Lightning

Advanced Initiation Systems

Understanding and Mitigation in Open Cast Blasting Operations

FOR **EXPLOSIVES** THINK

bme
A member of the Omnia Group

Purpose of this presentation

Advanced Initiation Systems

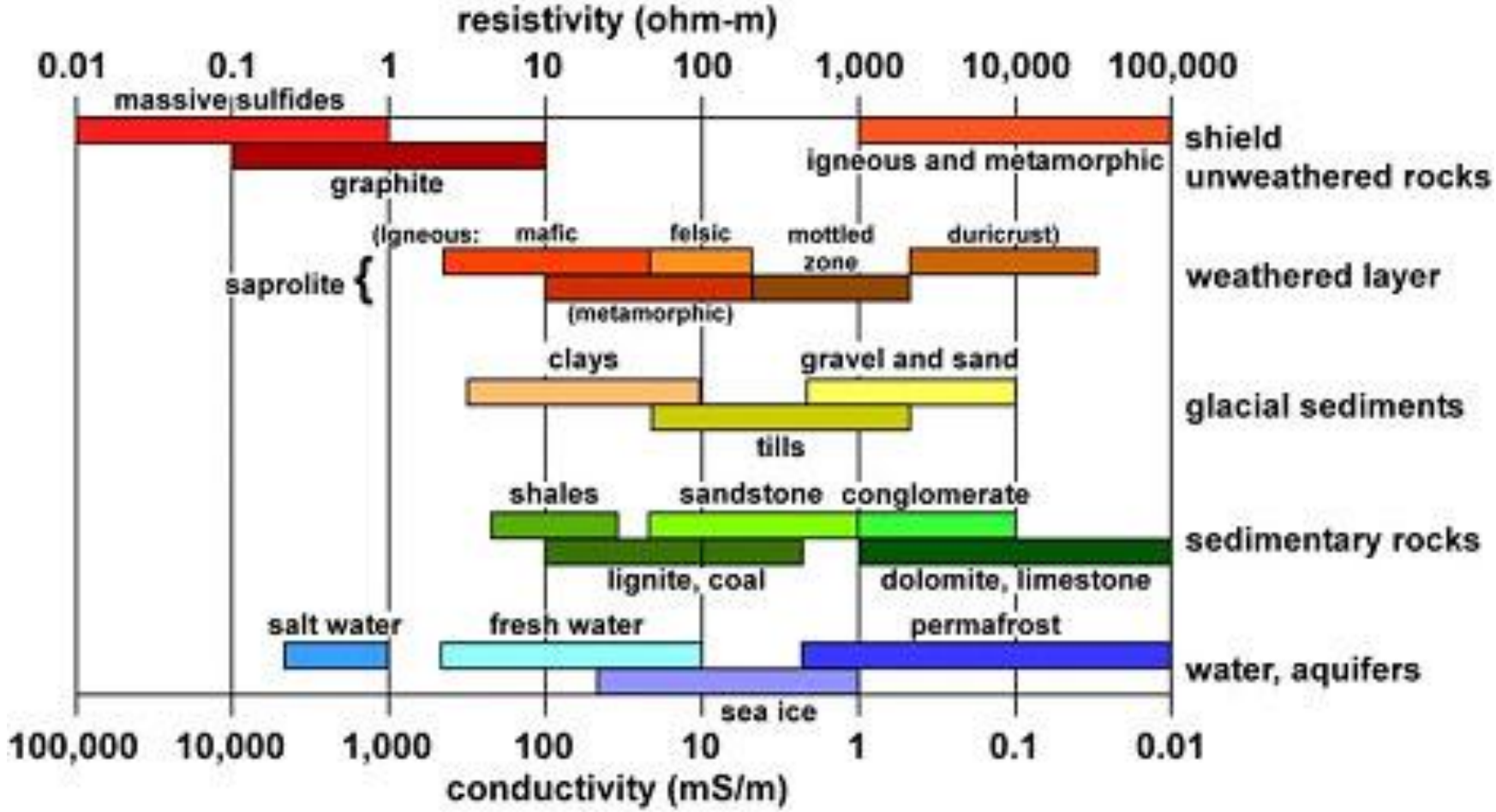
Alexius van der Westhuizen

Lightning Myths

- Lightning always strikes the highest point
- It must be raining for lightning to strike
- If you cannot see lightning or hear thunder, you are safe

Interesting facts

- A lightning bolt is hotter than the surface of the sun.
- Water is an excellent conductor, so it's wise to stay away from lakes and pools during a lightning storm.



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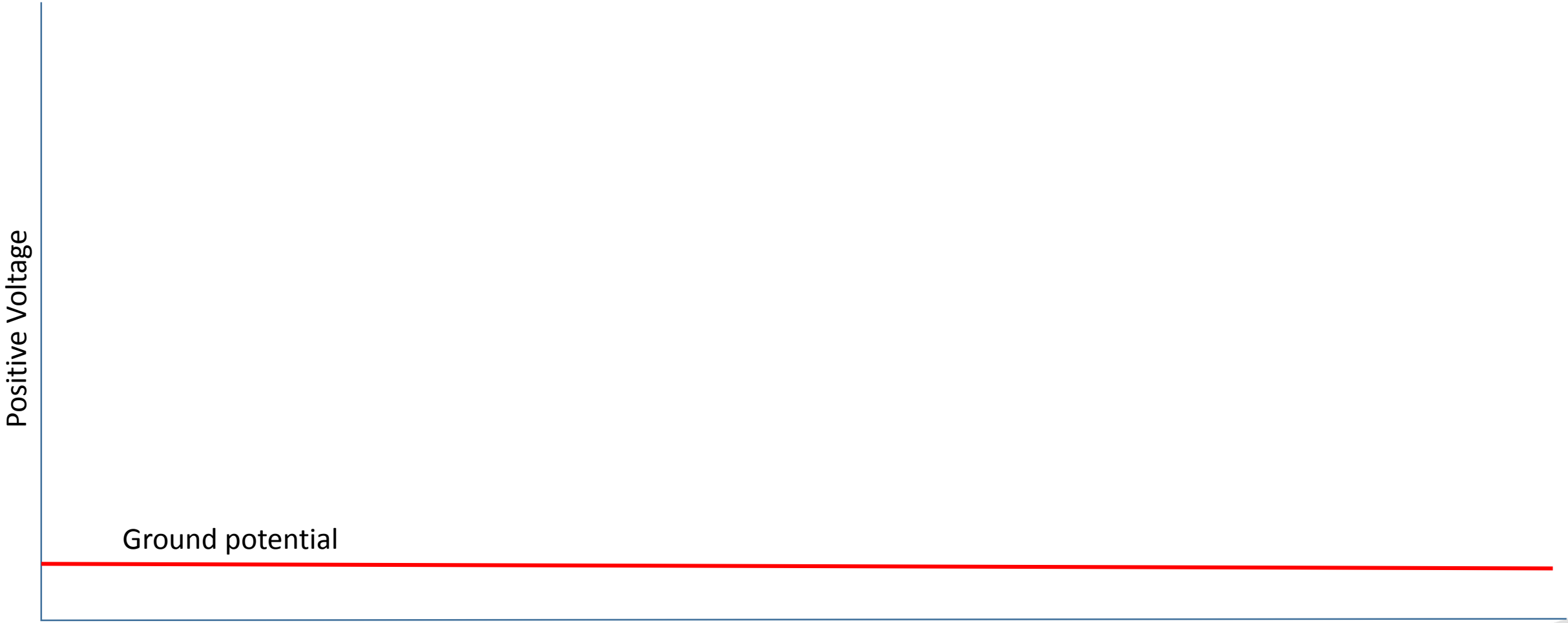
Some definitions

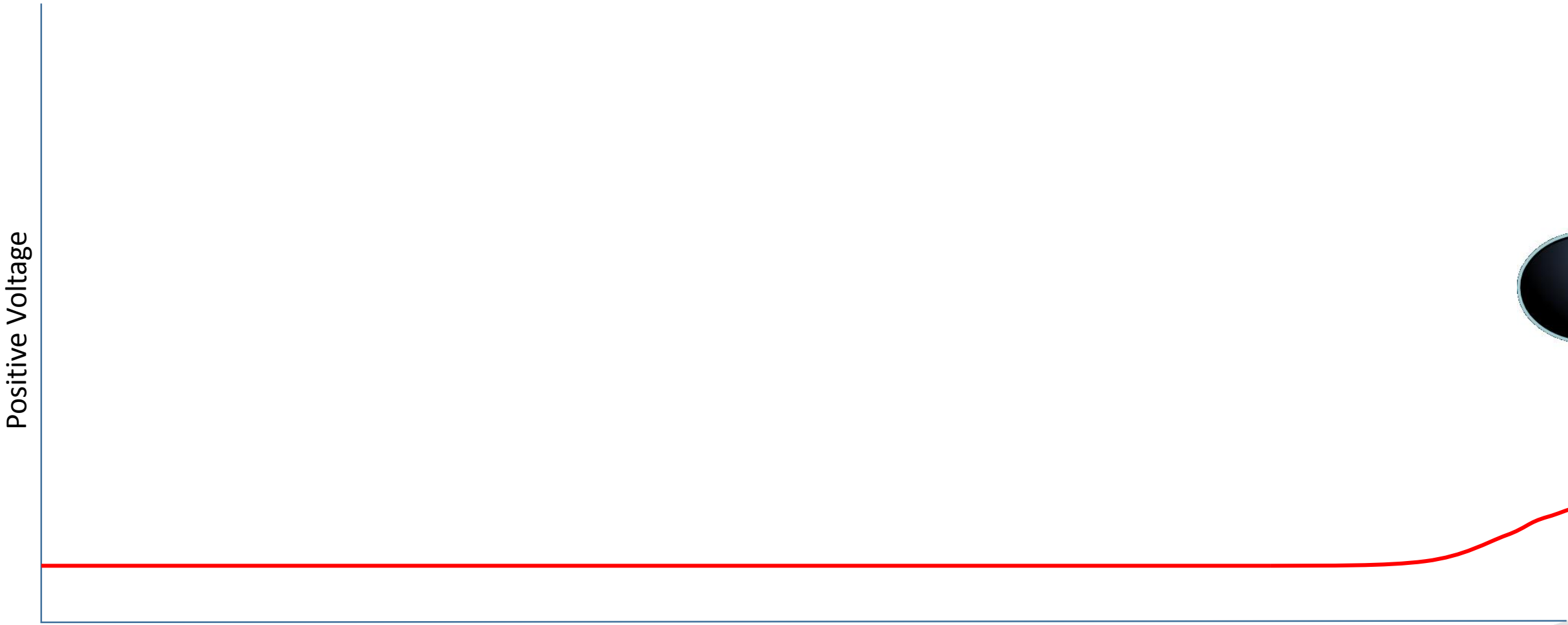
- Cloud-to-ground lightning is what most people associate with a lightning strike

- Negative CG strikes
  - Strike downwards
- Positive CG strikes
  - Strike upwards

How does lightning form

- CG lightning - massive spark between ground and clouds
- Equalises the potential difference
- Two conditions needed
  - An insulator such as air,
  - A huge voltage difference
- Colliding droplets and ice cause a charge build-up in clouds


Positive Voltage
Ground potential



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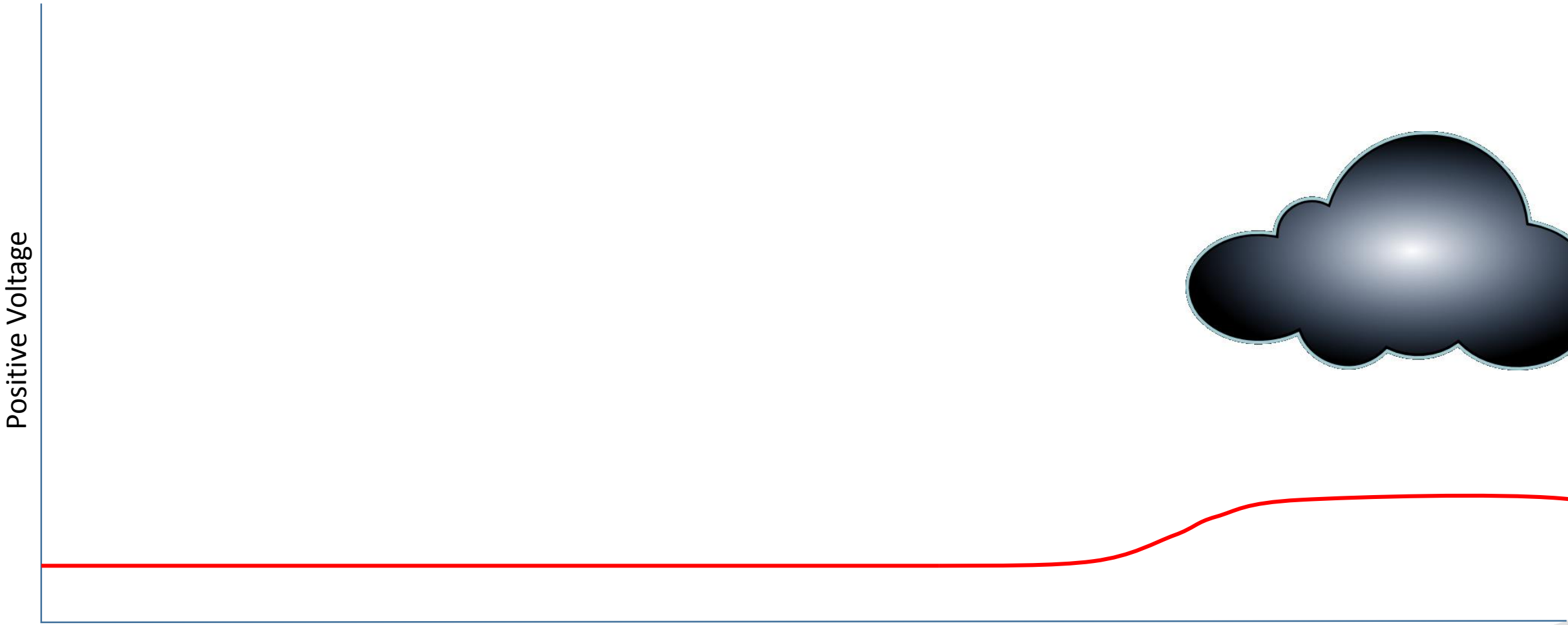

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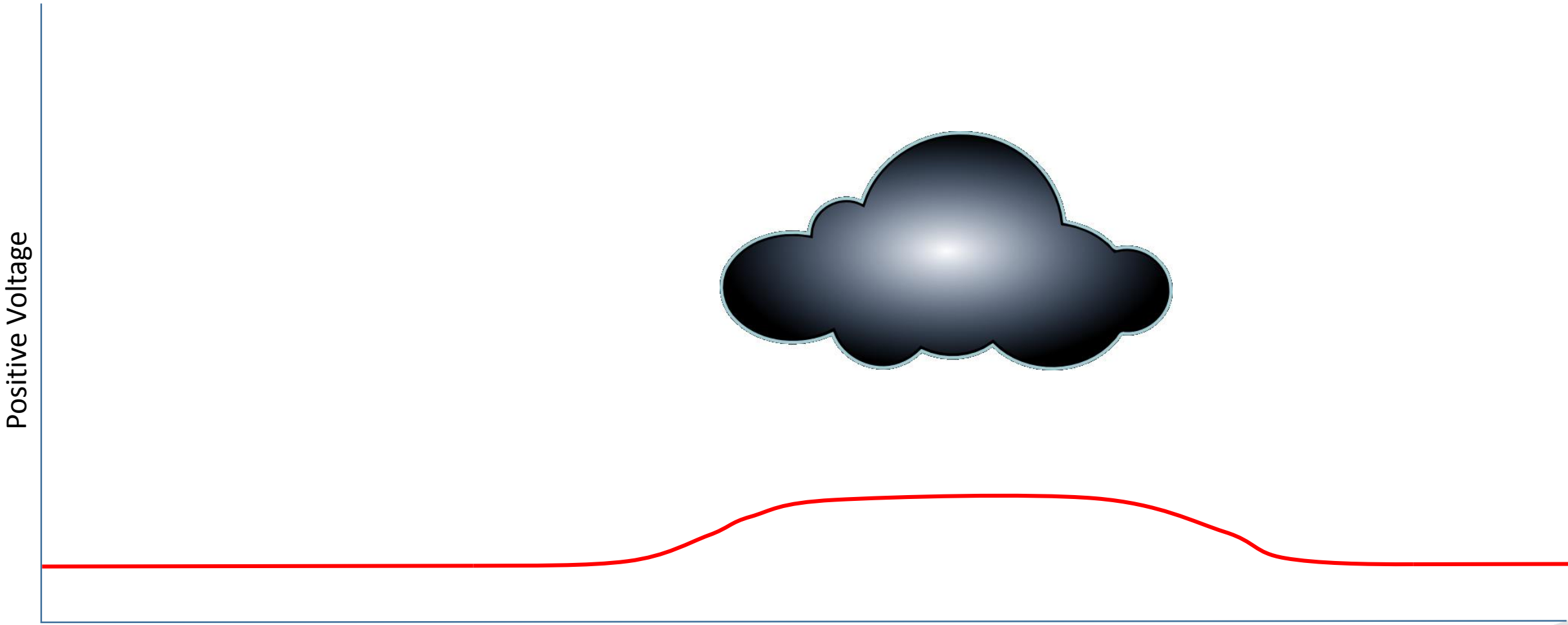

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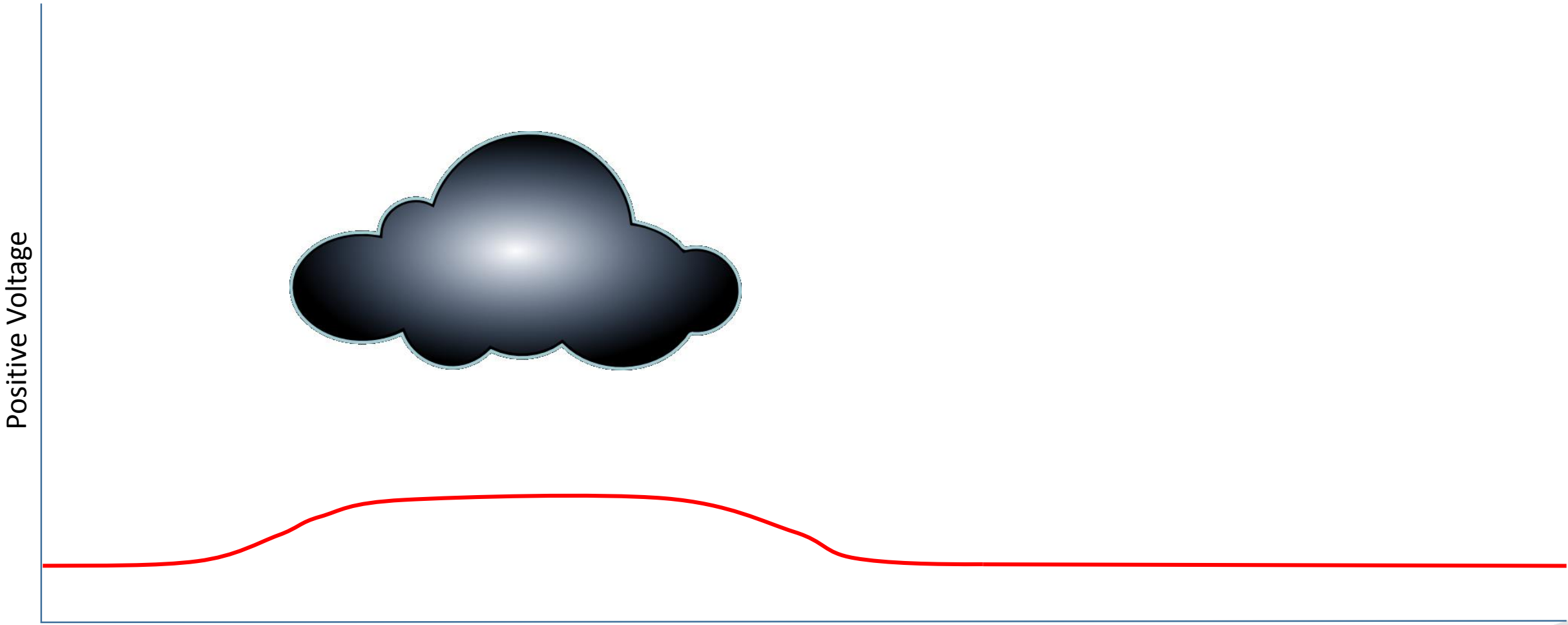

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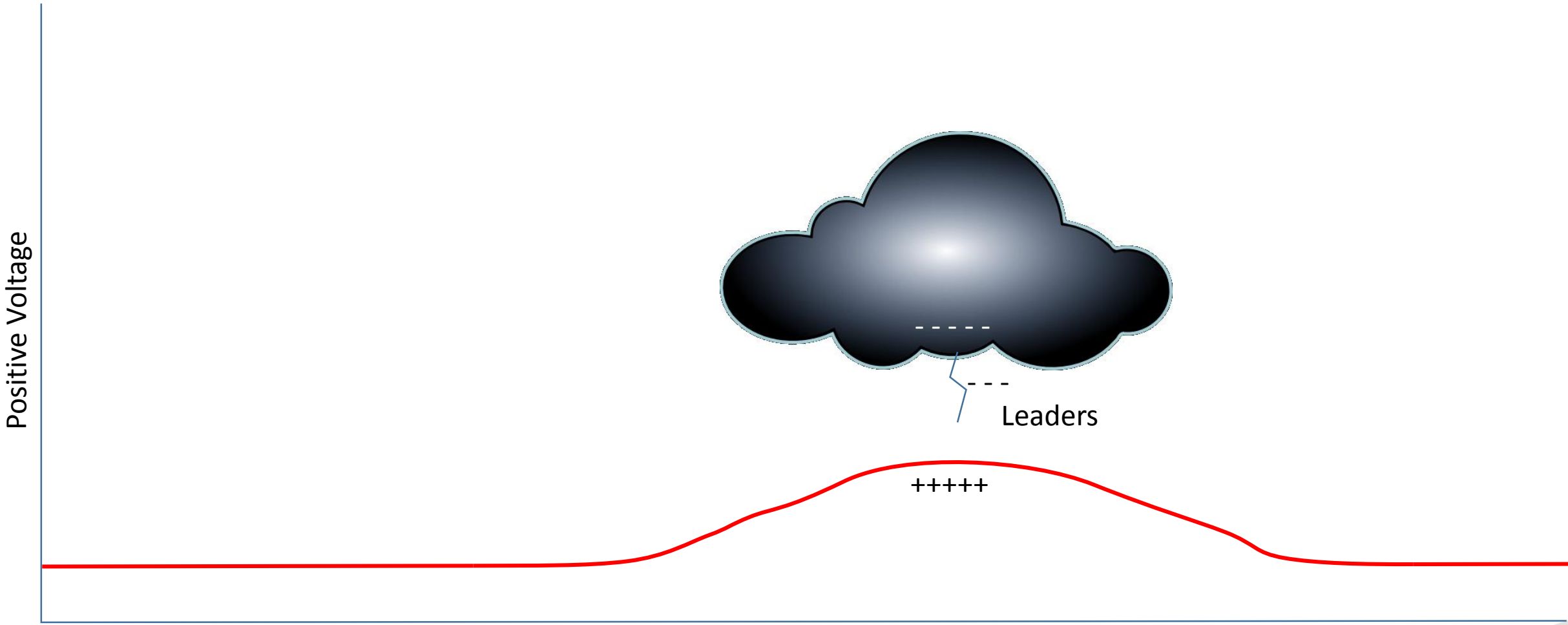

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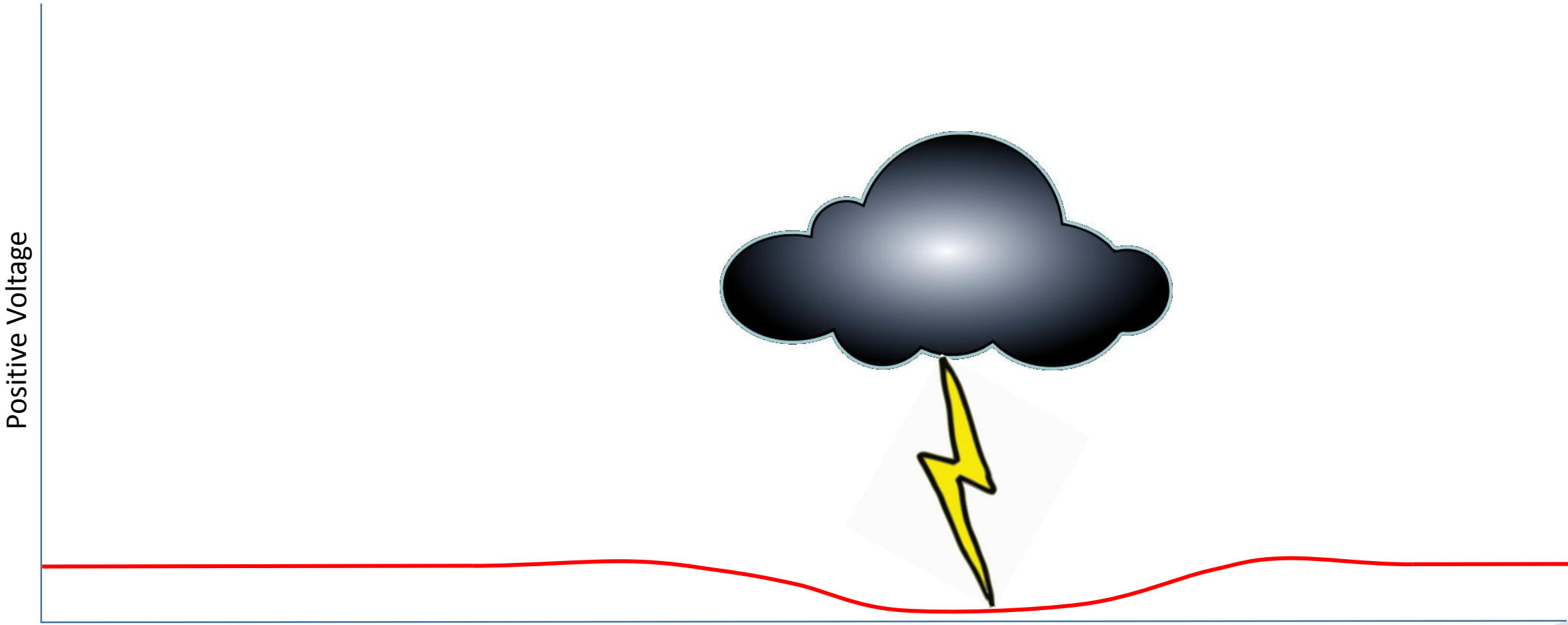

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- Most CG Strikes are negative
  - Up to 40 000 Amps (40kA)
- Positive CG strikes are the dangerous ones
  - Much less common than negative CG strikes
  - Much higher currents (up to about 400 kA)
  - Last longer than a negative CG strike

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  - Last longer than a negative CG strike
  - Travel much further
  - “bolt from the blue”

Understanding the danger

According to the National Weather Service (U.S.), workers in these occupations face the greatest risk from lightning:

- Logging
- **Explosive handling, blasting and storage**
- Heavy equipment operation
- Plumbing and pipe fitting
- Construction and building maintenance
- Farming and field labor
- Telecommunications field repair
- Power utility field repair

Quinn, 2011

Quantitative facts about lightning

	Quinn (2011)	Kithil (2005)	Lownds (2008)
Volts	Hundreds of millions	Hundreds of millions	500 kV/m
Current	Up to 400 000 A	Up to 400 000 A	
Temperature	Up to 15 000 C°	Up to 15 000 C°	Up to 30 000 C°
Magnetic pressure		600 MPa	
Duration of a strike			200 - 300 ms
Duration of first flash			140 µs
Average length of a lightning bolt	10 to 12 km		

- Magnetic pressure is carried by the magnetic field rather than kinetic energy of the gas molecules – same impact

- Booster temperature at detonation = 4000 to 5000 C°
- Emulsion explosives reacts at about 400 C°

Important facts

- The average lightning bolt is 10-12 km long.
- Longest measured 177 km
- 90% of lightning strike victims are struck under blue skies before a storm arrives or after it has passed

FloridaLightning.com

Quinn, 2011

Energy extensions below the strike point (frozen lightning)

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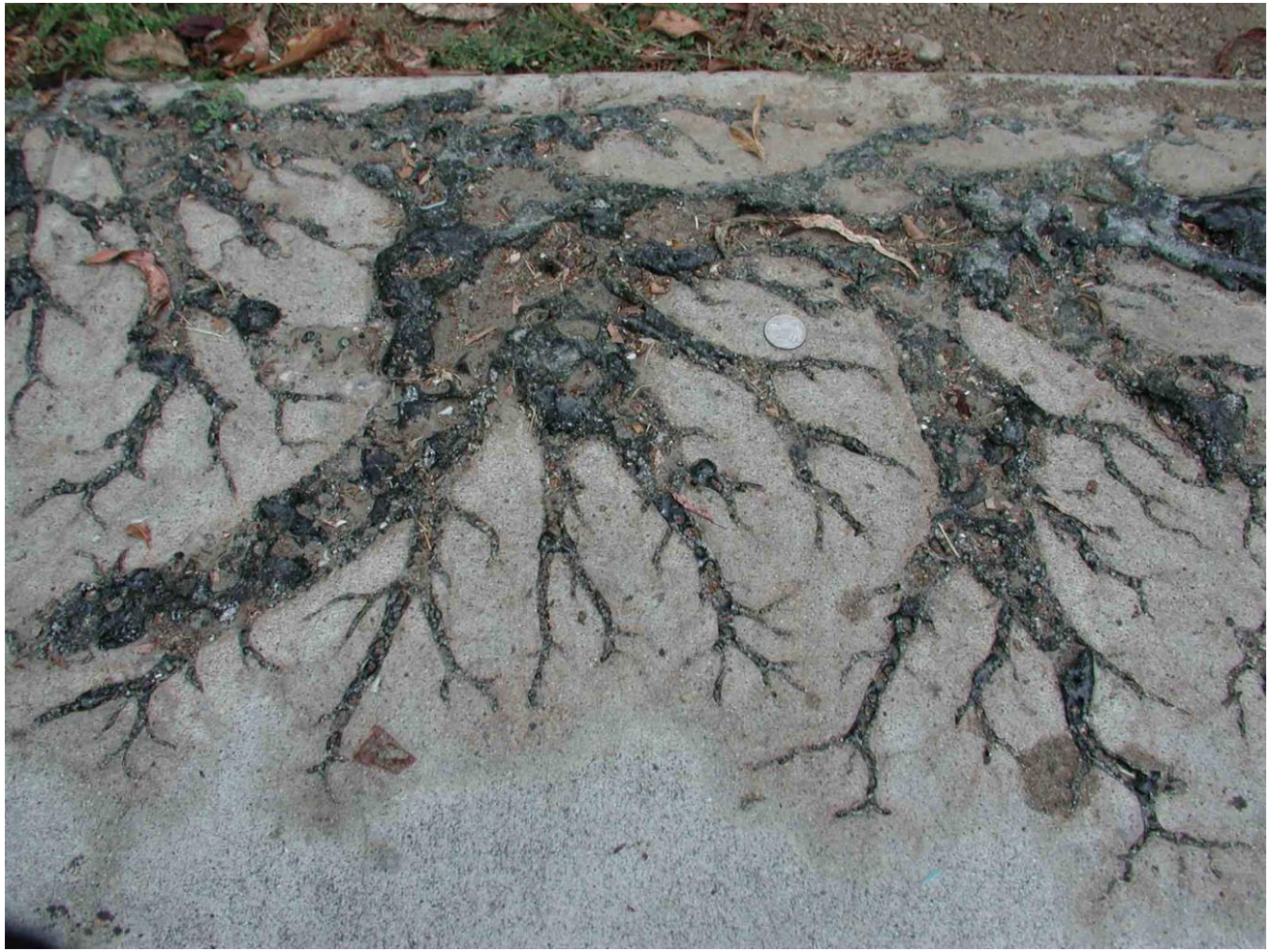
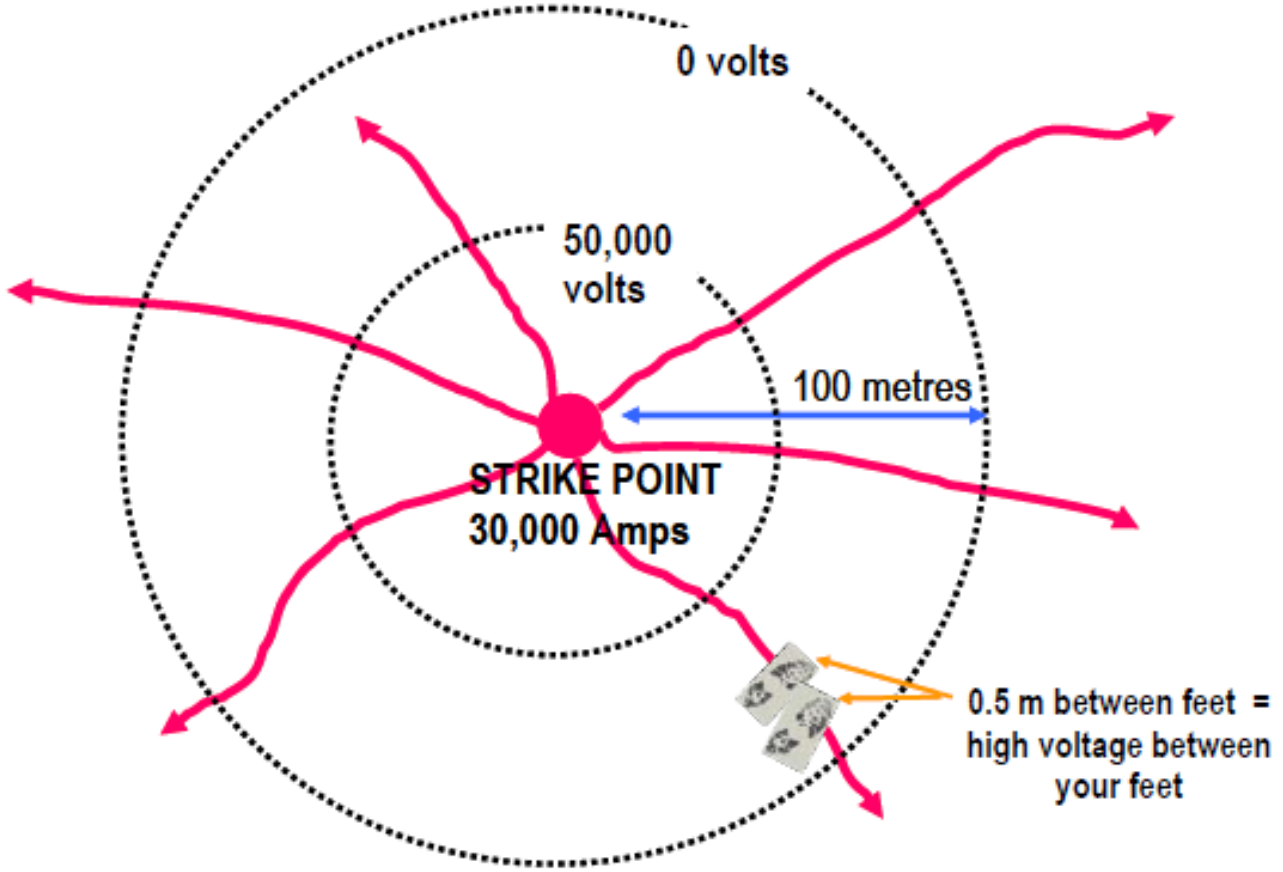
Uneven energy distribution around the strike point

Source: Surgetek

Uneven energy distribution around the strike point



The closer to the strike point, the higher the risk



Source: Surgetek

Lightning and explosives – recently reported events

- Initiation of a shocktube primed hole at a South African Colliery - lightning
- Initiation of two electronic detonator primed holes at a South African colliery - two lightning strikes
- Initiation of one EDD hole in a blast pattern on a gold mine in Ghana during a lightning storm.
- One EDD hole in a blast at an Alabama Coal mine as a result of a witnessed lightning strike.
- Seven EDD holes in a blast in an Alabama Coal Mine as a result of a recorded lightning strike.
- Four EDD holes initiated at a South African iron ore mine caused by a lightning strike

Lightning and explosives - cont.

- An entire non-electric detonator blast fired in South Africa when lightning struck near the initiating electric detonator
- Officials reported that nine workers were missing (presumed dead) after lightning initiated a quantity of explosives during road construction work. (China)
- Five persons were reported killed when lightning prematurely detonated explosives that had been laid out at a stone quarry (India).
- Lightning hit a detonating cord primed blasting work area in a surface mine in Western Australia. All holes detonated.

AXXIS Electronic detonator design to mitigate risk of initiation

- EDD's must survive and function normally after a 30 kV discharge
  - Human body model

- AXXIS – Five safety barriers
  - In-line resistors (block very high currents)
  - Voltage clamping circuit (for clamping lower voltages)
  - Sparking gaps to earth (for earthing high voltages)
  - Thermal barrier covering the electronics (to prevent heat related initiation)
  - Anti-static fusehead cover – axially aligned

- Tested Safety Limits (Lownds, 2009):
  - 800 kV at 8kA (1:10)
  - 6 kV at 18kA (0:10)
  - EDD's should tolerate most nearby negative CG strikes

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Managing the risk

Mining Industry:

Unanimous agreement that lightning poses a serious danger, however, no consensus on exactly how to manage the threat.

MSHA

“During the approach and progress of an electrical storm, blasting operations shall be suspended and persons withdrawn from the blast area or to a safe location.”

Common approaches to lightning warning in the Mining Industry:

- Use of detection devices and services coupled with predetermined buffers, or safe-operating distances.

- 30/30 Rule: *If it takes less than 30 seconds to hear thunder after seeing the flash, lightning is near enough to pose a threat; after the storm ends, wait 30 minutes before resuming outdoor activities.*

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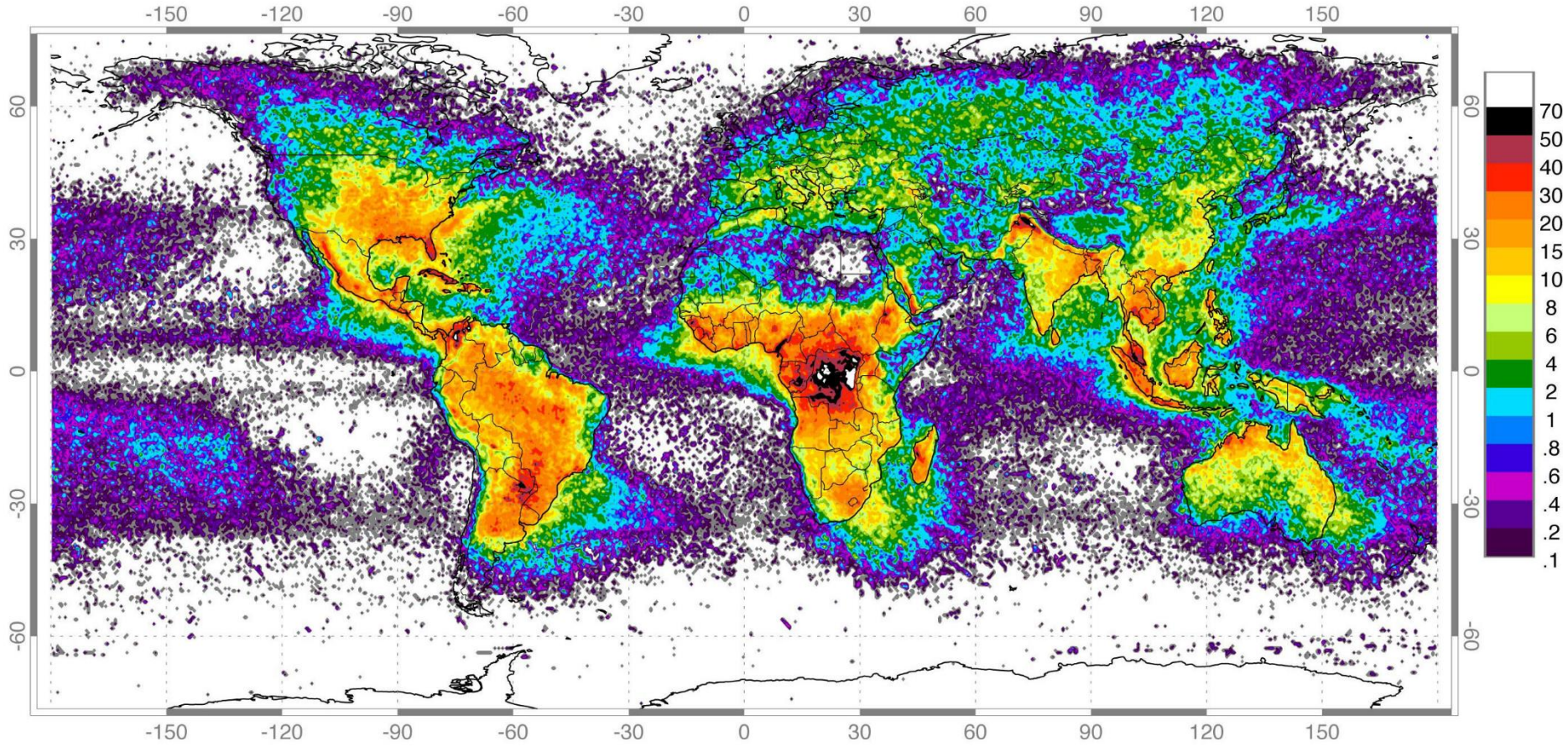
Highest annual lightning strike density (strikes per square km per year)

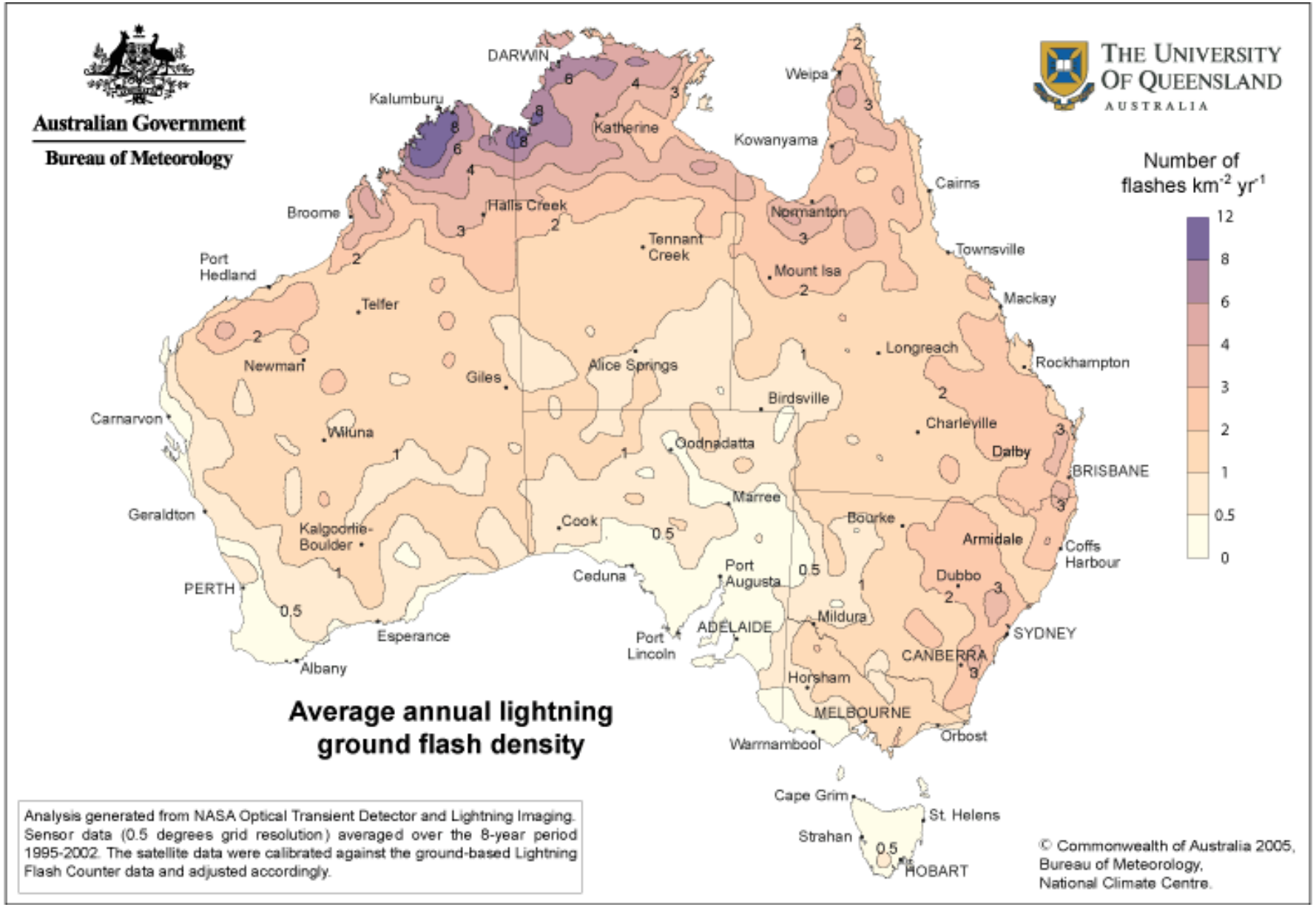
Africa	Dem Rep of Congo (kifuka)	158
South America	Columbia	110
Asia	Northern Pakistan	87
North America	USA / Florida	59
Europe	Northern Italy	28

$$y = \frac{1}{A \times f}$$ *(Santis 1998)*



High Resolution Full Climatology Annual Flash Rate

Global distribution of lightning April 1995-February 2003 from the combined observations of the NASA OTD (4/95-3/00) and LIS (1/98-2/03) instruments


Australian Government
Bureau of Meteorology
The University Of Queensland
AUSTRALIA
Number of flashes km-2 yr-1
12
8
6
4
3
2
1
0.5
0
DARWIN
Kalumburu
Katherine
Weipa
Kowanyama
Cairns
Townsville
Mackay
Rockhampton
Broome
Halls Creek
Tennant Creek
Normanton
Mount Isa
Port Hedland
Telfer
Newman
Giles
Alice Springs
Longreach
Birdsville
Charleville
Dalby
BRISBANE
Coffs Harbour
Carnarvon
Wiluna
Oodnadatta
Geraldton
Kalgoorlie-Boulder
Cook
Marree
Bourke
Armidale
Dubbo
PERTH
Ceduna
Port Augusta
Mildura
ADELAIDE
SYDNEY
CANBERRA
Esperance
Albany
Port Lincoln
Horsham
MELBOURNE
Orbost
Warrnambool
Cape Grim
St. Helens
Strahan
HOBART
Average annual lightning ground flash density
Analysis generated from NASA Optical Transient Detector and Lightning Imaging Sensor data (0.5 degrees grid resolution) averaged over the 8-year period 1995-2002. The satellite data were calibrated against the ground-based Lightning Flash Counter data and adjusted accordingly.
© Commonwealth of Australia 2005, Bureau of Meteorology, National Climate Centre.

Lightning Detection

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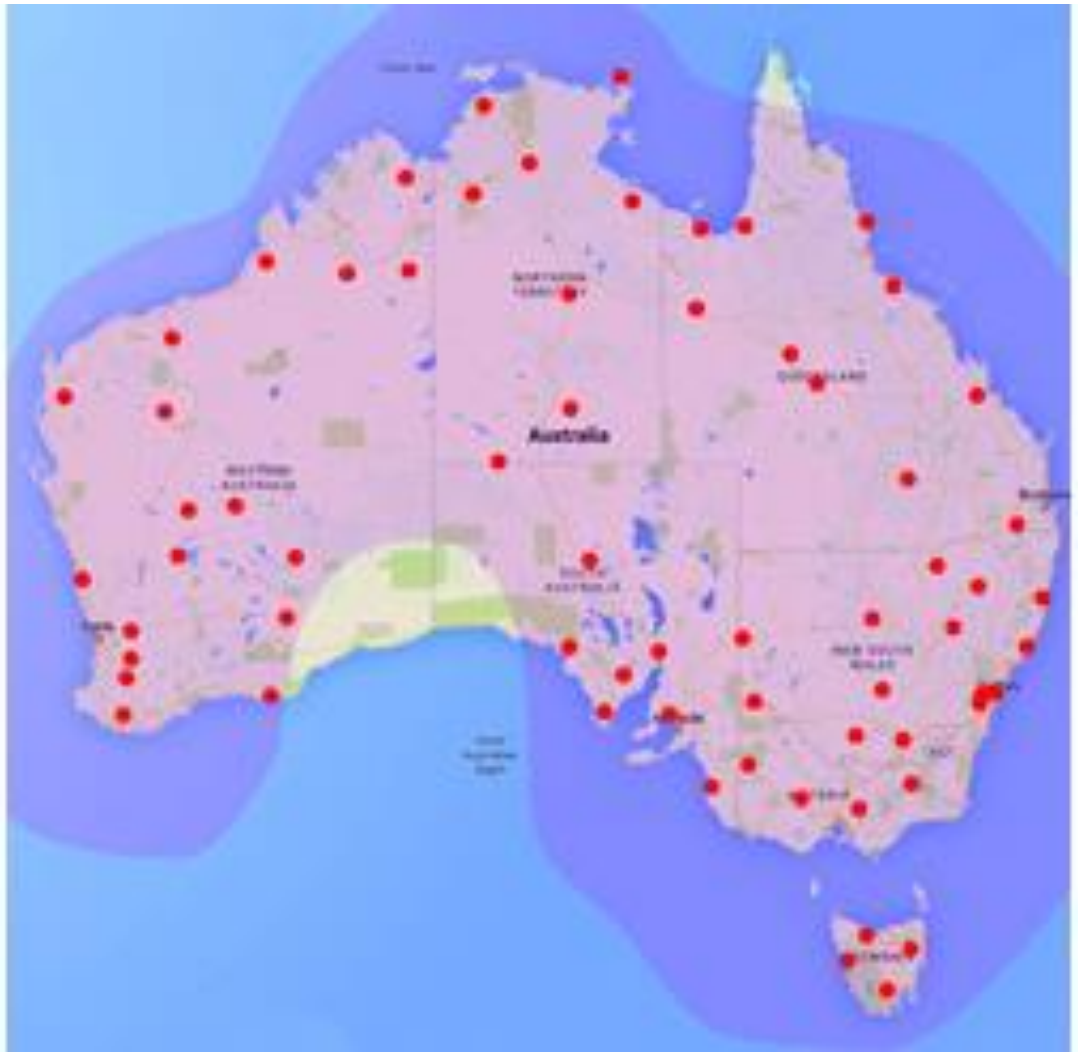
Lightning Detection



Weatherzone Total Lightning Network

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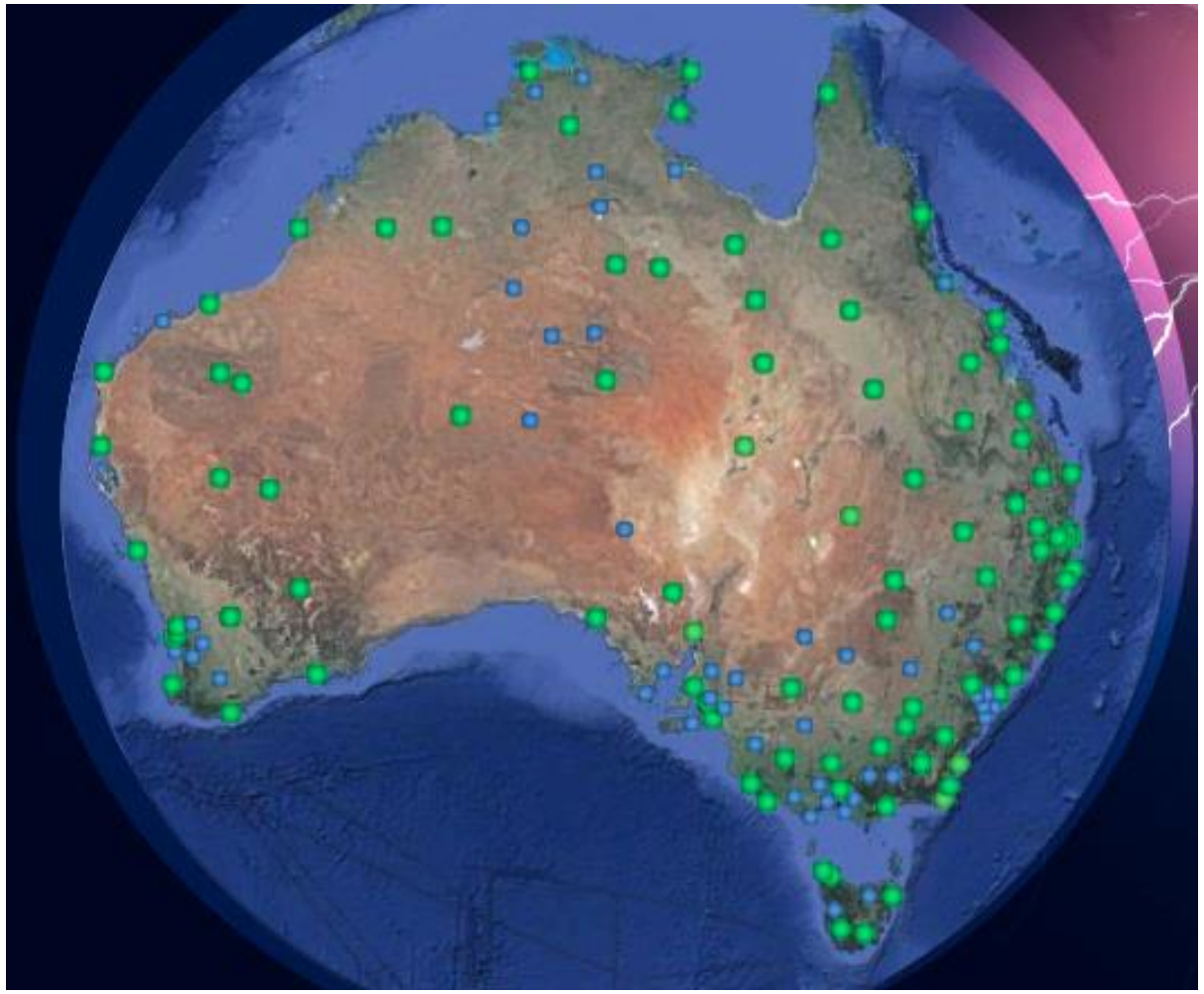
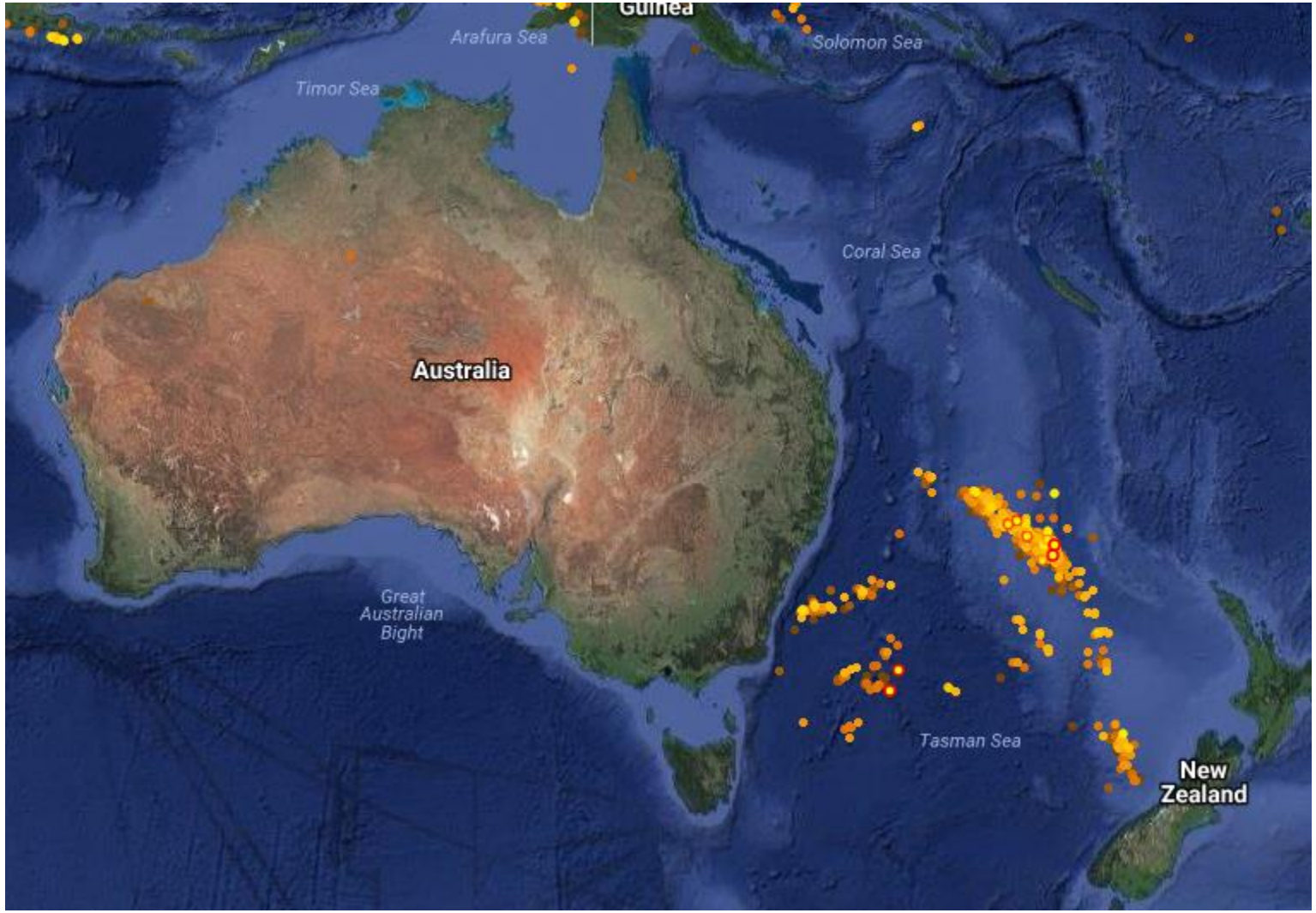
Lightning Detection



GPATS Lightning Detection Network

Lightning Detection



LightningMaps.org

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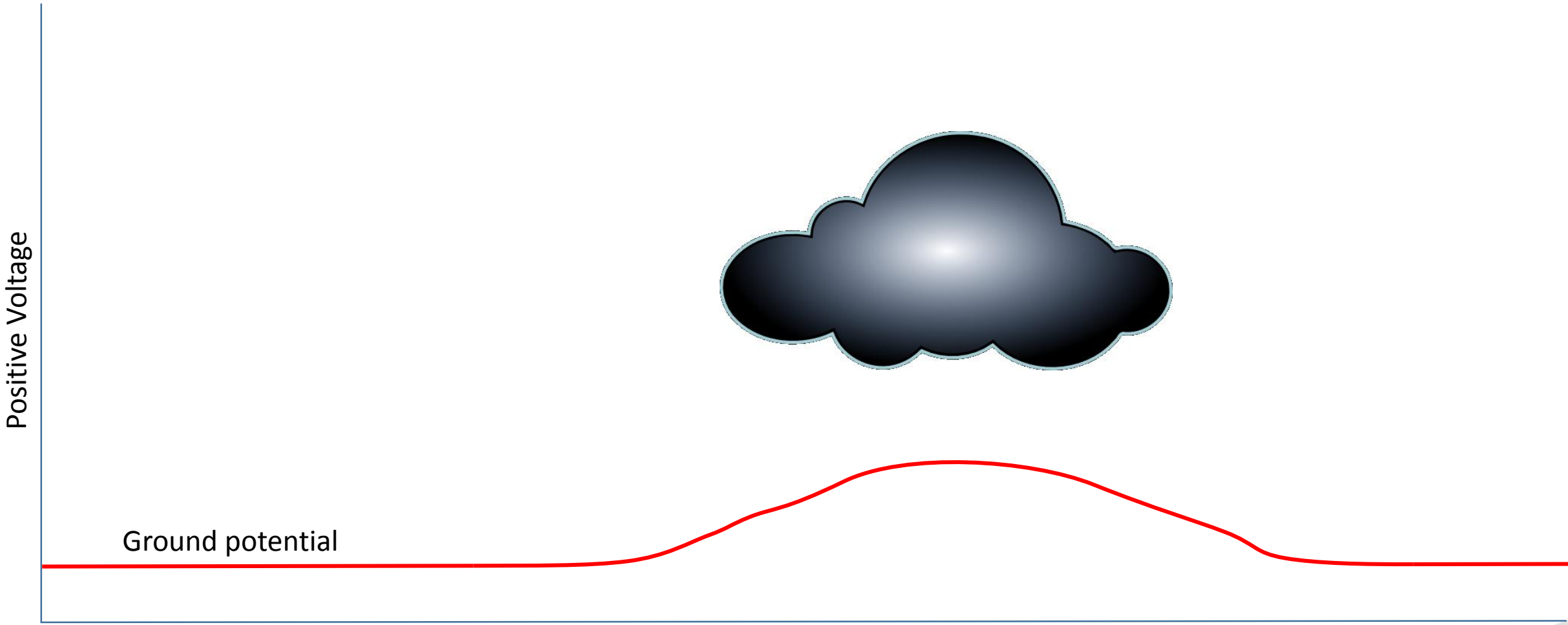
SAWS – SMS warning

+ 0 BME Kwagga: 20120309 15:23 Lightning Current Danger - 25.0KA Direction: 11km North West Date sent: 09/03/2012 15:24:00

+ 1 BME Kwagga : 20120309 15:21 Lightning 16 minutes clear. - 11.0KA Direction: 15km West North West Date sent: 09/03/2012 15:22:00

+ 0 BME Kwagga : 20120309 15:05 Lightning Current Danger - 11.0KA Direction: 15km West North West Date sent: 09/03/2012 15:06:00

+ 1 Kwagga BME: 20120309 15:05 Lightning 16 minutes clear. - 20.0KA Direction: 15km West Date sent: 09/03/2012 15:05:00


Positive Voltage
Ground potential

Lightning Prediction

- Prediction systems monitor the *electrostatic potential* to determine local areas of cloud to ground lightning potential.

- Lightning warning is based on time (before a strike occurs within a pre-defined area) not distance.

Conclusions – Lightning is dangerous

- Positive CG strikes are more likely to cause an induced detonation of electronic initiation systems
- Lightning induced initiation will only be limited to the few detonators immediately affected if electronic detonators are used
- Even though most operations have lightning detectors, they are usually non-operational or disregarded
- Lightning detection services and warnings are useful but cause major productivity losses.
- Lightning prediction systems should be used in conjunction with detection services