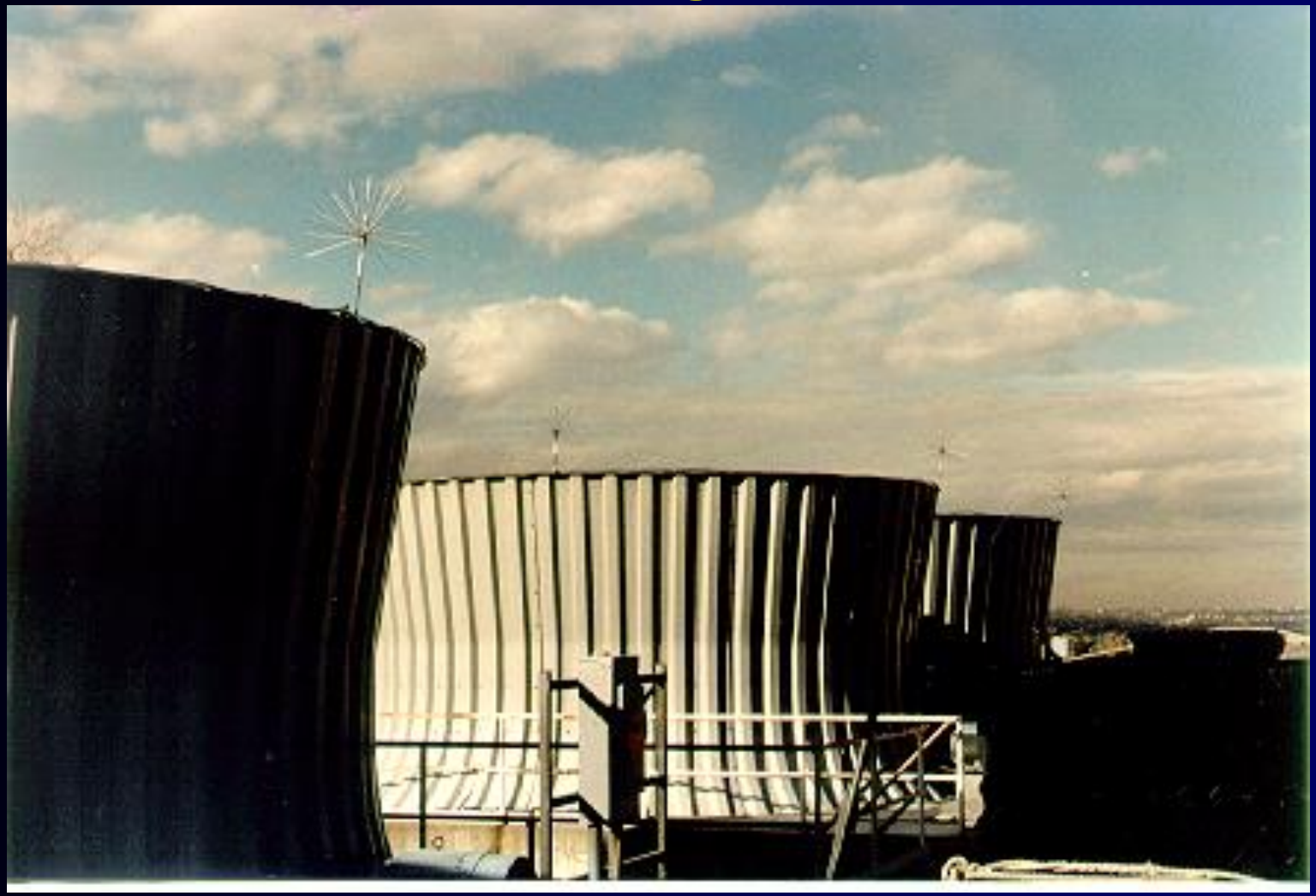
Petroleum Processing Site



DAS Sites in Colorado

Spline Ball Ionizers on Tower

Spline Ball Terminals on Cooling Towers



Spline Ball Ionizers on Generator Stacks

Spline Ball Terminals on Cabin

High Volume Data Center

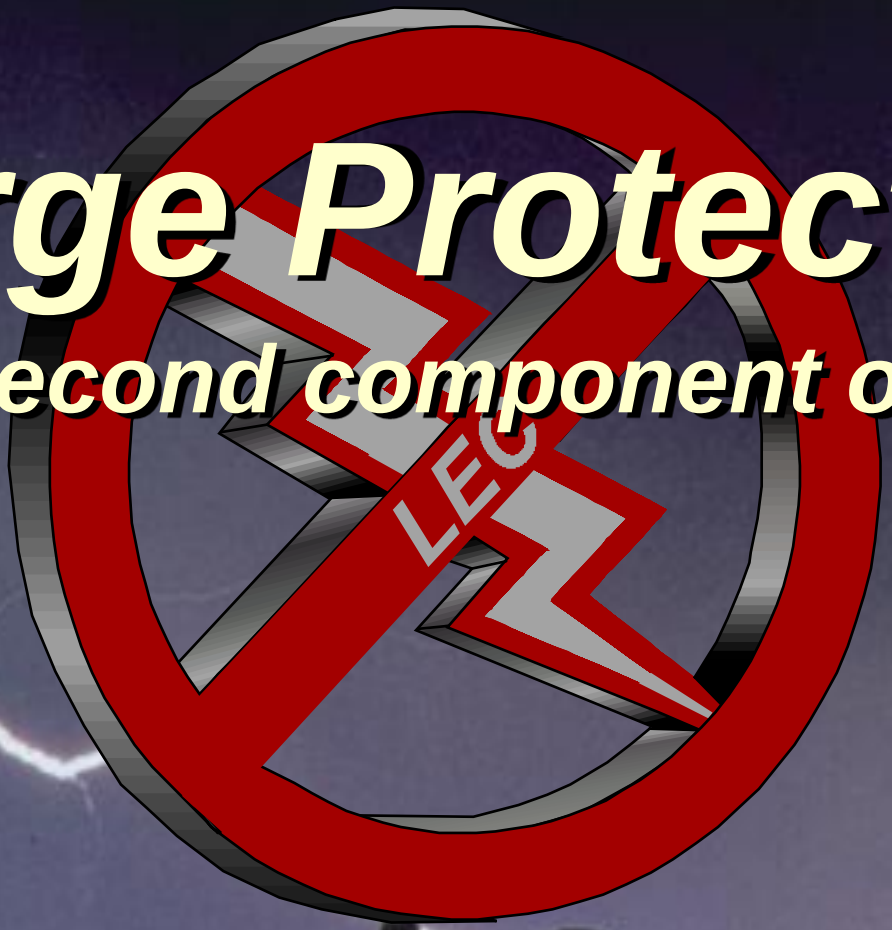
(Spline Ball Terminals in NFPA-780 system)

Holiday Inn Worldwide

Atlanta, Georgia

Surge Protection

(the second component of LPS)



Lightning Eliminators & Consultants, Inc.

" Lightning Eliminators Worldwide Since 1971"

Sources of Anomalies

- *Lightning (direct & nearby)*
- *Transients*
- *Local Electric Utilities*
- *In-House Systems*
- *Adjacent Facilities*

How Does Surge Enter Facility?

- **On ANY conductor**
  - ***Power***
  - ***Communications***
  - ***Grounding***
  - ***Computer***
- **In ANY direction**
  - ***From outside facility***
  - ***From strike within facility***

Series vs. Parallel Surge Protectors

- **Series protector has in-line inductor**
  - ***Inductor is sized by available current***
- **Use series protector for all low current applications, e.g. telephone, datacomm**
- **Use parallel protector for all high current applications, e.g. service entrance**

Service Entrance Protection

Facility Guard (FG)

- FG200 – 200kA/phase
- FG400 – 400kA/phase
- UL 1449 3rd Edition listed

Standard Features:
- Status Indicator
- Outdoor Enclosure
- Audible Alarm

Optional Features:
- Remote Monitor
- Internal Disconnect
- Surge Counter

Medium Voltage Protection

Medium Voltage Surge Protector (MVSPD)

- 480 to 4500 volts
- Surge capacity: 10 to 80kA/phase
- Outdoor enclosures
- Can be used on:
  - Control panels, e.g. MCC's
  - Variable speed drives (VSD's)
  - Variable frequency drives (VFD's)
  - Remote terminal units (RTU's)

MV-SPD Applications Table

Drive Horsepower	Recommended Product
< 25	Sheriff
25-100	Drive Pro or Subsaver
> 100	Heavy Duty Subsaver

Subpanel and Residential Protection

Transient Limiter 50 (TLX-50)

- Surge Capacity: 50kA/phase
- Nipple Mounted Enclosure
- UL 1449 Third Edition listed

Standard Features:
- Status Indicator
- Outdoor enclosure
- Tri-Mount Installation (nipple, DIN rail, bracket)

Optional Features:
- Audible Alarm
- Dry Contacts

Plug-In Protection

Pro Line (PL-55)

- Surge capacity: 85kA/phase
- UL Listed
- 8 outlets
- Fuse protected

Low Voltage Circuit Protection

Protection for:

Data Lines

Telephone Lines

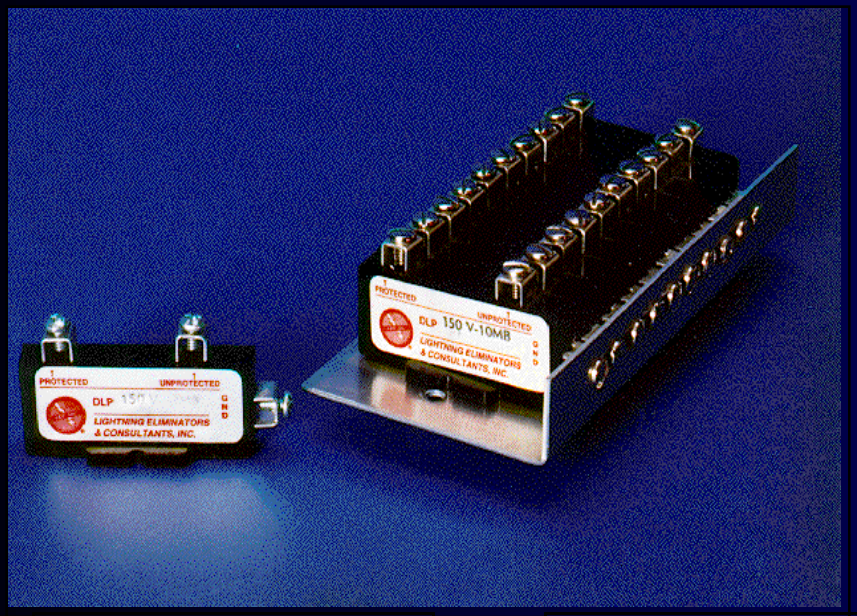
Instrument Lines

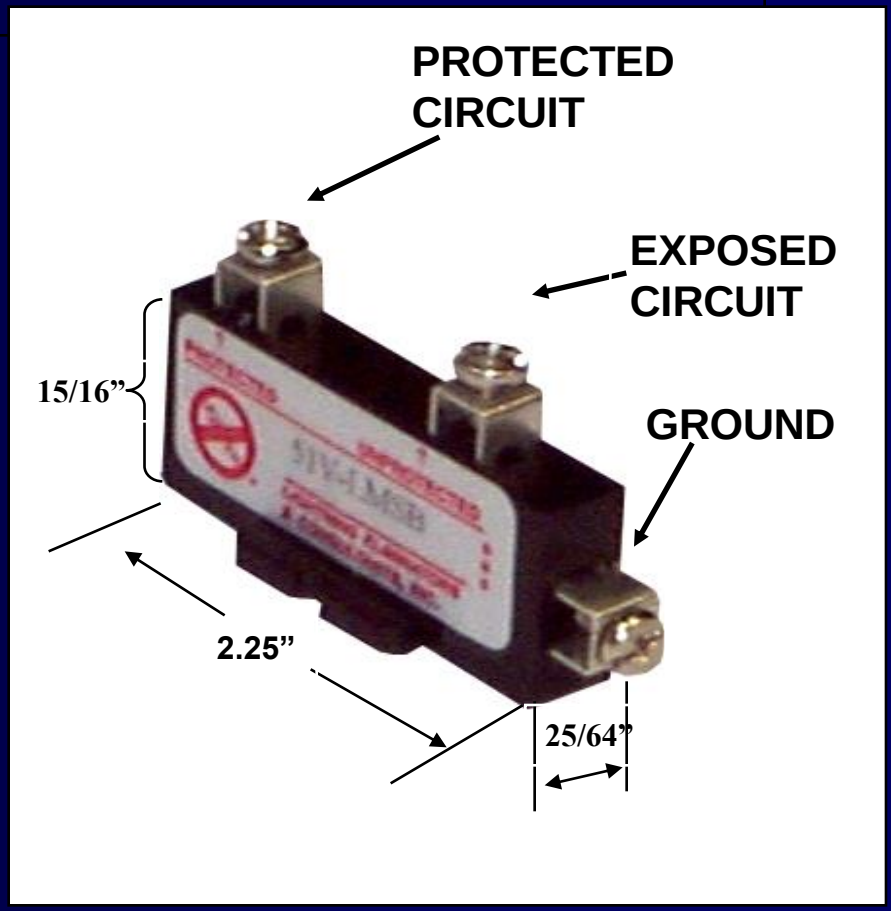
Hard-Wired Circuits

Control Circuits

DLP Single Line Application

DLP-MSB
DLP-LMSB
DLP-L2MSB
(10kA/wire)





DLP Paired Line Application

DLP-MHB

DLP-LMHB

(10kA/wire)

Coaxial Line Protection CLP

- Protection for all types of coax lines
  - N, TNC, SMA, 7/16, BNC, F
  - 20kA surge capacity
  - VSWR < 1.2
  - Up to 780 watts
  - 50 or 75 ohm lines
  - Insertion loss < 0.1db

TE-500 Family

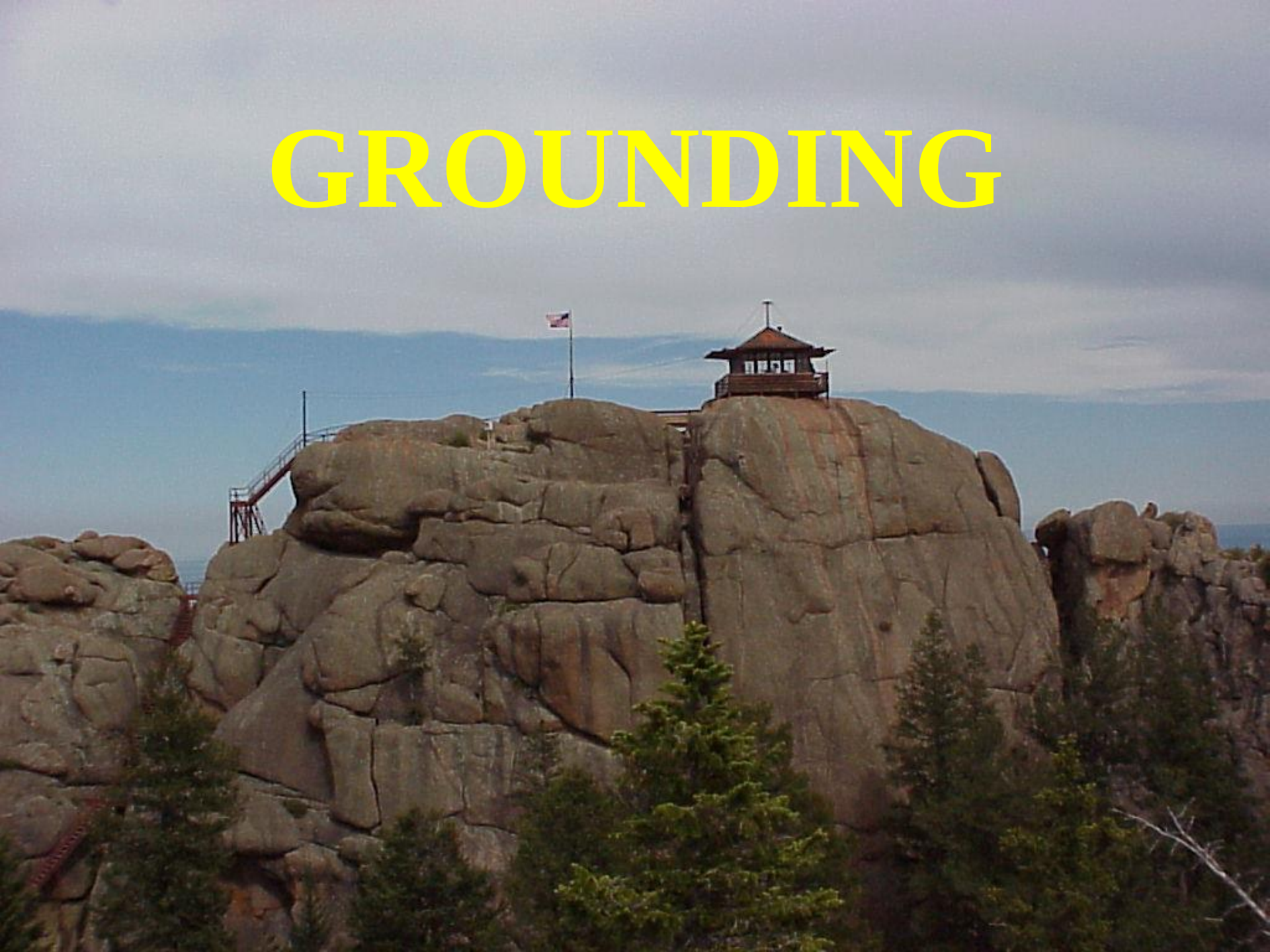
Surge Protection
General Recommendations

- Use adequate surge capacity
  - ≥ 200kA for critical AC power svc entrance
    - More for remote locations (reflection)
  - ≥ 10kA for data, telephone, instrument lines

- Use series devices for low current app's
  - Data, instrument, PC's, PLC's
- Install surge protectors on both ends

- Install surge protectors on all wires

GROUNDING



Why Ground?

(Grounding ≈ Earthing)

- **Proper operation of lightning and surge protection equipment**
- **Low fault circuit path impedance, to clear ground faults quickly and efficiently**
- **Proper operation of communications, computers and other sensitive electronics**

Why Ground?
(cont'd)

- **Achieving an electrical connection to earth, which is required to stabilize circuit potential**
- **Minimizing the noise on electrical and signal circuits**
- **Providing a common ground reference for the facility**
- **PERSONNEL SAFETY**

3 GROUNDING SUBSYSTEMS

- **EQUIPMENT GROUND**
  - ***Fault & Personnel Protection***
  - ***60 Hz Equipment Ground (NEC)***
- **SIGNAL REFERNCE**
  - ***High Frequency Applications***
  - ***Signal Reference Grid***
- **LIGHTNING PROTECTION**
  - ***Collection Devices (NFPA-780)***
  - ***Ionizing Devices***

• All 3 subsystems must be connected to a grounding electrode system.

HOW LOW IS LOW ENOUGH?

- **NEC 250-84**
  - ***If Resistance > 25 Ohms, Add One Electrode***
  - ***Does not Imply 25 Ohms is Safe***

- **AVERAGE LIGHTNING STRIKE OF 30kA**
  - ***Across 5 Ohms Yields 150kV***

COMMON POINT GROUNDING

- **BOND ALL GROUNDS TOGETHER**
  - ***Bond at One Location***
  - ***Typically at Service Entrance***
  - ***Includes Power, Telco, Datacomm, RF, Computer, Etc.***

- **Eliminates Differences in Potential Between Different Grounding Subsystems**

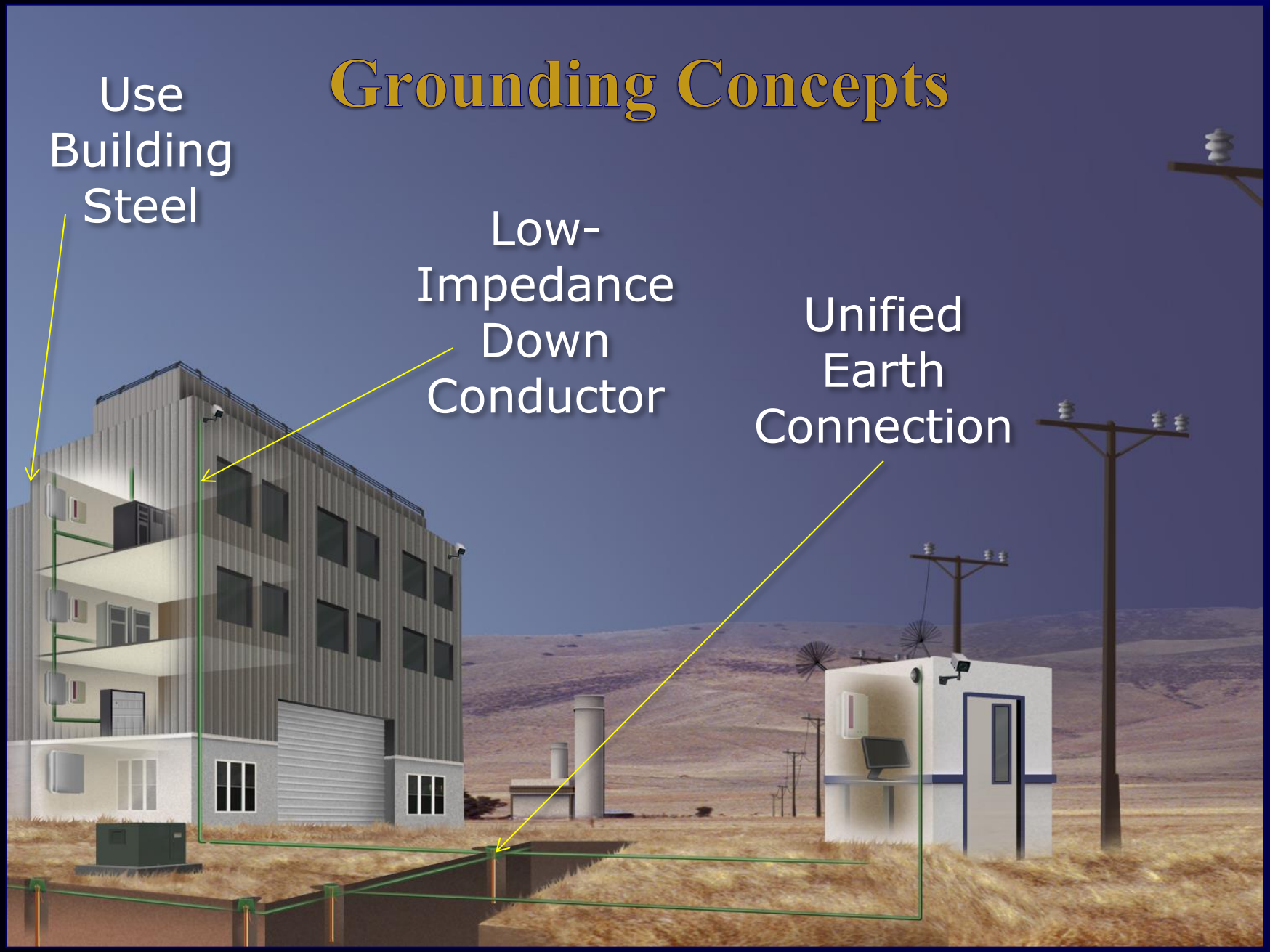
GROUND CONDUCTOR ROUTING

- **AVOID BENDS**
  - ***Bends Add Inductance***
- **SEPARATE GROUND FROM SIGNAL & POWER CABLES**
- **CONDUIT SHOULD BE NON-METALLIC**
  - ***Steel has Choking Effect on High Frequencies***

LEC Has Developed Grounding Expertise

- **Specialize in achieving low resistance in difficult situations**
  - **rock, sand, freezing locations, etc.**
- **Specialize in ground testing**
- **Can provide most cost effective solution**

Grounding Concepts



Chem-Rod Installation

Access Well Cover

Grounding Connection

GAF (Grounding Augmentation Fill)

Critical Cylinder

Progressive Steps for Poor Soil

Soil resistivity = 500 Ω/m	Resistance Ω	Number Required for 5 Ω
¾" x 10' Conventional Ground Rod	161	83
¾" x 10' Conventional Ground Rod in Conductive Fill	88	41
Chemical 10' Ground Rod in Conductive Fill	18	6

How to Measure a Grounding System

3 methods

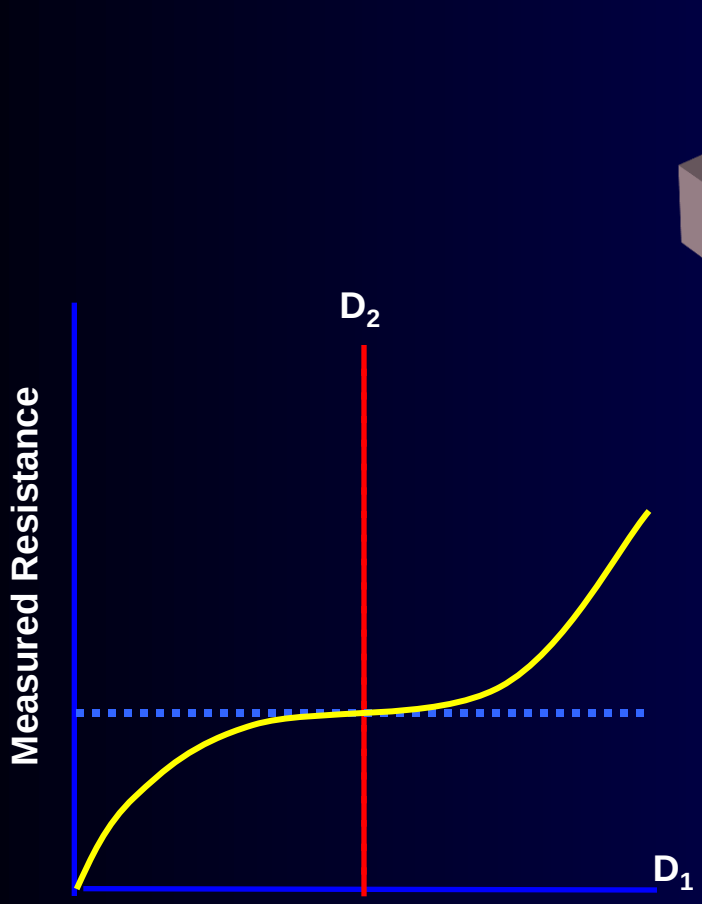
- **Traditional Method: Fall-of-Potential (FOP)**
  - **Also called the Three Point Method**
- **Newer Method (1990's): Clamp-On Tester**
- **Modern Method: Smart Ground Testing**

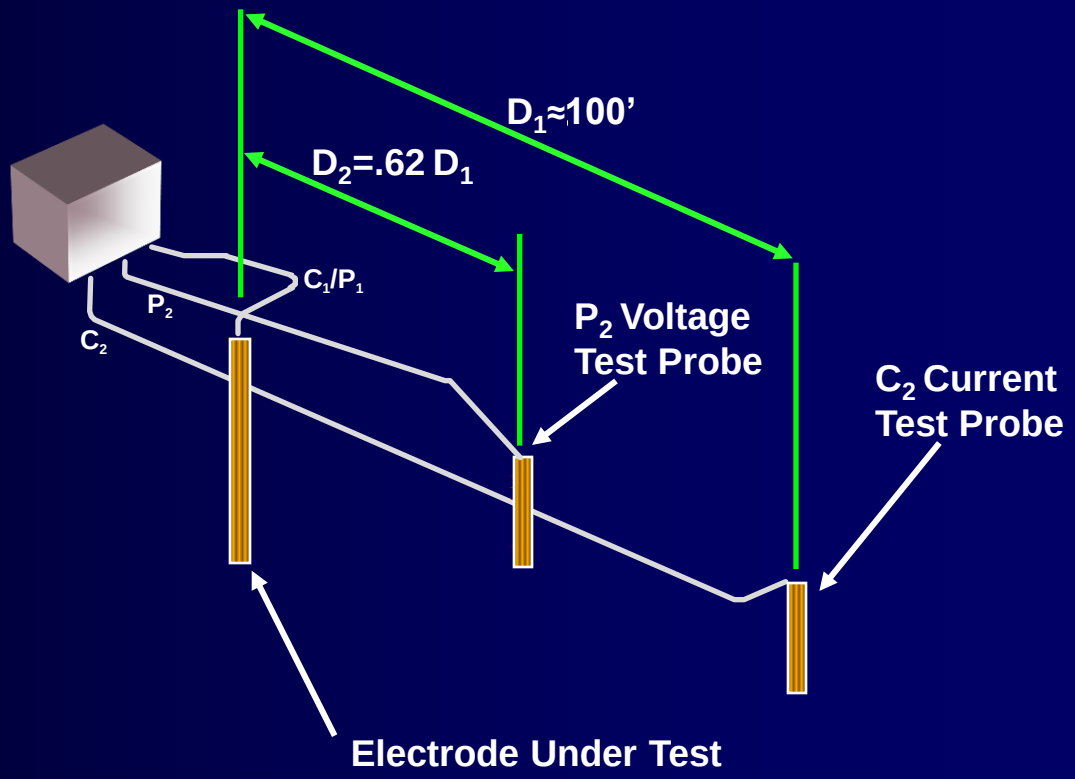
Three Point FOP Ground Resistance Tester

- **Device is used to perform FOP test**
- **FOP is the most common test method**
- **FOP test requires installation of current and voltage test probes, test leads, etc.**

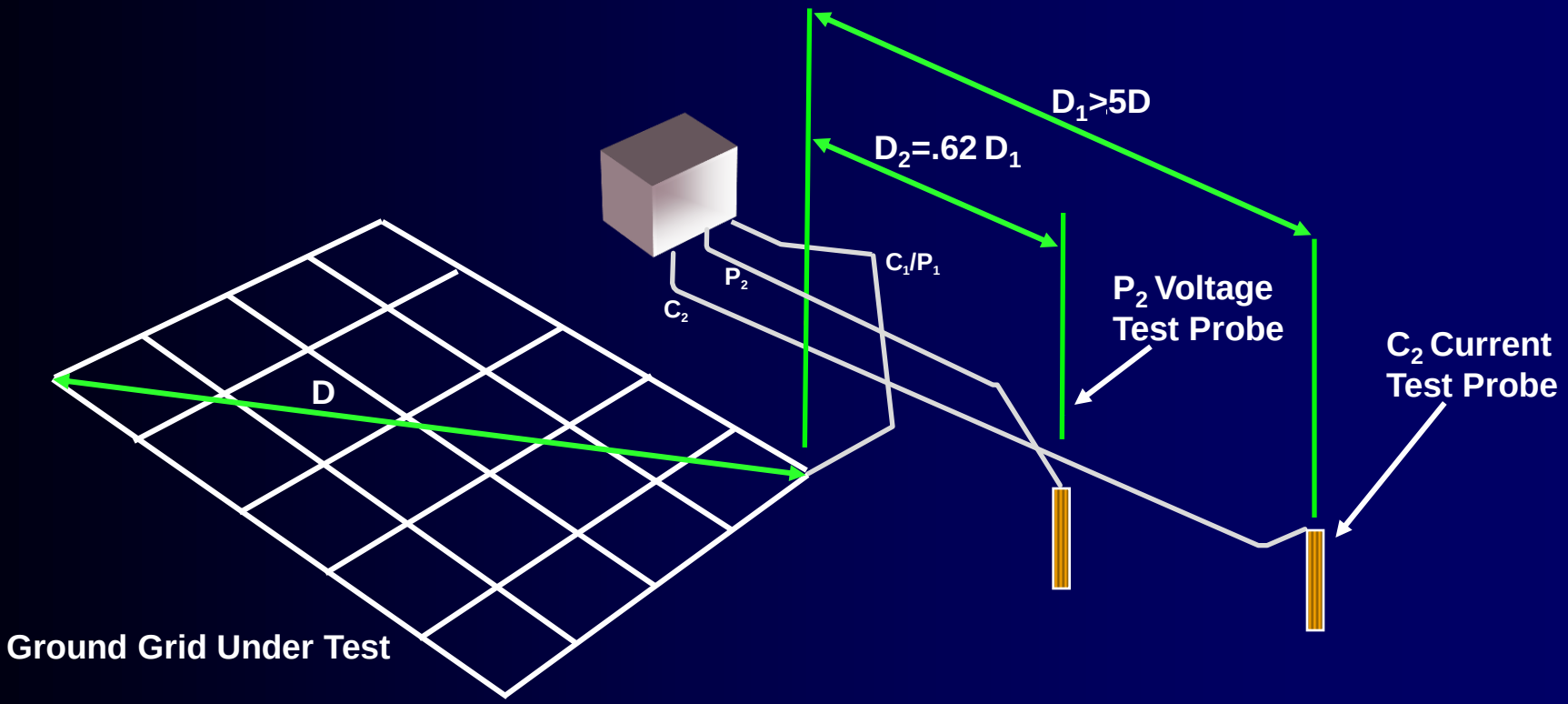
Fall of Potential Test

For Single Ground Rod

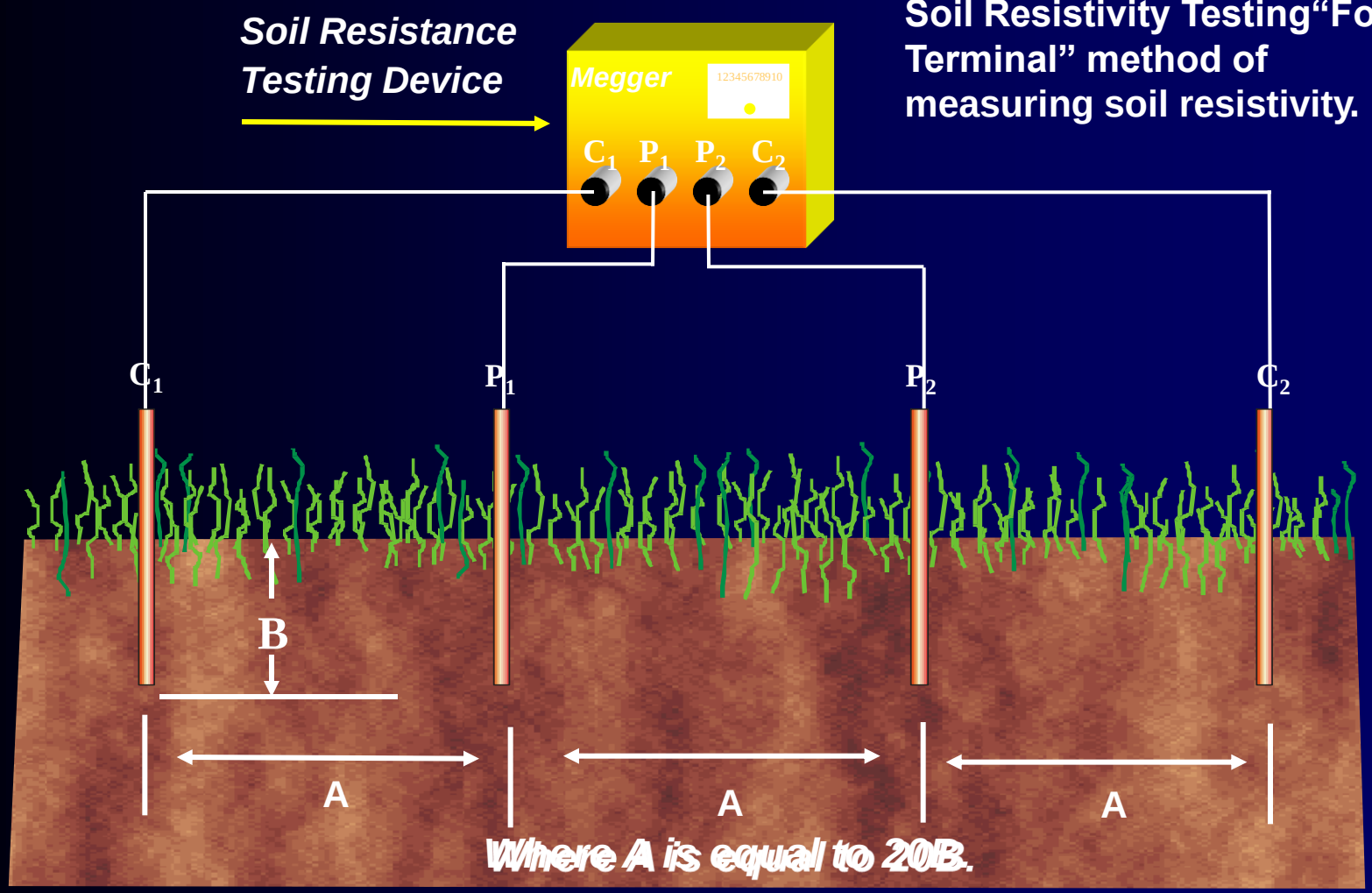




Fall of Potential Test
For Ground Grid



Measuring Soil Resistivity



Soil Resistivity Testing"Four-Terminal" method of measuring soil resistivity.

Clamp-On Ground Testing

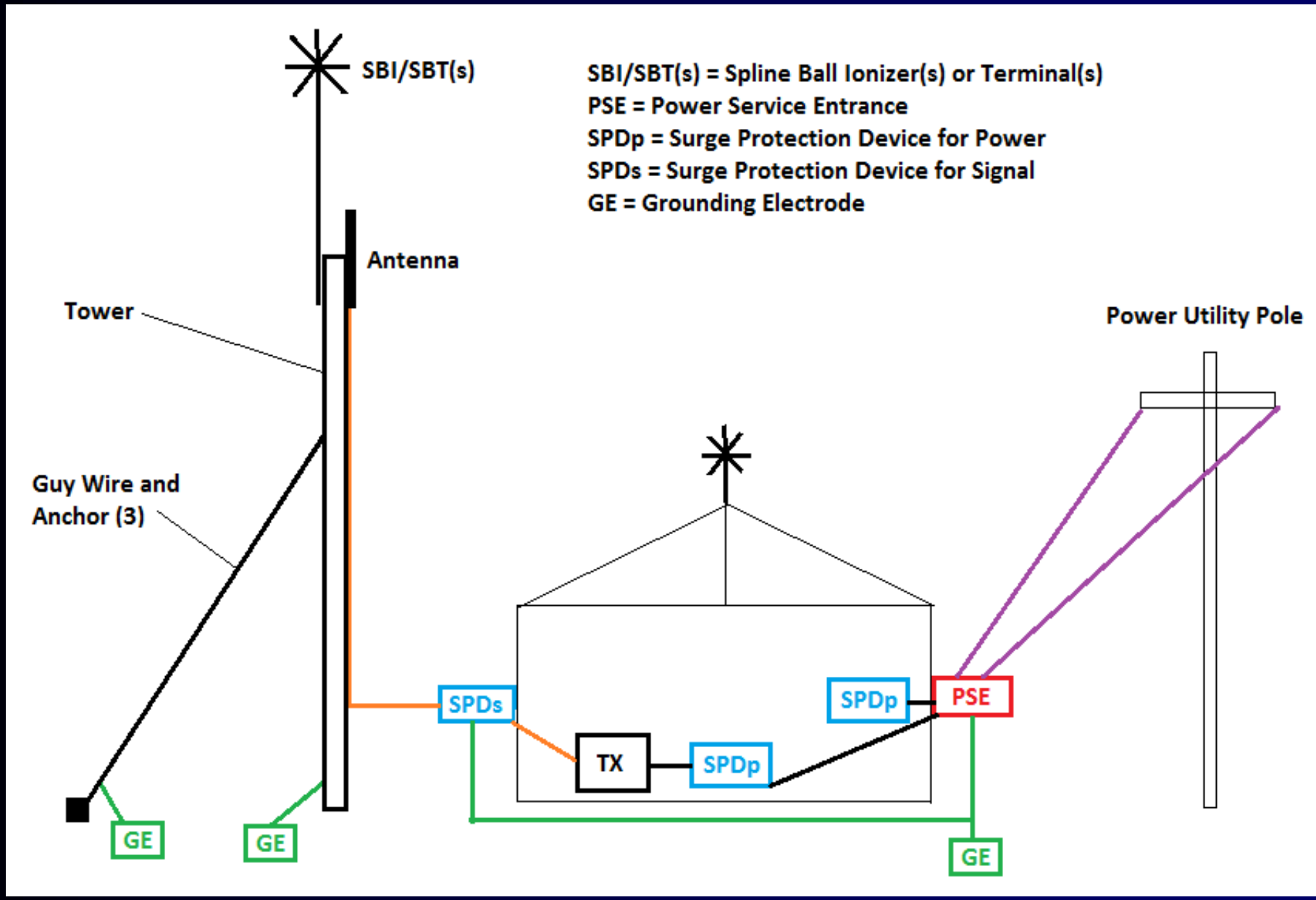
Good for:

- **Measuring grounds on T&D lines**
- **Measuring suburban locations, e.g. residential developments**

Ham Radio Operators
General Recommendations

- **Avoid direct lightning strikes**
  - **Install Spline Ball Ionizers/Terminals on tower**
  - **Lower when not in use**
- **Install surge protectors on all wires**
  - **Use adequate surge capacity**
    - **≥ 50kA for power, ≥ 10kA for low voltage lines**
  - **Staged protection, both ends, redundancy**
- **Install low <u>impedance</u> grounding system**
  - **Common point grounding**
  - **Test to verify low impedance**

Radio Station - Protected Layout



The End

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