

# *Overhead Transmission/Distribution Condition Assessment and Maintenance*

Geoffrey Bibo

**E**xacter

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St. Louis Section PES Chapter  
St. Louis, MO



# Agenda

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- The Problem: Overhead Performance
- Organizational Objective
- IEEE Failure Statistics
- What Fails?
- Methods to Mitigate Failures
- RF Emission Sources
- An Arc Emission Capture and Use Methodology
- Characteristics of Arc Emissions
- Evaluating Emission
- Field Experience and Case Studies

# The Problem: OVHD Performance

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$$\text{SAIDI} = \frac{\text{sum of all customer interruption durations}}{\text{total number of customers served}}$$

$$\text{SAIFI} = \frac{\text{total number of customer interruptions}}{\text{total number of customers served}}$$

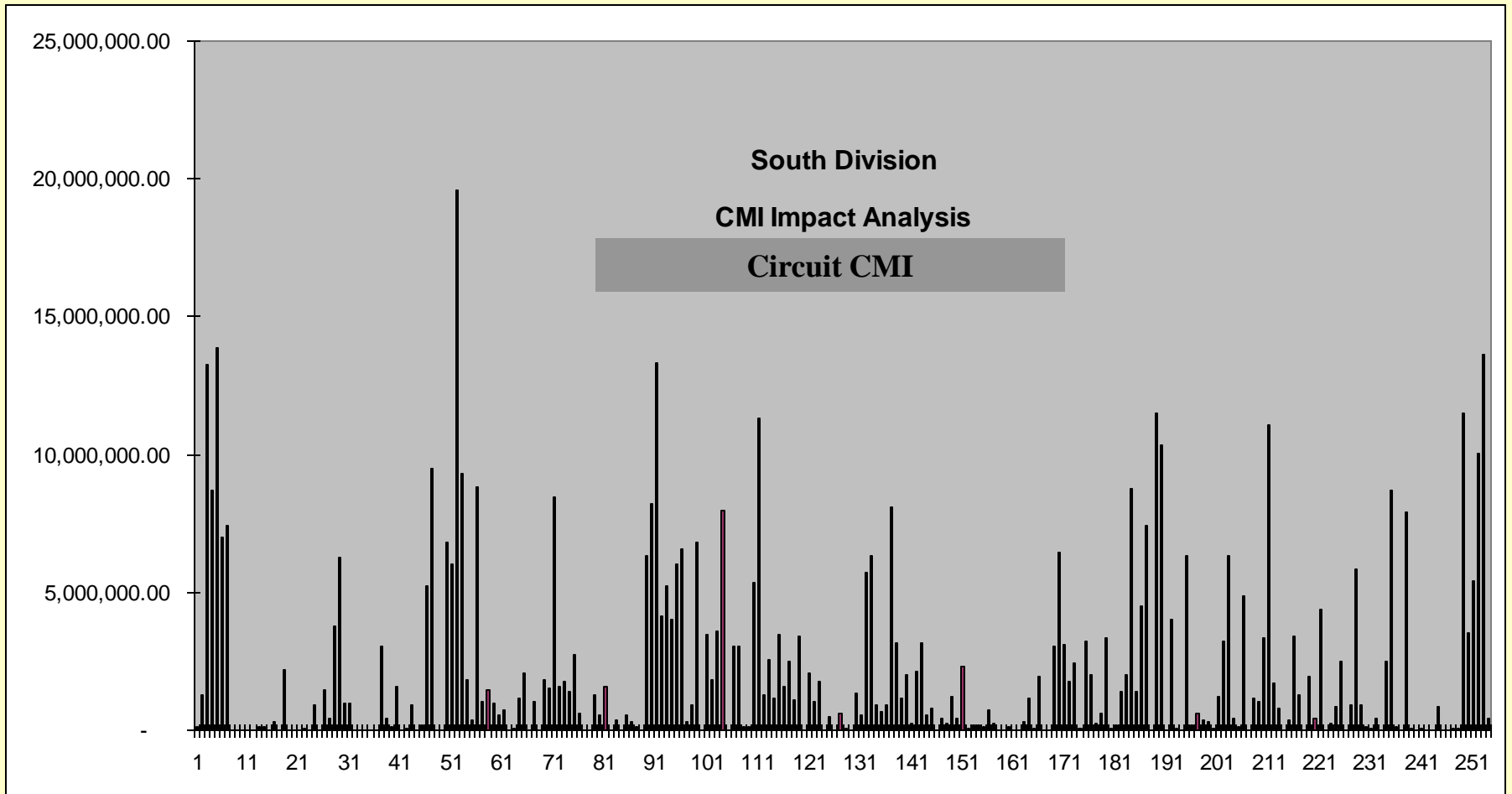
$$\text{CAIDI} = \frac{\text{sum of all customer interruption durations}}{\text{total number of customer interruptions}} = \frac{\text{SAIDI}}{\text{SAIFI}}$$

$$\text{MAIFI} = \frac{\text{total number of customer interruptions less than the defined time}}{\text{total number of customers served}}$$

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**CMI a Foundational Element**

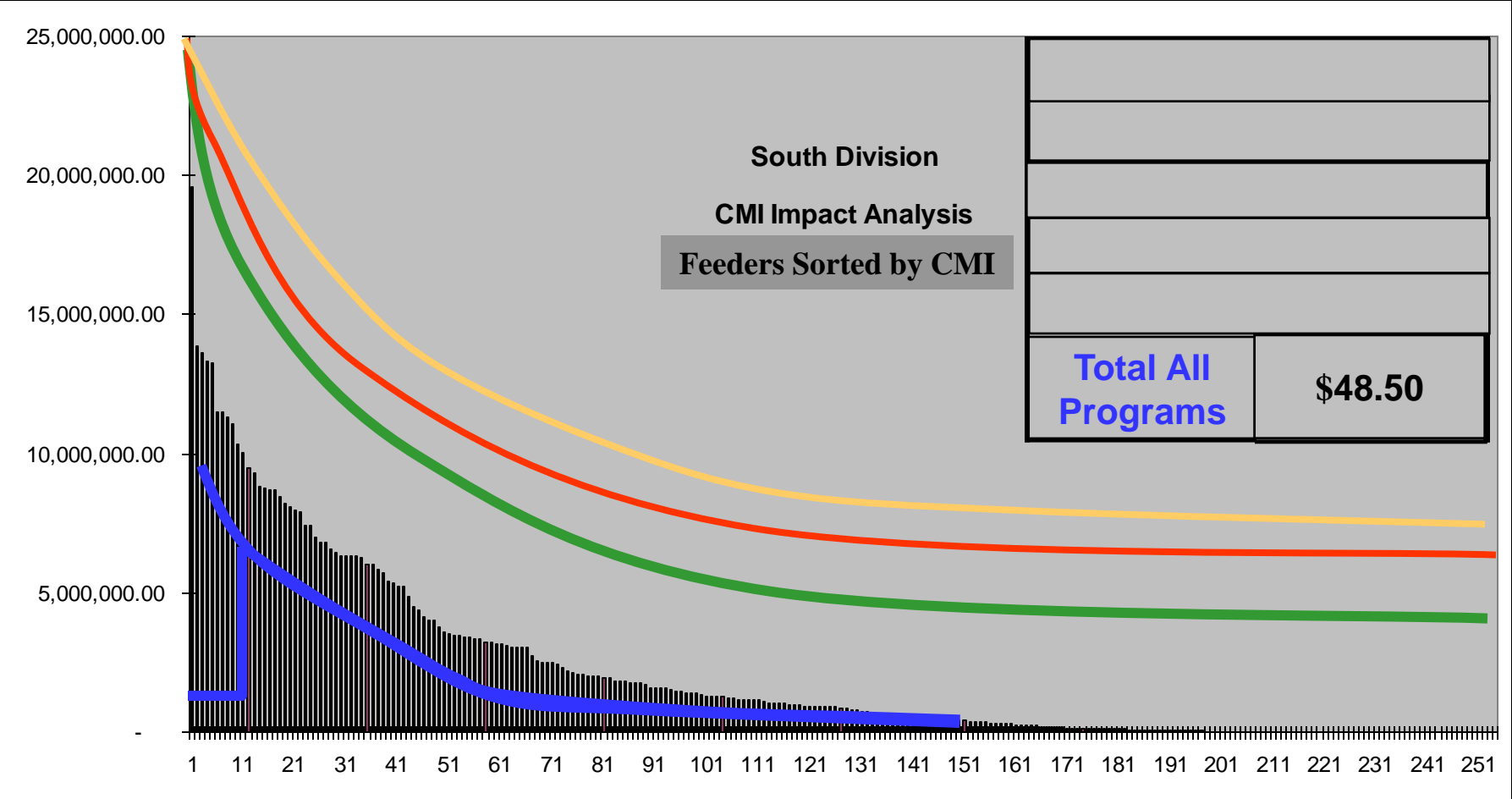
# Typical CMI Variations



# Methods to Mitigate Failures

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# Reliability Program Impacts



# Organizational Objectives

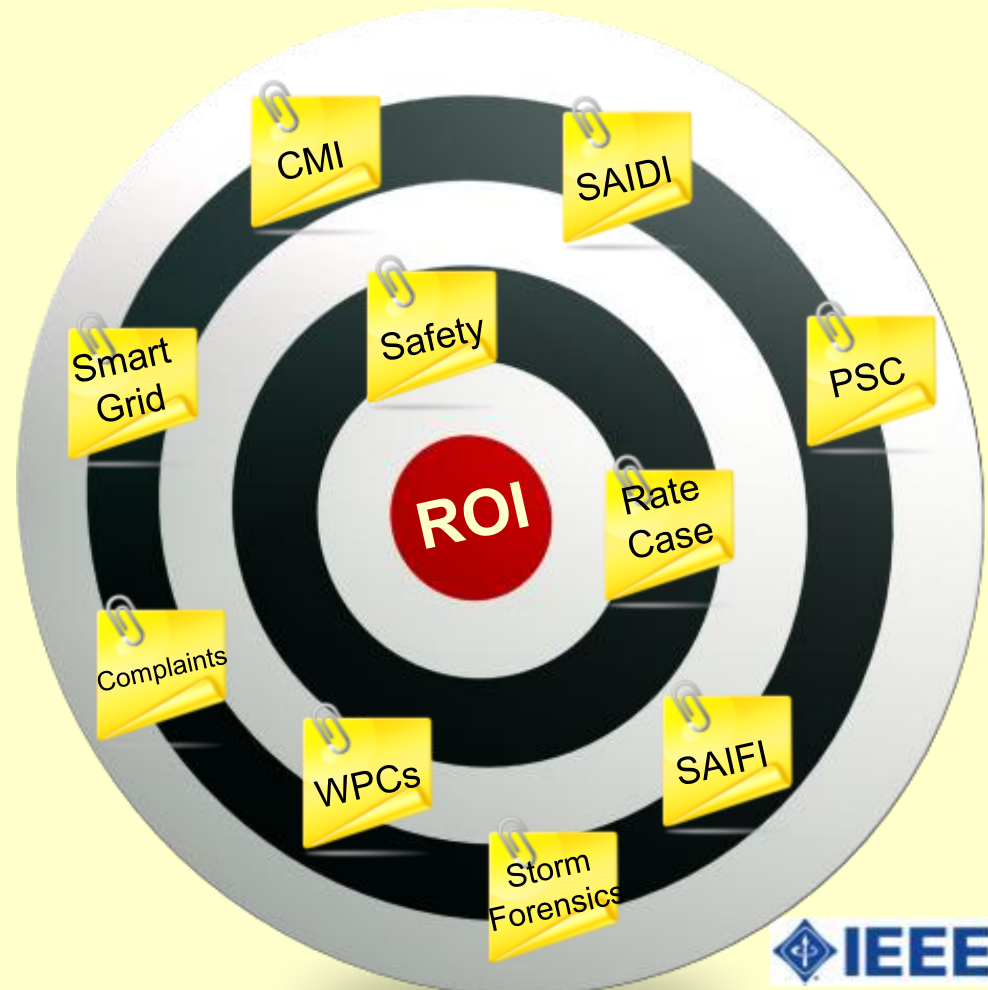
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# Support Multiple Business Objectives

Technology &  
Process  
Enablement

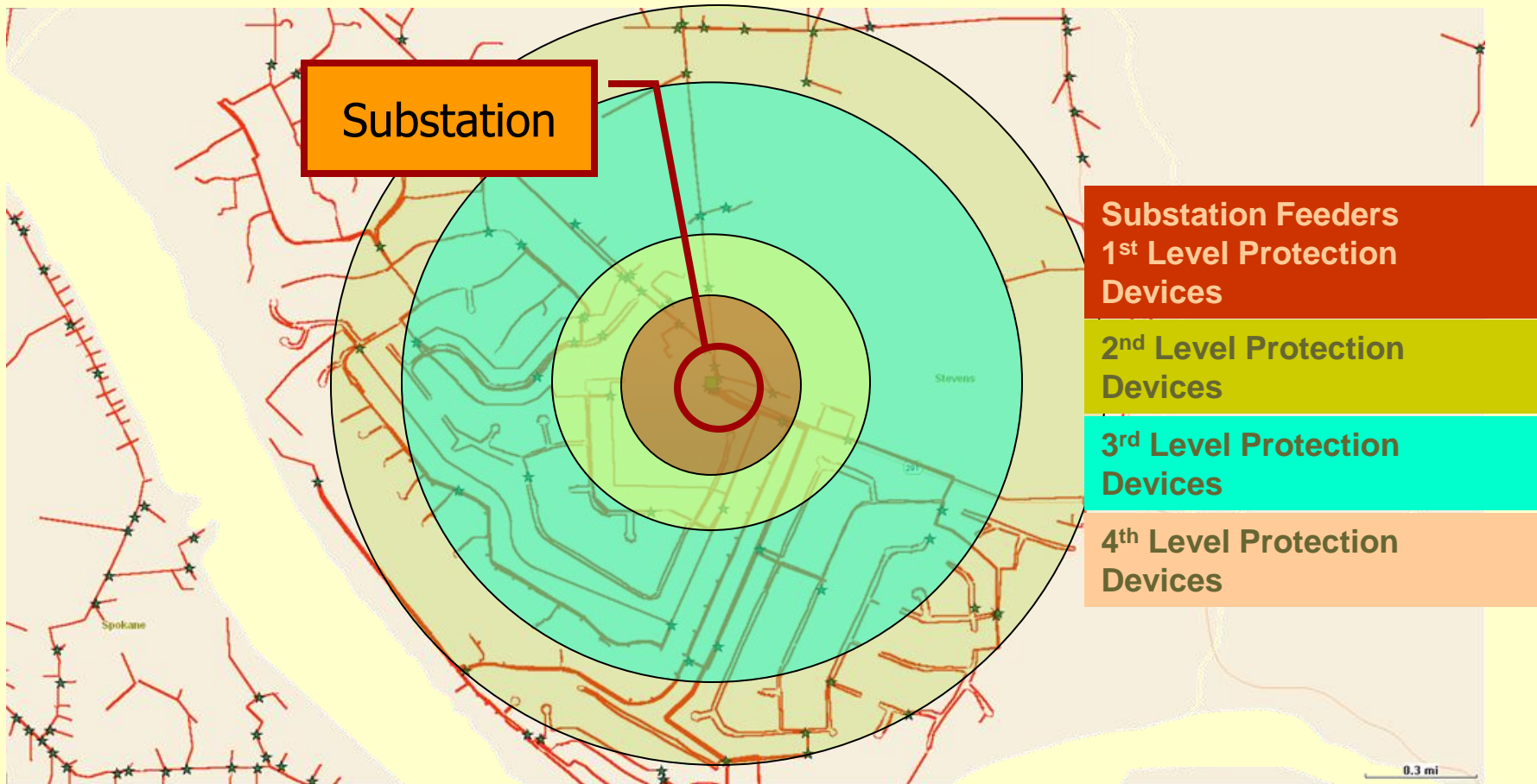


- *Empirical Data*
- *Leading Health Indicators*
- *Insight to Maximize Results*

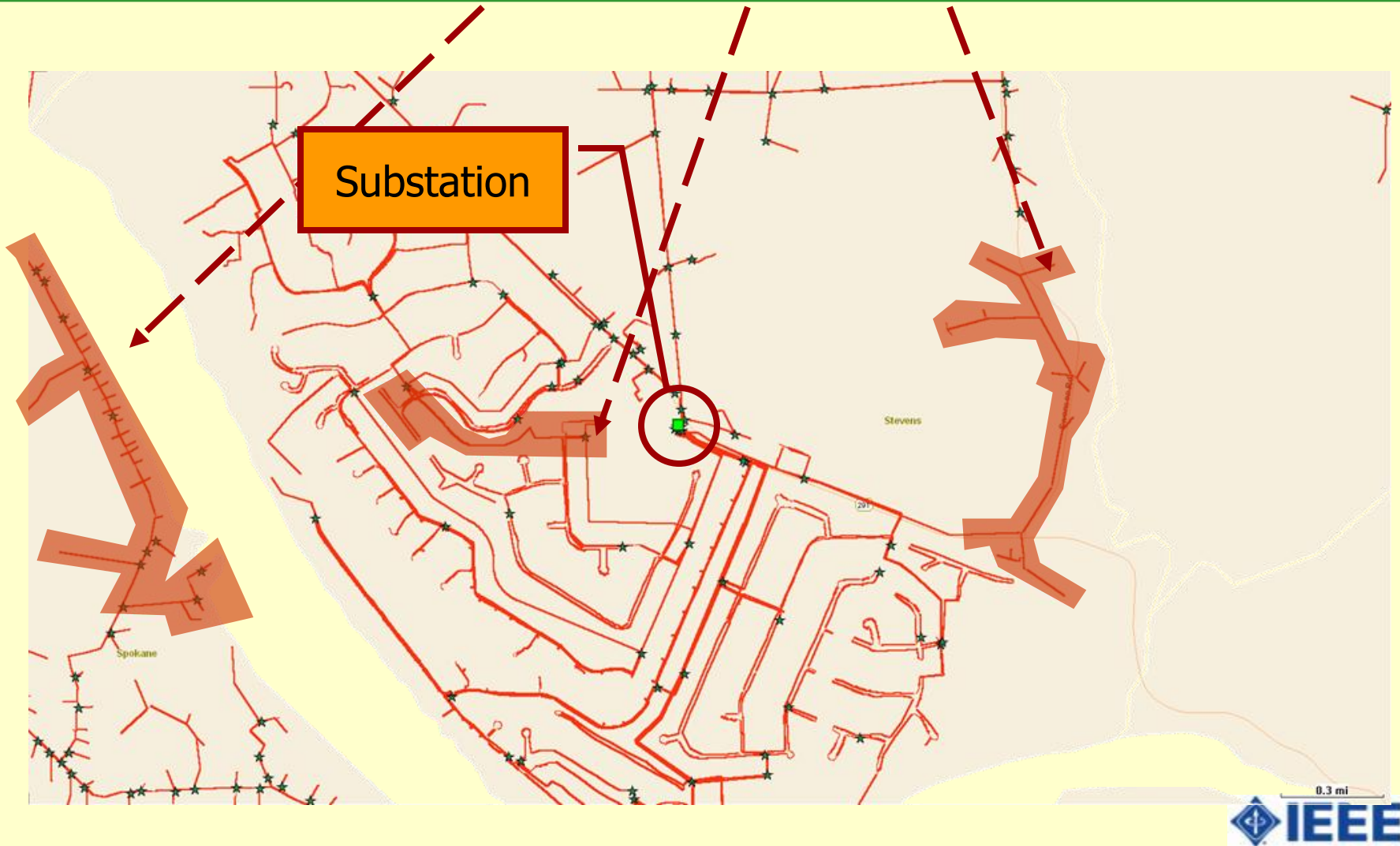




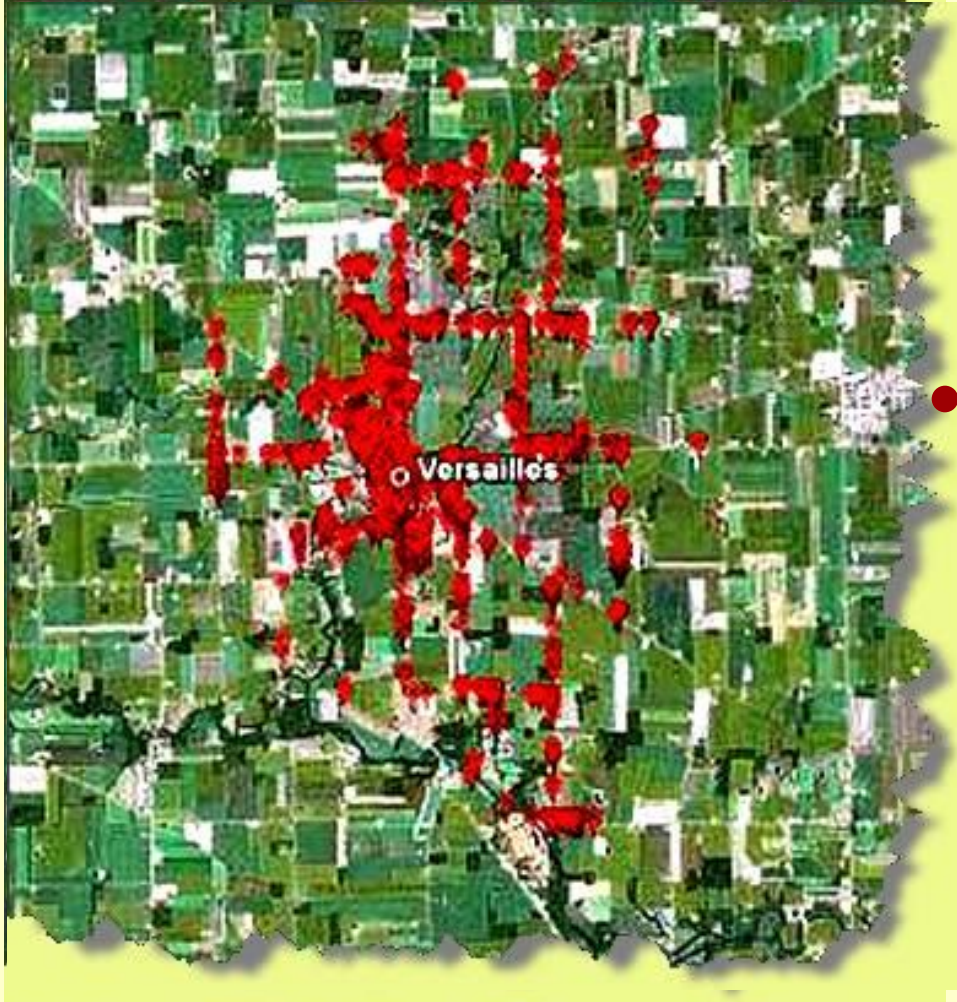
# SAIFI/SAIDI Reduction



# Worst Performing Circuits

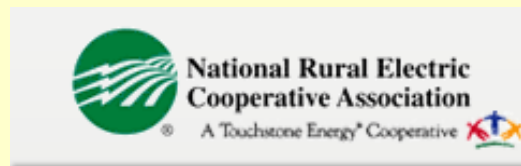


# Seasonal Damage



- *Support for FEMA Assistance*
  - *Preparedness*
  - *Post storm recovery*
  - *Post restoration hardening*
  - *Mitigation assessment*

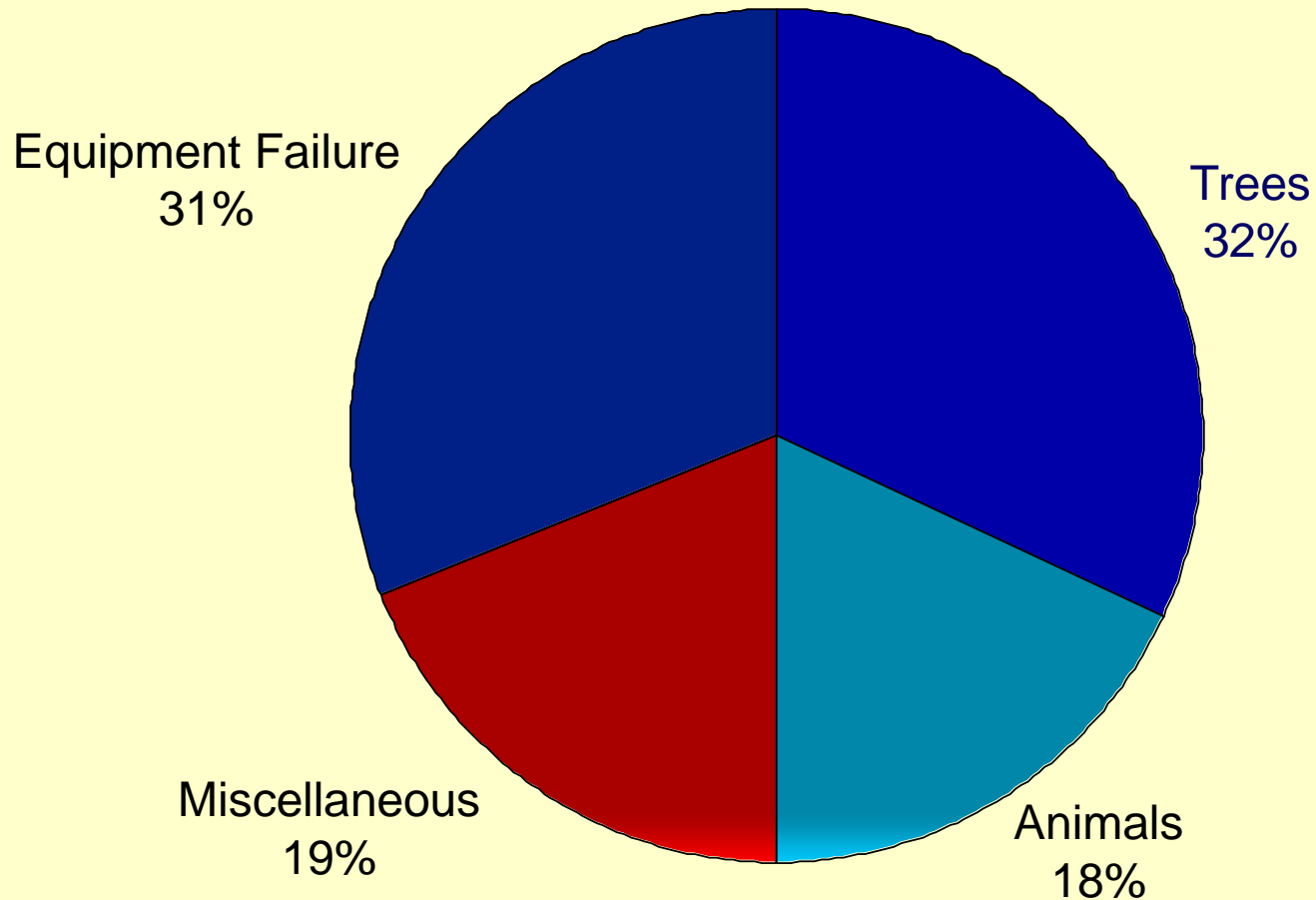
# The 31% Problem



**All Studies Agree:  
31% of Outages  
Are Due to  
Failing Equipment**

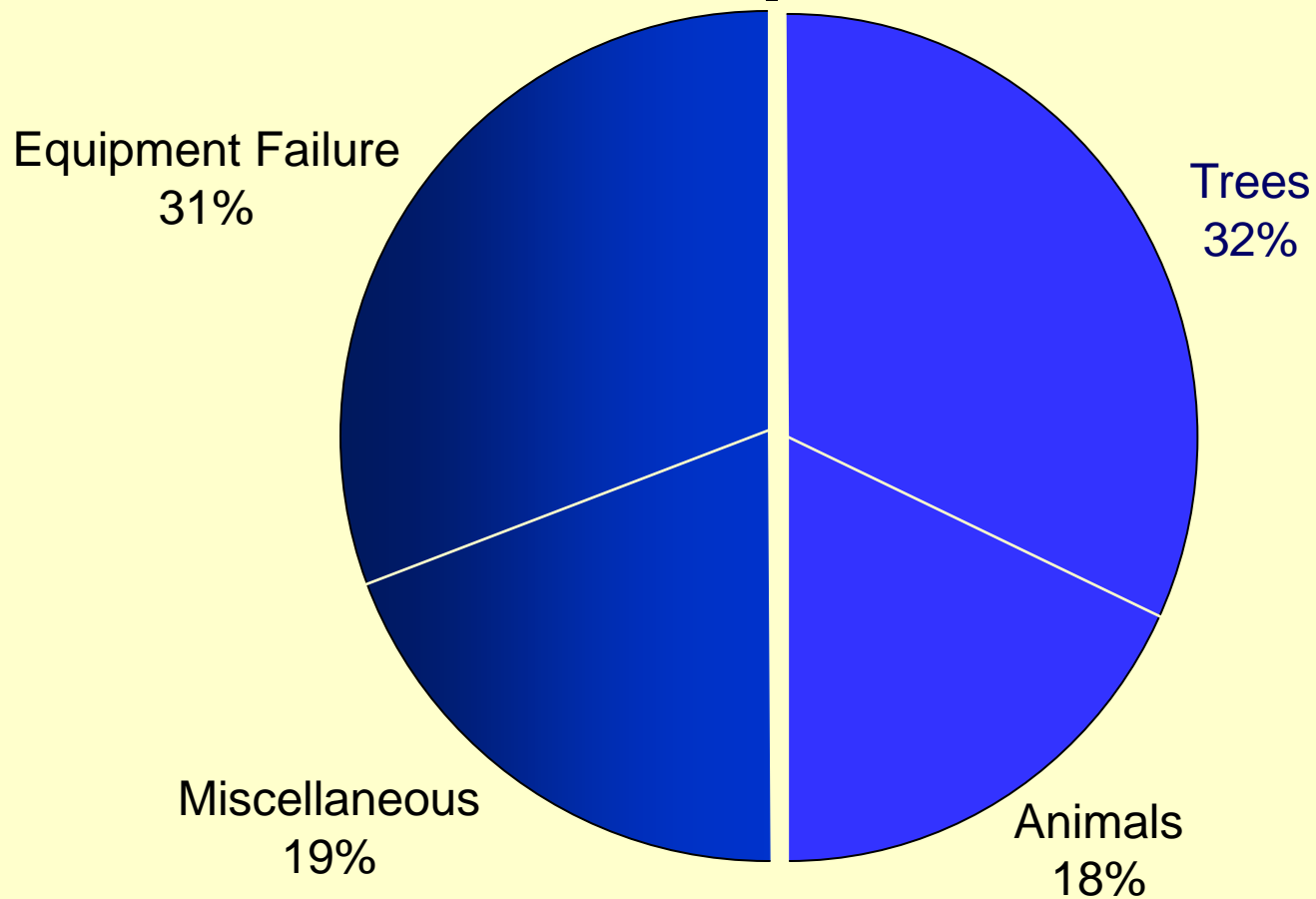


# Causes of Power Outages



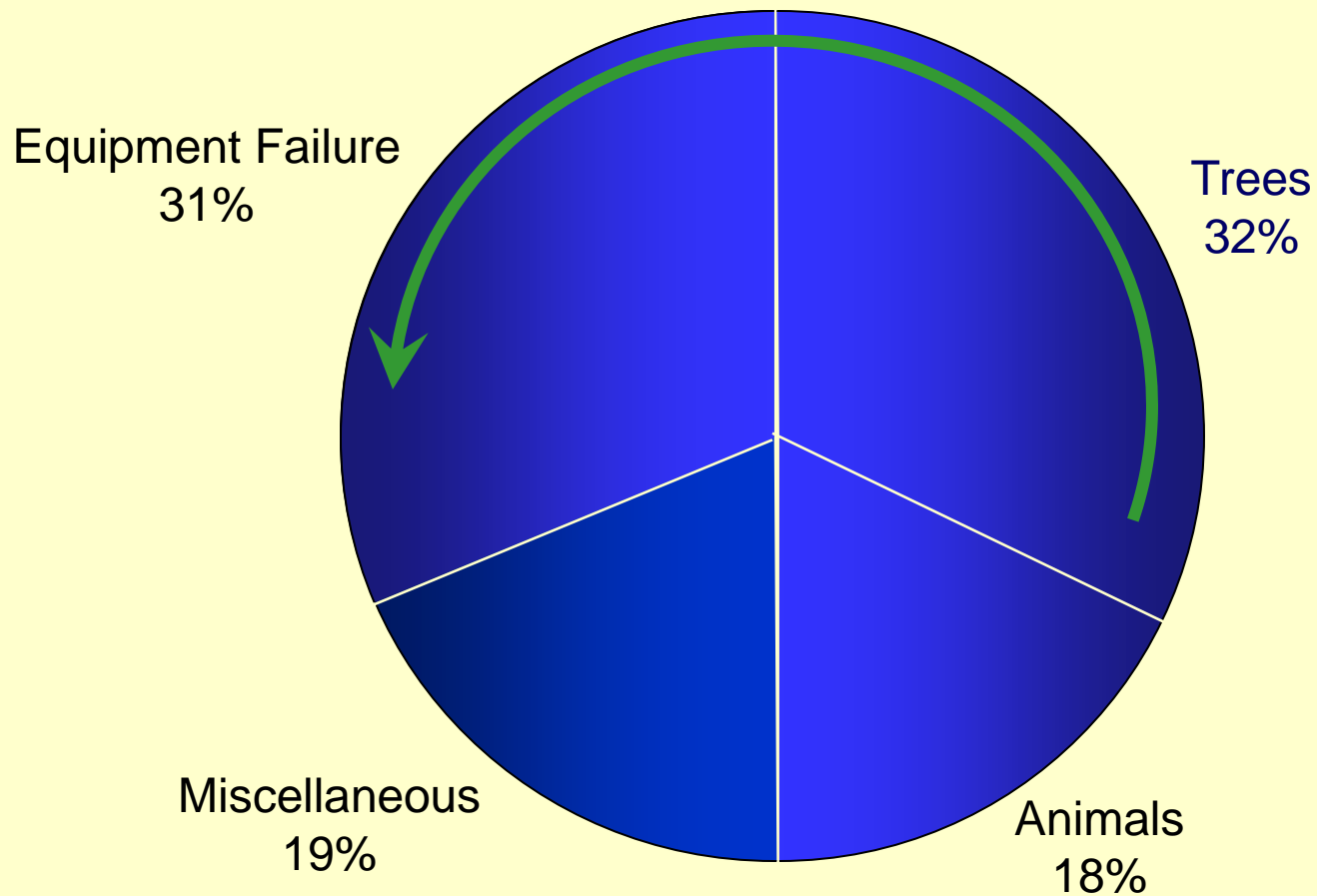
# Unavoidable

# Avoidable



# Predictive Impact

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# Conditions-Based Maintenance

## Predictive Maintenance

Equipment Strategy

## Reactive Maintenance

Response Strategy

O  
U  
T  
A  
G  
E

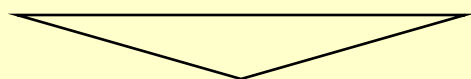
OMS, SCADA, Automation

## Outage Response

Storms, Animals, Accidents, Trees

← Identification **BEFORE**

← **Proactive** Process



Targeted Goals

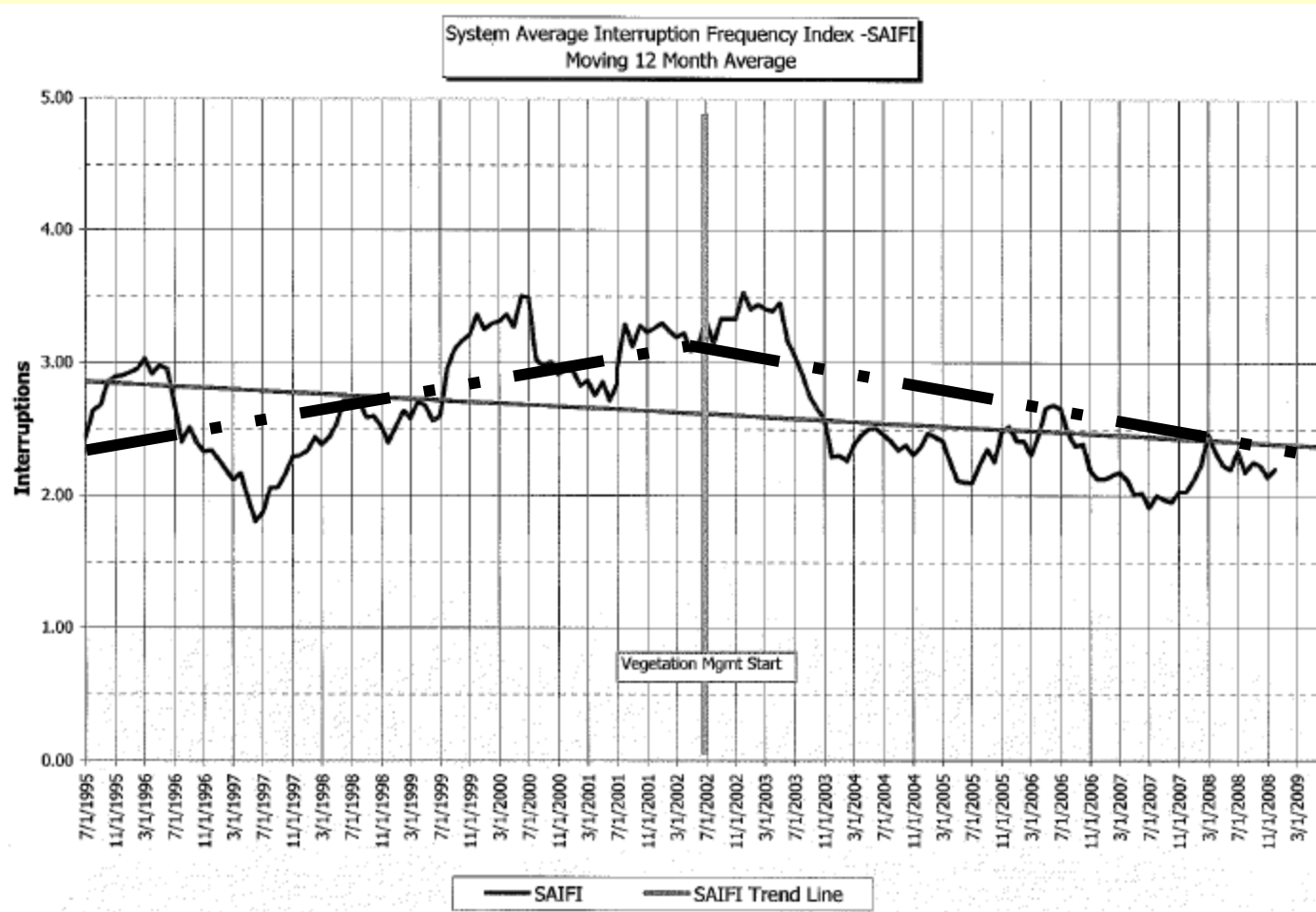
← Identification AFTER

← Reactive Process by Design

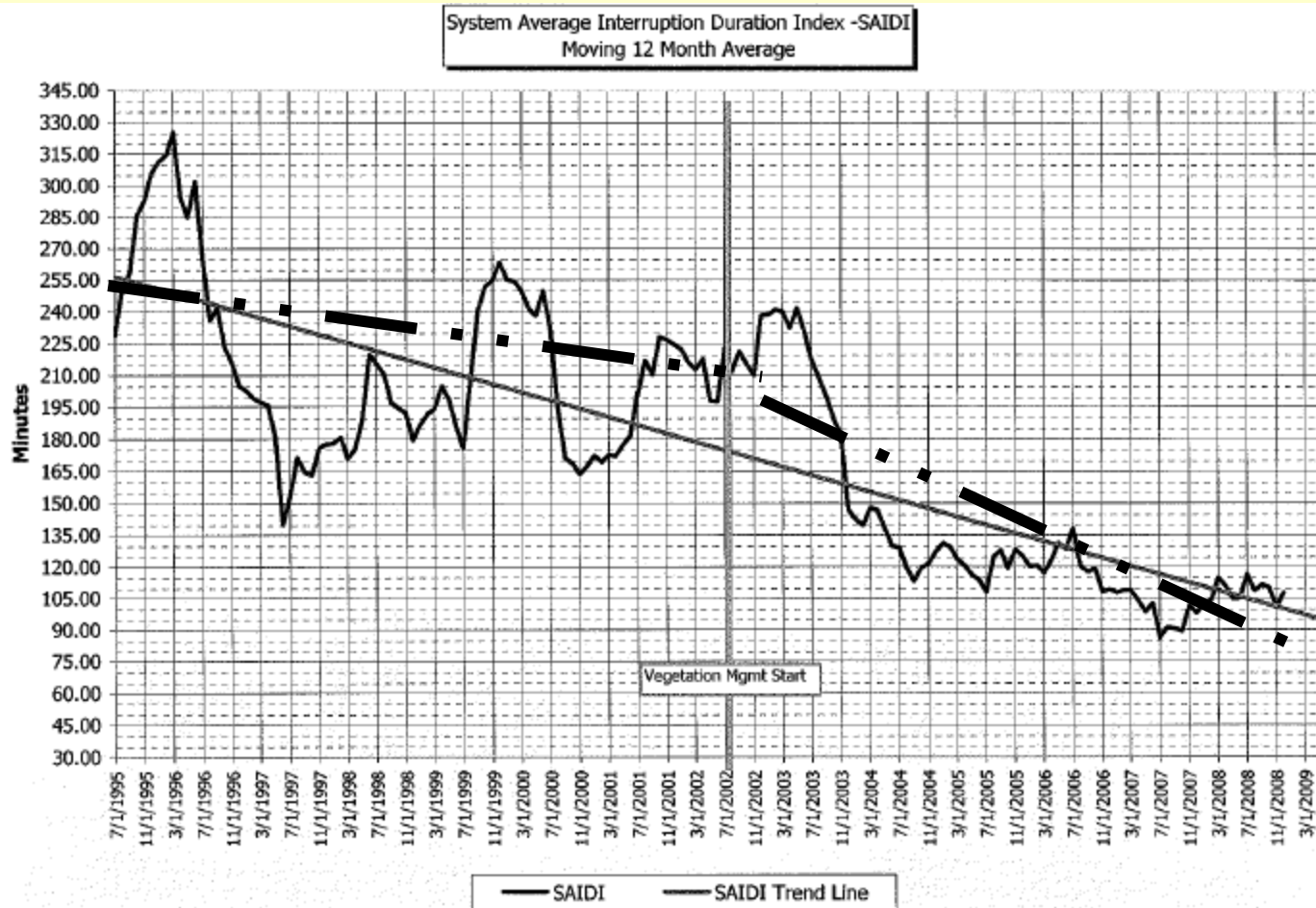
Equipment Failures Over Time



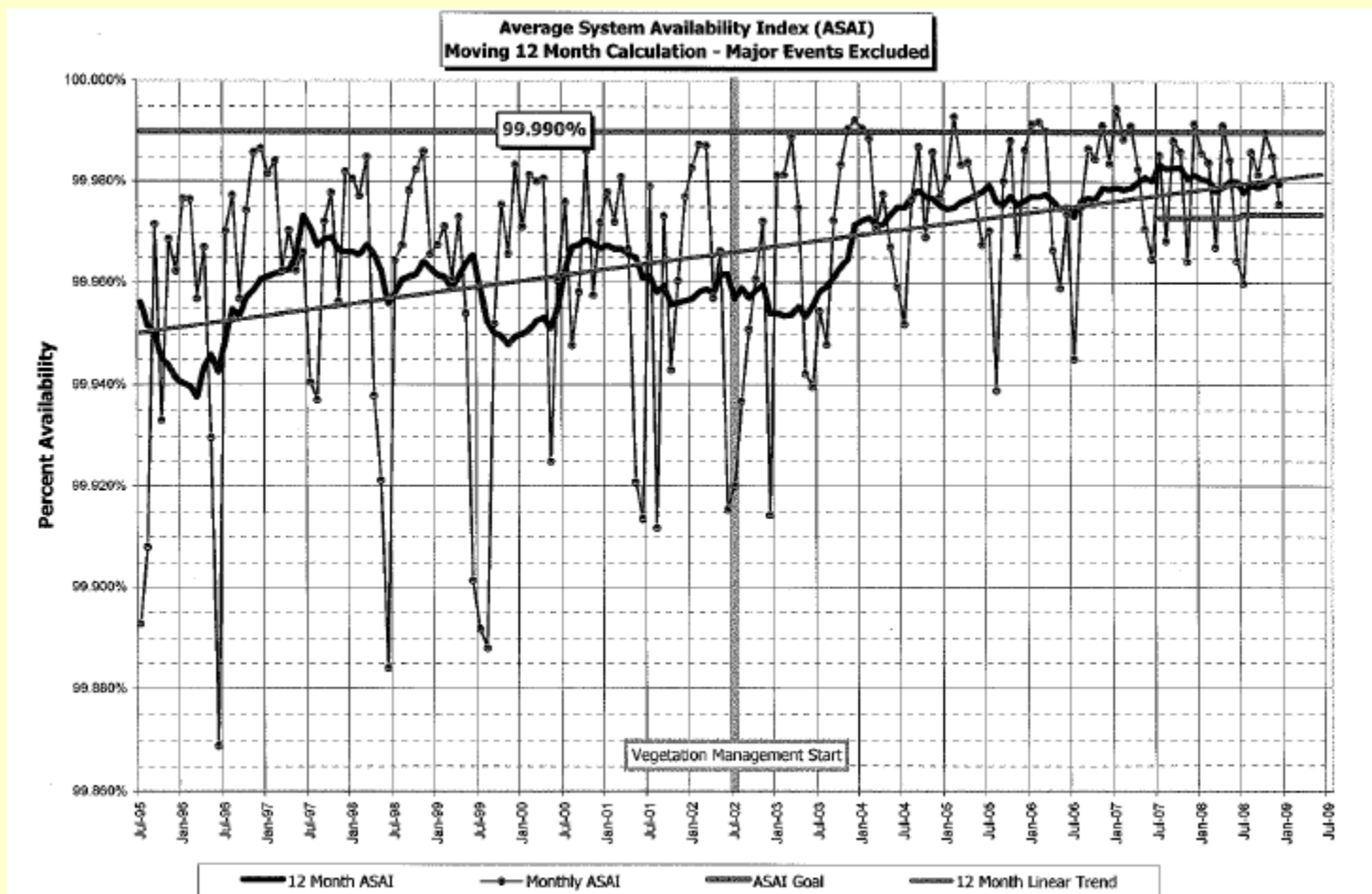
# Impact of Vegetation Mgmt: SAIFI



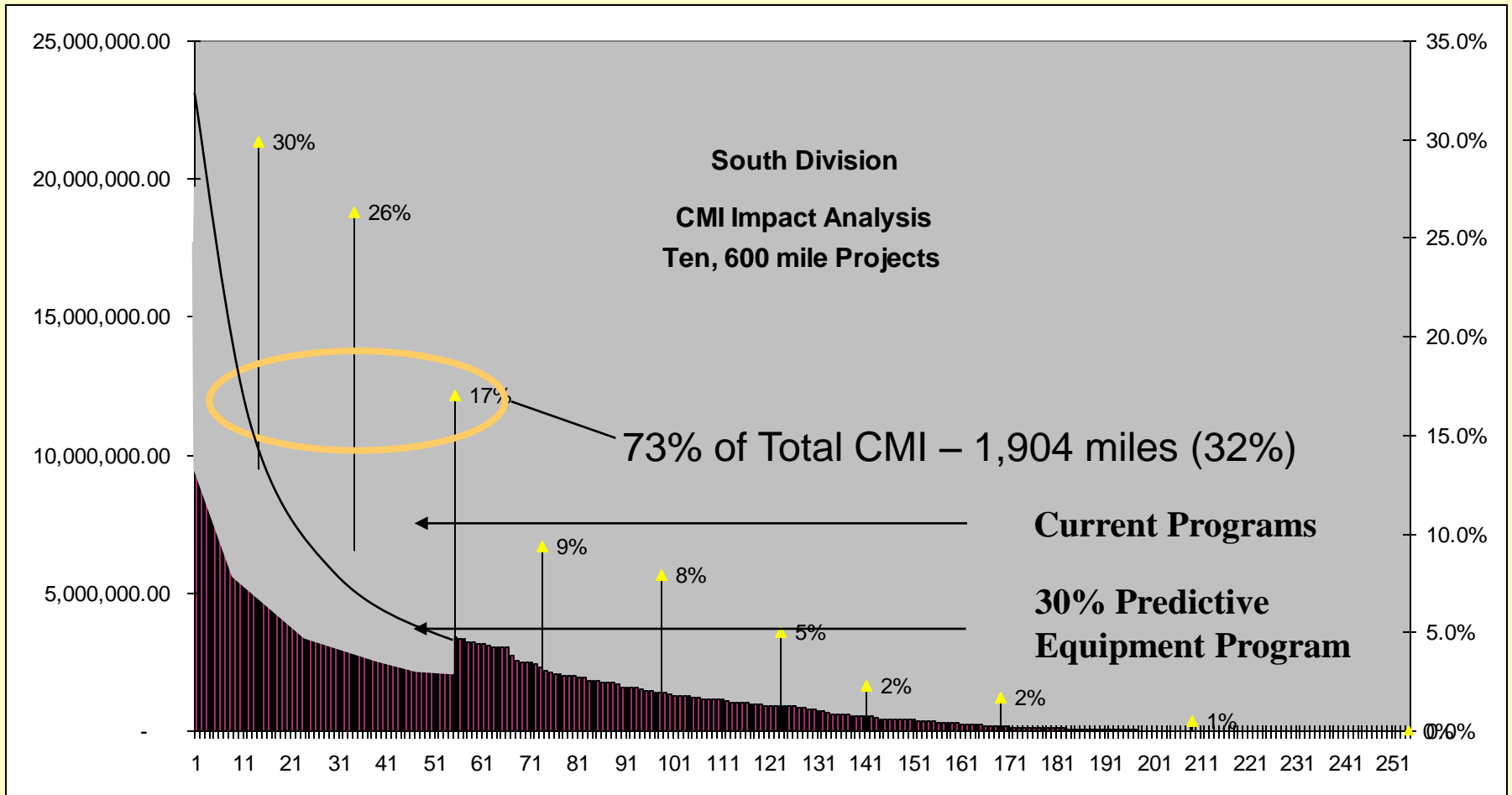
# Impact of Vegetation Mgmt: SAIDI



# Overall System Availability



# Plan for CMI Improvement

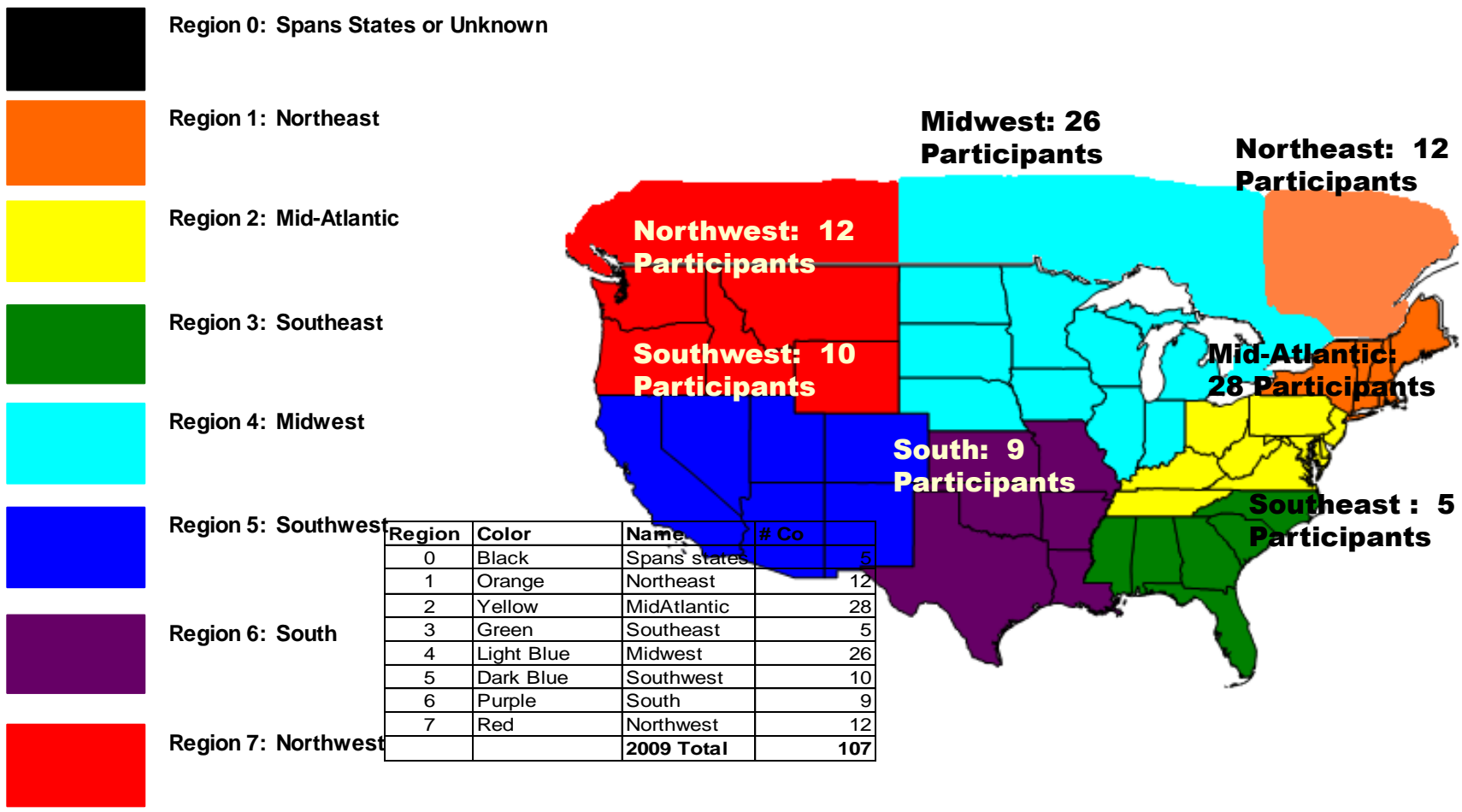


# IEEE

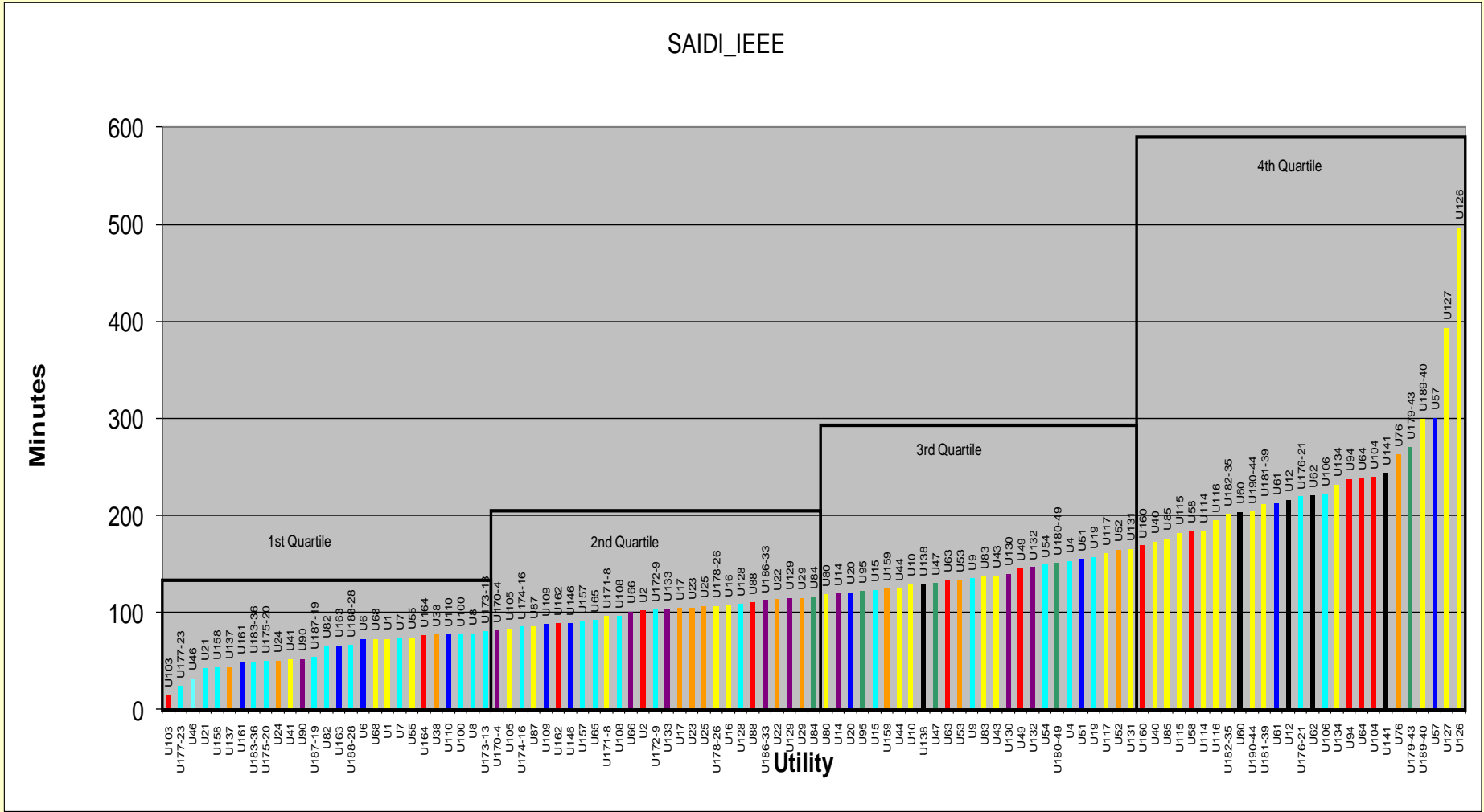
# Failure Statistics

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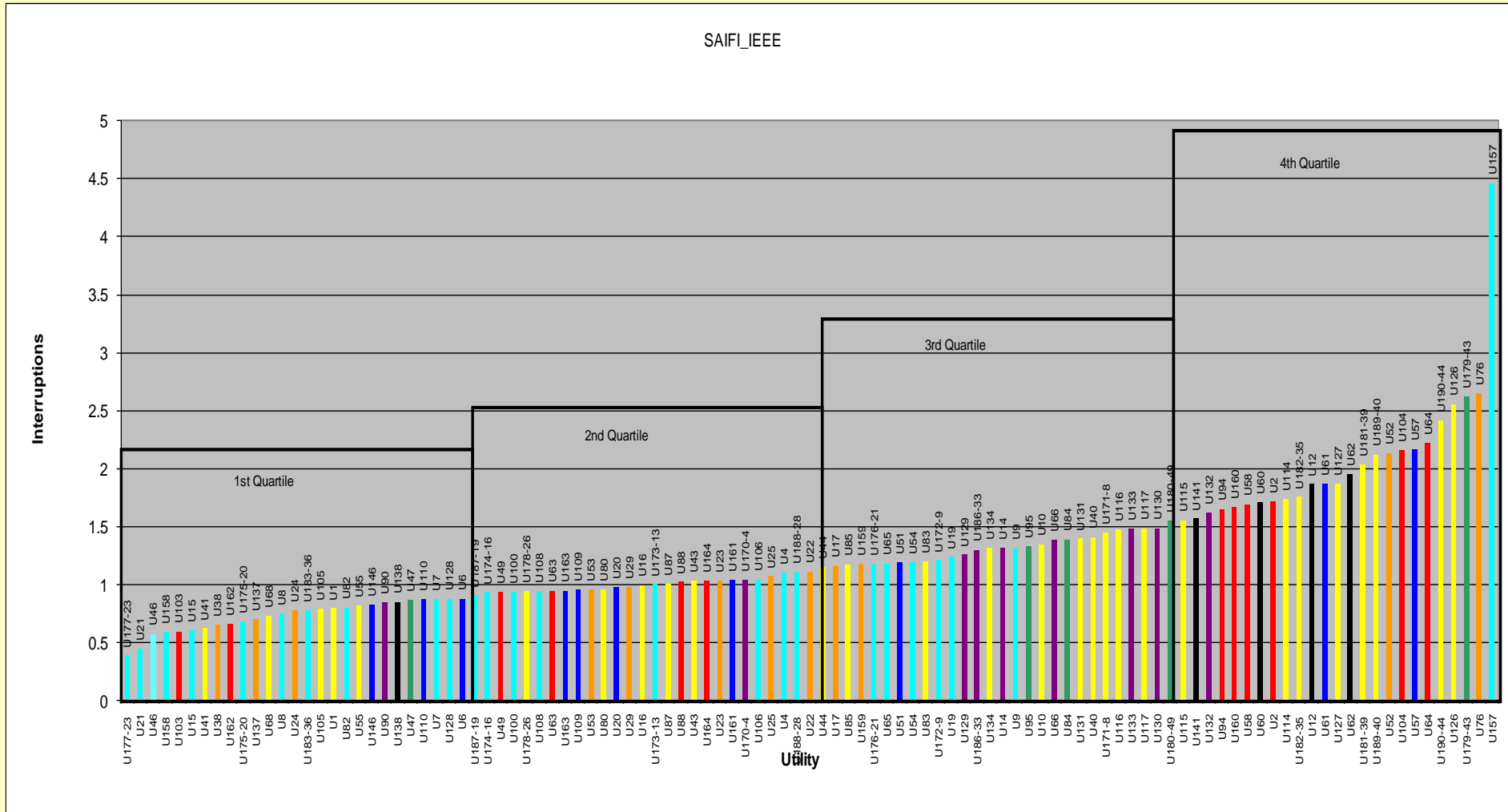
# Regions Represented by the Participants



# SAIDI IEEE, across the continent...

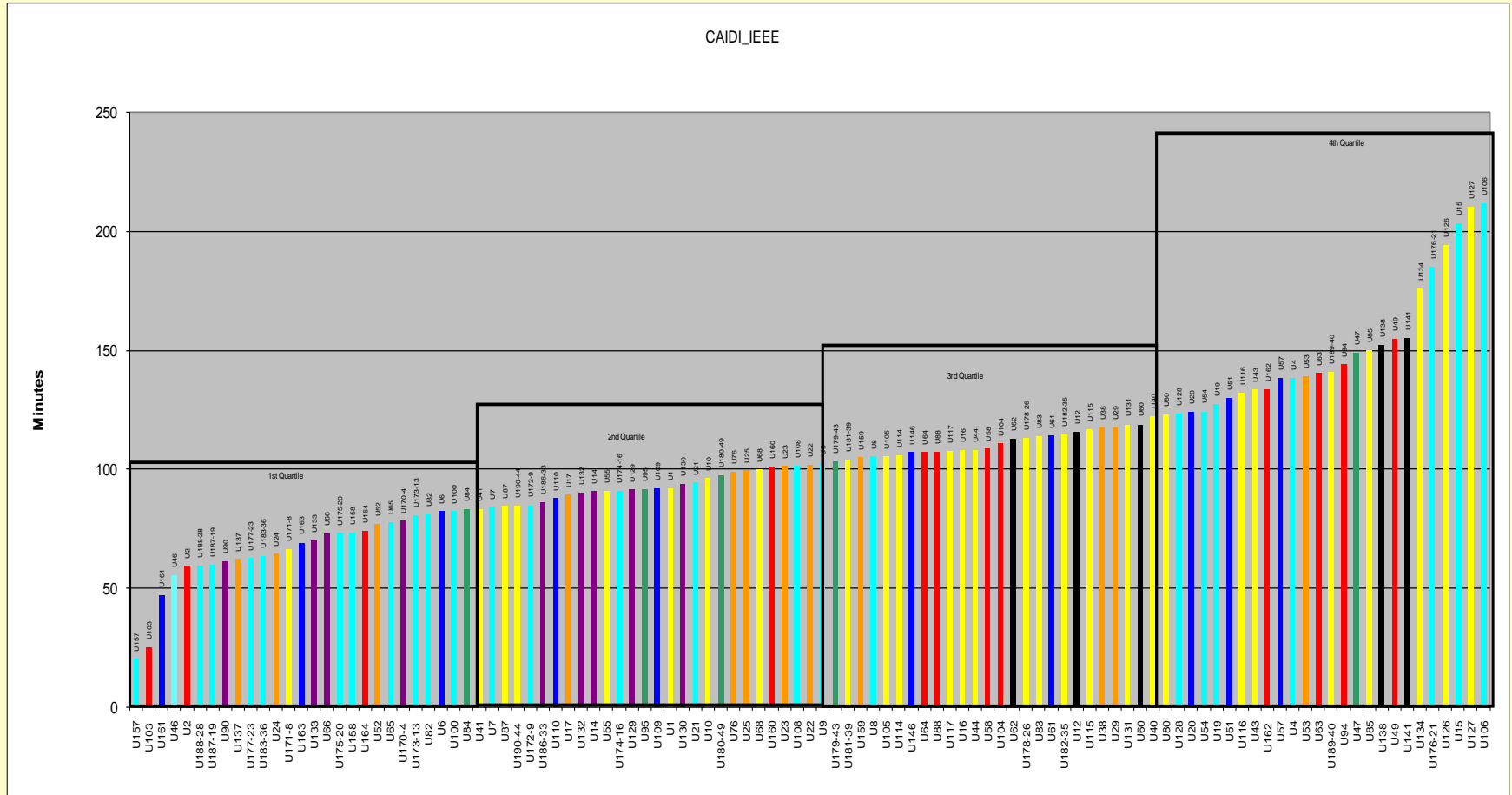


# SAIFI IEEE, across the continent...

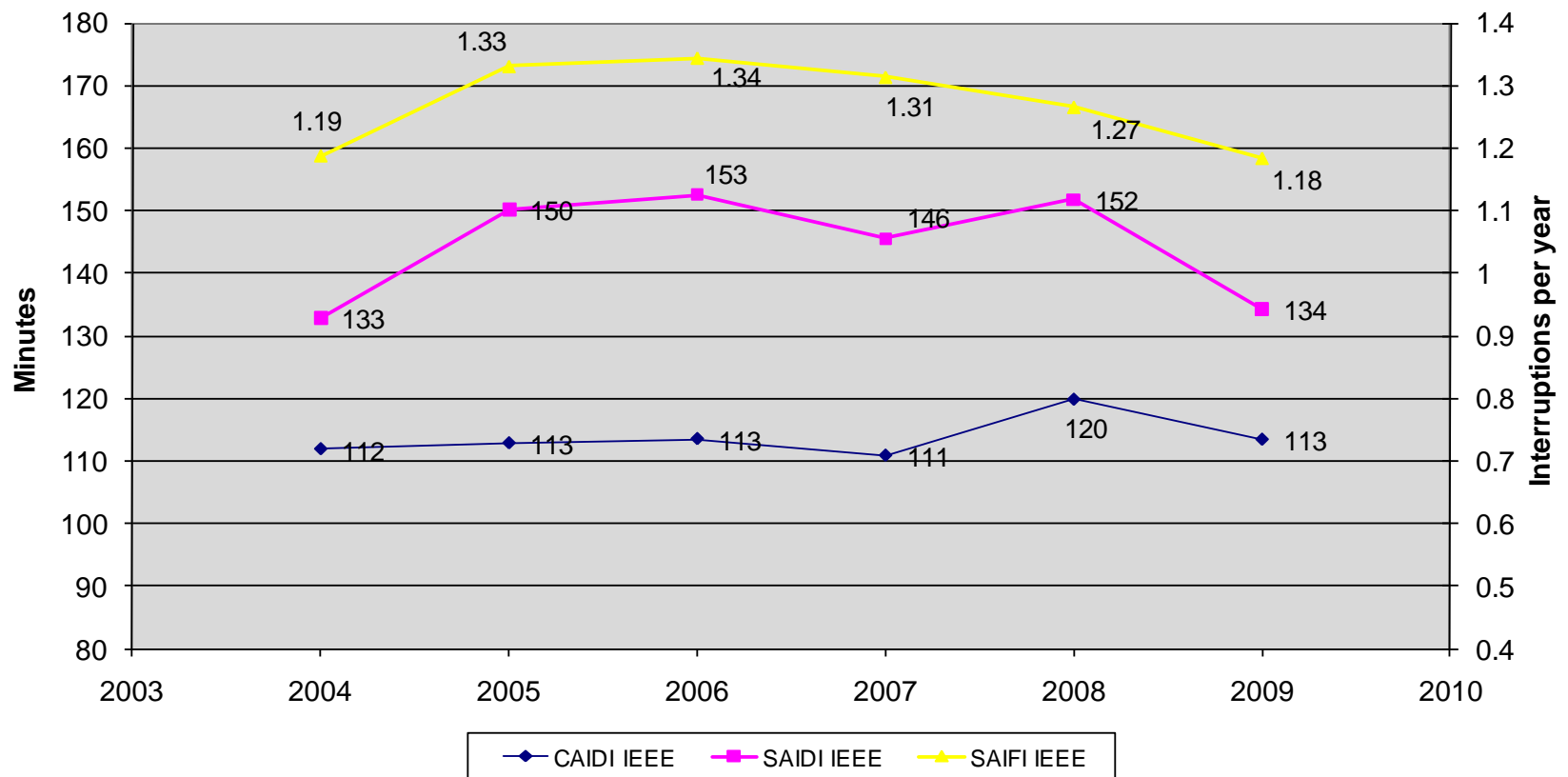




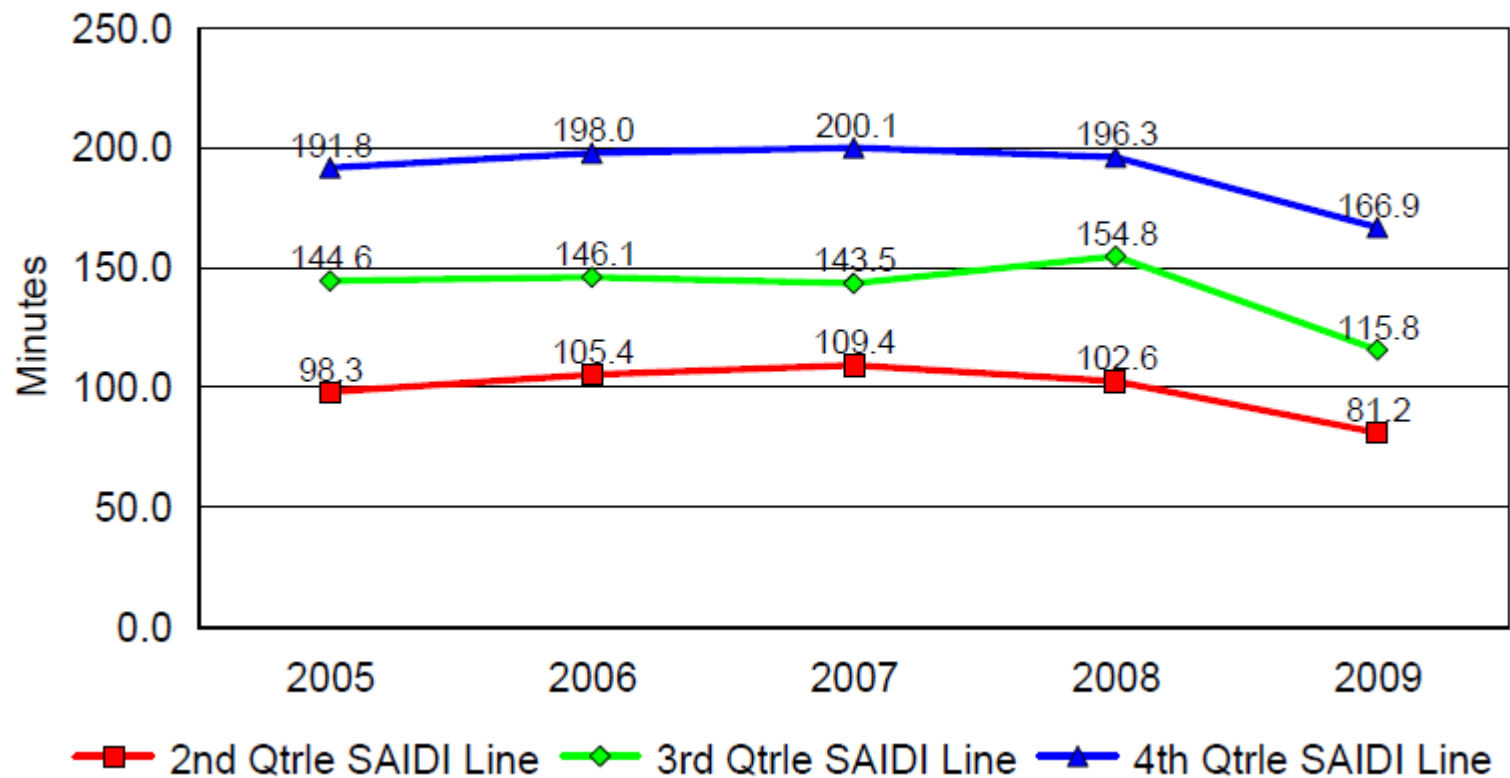
# CAIDI IEEE, across the continent...



## Trends for Utilities providing data: through 2009



## 2005 to 2009 IEEE SAIDI Benchmarking Quartiles



# What Fails

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# Everything!



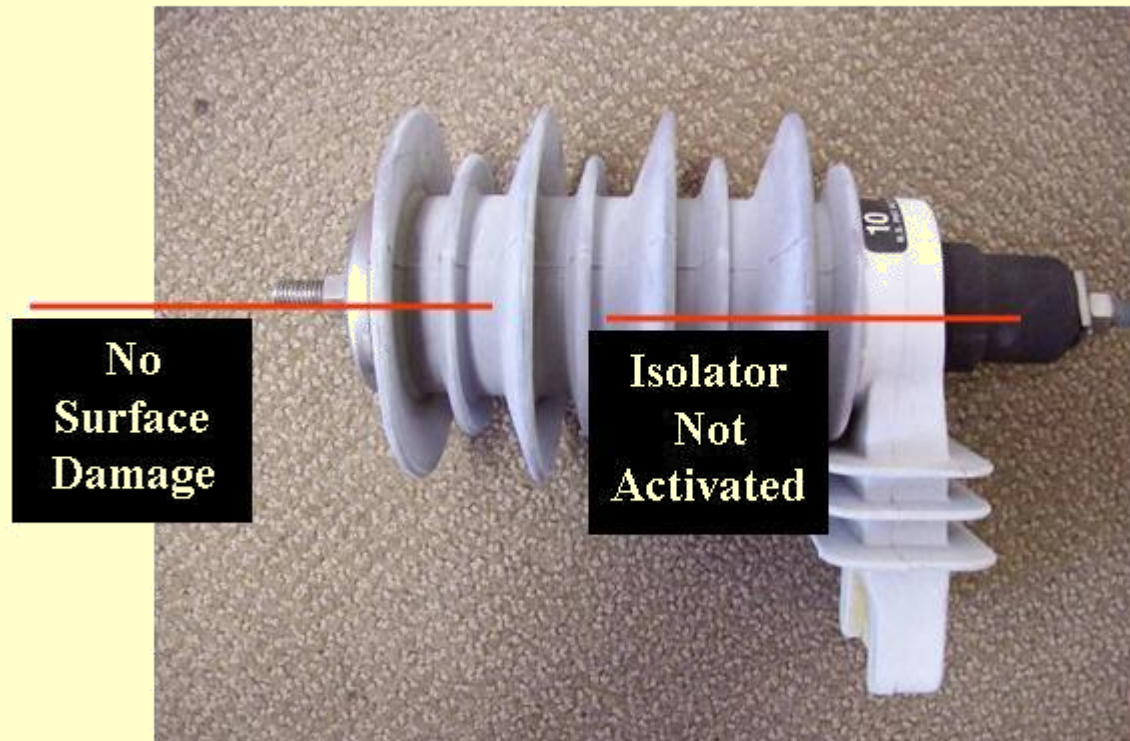
# Symptoms of Hidden Dangers

## Porcelain Cracks



# Hidden Damage – No Protection

## Example of No Visual Damage



**Represents about 50% of PD-Active, Lab Confirmed Failed, Findings**

# Insignificant Components Create Damage

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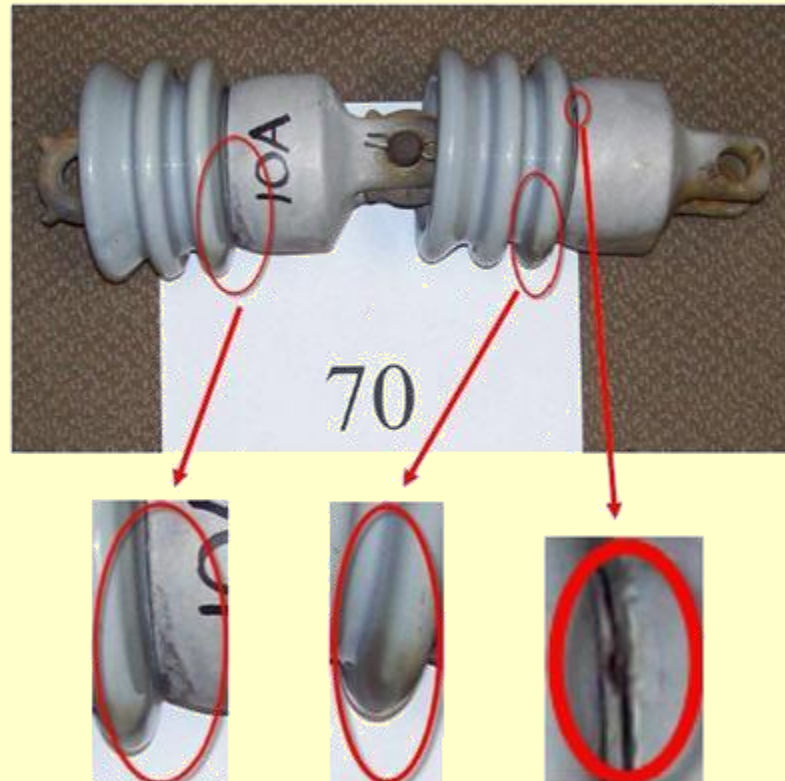
## Loose/Degraded Brackets and Clamps





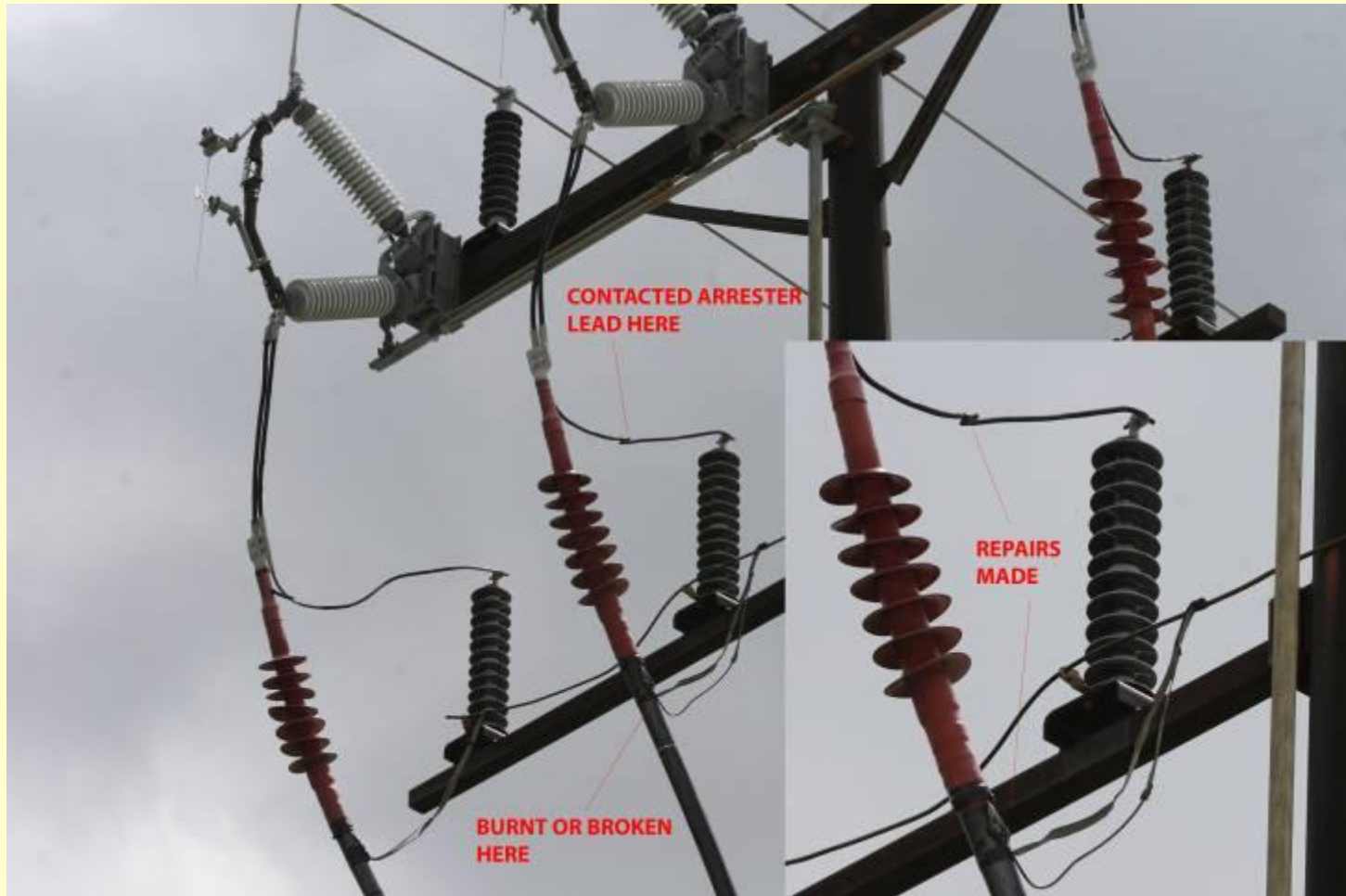
# Low Cost Parts Failures Lead to Expensive Pole Fires

## Damaged Dead-Ends



Findings: Tracking marks that are indicative of flashover ground current flow

# Surge-Damaged Grounds



# Weak Porcelain Produces PD

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# Insulator Fails Mechanical Test

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# Cutouts Often Show No Exterior Damage



# This Utility has Other Problems



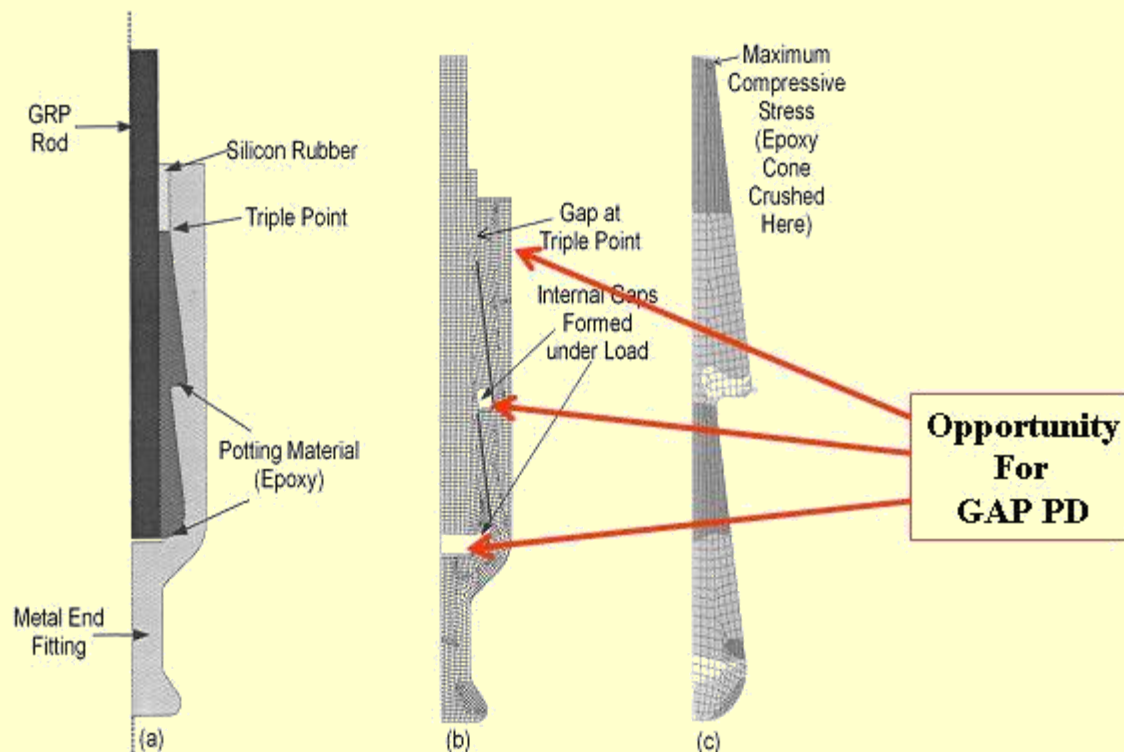
# RF Emission Sources

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- Anything in the electric field
- Arcing causes BIL reduction
- Weakened parts flashover
- Nuisance Fuse or Recloser operations
- SAIFI, MAIFI, and CMI increase

# Polymer Insulators

## Brittle Failure of Non Ceramic HV Insulators<sup>7</sup>





# Culprit in Unknown Operations

## Why Pin Insulators Pose Such a Problem

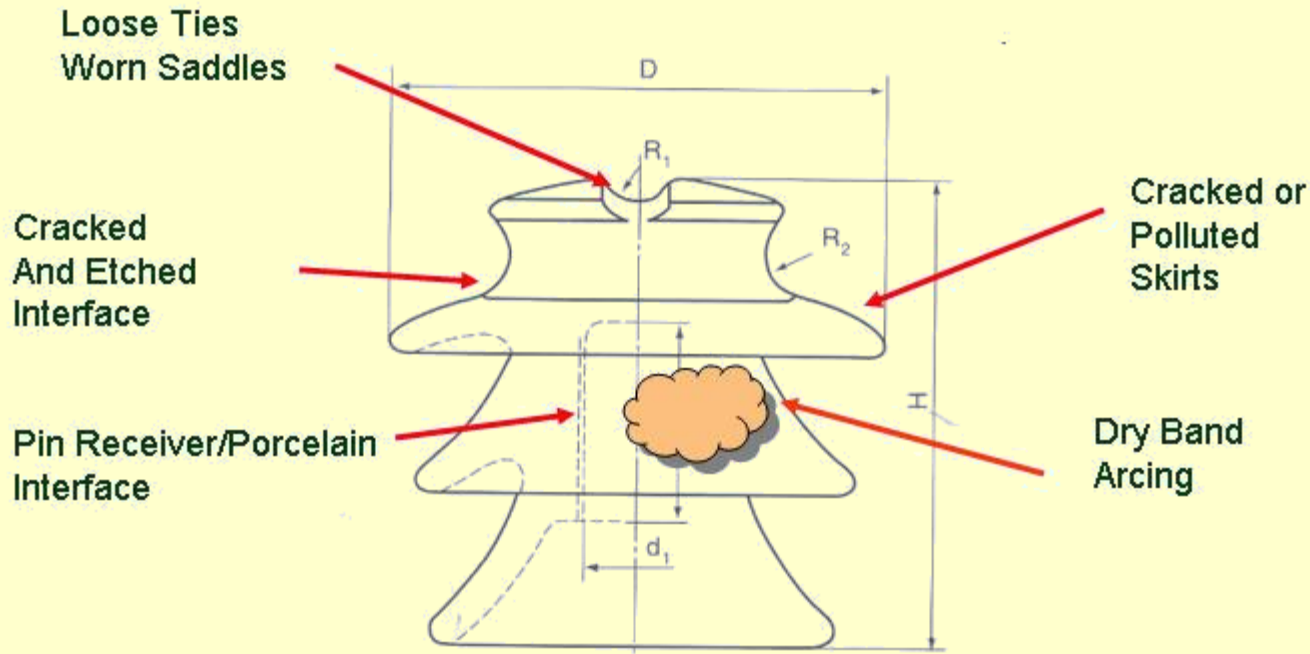


Fig 4

# Poor Workmanship Damages Conductor

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# Broke When Operated

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# Capacitor Located Before Explosion



# Transmission Component Lab Testing

- TMX Circuits chosen based on:
  - SGS Benchmarking Study
  - Previous known “noise” areas
  - Proximity to coastal areas
  - 3+ insulator failures last 5 yrs
- Independent Test of
  - Two post porcelain insulators
  - One polymer insulator
- Components Energized
  - Visual inspection
  - Daytime UV camera inspection
  - IR camera inspection
- Test results
  - 1 porcelain insulator – corona discharge and visual damage
  - 1 polymer insulator – visual inspection showed fitting seal interface damage



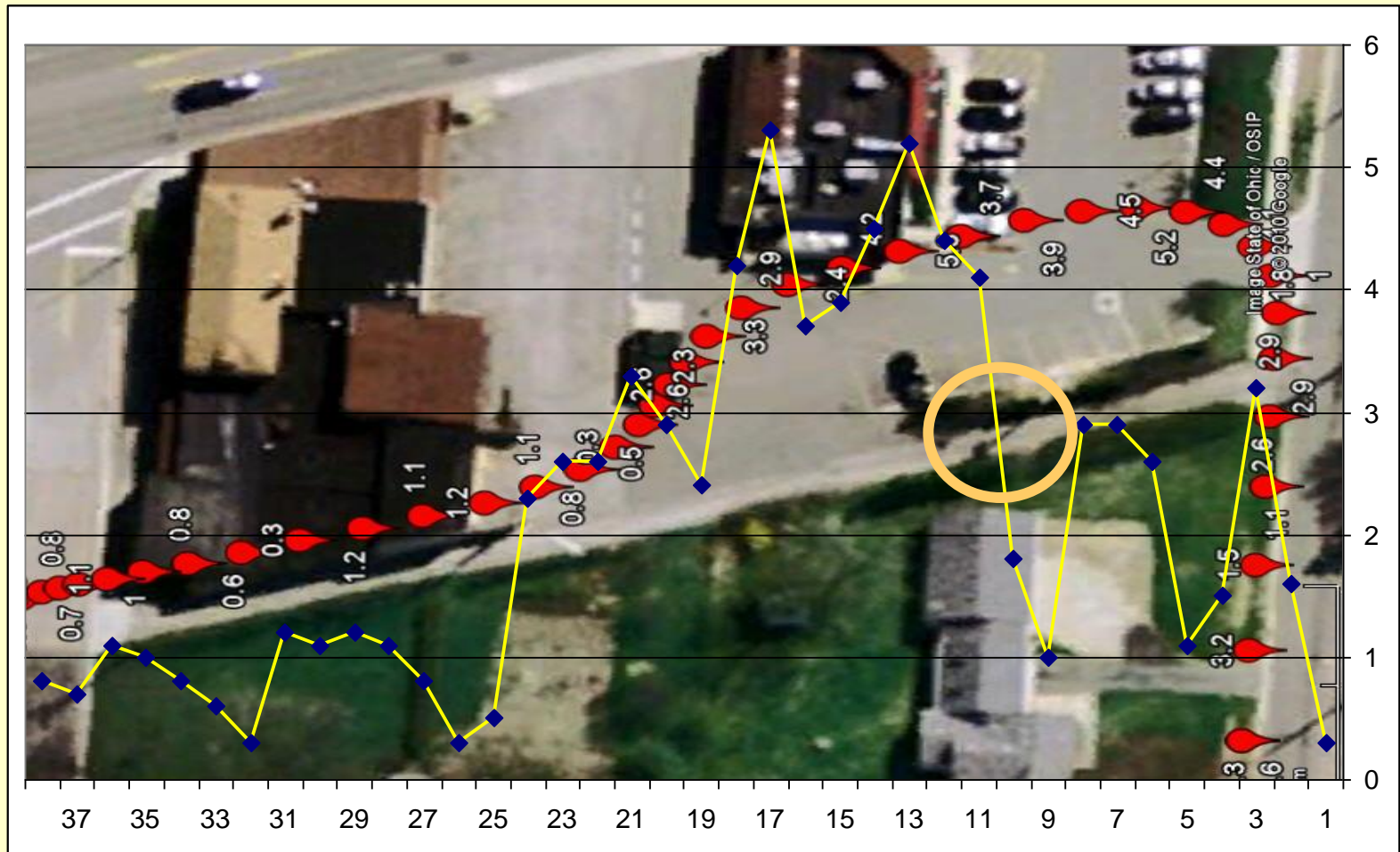
# Ouch!



# An Arc Emission Capture and Use Methodology

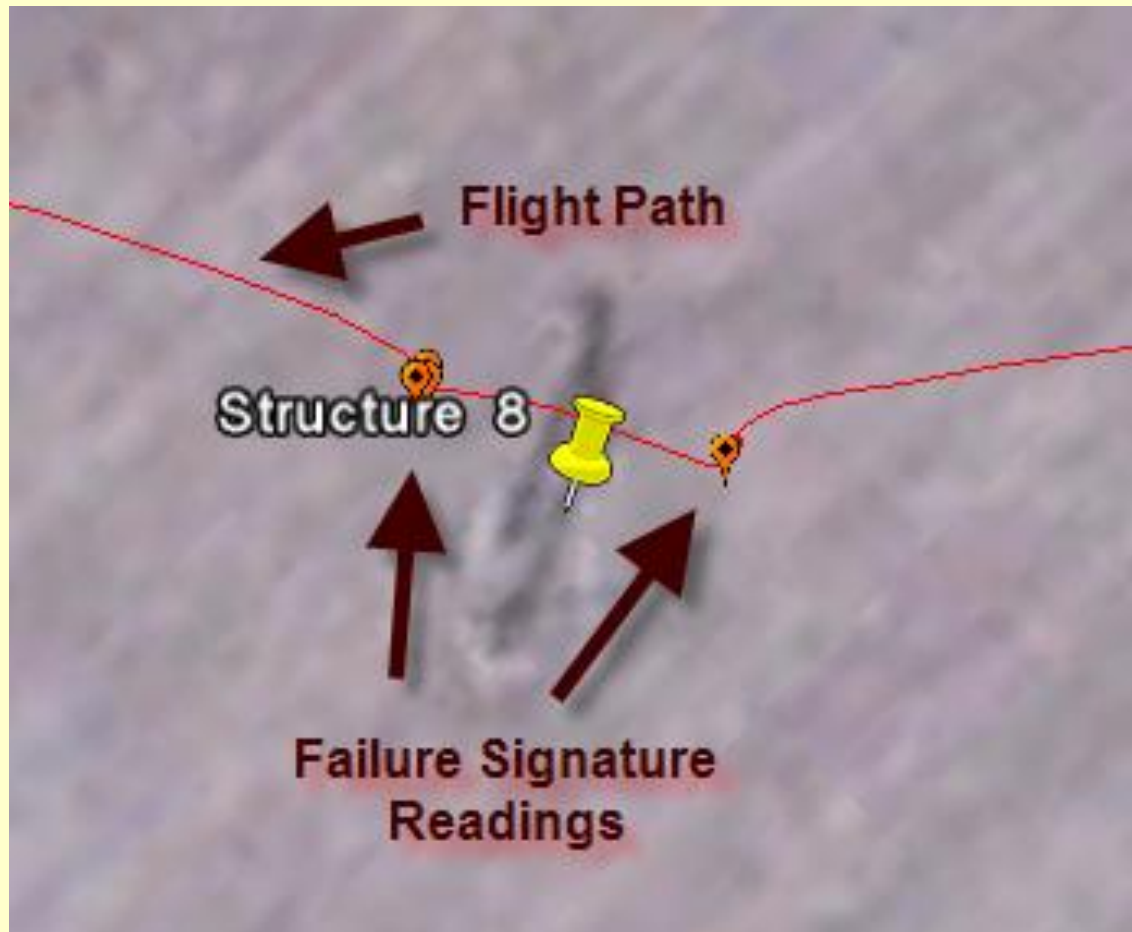
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# Challenges Using RF Emissions



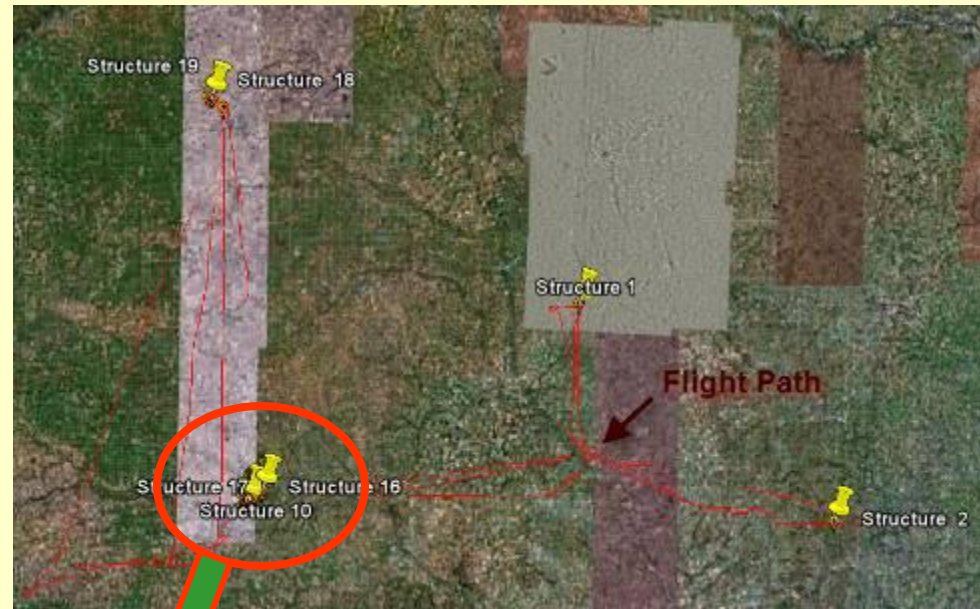


# Failure Signatures as Locators



# Density of Findings

- Few findings over a large area ~ 200 flight miles
- Consistent, localized findings ~ 2 miles



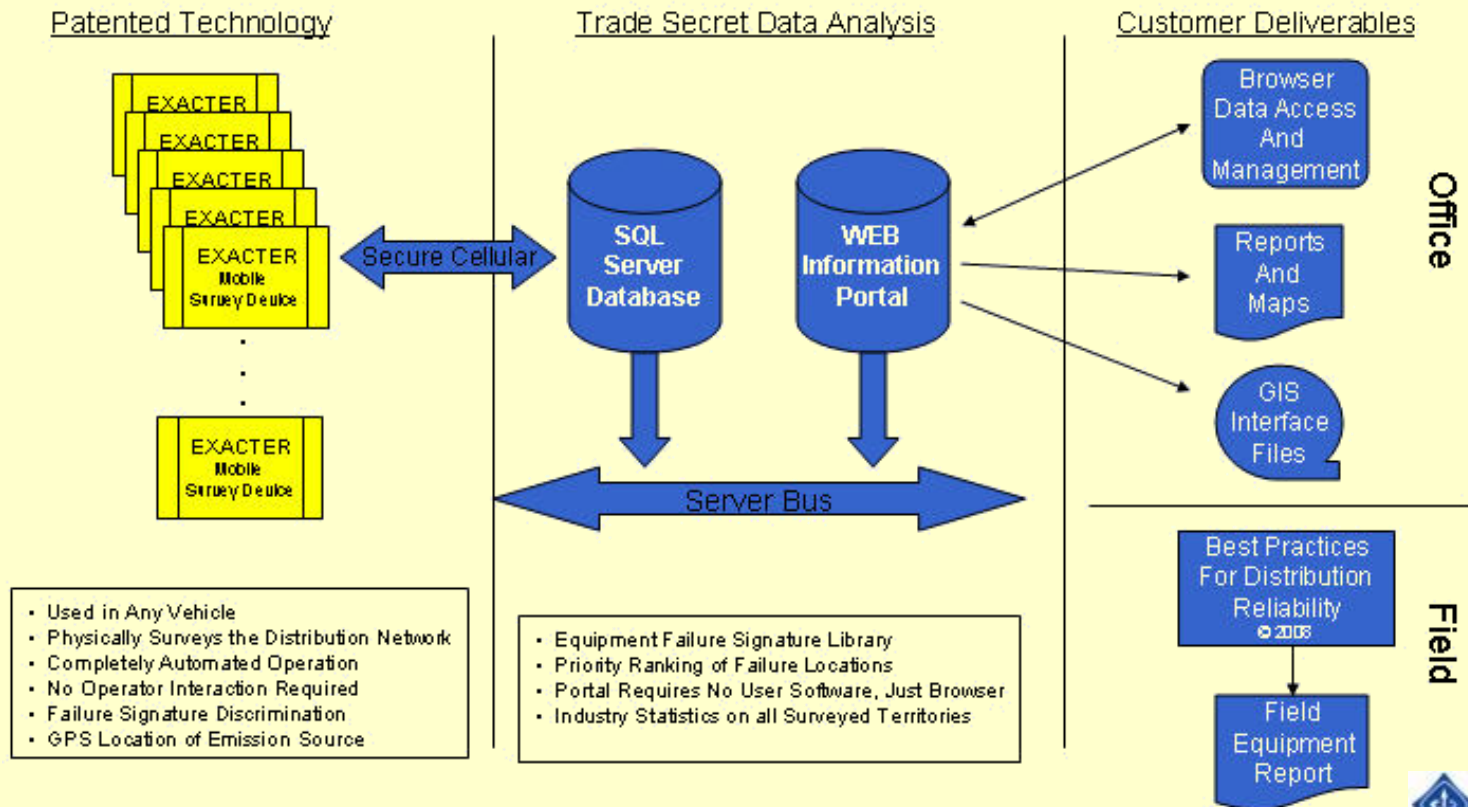
# Process to Evaluate

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- Survey 4 to 5 Times
  - Real-time analysis of emissions
  - Correlation to Failure Signatures and Weather influences
  - Geo-Spatial corrected references
- Statistical evaluation of geo-spatial data
- Conclusions on emission location

# System Architecture

## EXACTER® Overall System Architecture

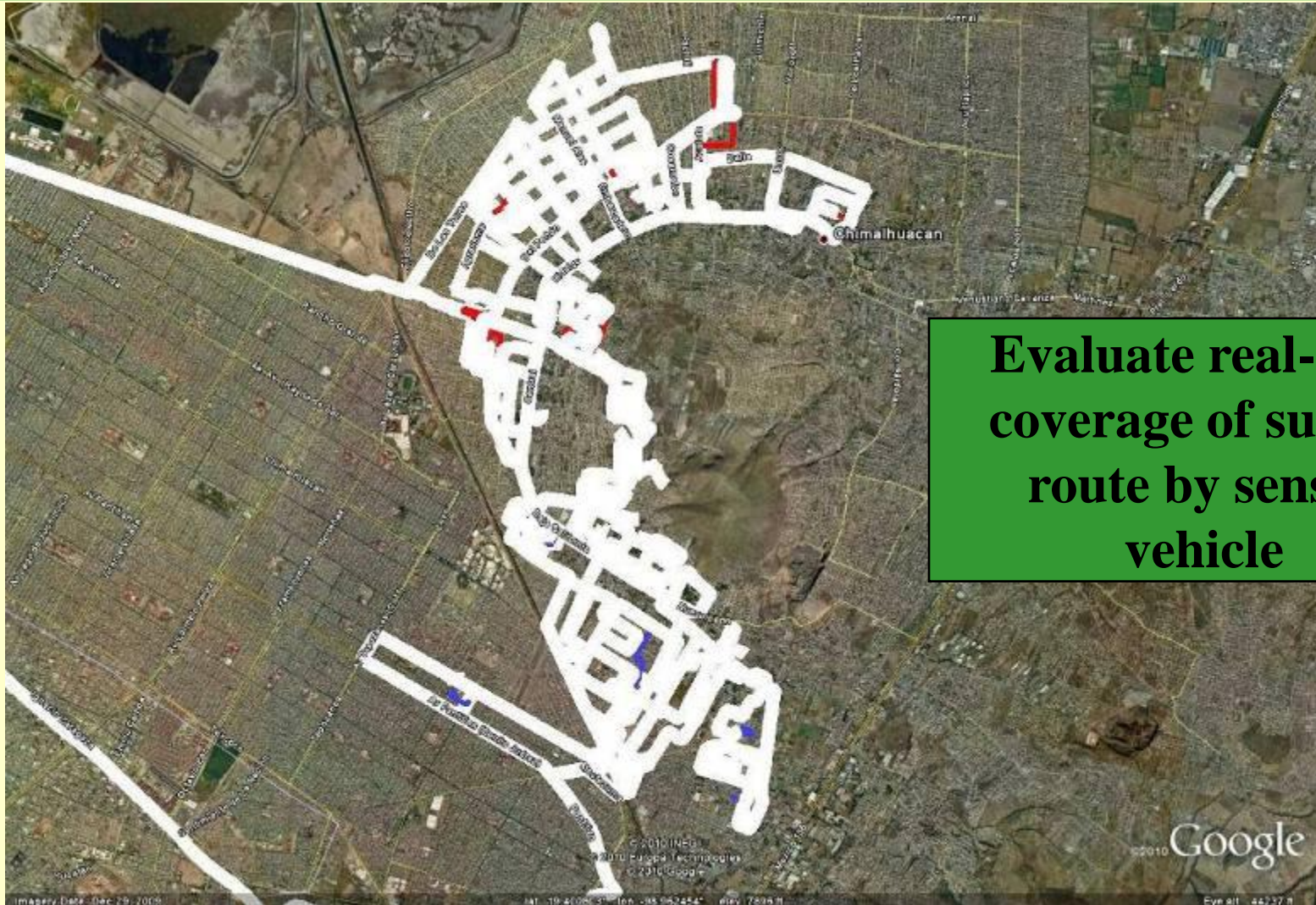


# Survey Design



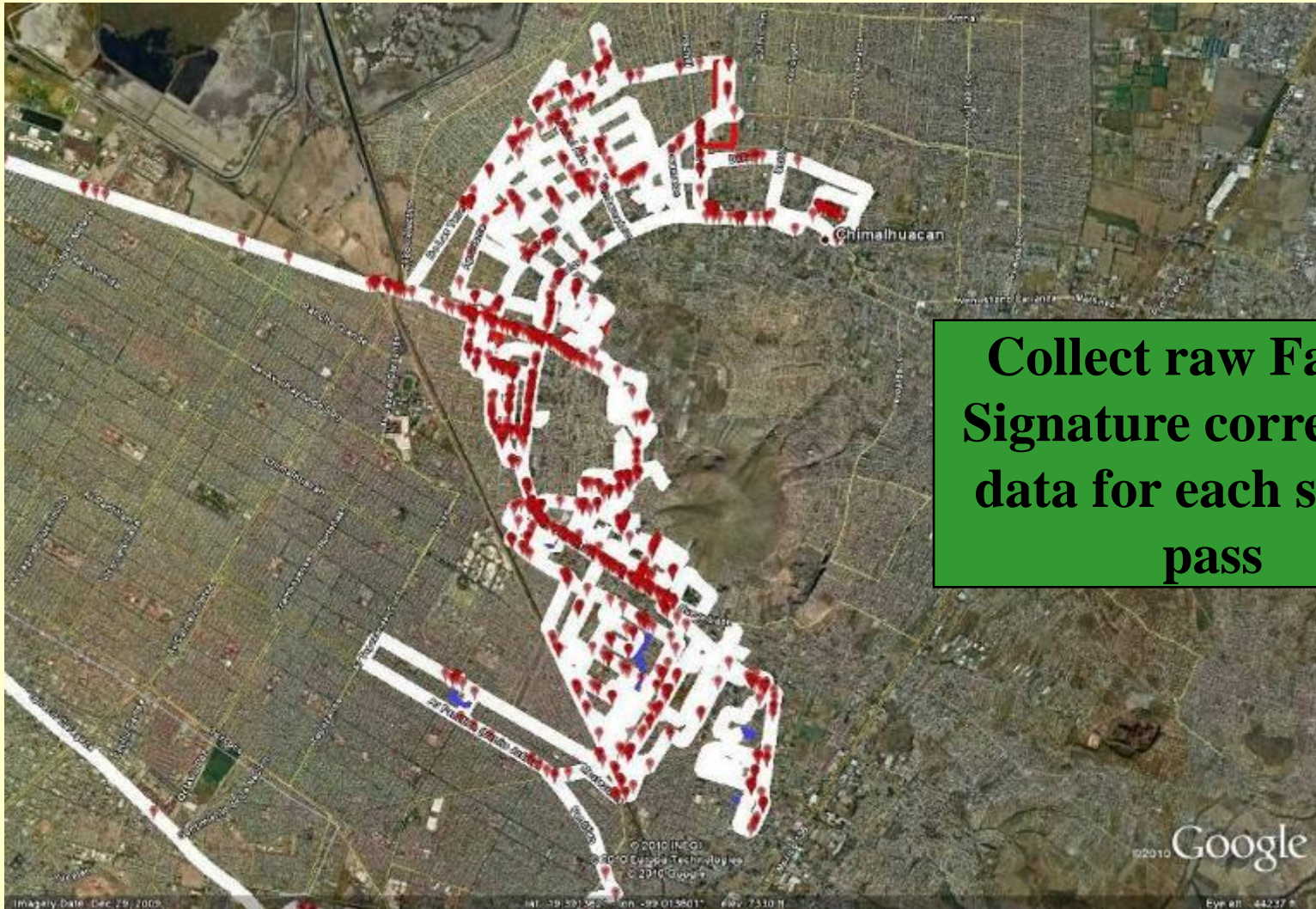
**Plan Survey Routes to be within 100 meters of Overhead circuits**

# Survey Management



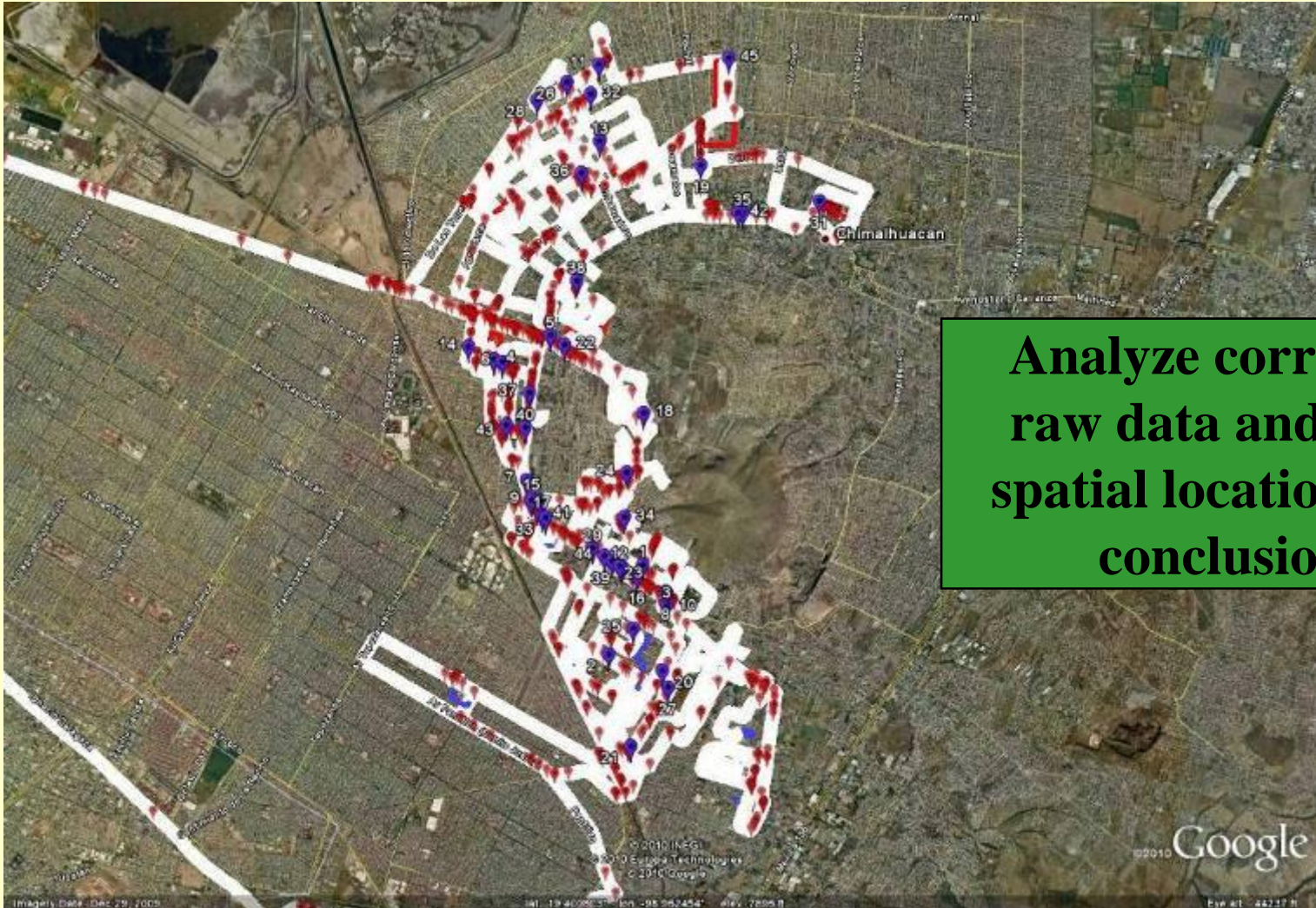
**Evaluate real-time coverage of survey route by sensor vehicle**

# Real-time Data



**Collect raw Failure Signature correlation data for each survey pass**

# Statistical Analysis Yields Accurate Results



**Analyze corrected  
raw data and geo-  
spatial locations for  
conclusion**

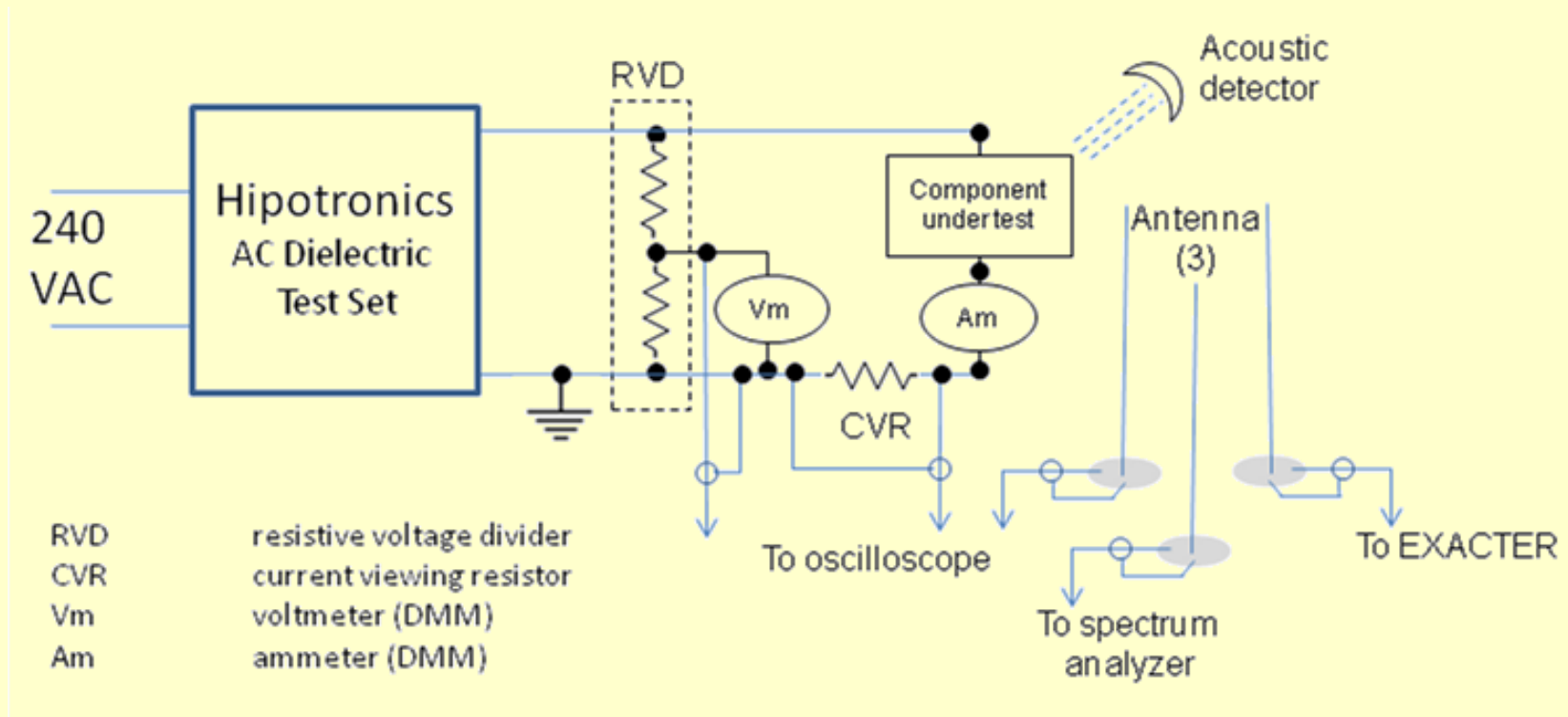


# Characteristics of ARC Emissions

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- Evaluation between 1 MHz and 1 GHz
- Coupling and reflections eliminated through multiple surveys
- Correlation to known Failure Signatures
- Data corrected for environmental influences

# Typical Specimen Test Setup

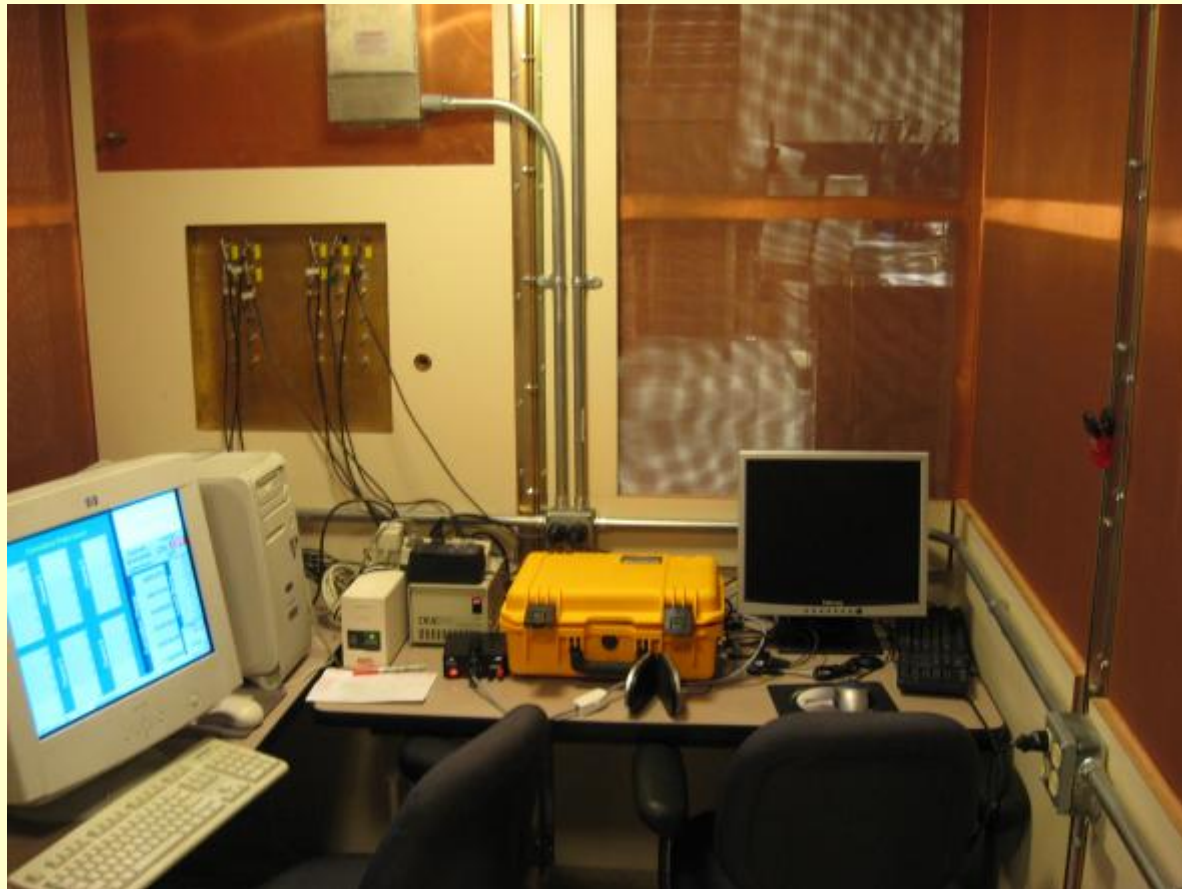


# Research Facilities



# Faraday Cage Research Station

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# Fog and Salt Spray Chamber

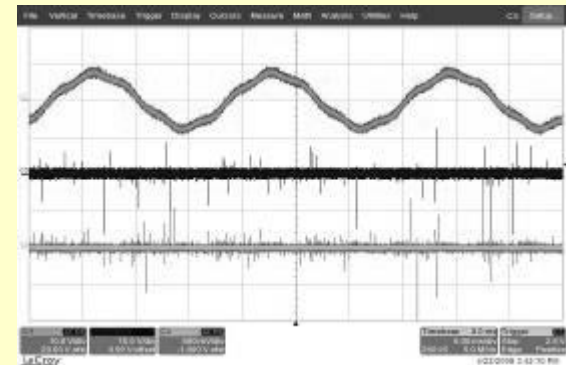
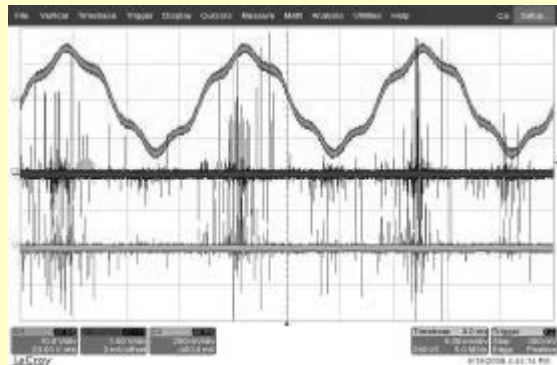


# Evaluating Emissions

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- Collect field samples
- Energize at field conditions
- Match with RF Image and Field Sensor
- Evaluate in various environmental conditions
- Create Failure Signature or correlate to known signature

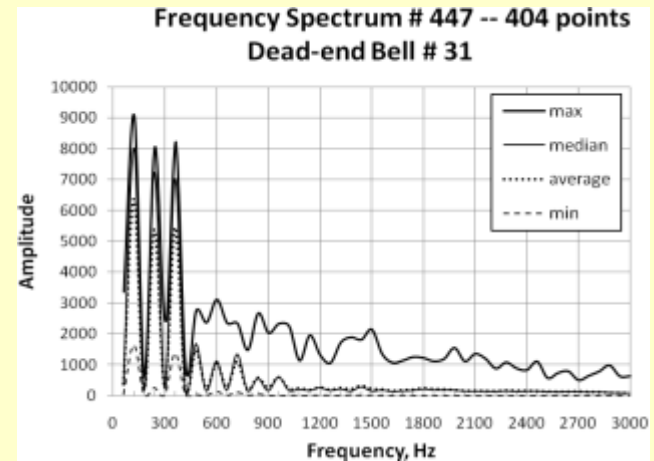
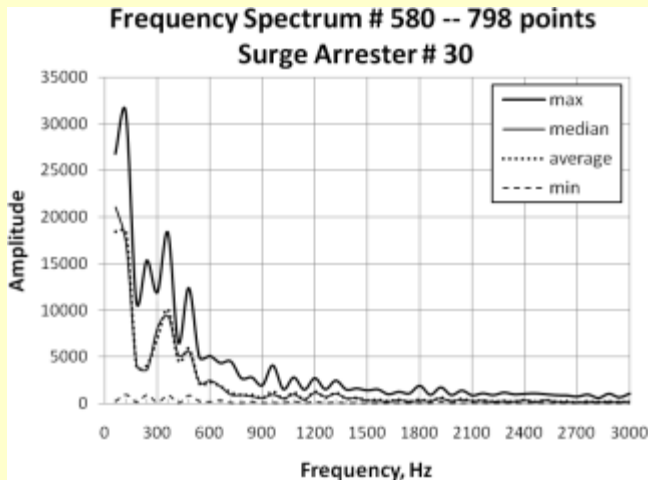
# Leakage and Breakdown Voltage



*Surge arrester log # 30 – scope waveforms at 15 kV; top trace: applied voltage; middle trace: voltage across CVR; bottom trace: spectrum analyzer input. Horizontal scale: upper: 5 ms/div; lower: 50 ns/div*

*Dead-end bell insulator log # 31 – scope waveforms at 12.5 kV; top trace: applied voltage; middle trace: voltage across CVR; bottom trace: spectrum analyzer input. Horizontal scale: upper: 5 ms/div; lower: 100 ns/div*

# Frequency Spectrum Analysis





# Field Experience and Case Studies

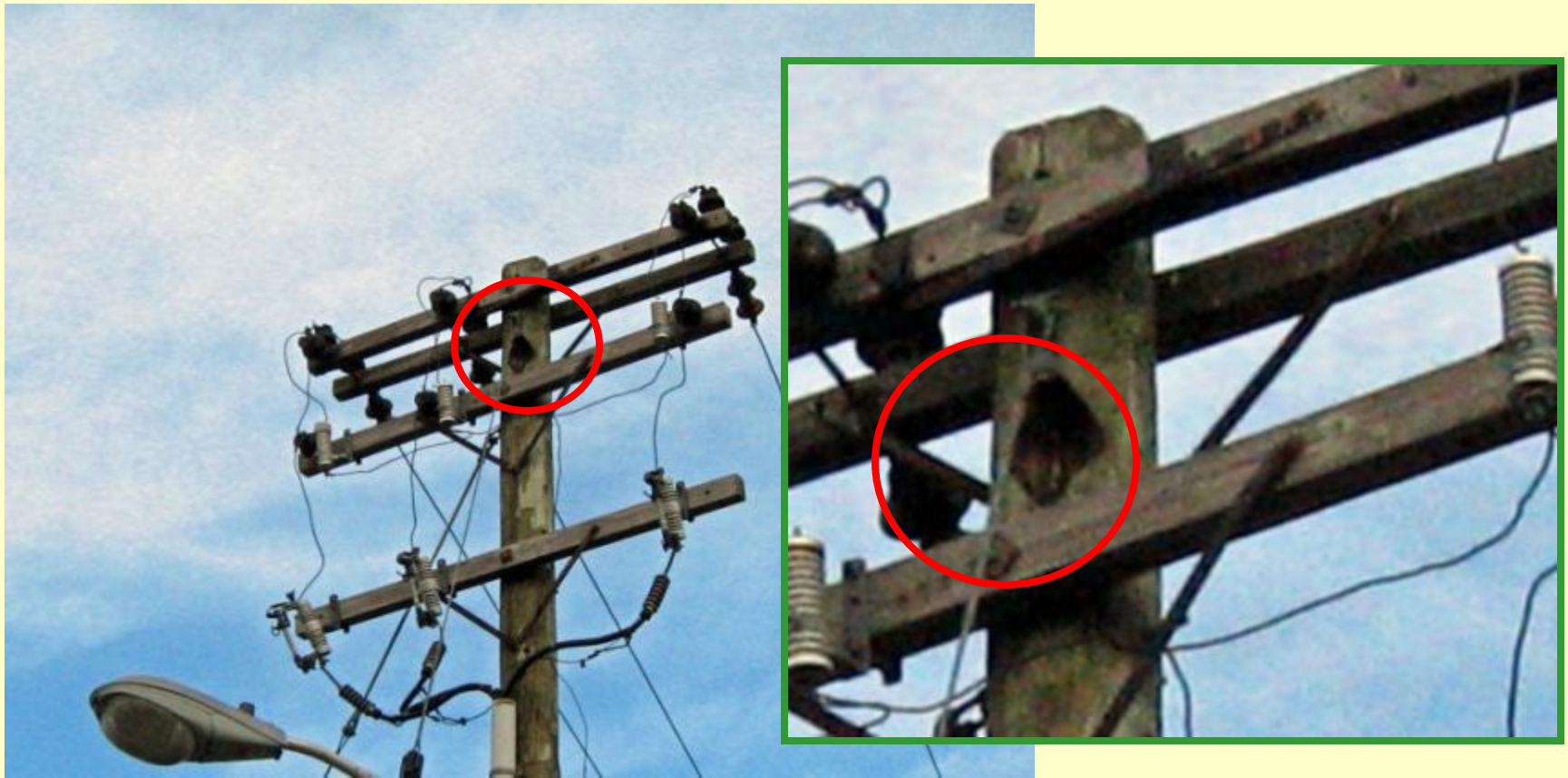
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# Case Study

- Problem – A Northeast IOU has a recurring 69kV line outage problem that 2 years of IR scanning cannot locate.
- Solution – An Exacter demonstration survey located a 69kV post insulator that when replaced, corrects the problem.

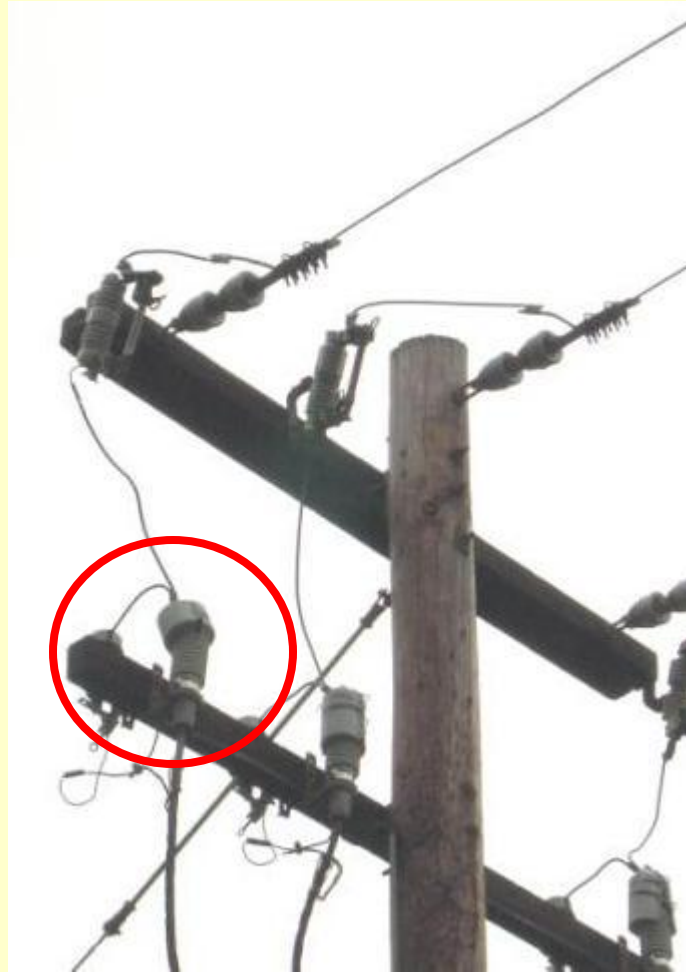


# Damaged Lightning Arresters



# Failed Lightning Arrester

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# Tree Limb Emission

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# Loose/Degraded Neutrals and Clamps



# Splices and Ties

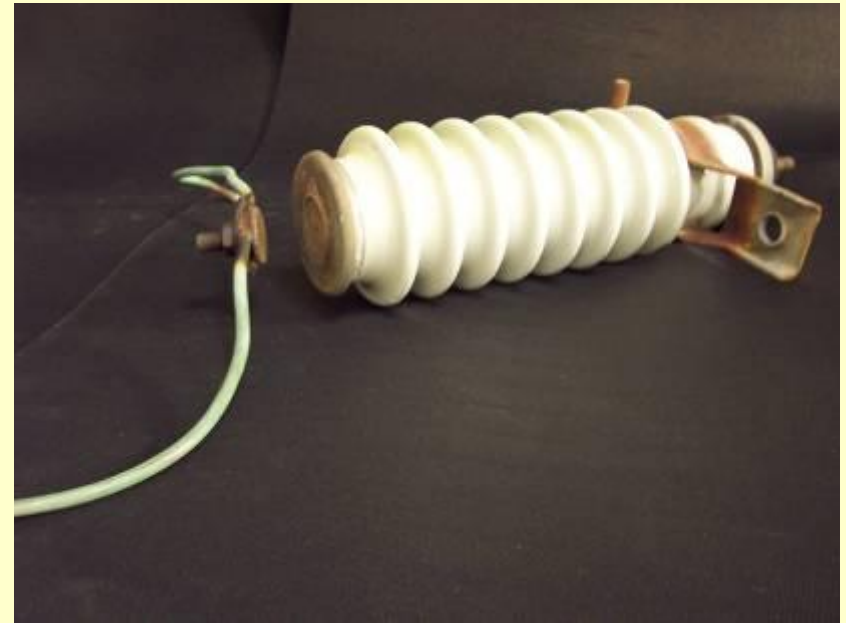
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# Examples of Smart Grid Interference Findings



Noisy Telephone Pedestal  
Faulty Ground – Atlanta, GA



Faulty Lightning Arrester  
Bowling Green, OH





**Geoffrey Bibo**  
**614.880.9320**  
**[www.exacterinc.com](http://www.exacterinc.com)**