

# Investigating Lightning-Related Fires

November 2023

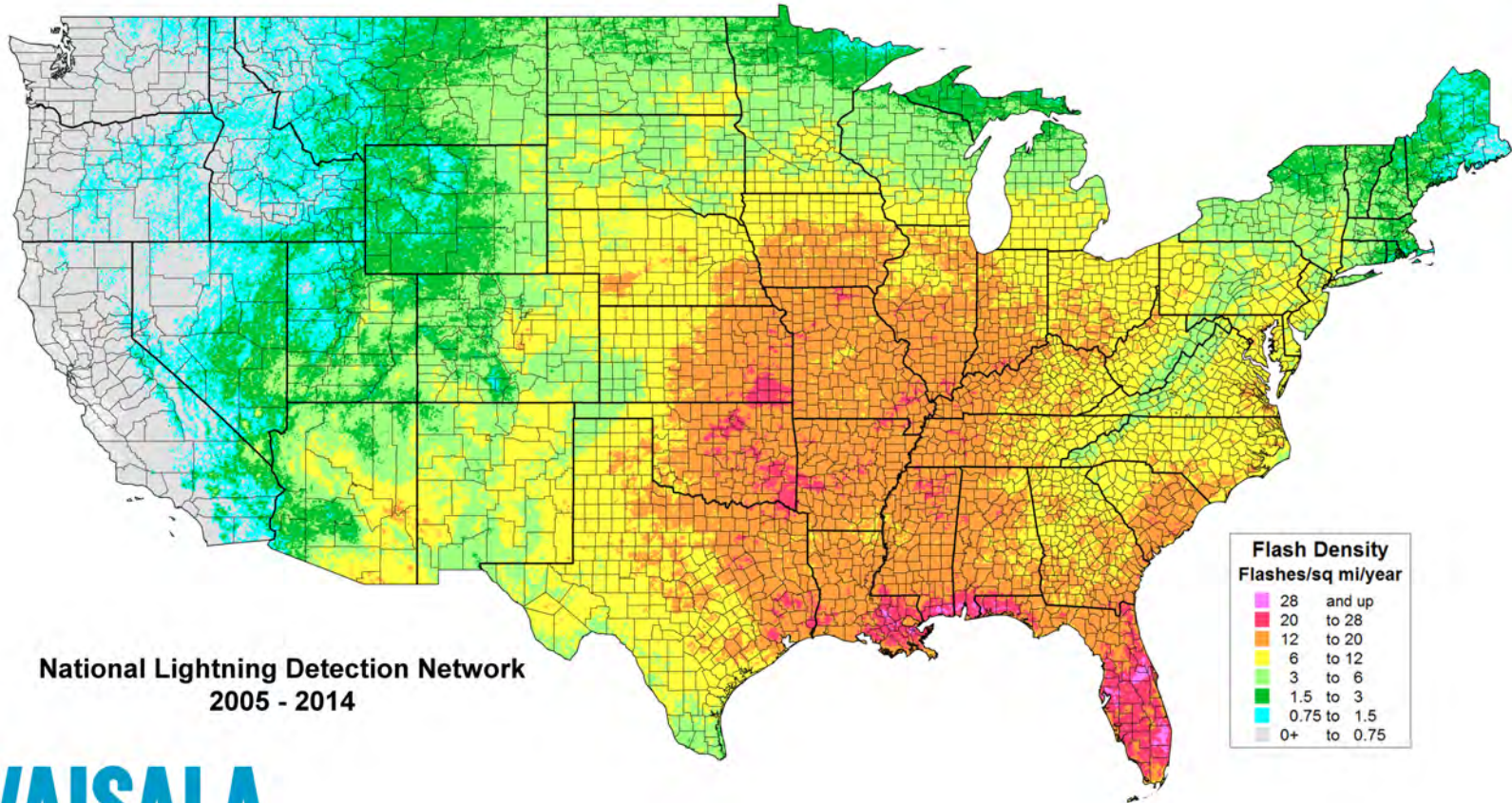


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# Lightning 101



# Lightning 101

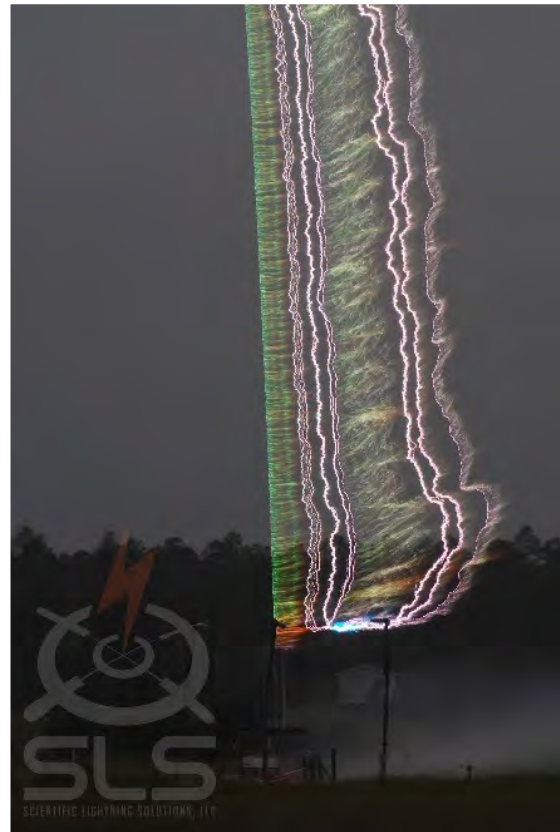
## ⚡ What is lightning (terminology)?

Lightning is an electrical discharge caused by separation of charges, which create large electric field gradients.

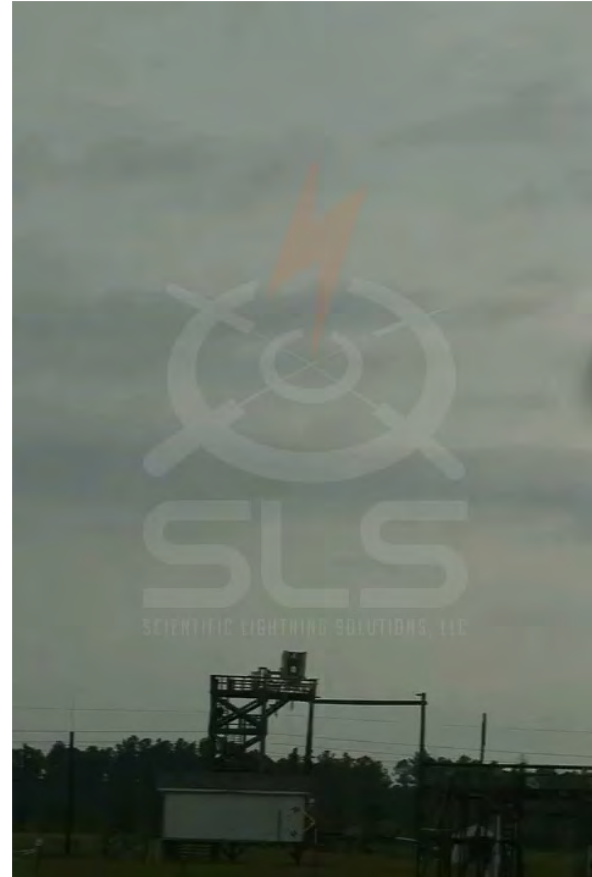
⚡ “**Lightning Flash**” or “**Flash**” refers to a lightning or a lightning discharge.

⚡ “**Lightning Strike**” is a lightning discharge that involves an object on ground or in the atmosphere.

⚡ “**Stroke**” is a component of cloud-to-ground lightning discharges.



# Lightning 101



# Lightning 101

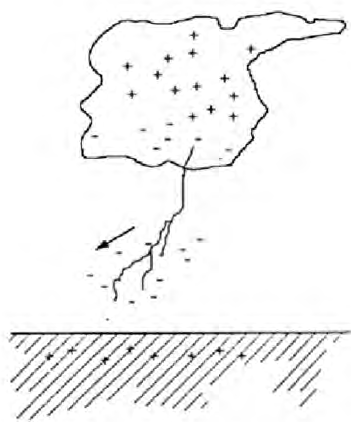




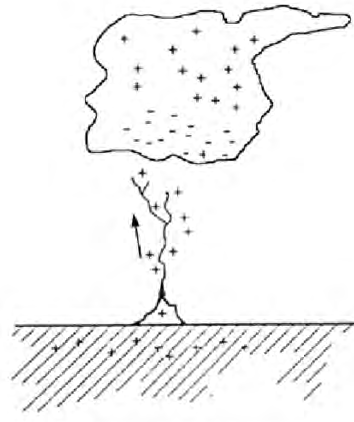
# Lightning 101

## Types of Lightning:

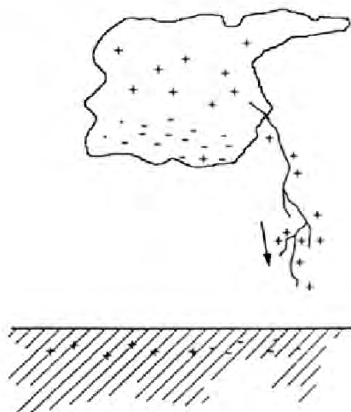
In this presentation we'll talk about positive and negative cloud-to-ground (CG or downward) and ground-to-cloud (GC or upward).



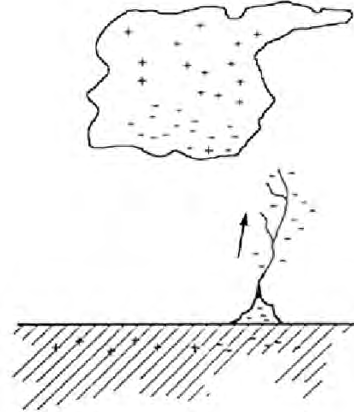
(a) Downward Negative Lightning



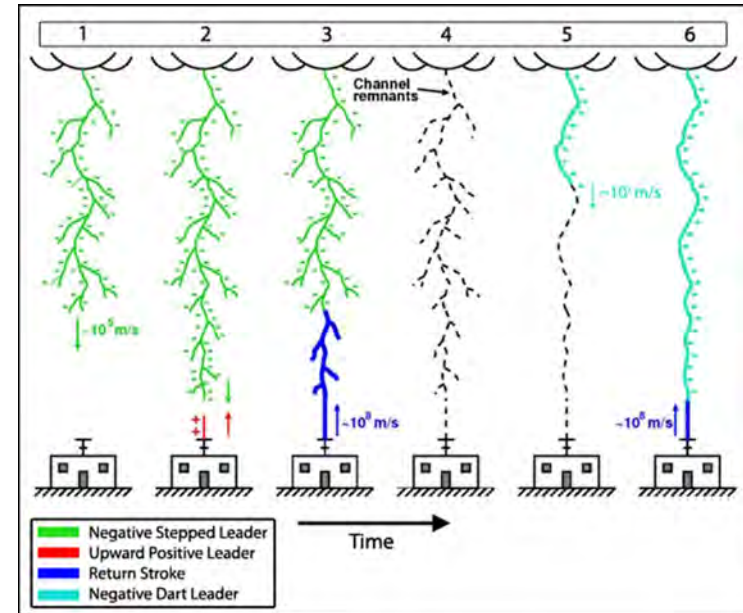
(b) Upward Negative Lightning



(c) Downward Positive Lightning



(d) Upward Positive Lightning



**Other types of lightning (not covered in this presentation):** cloud-to-cloud, intra-cloud, spider, ball, upward-illumination, transient luminous events or TLEs (sprites, blue jets, and elves), etc.

# Lightning 101

## Negative Flashes (CG)

- ⚡ Effectively lower negative charges to ground
- ⚡ About 90% of all CG flashes are negatives
- ⚡ Propagation tends to be vertical with branching proportional to peak current
- ⚡ 3-5 strokes, on average
- ⚡ First stroke: 95% 14 kA, 50% 30 kA, 5% 80 kA
- ⚡ Subsequent strokes: 95% 4.6 kA, 50% 12 kA, 5% 30 kA
- ⚡ Lower charge transfer

## Positive Flashes (CG)

- ⚡ Effectively lower positive charges to ground
- ⚡ About 10% of all CG flashes are positives
- ⚡ Stochastic propagation rarely with any branching
- ⚡ 1 stroke, typical
- ⚡ Peak Current: 95% 4.6 kA, 50% 35 kA, 5% 250 kA
- ⚡ Higher charge transfer



# Lightning 101, Negative Flash



# Lightning 101, Negative Flash



# Lightning 101, Negative Flash



# Lightning 101, Weak Positive Flash



# Lightning 101, Positive Flash





# Lightning 101, Positive Flash





# Simultaneous Upward Leaders

Direct Strike to LC-39B (07/08/2017)



# Upward Illumination (UI) Strokes

UI Stroke: Direct Attachment to LC-40 Lightning Protection System (06/18/2016)



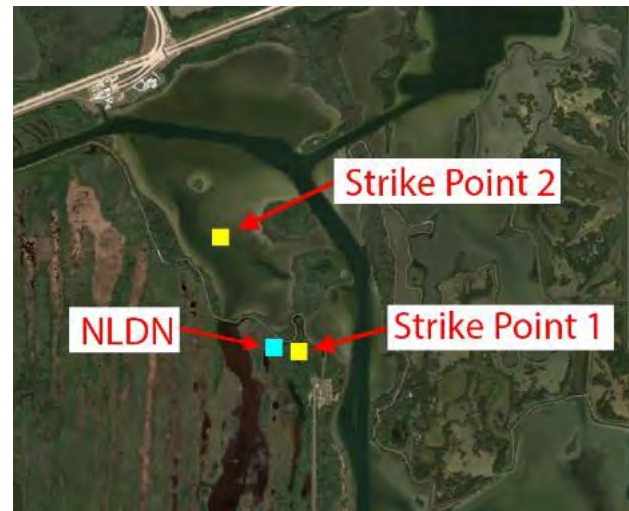
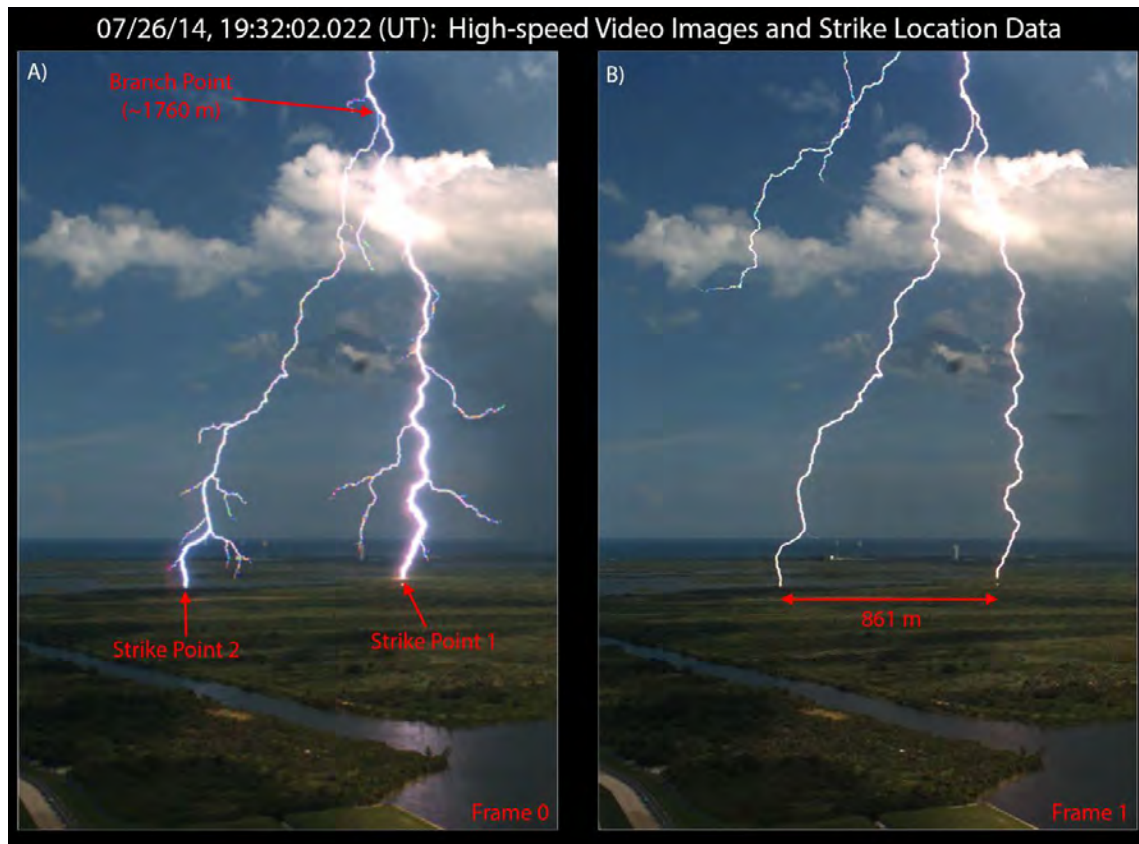
# Multiple Termination Points, Strike to Launch Pad

3-Termination Direct Attachment to LC-41 Lightning Protection System (07/19/2015)

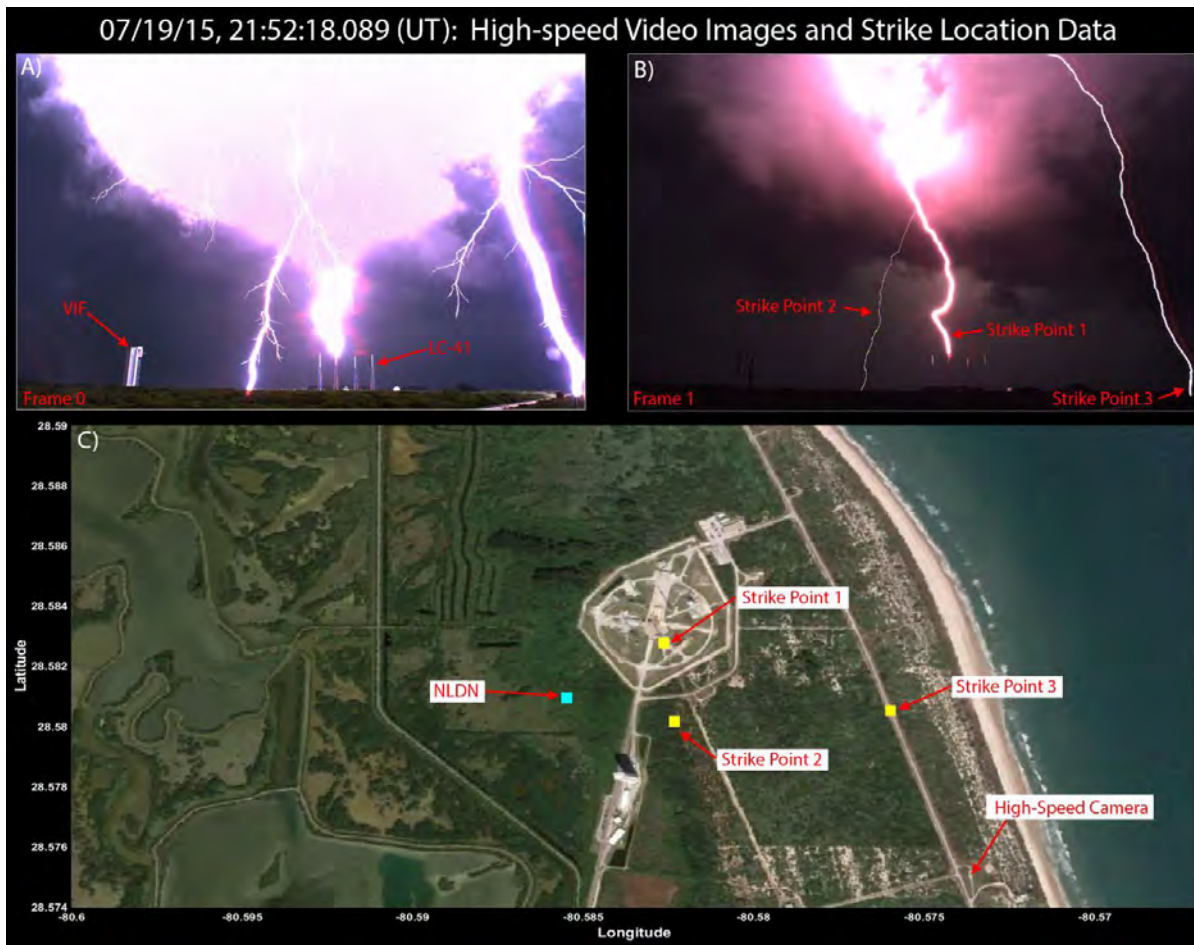


*Neither MERLIN or CGLSS reported a strike location for this flash (07/19/2015, 21:52:18.089)*

# Simultaneous Ground Termination Points



# Multiple Termination Points, Strike to Launch Pad





# Multiple Termination Points, Strike to Launch Pad





# Bolt from the Blue



# Bolt from the Blue



***Observed** to travel tens of miles from the edge of the cell. Extremely small sample size.*

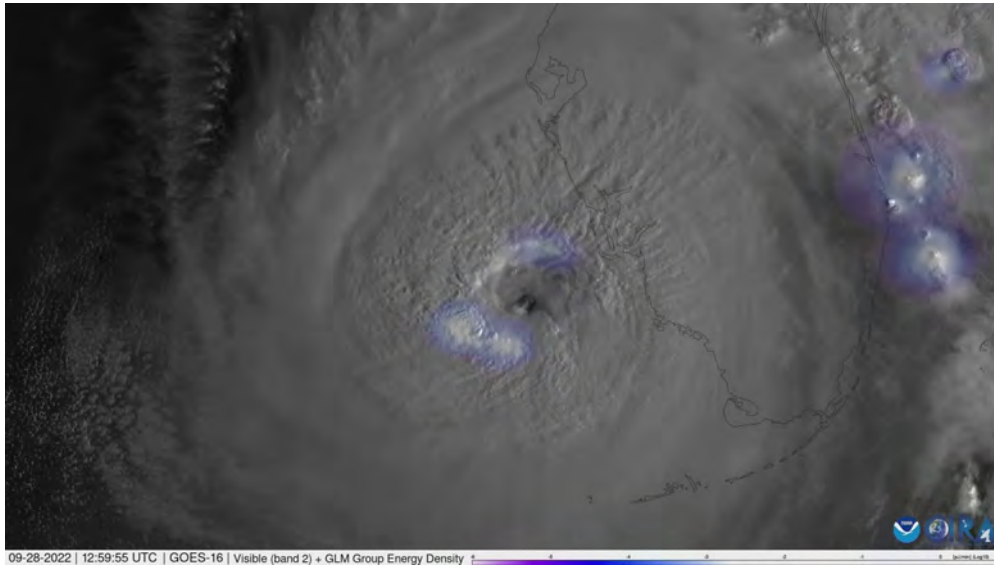
# Question

⚡ Can lightning strike a tree and a house at the same time?

# Lightning 101

## What causes lightning?

Lightning creation is a complicated process, but it can be simplified as follows: lightning is created by anything that can cause large charge separation between two masses: volcanic eruptions, extremely intense forest fires, surface nuclear detonations, heavy snowstorms, large hurricanes, and thunderstorms.



Credit: NOAA, Ian Hurricane before landfall in FL.



Credit: Marco Fulle, Eyjafjallajökull eruption april 17 2010 (Iceland).

# Lightning Hazards

- **To Humans:** injury or death to individuals or group of individuals.

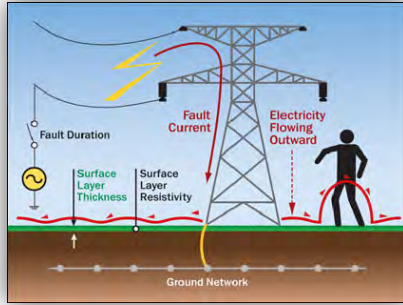
Most human-related lightning incidents are not due to lightning directly striking the individual or the immediate vicinity.

- **To Structures/Assets:** indirect, direct.

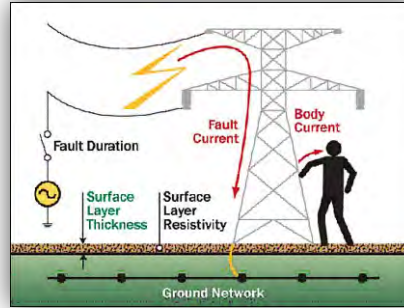
- Overview of lightning and ways that lightning can cause damage to facilities
- Basic protection methods against these damage modes

# Lightning Hazards to Humans

## ⚡ Step Potential



## ⚡ Touch Potential



## ⚡ Upward Leader & Direct Strike



## ⚡ Lightning-induced fire and explosions



## ⚡ Human Factors



- Falls
- Runway
- Chemical spills
- Car accidents
- Falling debris
- Etc.



# Lightning Hazards to Humans



# Lightning Hazards to Humans

- Heart attack/arrhythmia
- Central nervous system
- Amnesia
- Rupture eardrums
- Severe burns
- Death
- Human factor injuries: rocks, car accidents, heart attaches, falls, burns, chemical, etc.



Sebring, May 9, 2022, Ring Camera

# Personnel Safety

- Seek shelter in shelters that have been designed and assessed to protect people. Note that shelters may not be safe. Lightning Risk Assessments are always recommended to verify risks have been mitigated.
- Lightning Risk Assessments (LRA): productivity, evaluate tasks & activities, mitigate risks, etc.
- Follow standard personnel lightning safety guidelines
- Personnel outdoors are not safe during thunderstorms
- Question: what is outdoors?

# Lightning Warning Systems

Various technologies exist to aid forecasting lightning occurrence. These systems range greatly in size and cost. Lightning detection and location systems can be used as lightning warning systems, as they can track storms.

- ⚡ Single-station devices: unreliable, inaccurate, manufactures fail to disclose limitations.
- ⚡ Free Web/Mobile Apps: [lightningmaps.org](http://lightningmaps.org), [weatherbug.com](http://weatherbug.com), local maps/websites, etc.
- ⚡ Paid subscriptions: NLDN, Earth Networks, etc.
- ⚡ Complex, Multi-Station Systems: custom, best performance, more expensive.

**FACT:** There is no technology to predict when and where lightning will strike. We can only monitor when the conditions are favorable for lightning to occur (forecasting). There are no lightning prediction systems.

# STRIKnet Reports

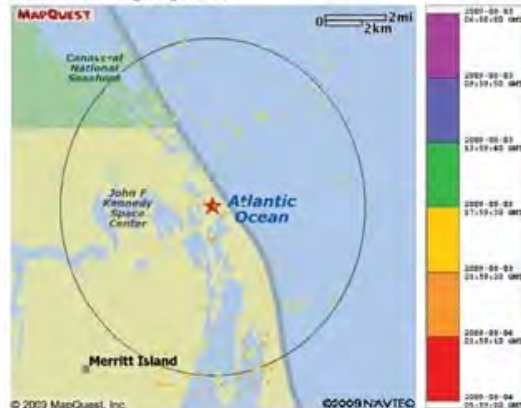
- ⚡ Most commonly used.
- ⚡ Shortcomings are across the board.



## STRIKnet Report 238904

Report Title: STRIKnet LC38A 6-3-09  
 Total Lightning Strokes Detected: 430  
 Lightning Strokes Detected within 5 mi/8 km radius: 274  
 Lightning Strokes Detected beyond 5 mi/8 km whose confidence ellipse overlaps the radius: 154  
 Search Radius: 5 mi/8 km  
 Time Span: Aug 3, 2009 06:00:00 GMT to Aug 4, 2009 05:59:00 GMT

### Location Points For Lightning Strokes



Lightning data provided by Vaisala's NLDN® and/or Environment Canada's CLDN.

Vaisala Inc.  
 Tucson Operations  
 2705 E. Medina Road  
 Tucson, AZ 85706, USA  
 thunderstorms@vaisala.com  
 Tel: +1 520 806 7300  
 Fax: +1 520 741 2848  
 thunderstorm\_sales@vaisala.com



Aug 4, 2009 06:50:43

Page 2

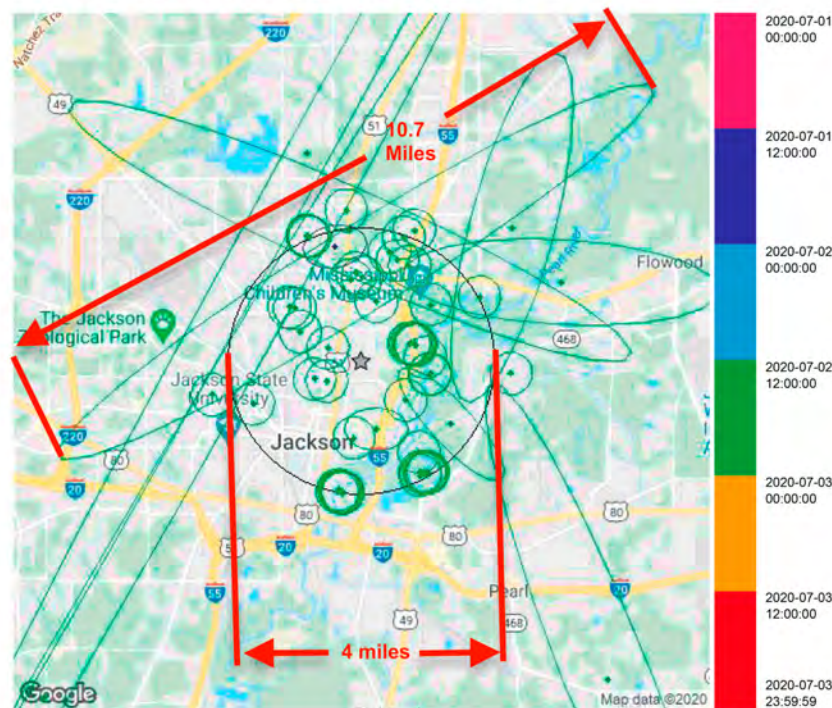
# STRIEnet Reports

STRIKE.net Report #11386674

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## Confidence Ellipses For Lightning Strokes

- ⚡ Report indicates center of confidence ellipse.
- ⚡ You must ask for confidence ellipses to be included in the report.
- ⚡ What is the detection efficiency?
- ⚡ What is the accuracy?
- ⚡ Have the error ellipses been validated?
- ⚡ Multiple attachment points?
- ⚡ See MERLIN Performance Study



Lightning Confidence Ellipse Map indicates with 99% certainty that the recorded lightning event contacted the ground within the bounds of the ellipse.

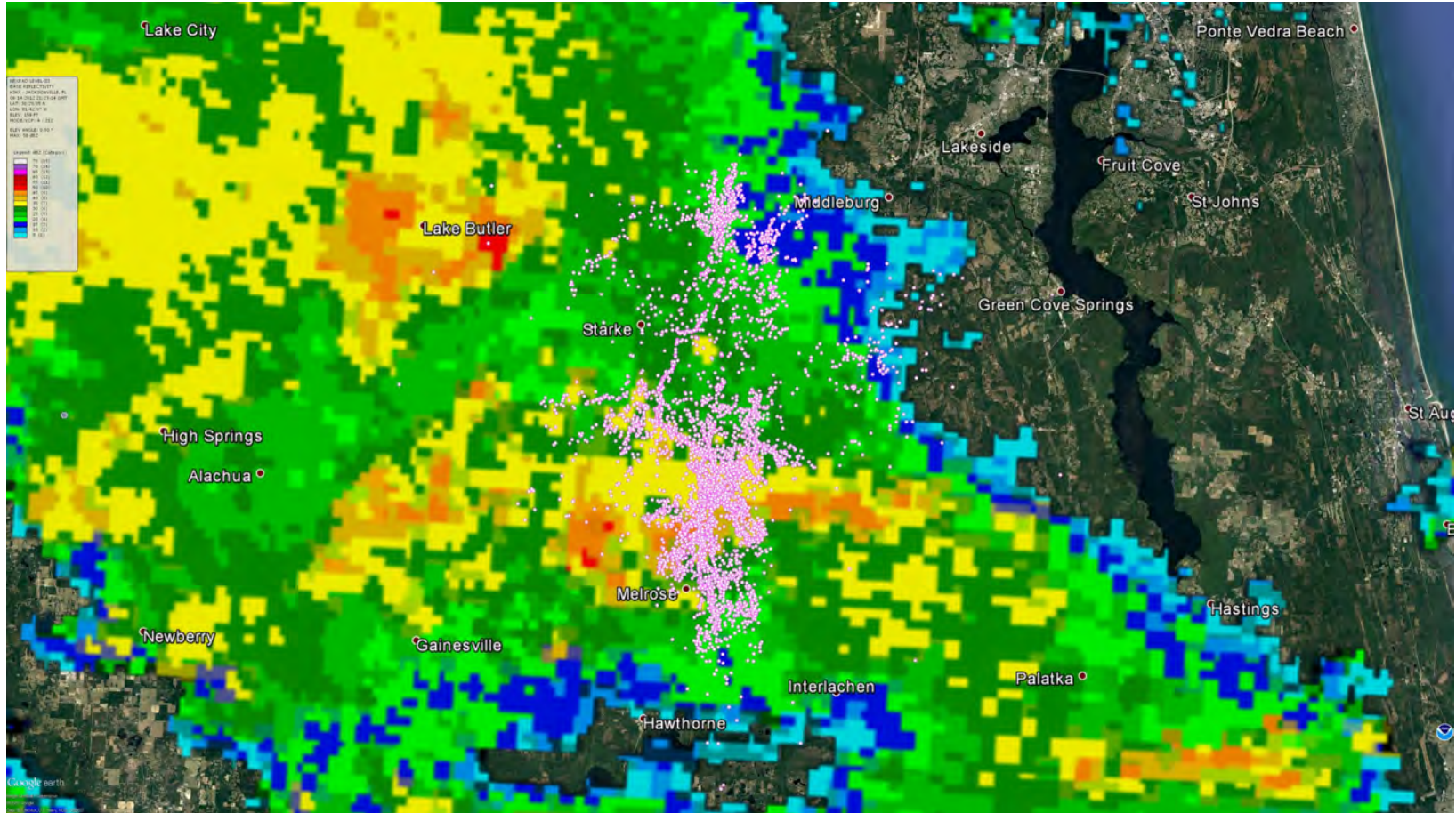
The small circles are approximately 0.6 miles in diameter.



# Question

- ⚡ If a STRIKEnet report identifies no lightning in the area, does that mean lightning didn't happen?
- ⚡ What else can we do?

# Base Reflectivity Radar Overlay



# Lightning Hazard to Assets

## Direct Strike Damage

- ⚡ Lightning strikes may damage building structures, electrical, mechanical, comm, electronic systems, equipment, runway surfaces, aircraft, etc. that are not protected by a lightning protection system (collateral damage).
- ⚡ Lightning can ignite fires, cause explosions, and it can ignite wildfires.



July 2014, Keystone Heights, FL



## Nearby Lightning Damage

- ⚡ Power transients can damage electrical, mechanical, comm, and electronic systems.
- ⚡ Surges can damage sensitive electronics.



# Impacts of Lightning On Industry

- ⚡ For industries where personnel work outdoors, lightning presents an immediate hazard that results in work stoppages.
- ⚡ Lightning damage to infrastructure, electro-mechanical systems, and sensitive electronics result in a loss of capital, productivity, bad publicity, customer relationship problems, etc.
- ⚡ Fires and explosions can generate substantial losses, bad publicity, customer problems, litigation, OSHA scrutiny, etc.



# Lightning Damage, NFPA 921

- ⚡ Lightning damage by two characteristics:
  - ⚡ High currents and energy
  - ⚡ Extremely high temperatures
- ⚡ Tree damage, scars, burn, or shatter
- ⚡ Conductors may be melted, severed, or completely vaporized
- ⚡ Concrete may be destroyed with explosive force as the lightning current finds its way to ground
- ⚡ Fuel gas systems may also catch on fire, appliances



Credit Fox Weather, Ohio July 8, 2022



# Lightning Damage, General

- ⚡ Wire insulation damage:
  - ⚡ How do we know if there has been wire insulation damage?
  - ⚡ What should we do?
  - ⚡ Consequences of compromised wire insulation?
- ⚡ Low voltage systems damage
- ⚡ Coils, transformers, high impedance faults





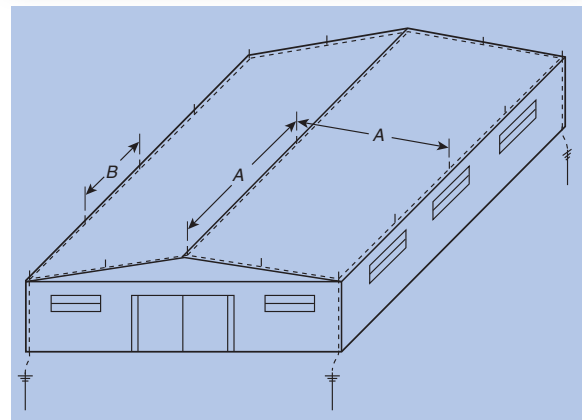
# Lightning Protection

## Types of Conventional Lightning Protection

- ⚡ Bonded Lightning Protection Systems
- ⚡ Isolated Lightning Protection Systems
- ⚡ A Combination of Both, Bonded and Isolated

## LPS Components

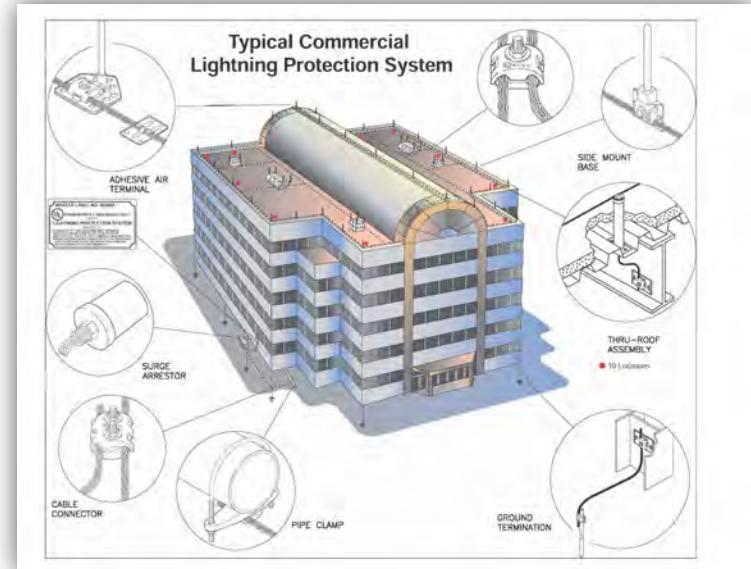
- ⚡ Strike termination devices
- ⚡ Downconductors
- ⚡ Grounding system
- ⚡ Anything else? Potential Equalization, Surge Protective Devices, Shielding & Isolation



# Bonded Lightning Protection Systems

## Lightning Protection Basics

- ⚡ Lightning protection systems **do not** statistically alter the probability that lightning will strike a structure.
- ⚡ Properly designed bonded LPS provide low-impedance paths for lightning currents to flow to ground.
- ⚡ These systems reduce probability of damage to structures being protected.
- ⚡ Typically used for buildings, regular structures, and non-flammable facilities



*Credit: Bonded Lightning Protection*

# Question

- ⚡ Can lightning start a fire on a facility/residence protected by a lightning protection system?

# Isolated Lightning Protection Systems

## Lightning Protection Basics

- ⚡ These systems keep lightning currents away from protected assets.
- ⚡ Properly designed isolated LPS reduce the EM environment that assets are subjected to.
- ⚡ These systems minimize the probability of damage to structures being protected.
- ⚡ Typically used for high-value assets, fuel and ordnance storage/processing facilities.

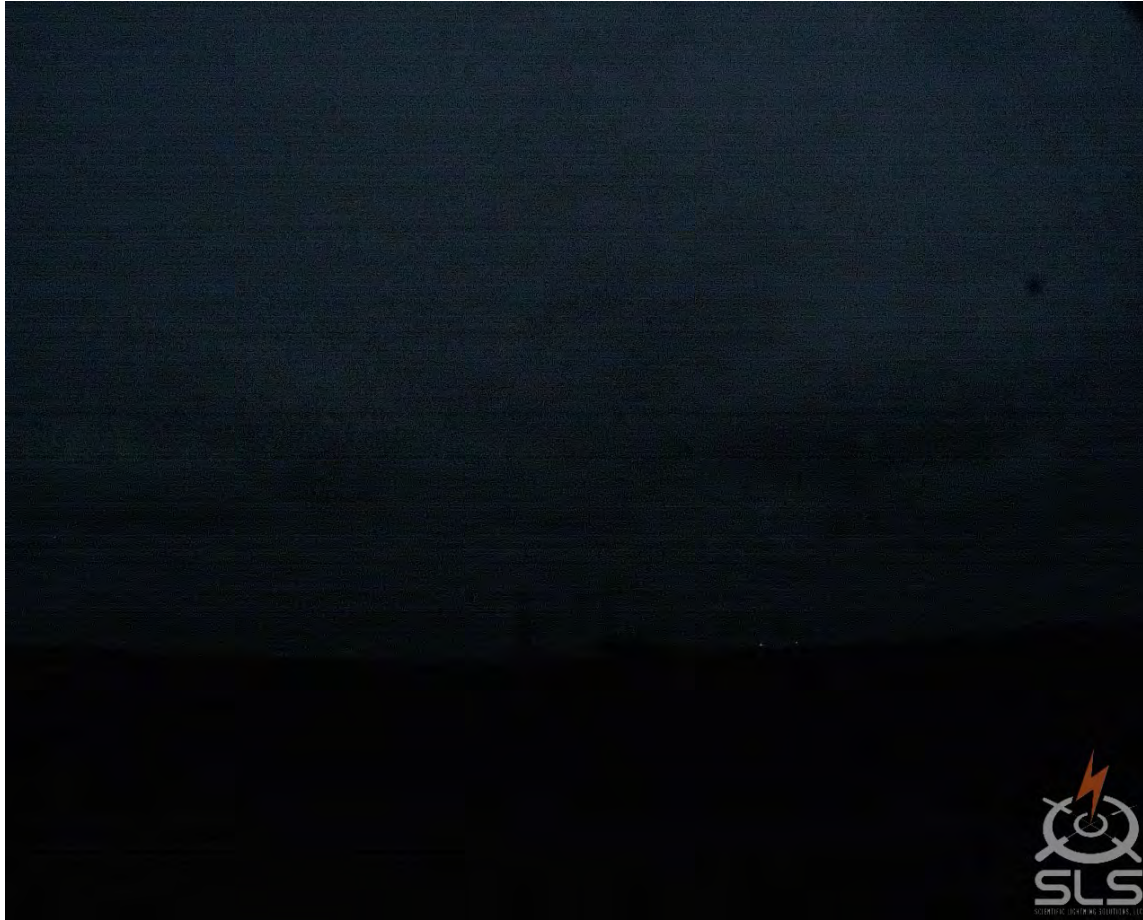


*Launch Complex 39B, Kennedy Space Center*

# Isolated Lightning Protection Systems



# Isolated Lightning Protection Systems





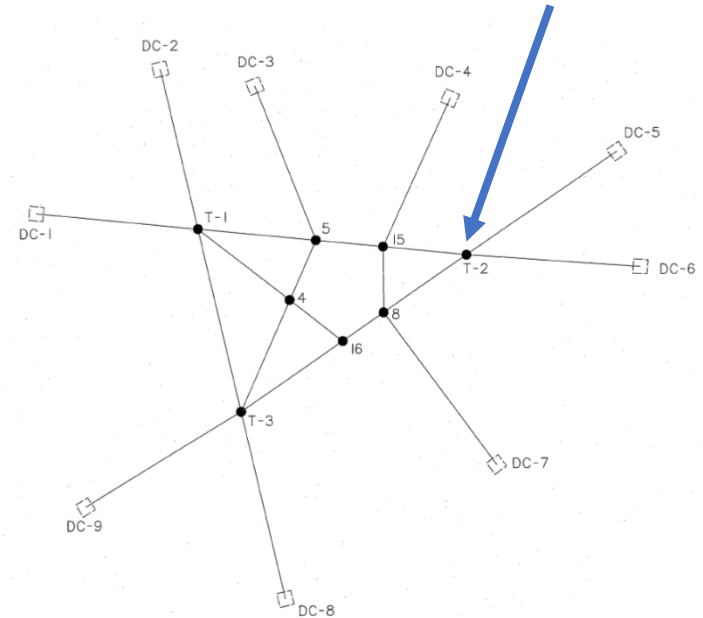
# Isolated Lightning Protection Systems

- Strike 1



Frame 4 Overlay

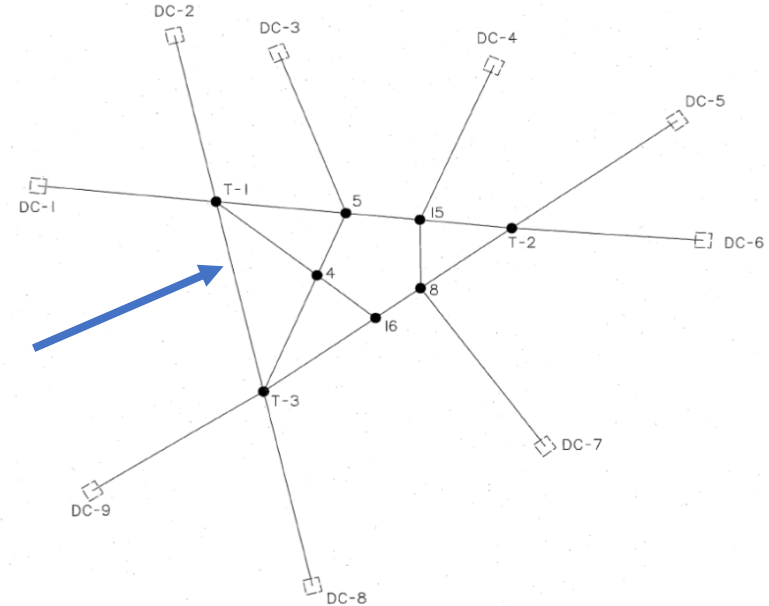
- Indication of direct strike to air terminal @ top of tower 2



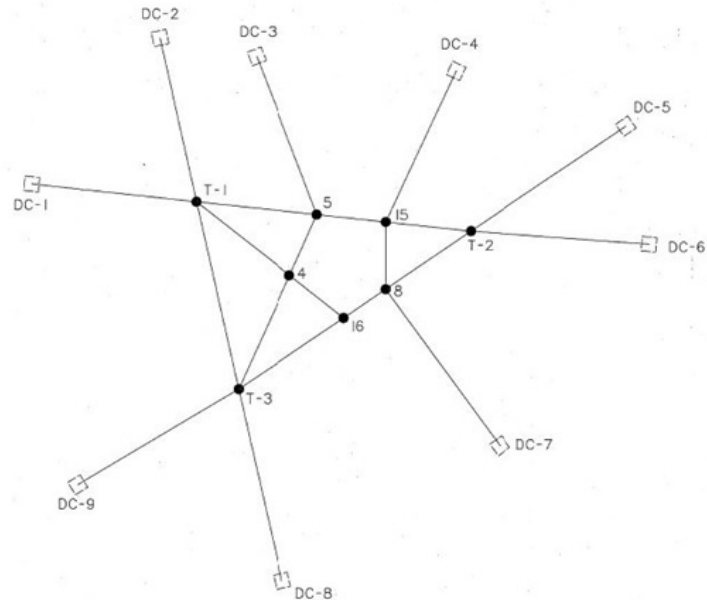
# Isolated Lightning Protection Systems

Strike 2

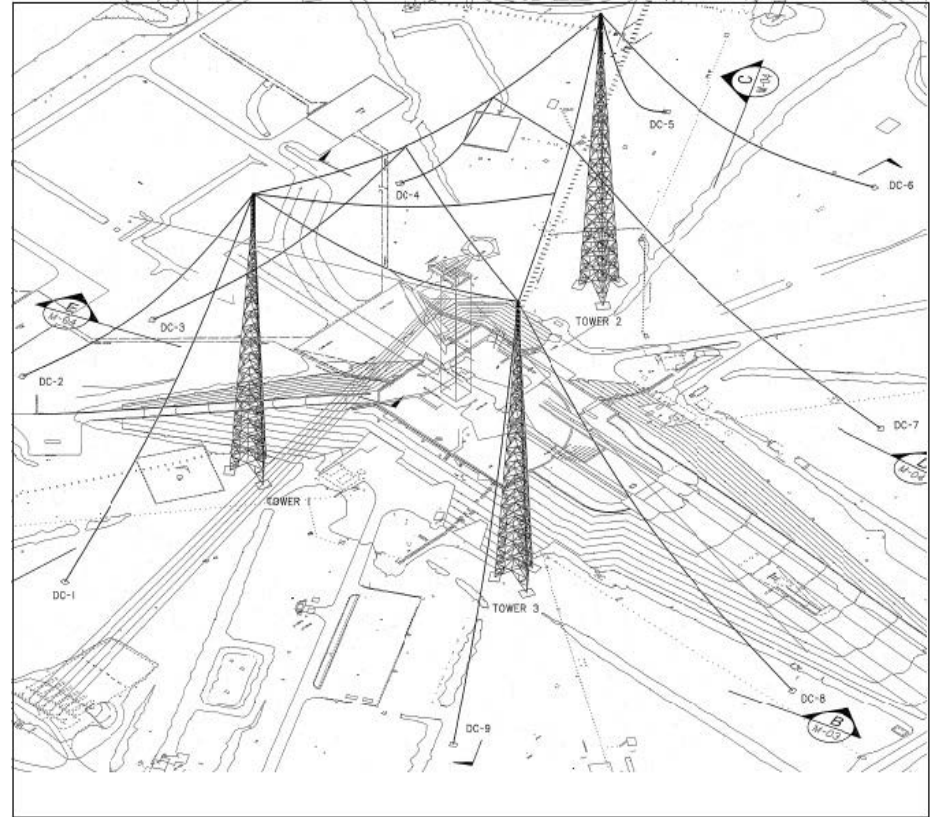
Indication of strike to catenary wire between tower 1 and tower 3



# Isolated Lightning Protection Systems



CABLE ARRAY KEY PLAN  
CONNECTION LOCATIONS AND NOMENCLATURE



# Isolated Lightning Protection Systems

- Top of Tower 2 air terminal
- Evidence of discoloration and molten slag but air terminal and connections found to be nominal.



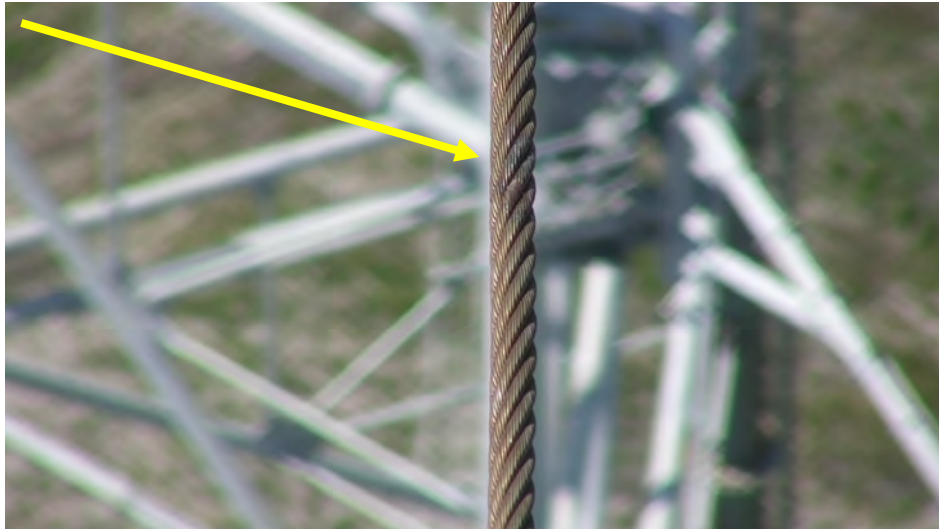
# Isolated Lightning Protection Systems





# Isolated Lightning Protection Systems

- Evidence of strike and slag.
- Molten slag/possible damage to multiple strands.





# Isolated Lightning Protection Systems



# Other Types of Lightning Protection?

- ⚡ Active: radioactive, triggered lightning.
- ⚡ Non-conventional LPS: These are **gadgets**. There is no scientific evidence. Vendors/Manufacturers advertise false performance, bogus empirical evidence, and virtual installations, to increase sales. **Note that no objects on the ground can discharge clouds.**

## Static Charge Dissipation



- ⚡ Smooth E field, upward leaders may require larger E field gradients. Self protects.
- ⚡ Like Franklin rods.
- ⚡ It does not spontaneously discharge anything.

## Early Streamer Emission (ESS)



- ⚡ Sharp, race condition, enhanced E field.
- ⚡ Like Franklin rods.
- ⚡ HV arc testing cannot be extrapolated to mother nature.

## Dissipation Array (DAS)



- ⚡ Smooth E field, upward leaders may require larger E field gradients. Self protects.
- ⚡ Like Franklin rods.
- ⚡ It does not eliminate or reduce lightning.

## Suppressor or Eliminator



- ⚡ “Collapses” E field because of “exotic” metals.
- ⚡ Like Franklin rods.
- ⚡ It does not eliminate or reduce lightning.

## What's next? Thor?



- ⚡ “Redirects lightning” to wherever customer wants
- ⚡ “Hammer will keep lightning away; whatever number of miles customer wants”
- ⚡ “Lightning at will”

# Gadgets, Do They Work?

- ⚡ ESE litigation in the 90s, permanent injunction.
- ⚡ Adventure Island waterpark has been found negligent in connection with the 2011 lightning strike death of a lifeguard, according to OSHA. ESE device.
- ⚡ Lightning Master Corp.'s lightning-protection devices failed to save NGL Energy Partners' buildings from a lightning strike that sparked a fire and caused \$5 million in lost profits and property damage, according to a Texas federal lawsuit filed in 2016.
- ⚡ Numerous reported cases of damage and fire in facilities protected by lightning protection “gadgets”, some of them in litigation.
- ⚡ **Nothing personal... do they really work? Let's look at two study cases where we use NLDN data to evaluate the performance of two sites where LEC devices have been installed and where LEC has “some” information regarding performance.**

# See Performance of Non-Conventional LPS

# Case Studies

⚡ Oil & Gas, Tank Battery

⚡ Chemical Plant

⚡ Residences

# Oil & Gas Separator

- ⚡ Catenary Wire System
- ⚡ Fiberglass tanks have dirty water / salt water
- ⚡ What can go wrong?





# Oil & Gas Separator



What happened?



# Oil & Gas Separator



What happened?

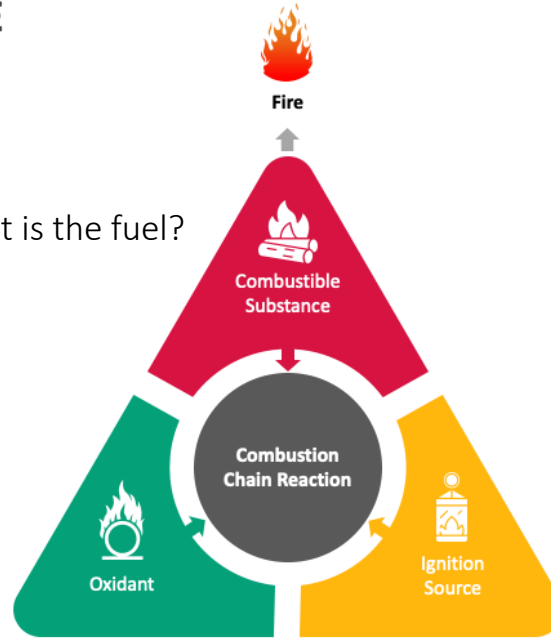


# Lightning Protection, Fuel & Explosives

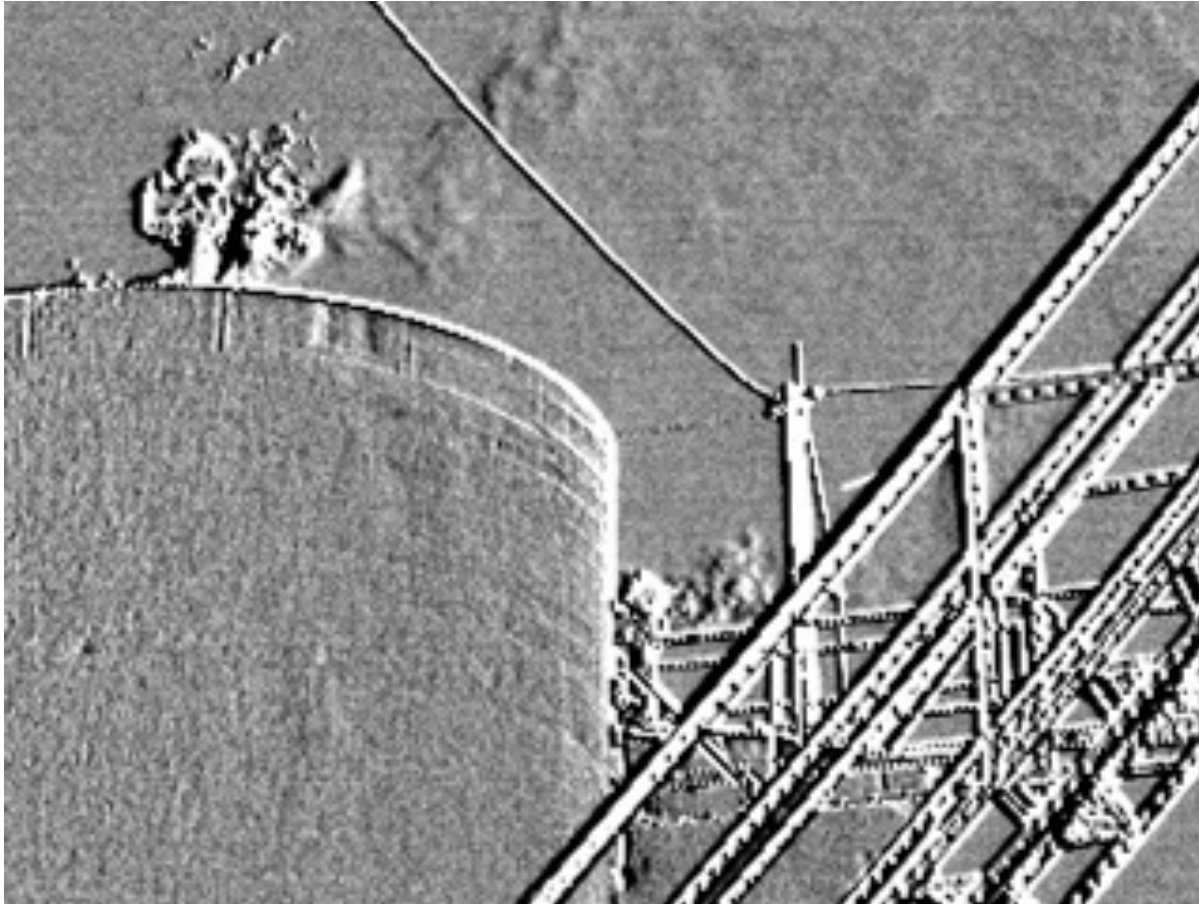
## FIRE TRIANGLE



What is the fuel?



# Lightning Protection, Fuel & Explosives

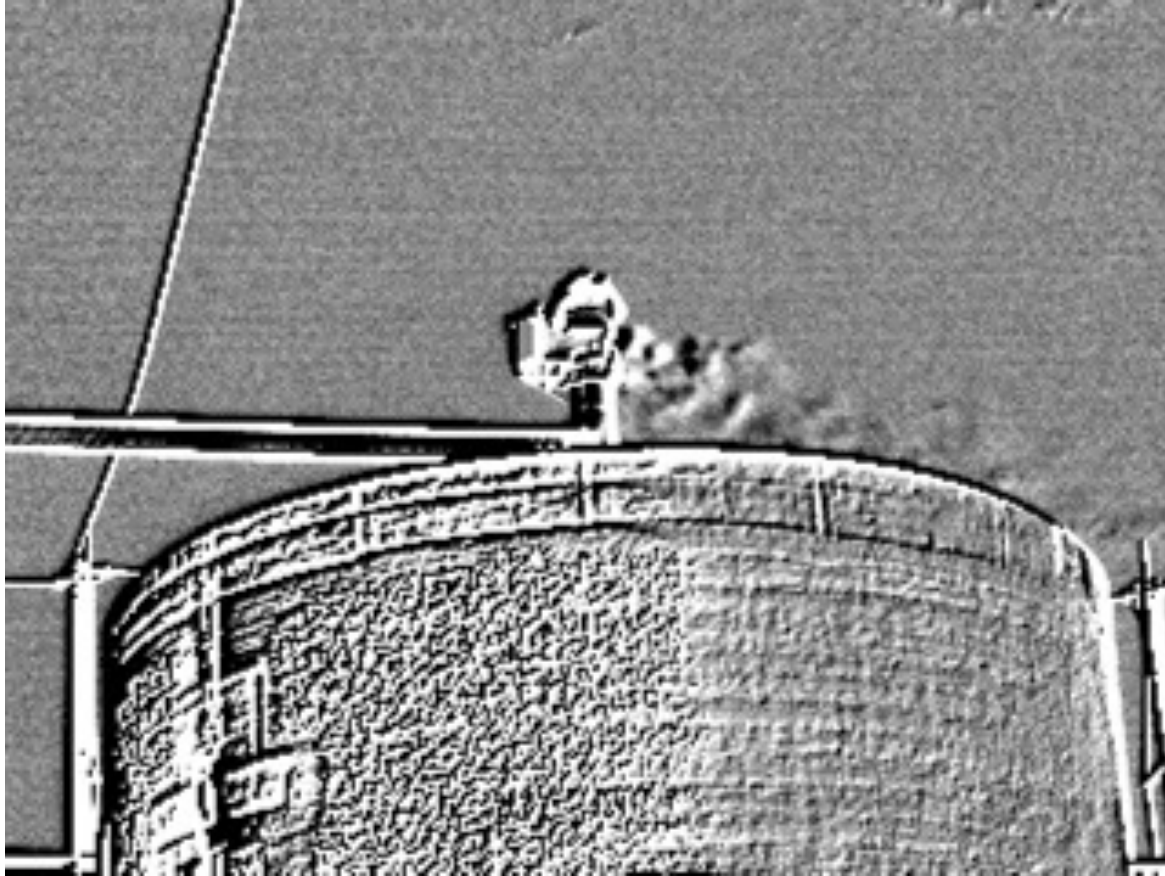


# Lightning Protection, Fuel & Explosives





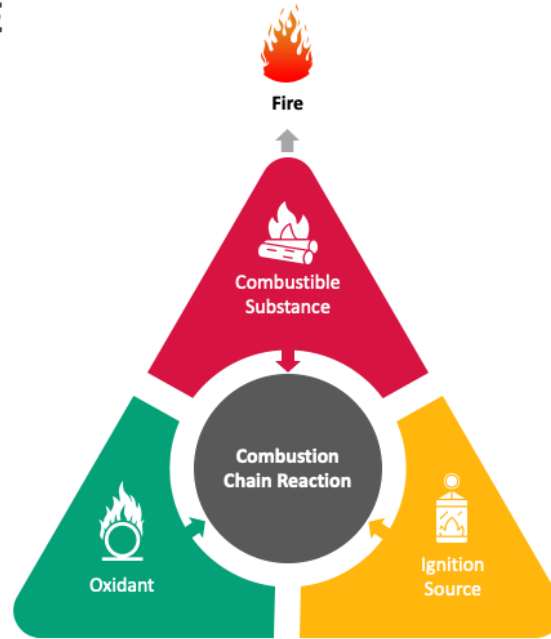
# Lightning Protection, Fuel & Explosives





# Lightning Protection, Fuel & Explosives

## FIRE TRIANGLE

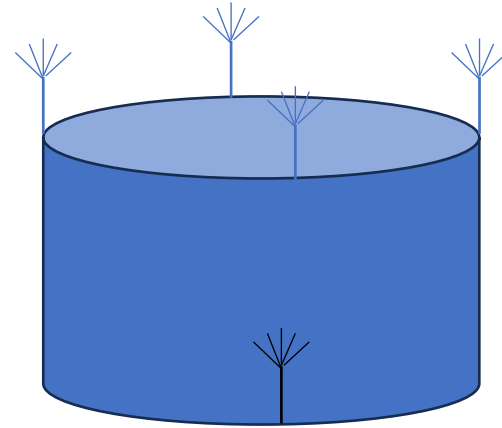
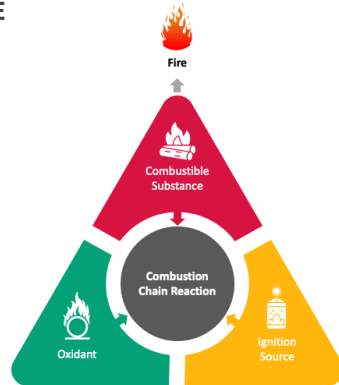


- ⚡ What is the ignition source?
- ⚡ How?
- ⚡ Did the catenary wire system work?

# Lightning Protection, Fuel & Explosives

- ⚡ How about if we dissipate the charges?
- ⚡ Would that work?
- ⚡ What did I do to the fire triangle?

## FIRE TRIANGLE



# Lightning Protection, Fuel & Explosives

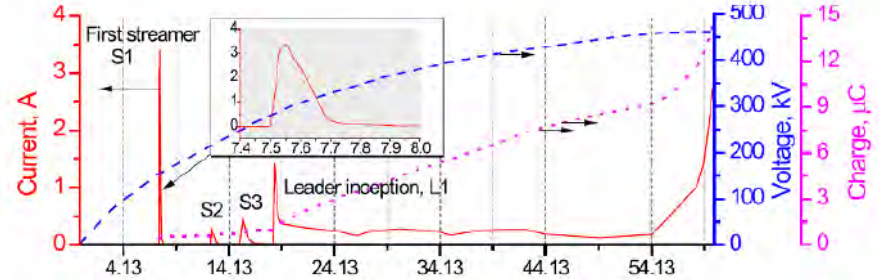
- ⚡ NFPA 780, Chapter 7 (fuel) and Chapter 8 (explosives)
- ⚡ Hazardous (classified) locations are defined by Chapter 5 of NFPA 70
- ⚡ Identify, quantify, and mitigate risks, lightning risk assessments (LRA)
- ⚡ The LPS should mitigate the risks identified by the LRA
- ⚡ Fires and explosions can occur if LPS is not “properly” designed
- ⚡ Avoid arcs (large emfs). Use equipotential surfaces, shielding, and bonding

# Lightning Protection, Fuel & Explosives

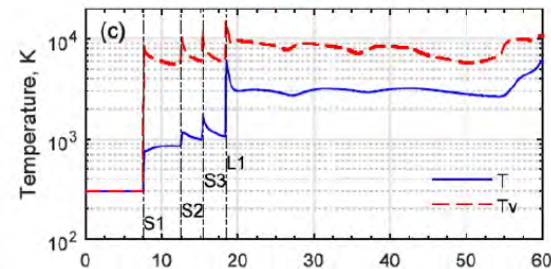
## Case study: Chemical plant



Charge transfer during leader inception process



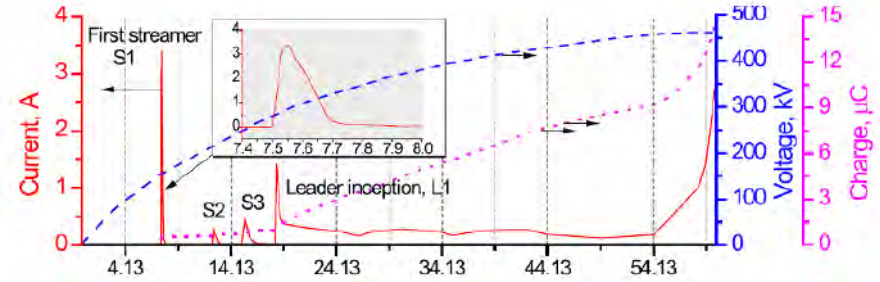
Leader temperature vs streamer charge



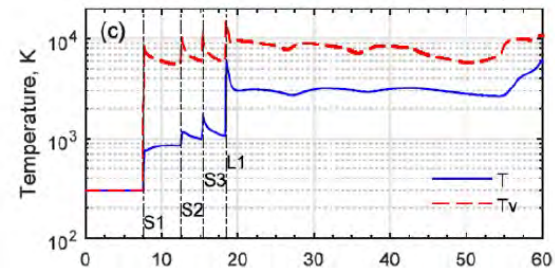
# Case Study, Chemical Plant



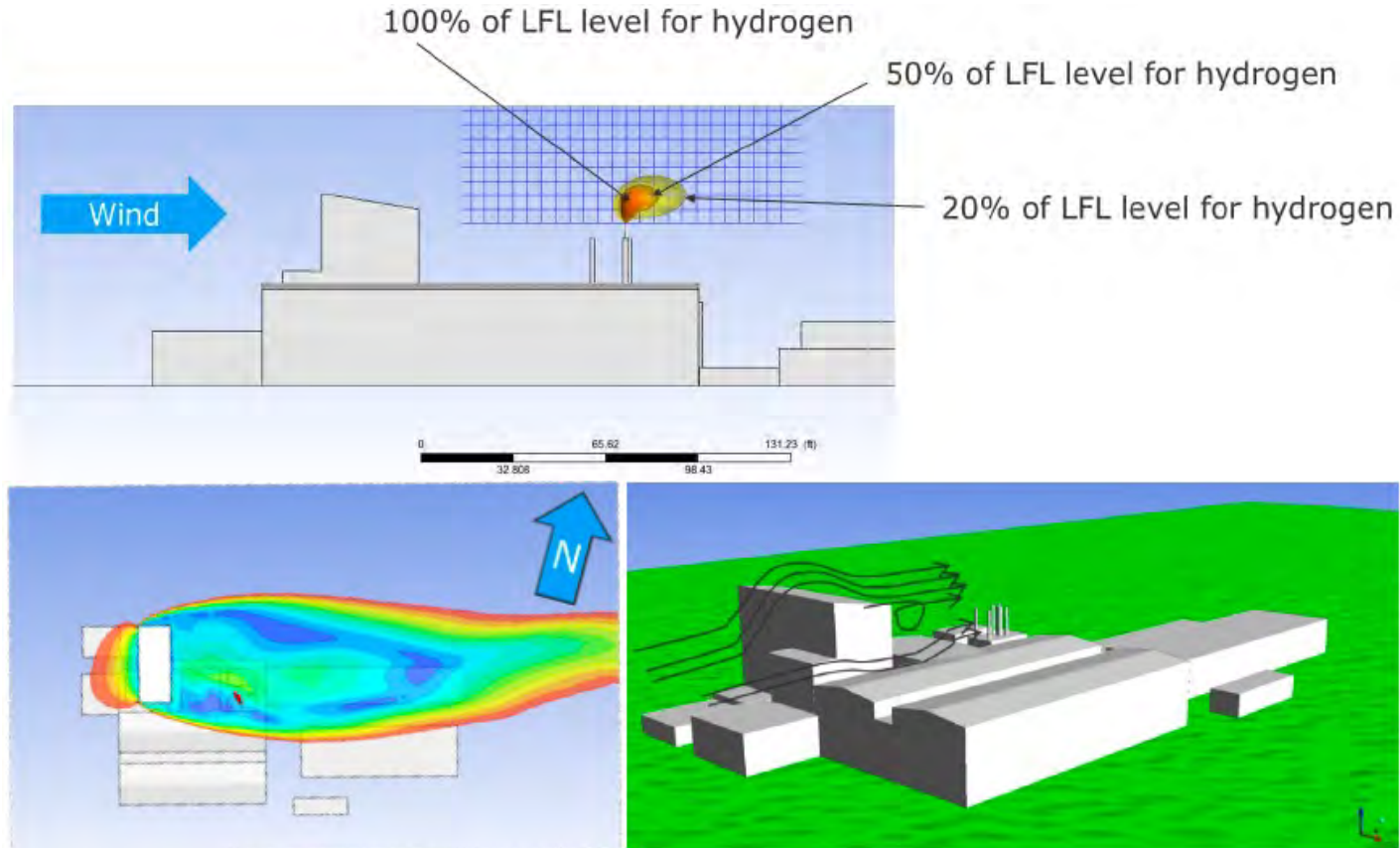
Charge transfer during leader inception process



Leader temperature vs streamer charge

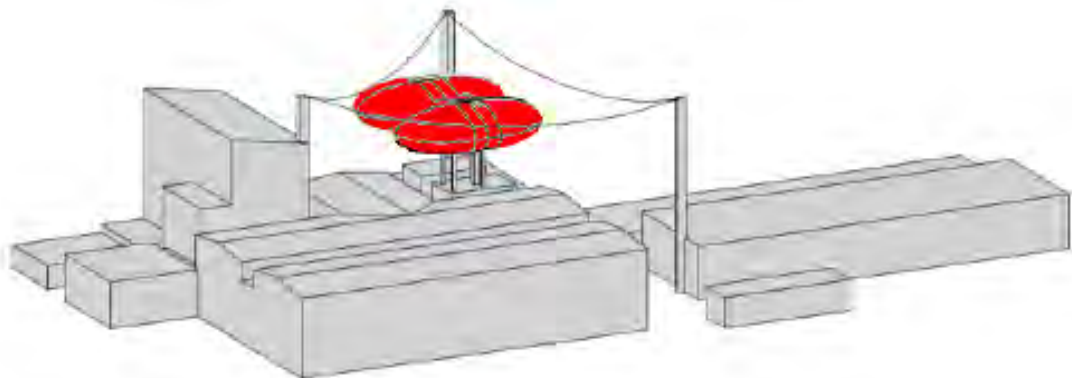
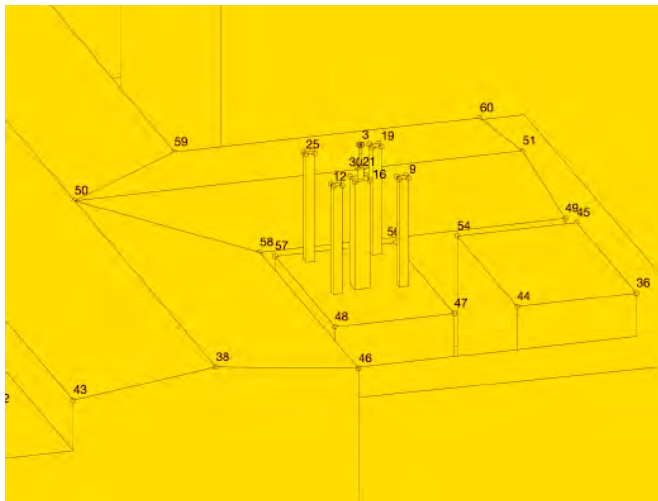


# Case Study, Chemical Plant





# Case Study, Chemical Plant



Protection Scheme	Ignitions per year		# Years between ignitions	
	Min	Max	Min	Max
3-Pole, 12-in Toroid	0	1	17	38
3-Pole, 14-in Toroid	0	1	10	23
3-Pole, 16-in Toroid	0	1	7	16

# Case Study, Residence, where did lightning strike?



## Case Study, Residence



# Case Study, Residence



## Case Study, Residence





## Case Study, Residence





## Case Study, Residence



# Case Study, Residence, Nearby Lightning Strike



# Case Study, Residence, Nearby Lightning Strike





# Case Study, Residence, Nearby Lightning Strike

- ⚡ STRIKEnet report shows no lightning activity in the area, how can this be?
- ⚡ Was there additional damage to the house or house electrical and electronic equipment?
- ⚡ Smart houses are extremely susceptible to lightning...
- ⚡ Low voltage systems can be compromised, latent damage, fire risk



# CSST – Lightning

- ⚡ CSST – Corrugated Stainless Steel Tubing
- ⚡ Many cases where lightning strikes have caused CSST damage, resulting in fire
- ⚡ CSST is extremely thin, with walls being about 10 mils or less in thickness
- ⚡ Frisco (Texas) Fire Department noted a relationship between lightning and CSST fires
- ⚡ Arcing can create holes in the CSST tubing walls
- ⚡ CSST has a high melting point. Stainless steel is not prone to melt during a fire, so if a hole is found in CSST after a fire, source or cause of the hole needs to be determined



Credit to: Investigating the causal link between lightning strikes, CCST and fire, M. Goodson and M. Hergenrether

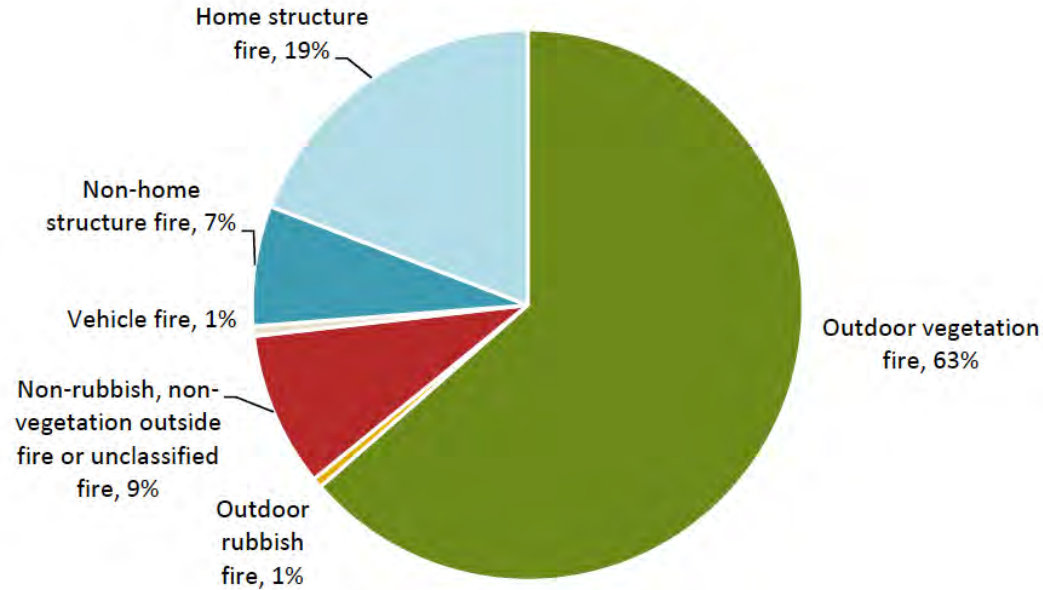
# Lightning and Fires

- ⚡ NFPA Research, Marty Ahrens
- ⚡ From 2007 to 2011, NFPA estimates US local fire departments responded to an estimated average of 22,600 fires started by lightning per year
- ⚡ Nine civilian deaths, 53 civilian injuries, and ~\$451 million in direct property damage per year
- ⚡ 19% of reported lightning fires occurred in homes
- ⚡ Lightning-related fires are more common in June through August and in the late afternoon and evening
- ⚡ Peak seasons for lightning-related fires vary by region, as do weather patterns
- ⚡ From 2003-2012, 42 US firefighters were killed as a result of lightning-caused fires
- ⚡ In 2003, 10,200 non-fire lightning strikes were reported to local fire departments. 62% of these occurred at home properties



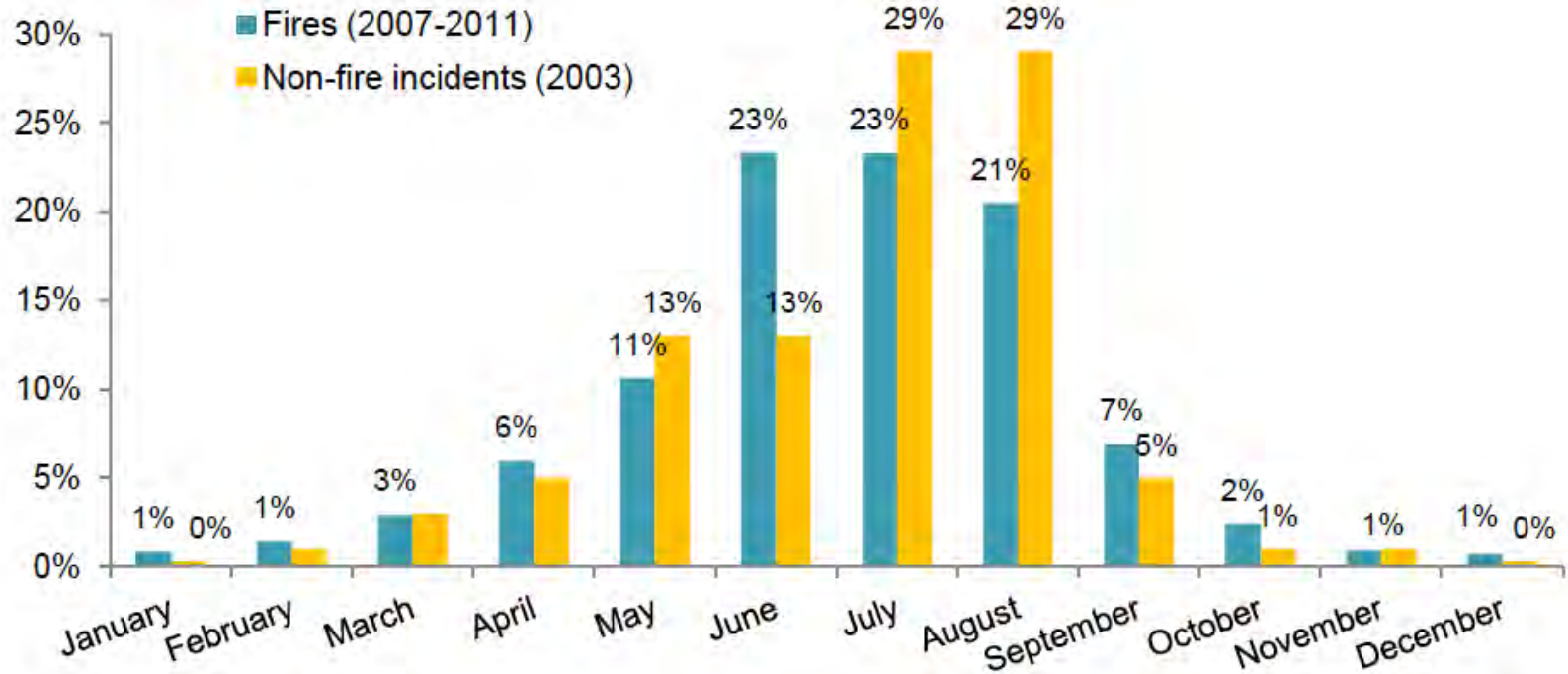
# Lightning and Fires

Figure 1. Lightning Fires by Incident Type  
2007-2011



# Lightning and Fires

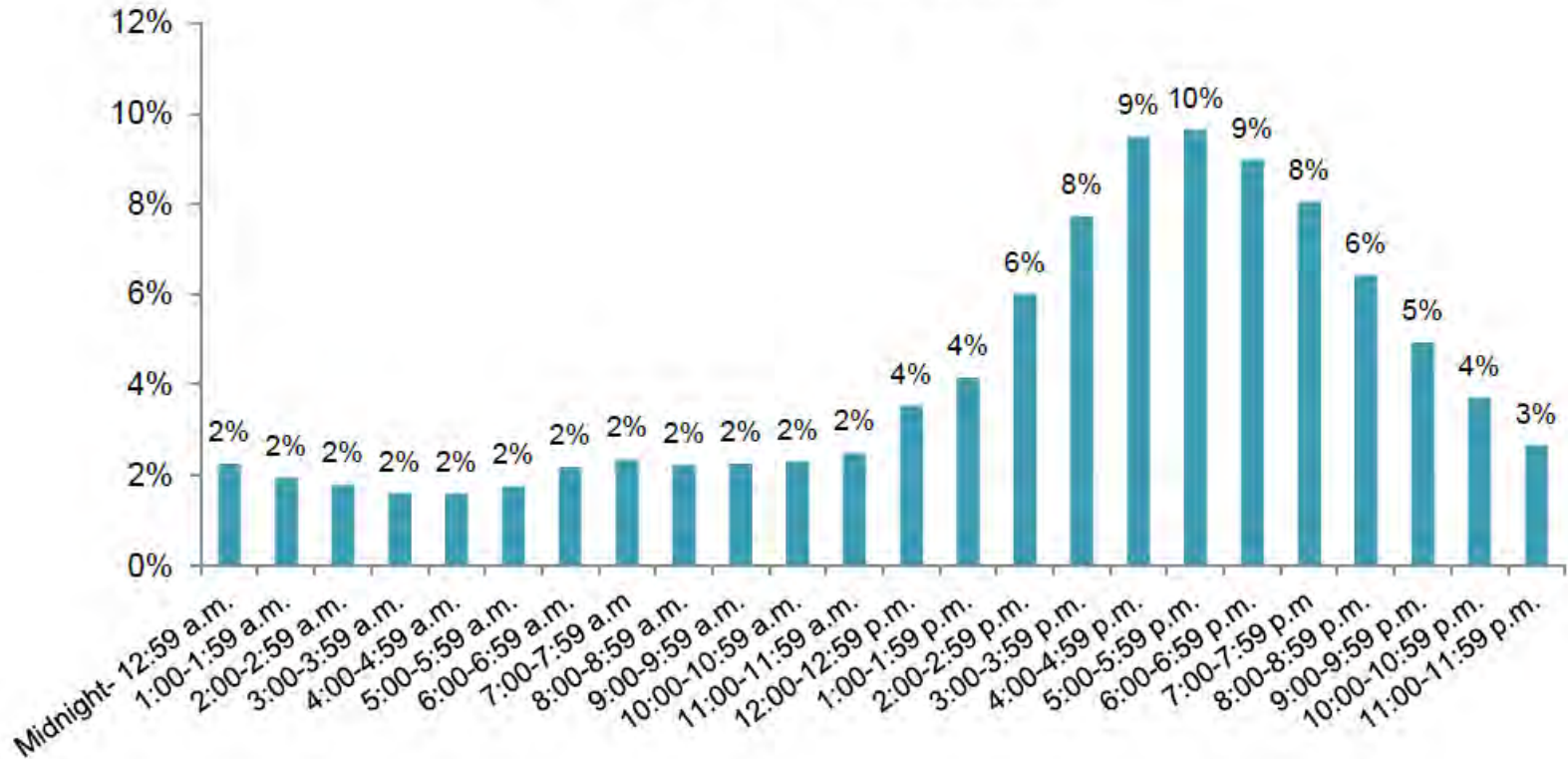
Figure 2. Lightning Incidents by Month



US cases, probabilities may not apply to specific regions.

# Lightning and Fires

**Figure 3. Lightning Fires by Hour of Day  
2007-2011 Annual Averages**



# Lightning and Fires

**Table 1.**  
**Lightning Fires Reported to Local Fire Departments, by Type of Fire**  
**2007-2011 Annual Averages**

Type of Fire	Fires		Civilian Deaths		Civilian Injuries		Direct Property Damage (in Millions)	
Structure fire	5,900	(26%)	9	(100%)	49	(93%)	\$413	(92%)
Home structure fire	4,300	(19%)	7	(86%)	40	(76%)	\$305	(68%)
Non-home structure fire	1,600	(7%)	1	(14%)	9	(17%)	\$108	(24%)
Outdoor or unclassified fire	16,500	(73%)	0	(0%)	1	(2%)	\$35	(8%)
Outdoor vegetation fire	14,200	(63%)	0	(0%)	1	(2%)	\$19	(4%)
Outdoor rubbish fire	300	(1%)	0	(0%)	0	(0%)	\$0	(0%)
Non-rubbish, non-vegetation outside fire or unclassified fire	2,000	(9%)	0	(0%)	0	(0%)	\$16	(4%)
Vehicle fire	100	(1%)	0	(0%)	2	(4%)	\$2	(0%)
Total	22,600	(100%)	9	(100%)	53	(100%)	\$451	(100%)

# Lightning and Fires

Table 2.  
Lightning Fires in Non-Home Structures, by Property Use  
2007-2011 Annual Averages

Property Use	Fires		Direct Property Damage (in Millions)	
<b>Storage</b>	<b>820</b>	<b>(50%)</b>	<b>\$28</b>	<b>(26%)</b>
Shed, outside material storage or unclassified storage	610	(37%)	\$15	(14%)
Vehicle storage, garage or fire station	130	(8%)	\$5	(5%)
Grain or livestock storage	40	(3%)	\$2	(2%)
Residential or self-storage warehouse	30	(2%)	\$6	(6%)
Other known storage property	10	(0%)	\$0	(0%)
<b>Non-home residential</b>	<b>210</b>	<b>(13%)</b>	<b>\$19</b>	<b>(17%)</b>
Unclassified or unknown-type residential	180	(11%)	\$17	(16%)
Hotel or motel	10	(1%)	\$1	(1%)
Other defined residential structure	10	(1%)	\$1	(0%)

<b>Public assembly</b>	<b>120</b>	<b>(8%)</b>	<b>\$22</b>	<b>(21%)</b>
Place of worship or funeral property	70	(4%)	\$20	(19%)
Eating or drinking establishment	20	(1%)	\$1	(1%)
Club	10	(1%)	\$0	(0%)
Other known assembly property	20	(1%)	\$1	(1%)
<b>Mercantile and Business</b>	<b>120</b>	<b>(7%)</b>	<b>\$15</b>	<b>(14%)</b>
Office, bank or mail facility	30	(2%)	\$5	(4%)
Service station or vehicle sales, service or repair	20	(1%)	\$5	(5%)
Grocery or convenience store	20	(1%)	\$1	(1%)
Unclassified mercantile or business	10	(1%)	\$1	(1%)
Specialty shop	10	(1%)	\$1	(1%)
Other known mercantile or office property	20	(2%)	\$3	(3%)



# Lightning and Fires

Property Use	Fires	Direct Property Damage (in Millions)			
<b>Outside or special property</b>	<b>120</b>	<b>(7%)</b>	<b>\$3</b>	<b>(3%)</b>	
Bridge, tunnel, or outbuilding	60	(4%)	\$1	(1%)	
Open land, beach, or campsite	20	(1%)	\$0	(0%)	
Highway, street or parking area	20	(1%)	\$0	(0%)	
Construction site, oil or gas field, pipeline, power line, or industrial plant yard	10	(1%)	\$2	(1%)	
Unclassified special property	10	(1%)	\$0	(0%)	
Other known outside or special property	0	(0%)	\$0	(0%)	
<b>Industrial, utility, defense, agriculture, mining</b>	<b>80</b>	<b>(5%)</b>	<b>\$10</b>	<b>(9%)</b>	
Agricultural property	40	(2%)	\$2	(2%)	
Unclassified or unknown type industrial, utility, defense, agriculture, mining property	20	(1%)	\$4	(4%)	
Utility or distribution system	10	(1%)	\$1	(1%)	
Other known industrial, utility, defense, agriculture or mining property	0	(0%)	\$2	(2%)	
<b>Manufacturing or processing facility</b>	<b>40</b>	<b>(3%)</b>	<b>\$5</b>	<b>(4%)</b>	

<b>Educational</b>	<b>20</b>	<b>(1%)</b>	<b>\$1</b>	<b>(1%)</b>	
Preschool through grade 12	20	(1%)	\$1	(1%)	
Other known educational property	10	(0%)	\$0	(0%)	
<b>Health care, detention or correctional facility</b>	<b>20</b>	<b>(1%)</b>	<b>\$2</b>	<b>(2%)</b>	
Nursing home	10	(1%)	\$0	(0%)	
Other known health care or correctional facility	10	(1%)	\$2	(2%)	
<b>Unclassified or unknown-property use</b>	<b>80</b>	<b>(5%)</b>	<b>\$3</b>	<b>(3%)</b>	
<b>Total</b>	<b>1,630</b>	<b>(100%)</b>	<b>\$108</b>	<b>(100%)</b>	



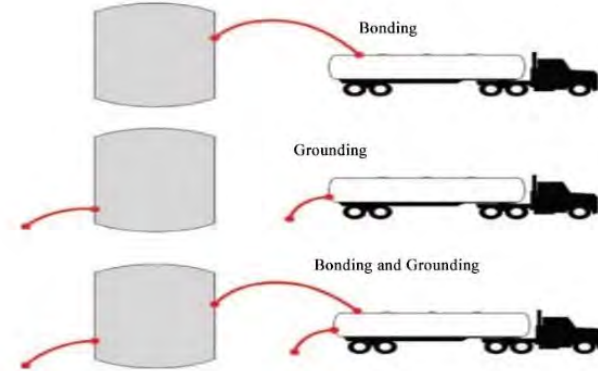
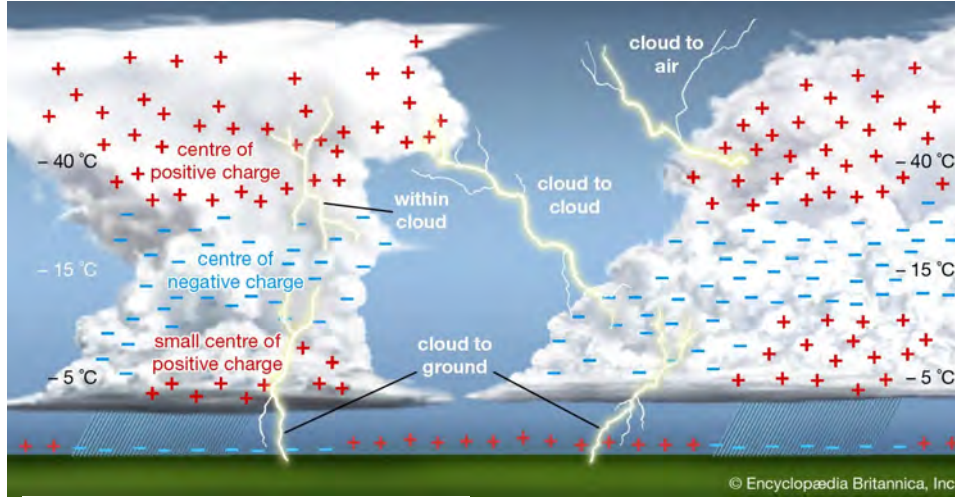
# Lightning Kennedy Space Center, June 22, 1998

“Lightning touched off three different fires Sunday evening in and around Kennedy Space Center”

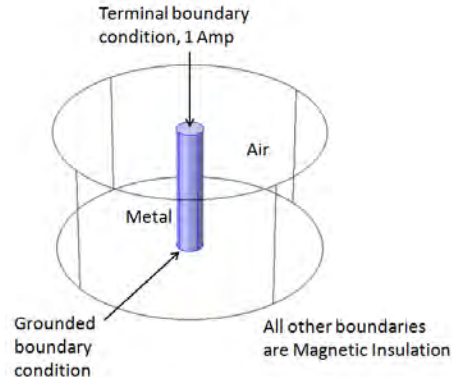
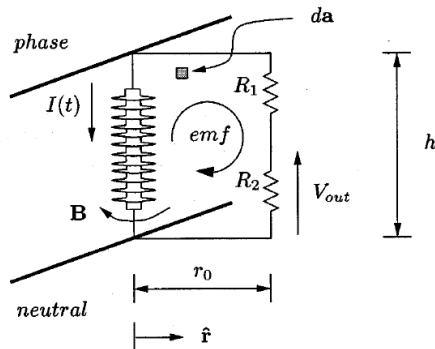
Credit: NASA



# Lightning Strike - Static Electricity



Credit to OSHA

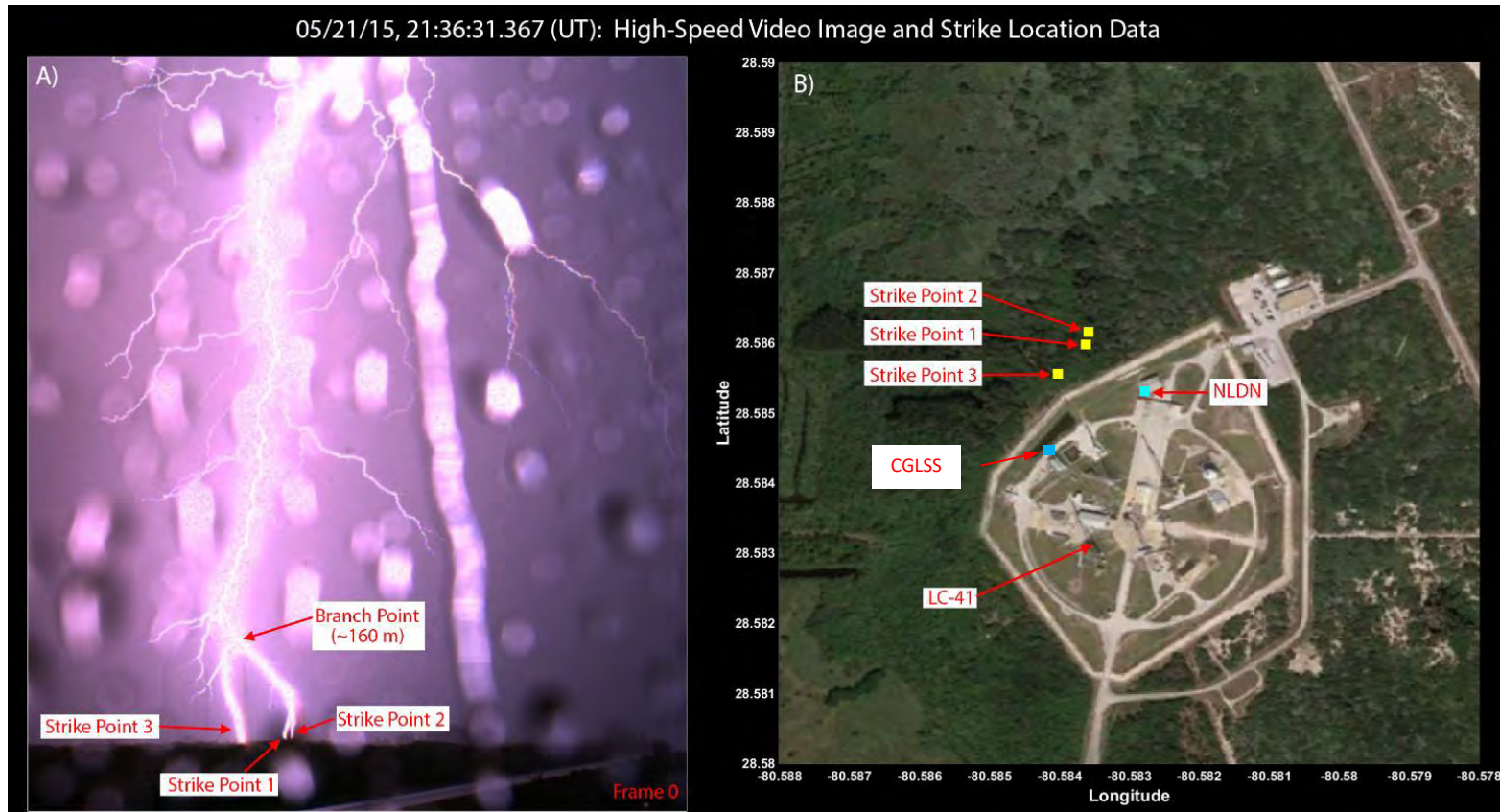


- ⚡ Flashover (arc), leader, streamer
- ⚡ Safety distance
- ⚡ Three elements:
  - ⚡ Fuel
  - ⚡ Oxygen
  - ⚡ Ignition Source

# Additional Lightning Images

# Multiple Ground Termination, Strike near Launch Pad

05/21/15, 21:36:31.367 (UT): High-Speed Video Image and Strike Location Data



***MERLIN reported a single ground termination point.***

# Multiple Ground Termination, Simultaneous UI Strokes



*MERLIN did not report any of these strokes.*



# Multiple Ground Termination, Simultaneous UI Strokes



*MERLIN did not report any of these strokes.*



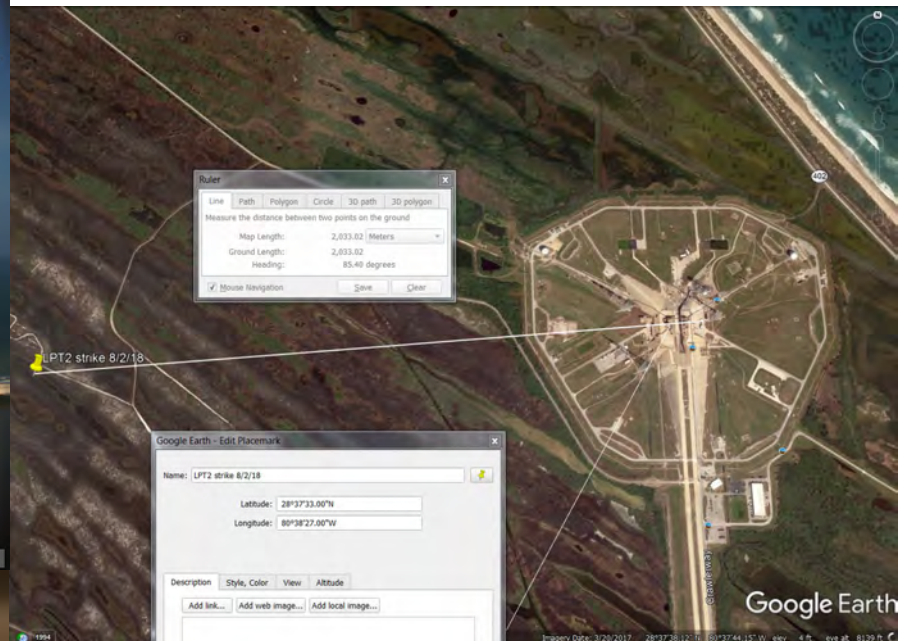
# Multiple Termination Points, Strike to Launch Pad



Two Termination Direct Strike to LC-39B Tower 1 and Tower 2  
May 14, 2018 (18:06:13.246 & 18:06:13.255)

*MERLIN did not report a strike location for this flash.*

# Strike to Launch Pad LPS, Reported with Large Error



UTC Date	UTC Time	Latitude (N)	Longitude (E)	Signal Strength (KAmps)	Event	SemiMajor Axis 50% CI (KM)	SemiMinor Axis 50% CI (KM)	Ellipse Angle (DEG)	Sensors
08/02/2018	01:09:28.4771600	28.625833	-80.640833	-38.20	Real	0.10	0.10	275	42,43,44,45,46,47,48,49,50,5

***MERLIN reported the stroke to LC-39B, but with > 2 km error  
(08/02/2018, 01:09:28.478)***

# Direct Strike to the Delta Launch Pad (LC-37)

UTC Date 📅	UTC Time	Latitude (N)	Longitude (E)	Signal Strength (KAmps)	Event	SemiMajor Axis 50% CI (KM)	SemiMinor Axis 50% CI (KM)	Ellipse Angle (DEG)	Sensors
07/21/2018	18:59:25.7932378	28.530000	-80.562222	-122.00	Real	0.20	0.10	68	43,44,45,46,47,48,51





# Direct Strike to the Delta Launch Pad (LC-37)

UTC Date 	UTC Time	Latitude (N)	Longitude (E)	Signal Strength (KAmps)	Event	SemiMajor Axis 50% CI (KM)	SemiMinor Axis 50% CI (KM)	Ellipse Angle (DEG)	Sensors
07/21/2018	18:59:25.7932378	28.530000	-80.562222	-122.00	Real	0.20	0.10	68	43,44,45,46,47,48,51



# Simultaneous Upward Leaders

Direct Strike to LC-39B Down Conductor





# Lightning Myths

**Myth:** Cars are safe during thunderstorms because of the rubber tires.

**Fact:** Cars are usually safe during thunderstorms because the metal frame of the car creates a Faraday Cage, confining the lightning current flow to the outside of the vehicle.



*Triggered lightning strike to car with live rabbit inside (Japan). The rabbit was unharmed. Notice current arcing to ground from hubs.*

But...



*Lightning strike directly through car window, Merritt Island, FL*

# Lightning Myths

**Myth:** *Lightning can be eliminated in a given area.*

**Fact:** No device or technology exists than can eliminate lightning in an area.

**Myth:** *Lightning never strikes the same place twice.*

**Fact:** Many tall man-made structures are struck dozens by lightning of time per year.

**Myth:** *I've been struck by lightning many times and survived.*

**Fact:** Survival rates for direct lightning strikes are low. Most people “struck” by lightning experienced step/touch potentials, side-flashes, or unconnected upward leaders.

**Question:** Is there a lightning protection system that provides 100% protection?

**Thank you for your attention.**

**Questions?**