IEEE 1692-2011 Guide

What this Guide Doesn't Mention

or thoroughly discuss

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IEEE Guide for the Protection of Communication Installations from Lightning Effects

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IEEE Guide for the Protection of Communication Installations from Lightning Effects

1. Overview

1.1 Scope

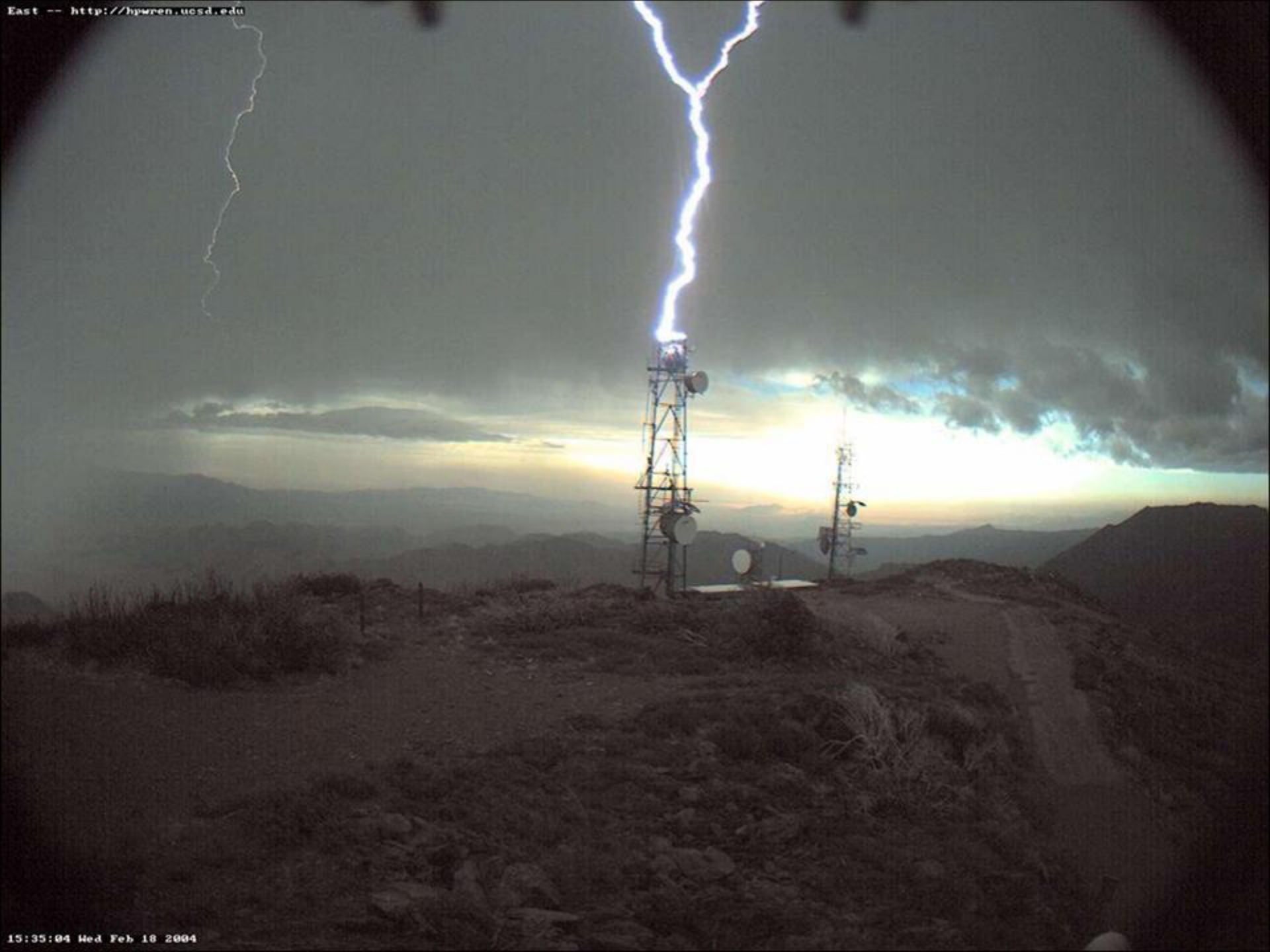
This document presents engineering design guidelines for the prevention of lightning damage to communications equipment within structures.

1.2 Purpose

The purpose of this guide is to provide reliable engineering methods and practices to minimize damages to communications equipment located within a structure.

1.3 Application

The protection of the structure plays an important role in the protection of the equipment within the structure. While the protection of the equipment is the main objective of this document, the protection of the structure housing the equipment is also covered in this document.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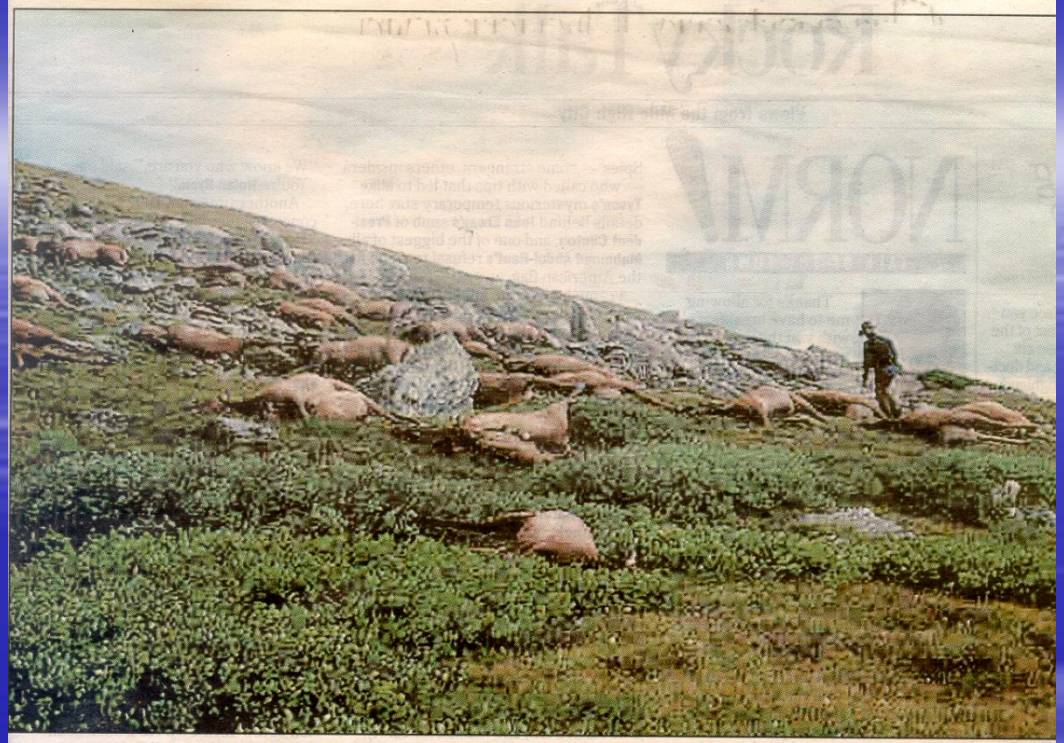


Colorado Division of Wildl

Wildlife official Russ Mason examines elk carcasses in the Mount Evans wilderness. Lightning is blamed for the deaths of the 56 an mals. "It's quite rare to find so many animals killed in a single incident," biologist Janet George said.

Lightning kills herd of 56 elk

Group's grisly find above timberline on Mount Evans stuns state wildlife officials

By John C. Ensslin
News Staff Writer

A herd of 56 elk have been discovered dead on remote tundra in the Mount Evans wilderness, the victims of an apparent lightning strike, state wildlife officials said Thursday.

While such deaths are common above timberline, the number killed is the largest in the memory of state officials.

"We've found big game animals before that were killed by lightning — it's probably something that happens every year in Colorado," said Janet George, a wildlife biologist with the Colorado Division of Wildlife. "But it's quite rare to find so many animals killed in a single incident."

A Jefferson County man scouting hunting sites made the grisly discovery Aug. 17 on a ridge at 12,200 feet, about four miles south of the summit of Mount Evans.

"We got up there and our chins just about hit the ground," said Dave Workman.

Workman, his 12-year-old son, Thomas, and several friends had been riding horses for about four hours when they found the herd.

"I said, 'OK, there are a couple elk up there on the ridge bedding down,' " Workman said.

But when he borrowed a telescope from his friend Glenn Reynolds, Workman said he was surprised to see the hooves on one animal pointing up.

As they drew closer, they realized all the elk were dead. The bodies were decomposed and other wildlife — ravens, golden eagles and coyotes — appeared to have been feasting on them.

In all there were 34 cow elk, 1 bull elk and nine calves. Officia said 48 were grouped within a 6(foot circumference. Another fiv were 75 feet away and three mor were 130 feet away.

George said a combination factors led to a conclusion tha they had been hit by lightnin recent thunderstorms and the ele vation where the deaths occurred

The bodies were too badly de composed to check for the dime sized burns that lightning leaves George said.

There are more than 2,000 el in the Mount Evans area.

Wildlife officials plan to let na ture take its course and are leav ing the carcasses alone.

"One thing's for sure," Georg said. "There's a lot of happy rav ens, eagles and coyotes up there."

WILDLIFE DEATHS

Other wildlife deaths blamed on lightning:

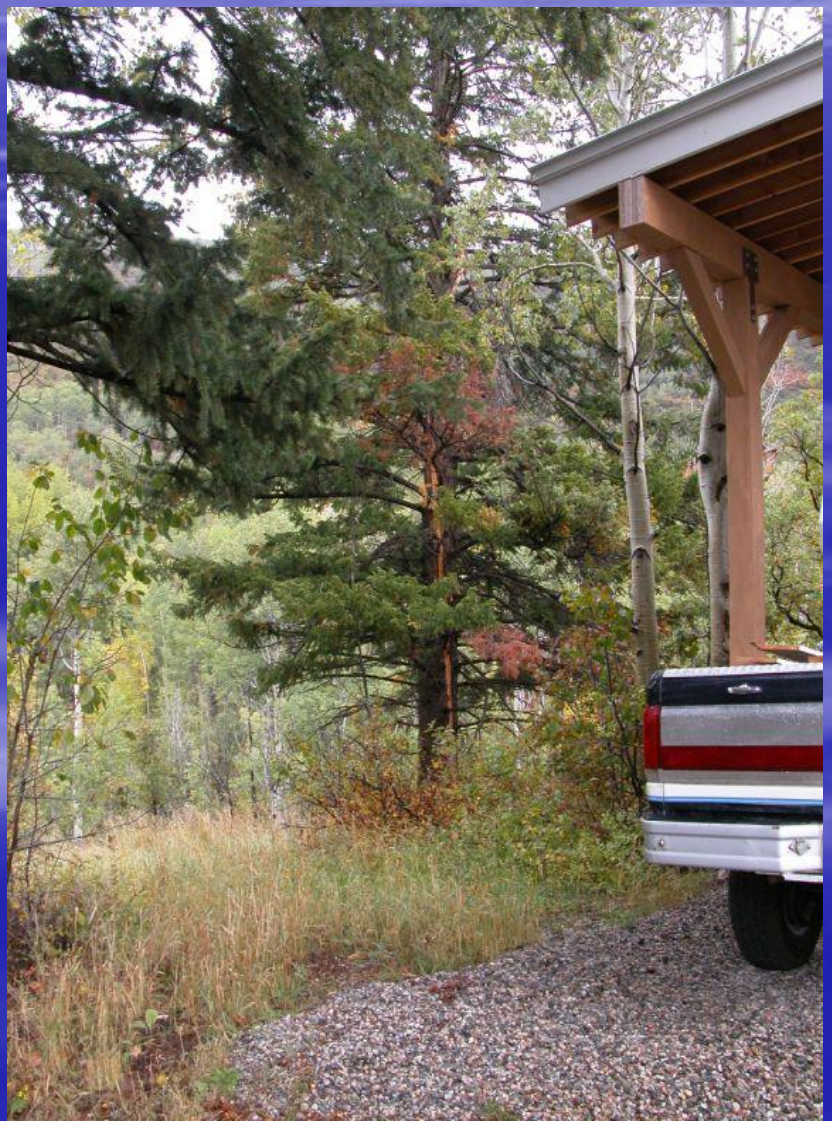
1997 — Six bighorn sheep killed in Colorado's Kenosha Mountains.

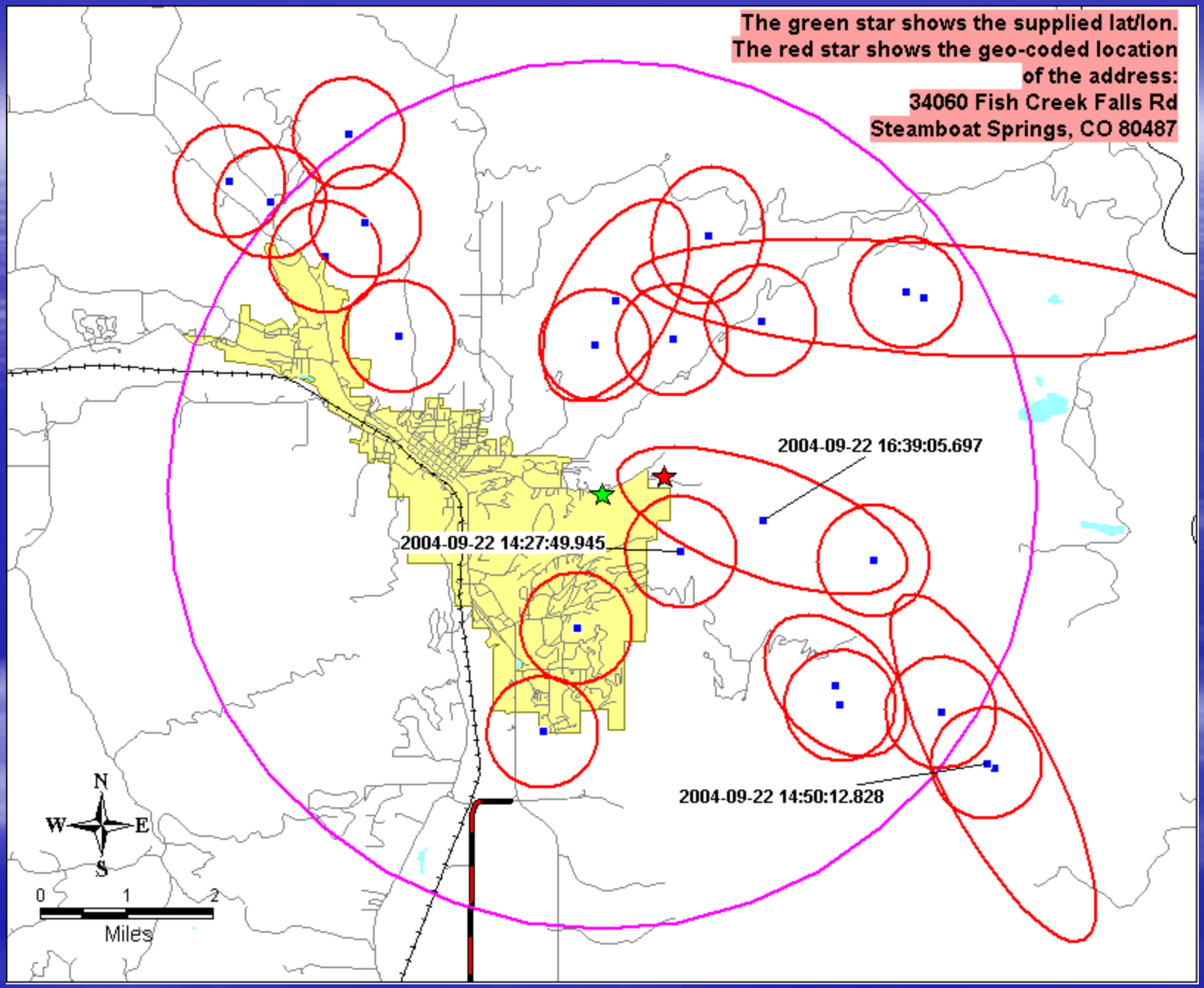
1986 — 12 elk killed on the Continental Divide north of the Eisenhower Tunnel.

1972 — 52 caribou killed in Central Alaska.

Source: Colorado Division of Wildlife.

90KA Positive Stroke to a tree 80 feet from home

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Steamboat Springs, CO 80487
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HOW ARE WE GOING TO GROUND A FACILITY?

- **Against 60 Hz power contact?**
  - The NEC and NESC apply as stated in the scope of these two codes
- **Against a Lightning Strike?**
  - NFPA 780 code covers "traditional lightning protection system installation, i.e., air terminals, ground rods, with no thought to there being such a thing as Ground Potential Rise!
  - IEEE Std. 1692-2011 covers the protection of equipment from lightning induced Ground Potential Rise (GPR) as well as a Grounding System to minimize GPR.
- "If you design a grounding system to protect against a lightning strike, you have also protected against 60 Hz power contact by a *very large margin*"!
- **The reverse *is not* so!**

Triggered lightning test, Sandia Labs, 1993, grounded using vertical ground rods.

This picture shows the results of a triggered lightning test (with a current of 29.5 kiloamps) by Sandia National Laboratories in 1993. The **vertical ground rods** used to ground the rocket launching platform **were ineffective** in lowering the ground potential rise. As a result, a flashover occurred forming a radial pattern in the horizontal plane.

In 1996, at the suggestion of SAE Inc., Sandia used a horizontal radial system to ground the launching platform. This configuration was hit repeatedly by triggered lightning and no flashover occurred. The Sandia tests demonstrate that **horizontal grounding systems effectively dissipate lightning energy**.

Resistance-Resistance-Resistance

what about

Impedance?

- Can we get out our impedance meter now and check our grounding system for its impedance to a lightning strike?
- Not hardly
- Can we still design a grounding system keeping in mind what we do know about surge impedance?
- Yes, you bet we can! The answer is radial capacitive grounding
- Large flat conductive concrete radials are even better
  - Sankosha Lo-Ohm Cement / Electric Motion Company, Winsted CT (860) 379-8515
  - A radial capacitive grounding system is much more effective than a ground system employing exclusively ground rods
    - Because of reduced impedance
    - Because of the principle of division
    - Because of high frequency components of lightning

Secret to Effective Lightning Grounding

- Lightning current ranges from dc to approximately 2Mhz with most of the current frequency ranging at the upper end of the spectrum
- Impedance in conductors for lightning current is thus very large, resulting in an approximate voltage drop of 1500 V per foot for a 2/0 AWG copper conductor
- Impedance is a little less, approximately 800 volts per foot, for a copper conductor the size of your wrist!
- Thus a ground rod with a ten foot pig tail from a tower leg has a voltage drop of 15,000 volts to just get to the ground rod!
- The answer has to be many paths for lightning currents and ground rods are not the answer either!

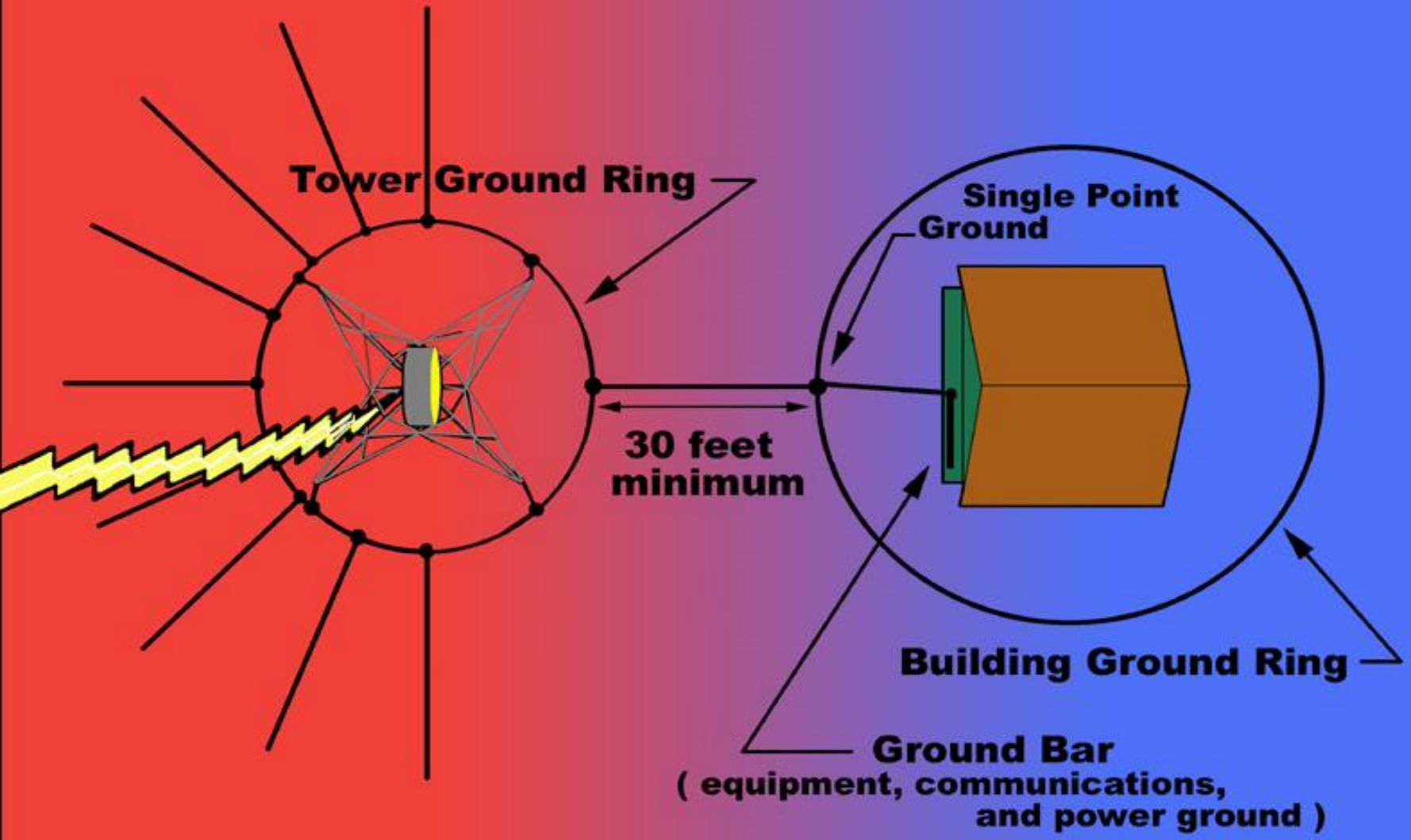
Secret to Effective Current Paths for Lightning

- A radial (horizontal conductor) is similar to one side of a Capacitor and the other side of the Capacitor is the Earth
- At Time (T) = 0 a Capacitor is a short circuit, thus lightning current (at less than 5 nanoseconds) is flowing current in that radial
- At Time (T) = 0 an Inductor (like a vertical ground rod) is an open circuit and hindering the flowing lightning current to the Earth
- Ironically, ground rods placed horizontally are better dissipaters of lightning current by acting like Capacitors
- The more radials the better. This is current division and very important to reduce overall impedance.

GROUNDING FOR LIGHTNING

- Ground rods are placed around the tower ground ring to sink the lower frequencies of current to remote earth
- Radials are placed off of each ground rod to sink the higher frequencies of current to remote earth
- Maximum length of a radial is 80 feet, 40 feet being ok
- Number of radials is determined by the required grounding system resistance to remote earth; number is more important than length
- Each Radial length can vary because only the total sum lengths is necessary to achieve required grounding system resistance value
- A two (2) ohm or better tower grounding system to remote earth, using radials, will prevent almost all equipment damage, only if equipment building is also properly grounding and equipment is either isolated or surge protected from any remote ground.

Ideal Lightning-Dissipating Single-Point Grounding System



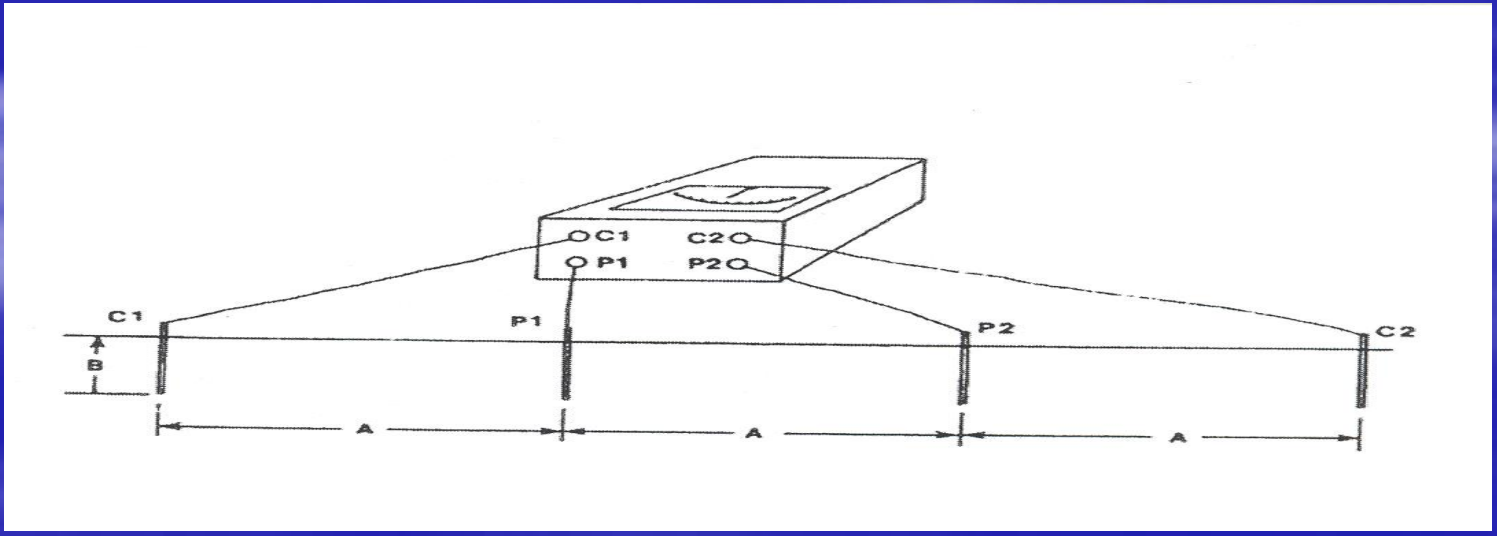
Designing a Grounding System

- **Make Four (4) Probe Soil Resistivity Measurements** for the planned depths of the ground rings, radials, and the ground rods.
- **Use Erling Sunde's formulas** to calculate the multitude of different system component ground resistances, i.e.; rings, ground rods, radials, straight wire, etc.
- **Calculate total system ground resistance**, i.e.(in parallel); 1/R = 1/r + 1/r...
- **Add radials** (as necessary) off of the tower ring to lower system ground resistance to the required design specification. Six (6) radials approximately 40 to 60 feet in length are all that is usually necessary to obtain a 2 ohm or better ground to remote earth.
- **This method provides very accurate results** (97%+) to the actual measured total system ground resistance as a final check of the grounding system impedance to remote earth.
- **Any Wenner Three Probe final system grounding system test** must be measured without a bond to multi-grounded neutral (MGN).

Measuring Earth Resistivity

- **The four-point (Wenner) method** is the most accurate for measuring large volumes of undisturbed earth.
- **Earth resistivity in meter-ohms: ρ=2x(3.1416)x(a)x(R)** where **a**=probe spacing in meters & **R**= meter reading in ohms.
- **At a 4 foot depth** (which is a 4 foot probe spacing):

ρ=7.66 x meter reading in ohms (R)



Equipment Building Design for Lightning Surge Energy

- Provide a Single Point Ground (SPG) for the equipment building to equalize all potential throughout
- Locating the tower at least 30 feet away from equipment building will almost eliminate the electromagnetic radiation from the lightning strike
- Provide radials in the grounding system to current divide the lightning strike energy
- Use a bulkhead to ground lightning surges on the tower coaxial cables from entering the equipment building
- Do not confuse the function of the Internal Equipment Ring Ground (IERG) with the function of the HALO Ground.
- IERG must be at the height of bulkhead and only bonded to earth ground at the SPG
- HALO Ground is an RF grounding of metal building objects, i.e.; window frames, door jams, air conditioners, etc. which may be bonded to the building ring ground at the four corners of a building
- Accidentally bonding equipment to the HALO Ground will result in catastrophic damage to equipment by placing four (4) different voltage potentials from resulting lightning strikes

Cont' Equipment Building Design for Lightning Surge Energy

- Isolate wire-line communications from remote ground using optical isolators or very fast type surge protection
- Provide for AC Power surge protection at the power entrance facility
- Protect equipment using very fast surge protection
- Surge Protection must be Silicone Avalanche Diode (SAD)
- SAD will fire under 5 nanoseconds and protects against lightning
- Metal Oxide Varistors (MOV) fire between 35 and 50 Nanoseconds and will not protect against all of the lightning surge
- Use cathodic protection (sacrificial anode) to protect a grounding system from corrosion to essentially double its life from approximately 20+ to 40+ years
- Use #2 AWG, Solid Bare Tinned Copper {SBTC} for all ring grounds and radials
- Design a tower & building grounding system that has a combined resistance to remote earth of less than one (1) ohm if possible

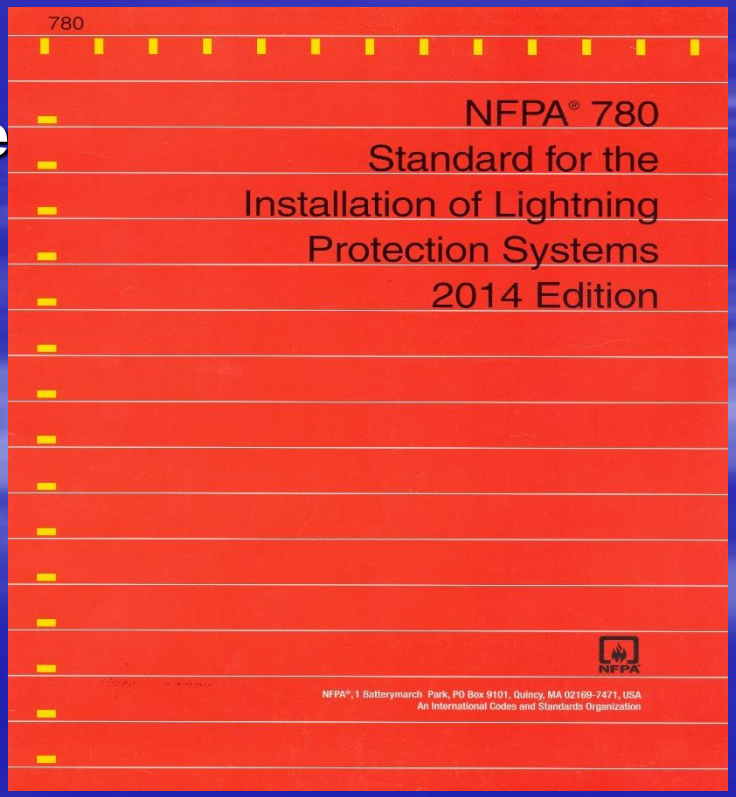
NFPA 780-2014 is a Building Lightning Protection Standard

"Don't forget to always consider this standard when designing the physical protection installation of the equipment building"

However, be aware of the Scope

Scope: This document covers traditional lightning requirements for the following:

- Ordinary structures
- Miscellaneous structures
- Heavy-Duty Stacks
- Watercraft
- Structures containing flammable vapors, gases, or liquids
- No GPR discussion
- No radial grounding
- No protection of equipment



WIND FARMS

"Trouble in River City"

- Placed on ridges where soil resistivity is usually greater than 5000 Ohm-Meters
- Switchyard is located at a remote distance from its generators
  - This significantly increases the potential difference between locations stressing turbines
- Wind Turbines are placed 800 to 1000 feet apart
  - Making the interconnection of wind turbine grounding difficult to impossible
  - This maximizes lightning stroke stress at a single wind turbine
- GE requires a wind farm grounding system design value of less than two (2) ohm to remote ground
  - Can only be achieved by specifying Sankosha Lo-Ohm Cement
  - Requires many radials in number
  - Requires radials in excess of the excepted maximum length at each wind turbine of 80 feet
  - Two (2) ohm ground at each turbine may not be achievable

CAROLINA WEST WIRELESS

is a Perfect Success Story from Following the Principles Just Discussed

- In 1996 Caroline West implemented Single Point Grounding (SPG) at their PCS tower locations and isolated their T1-Carrier with Positron's Teleline Isolator
- There has been no equipment lightning strike damage since at any of their 50+ sites in Carolina and on the Blue Ridge Mountains
- Prior to implementing these two recommendations, lightning damage to equipment was keeping many repair crews working overtime and being called out at all hours of the night
- Repair crews were cut down by half and overtime was almost totally eliminated

PROGRESS ENERGY SERVICE COMPANY

- Methods Communication Building [Progress Energy's Control Bldg.]
  - 300 foot tower was being struck by lightning 2-3 times a year resulting in equipment damage within the control room
    - Tower located against building with a 3 ohm ring ground measured to remote earth
- Seven (7) radials added in 1.5 foot wide trenches (each 40' to 50' in length)
  - Radials were placed under an asphalt parking lot
  - 330 feet of radials were added
- Tower ground with radials calculated at 0.78 ohms to remote earth
- Tower grounding completed in September of 2006

- NO FURTHER DAMAGE TO EQUIPMENT FROM LIGHTNING STRIKES TO THIS TOWER HAS OCCURRED
  - RADIAL GROUNDING IS MORE IMPORTANT THAN THE GROUNDING SYSTEM RESISTANCE VALUE TO REMOTE EARTH

911 PSAP LOCATIONS

- Carroll County PSAP, Maryland
- Wicomico County PSAP, Maryland
- Hilton Head PSAP, South Carolina
- Not one more case of equipment lightning damage has occurred at these three locations since tower grounding, wire-line isolation, and SPG was installed in 1995 and 1996.

- NOTE: These were the first cases on record of protecting equipment by isolation from a GPR that were not within a power substation environment