Phasors, the next generation

NASPI Webinar -- May 6, 2020

Terry Boston, Grid Protection Alliance

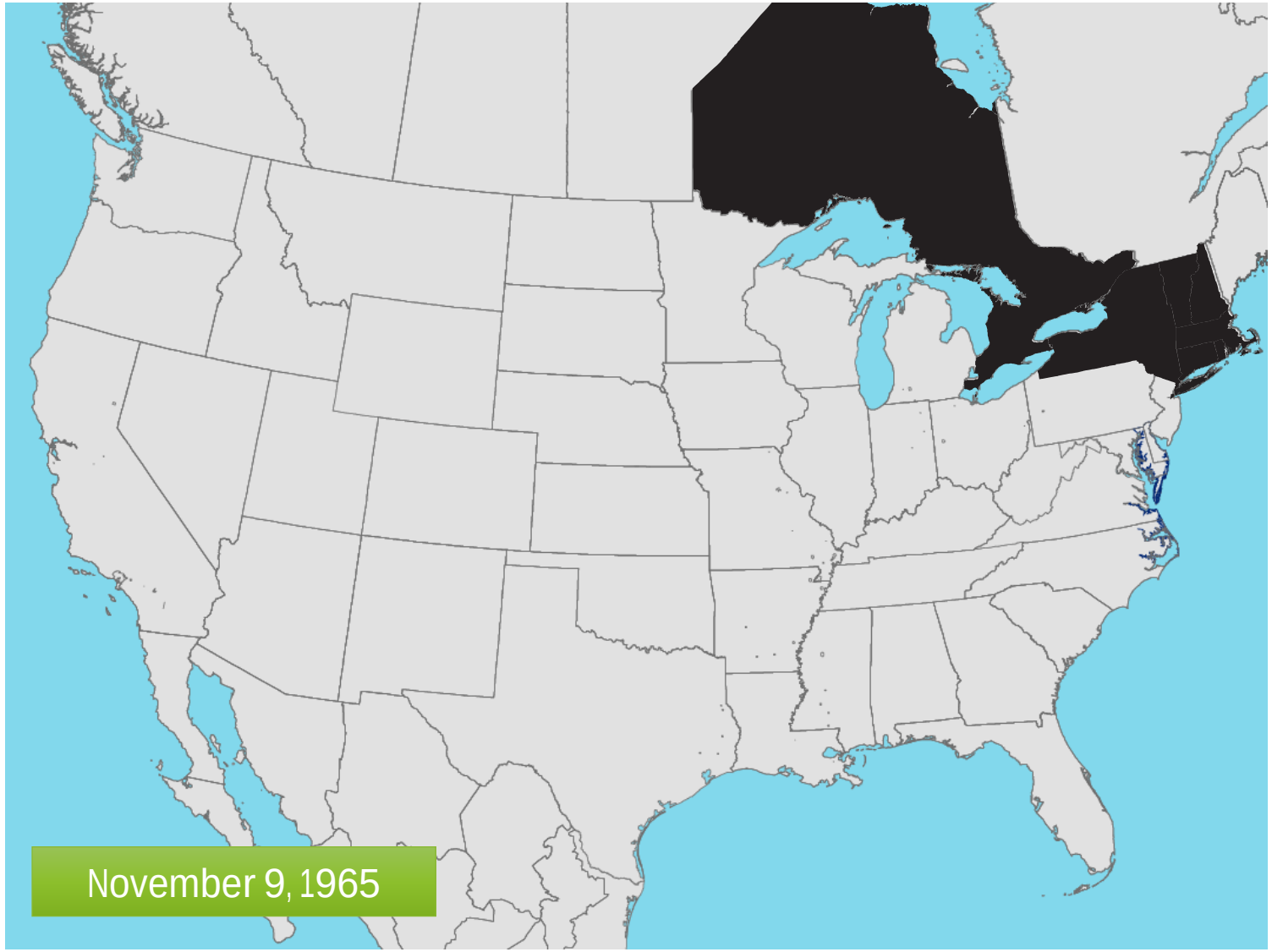
Russell Robertson, Grid Protection Alliance

How did we get here?

A Brief History of Major Power Disturbances

(Not including Hurricanes)

Power Disturbances – November 9, 1965



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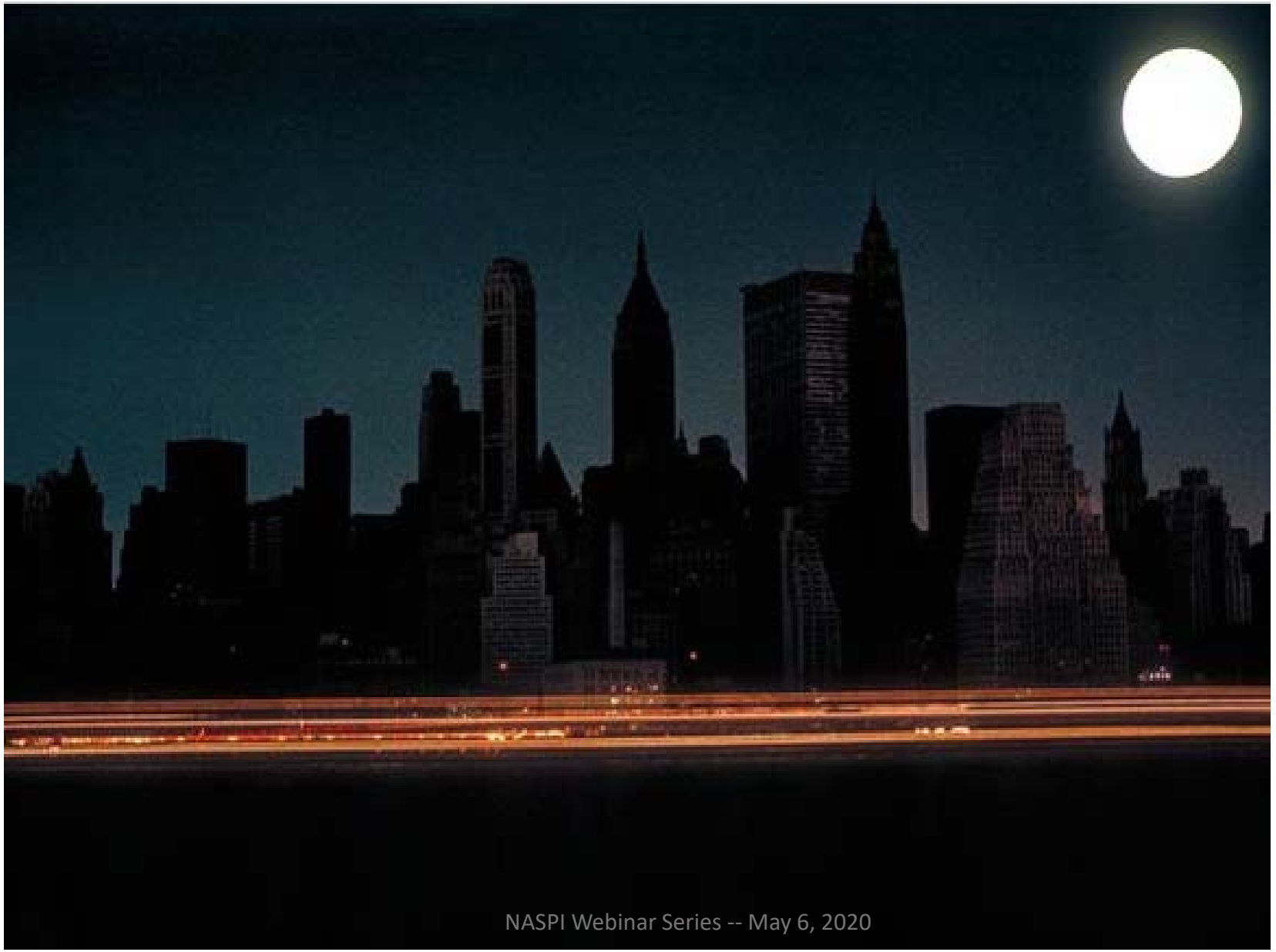
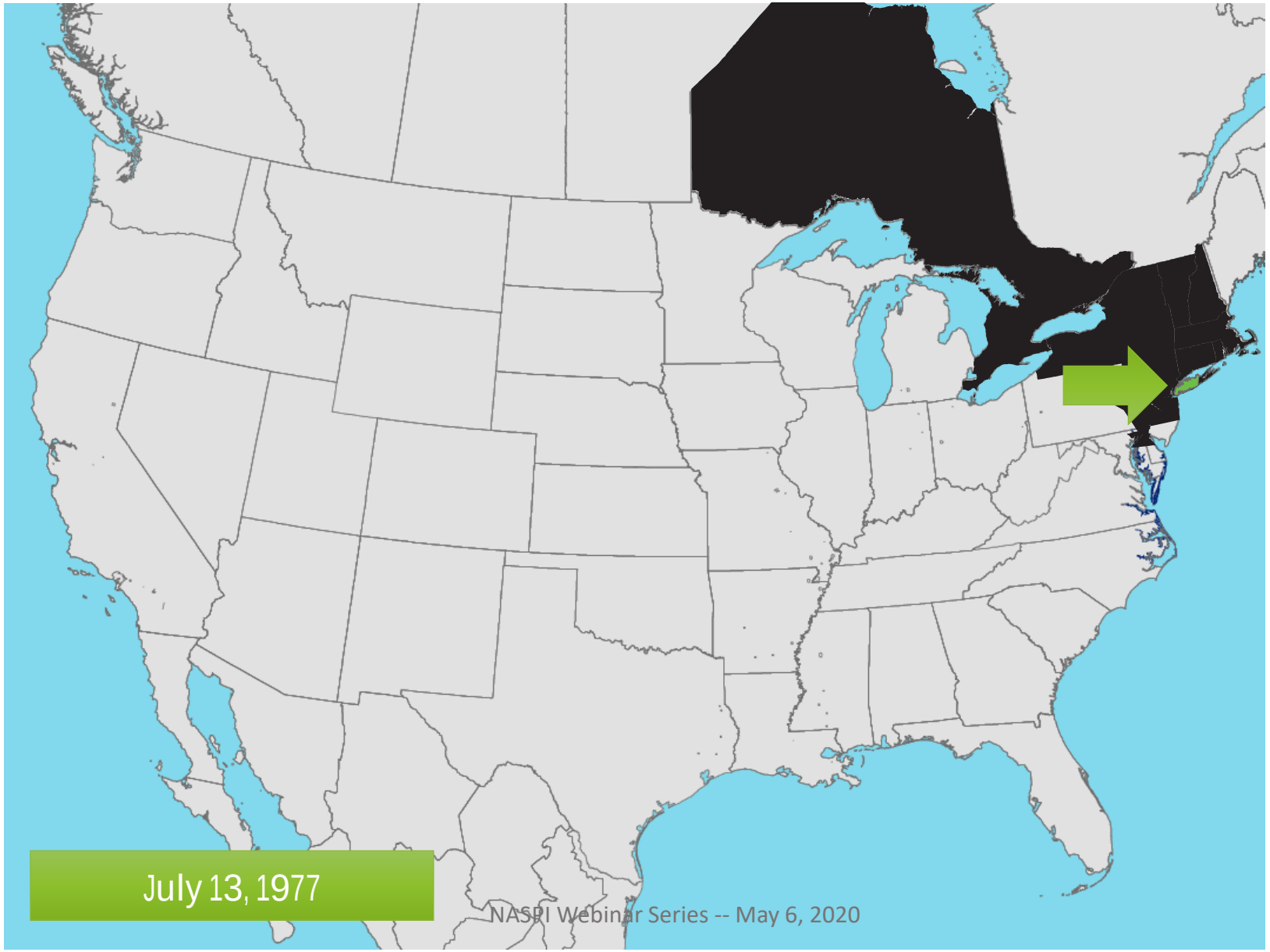
1965 – The Northeast and Canada



Operating without Power in NYC

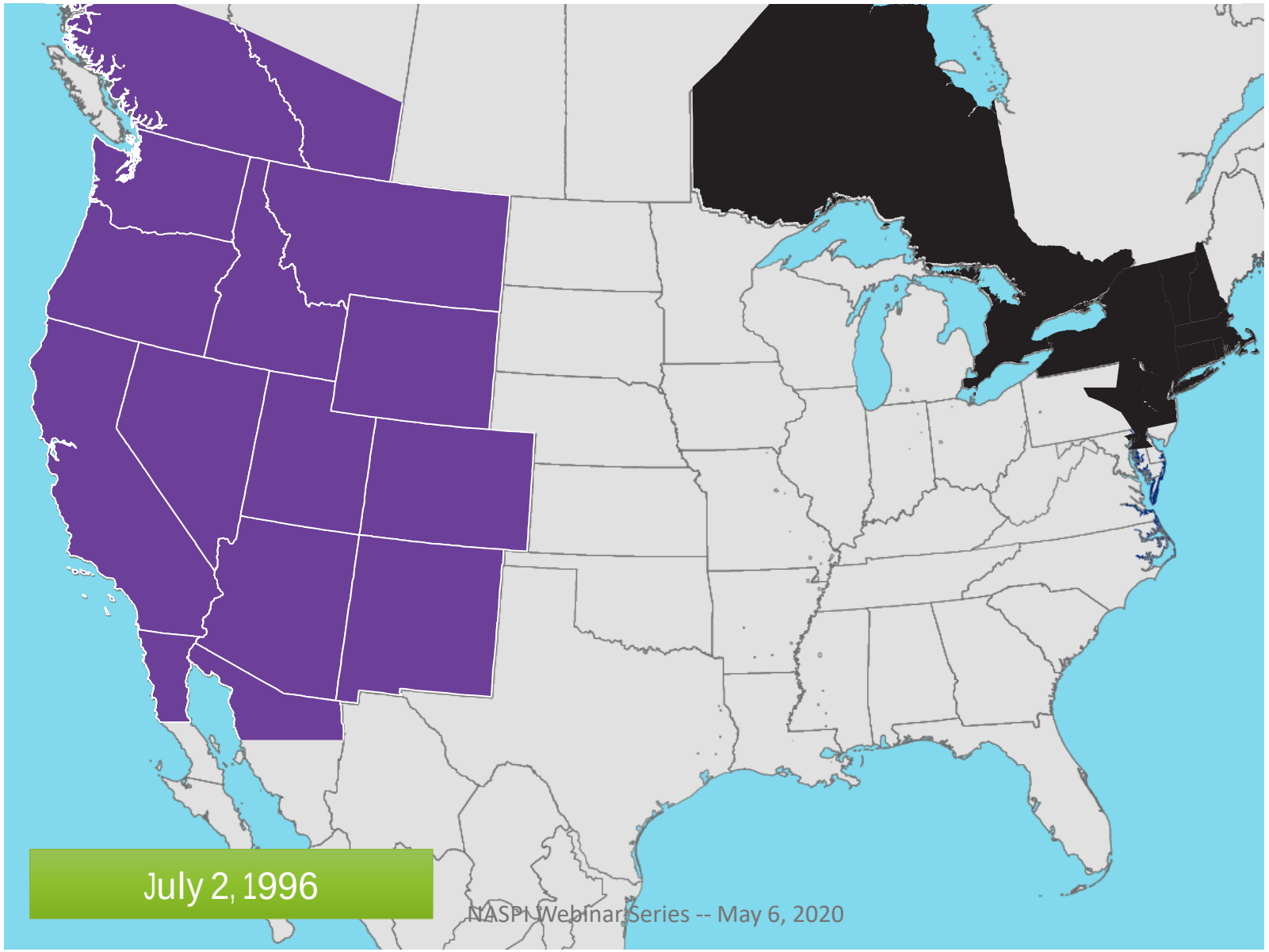
Power Disturbances – June 5, 1967

Power Disturbances – July 13, 1977

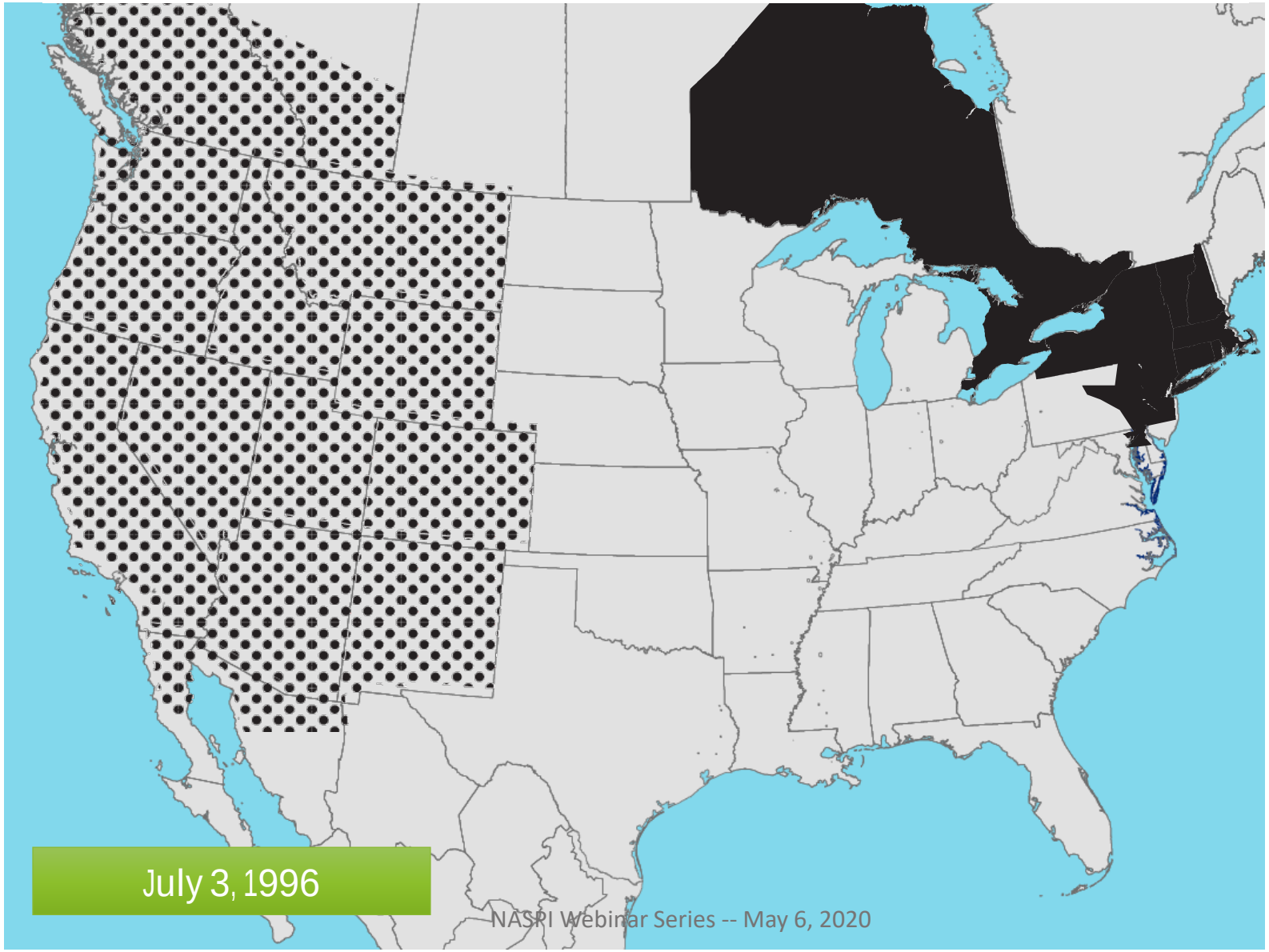


1977 – Vandalism in NYC

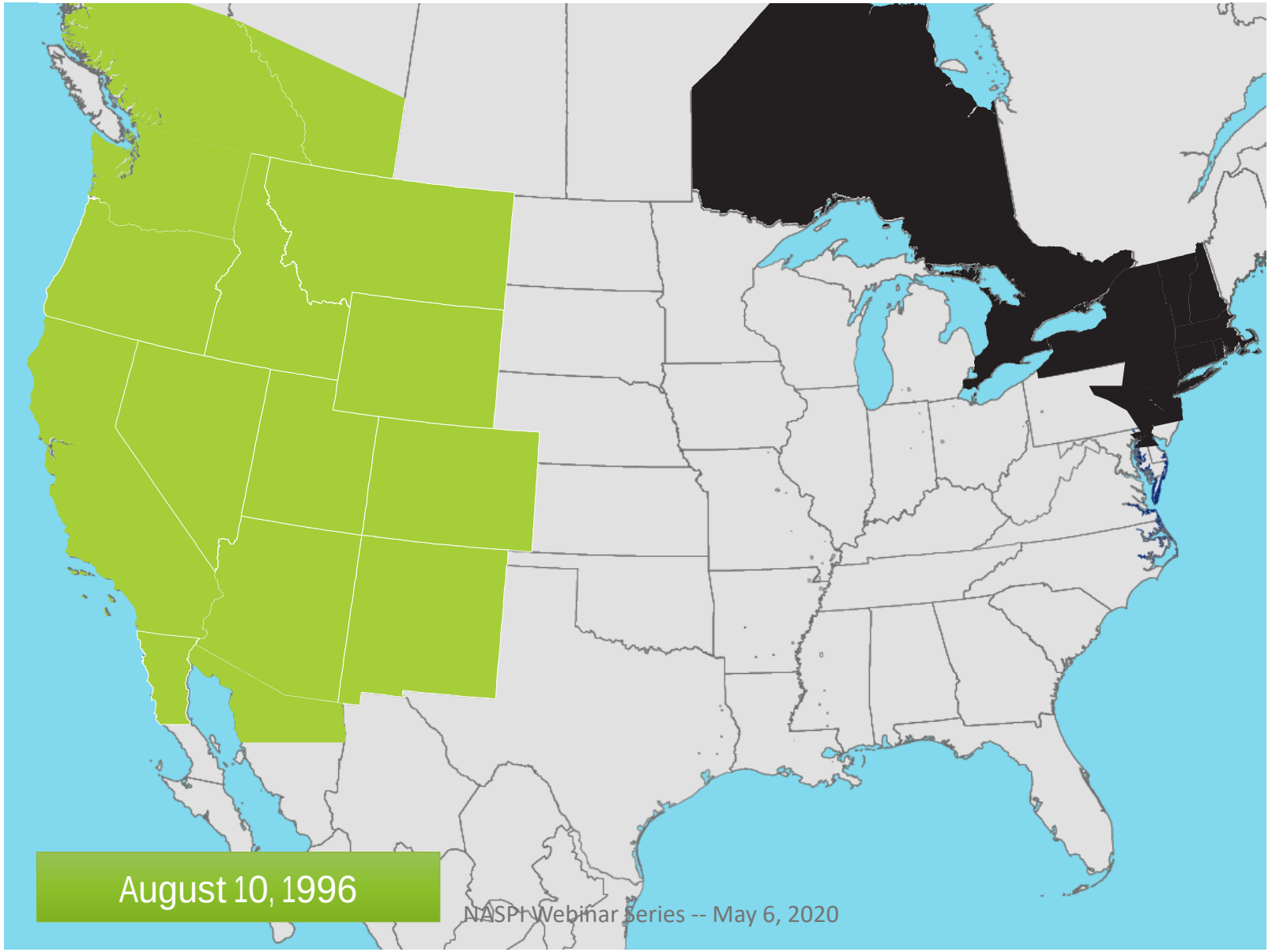
Power Disturbances – July 2, 1996



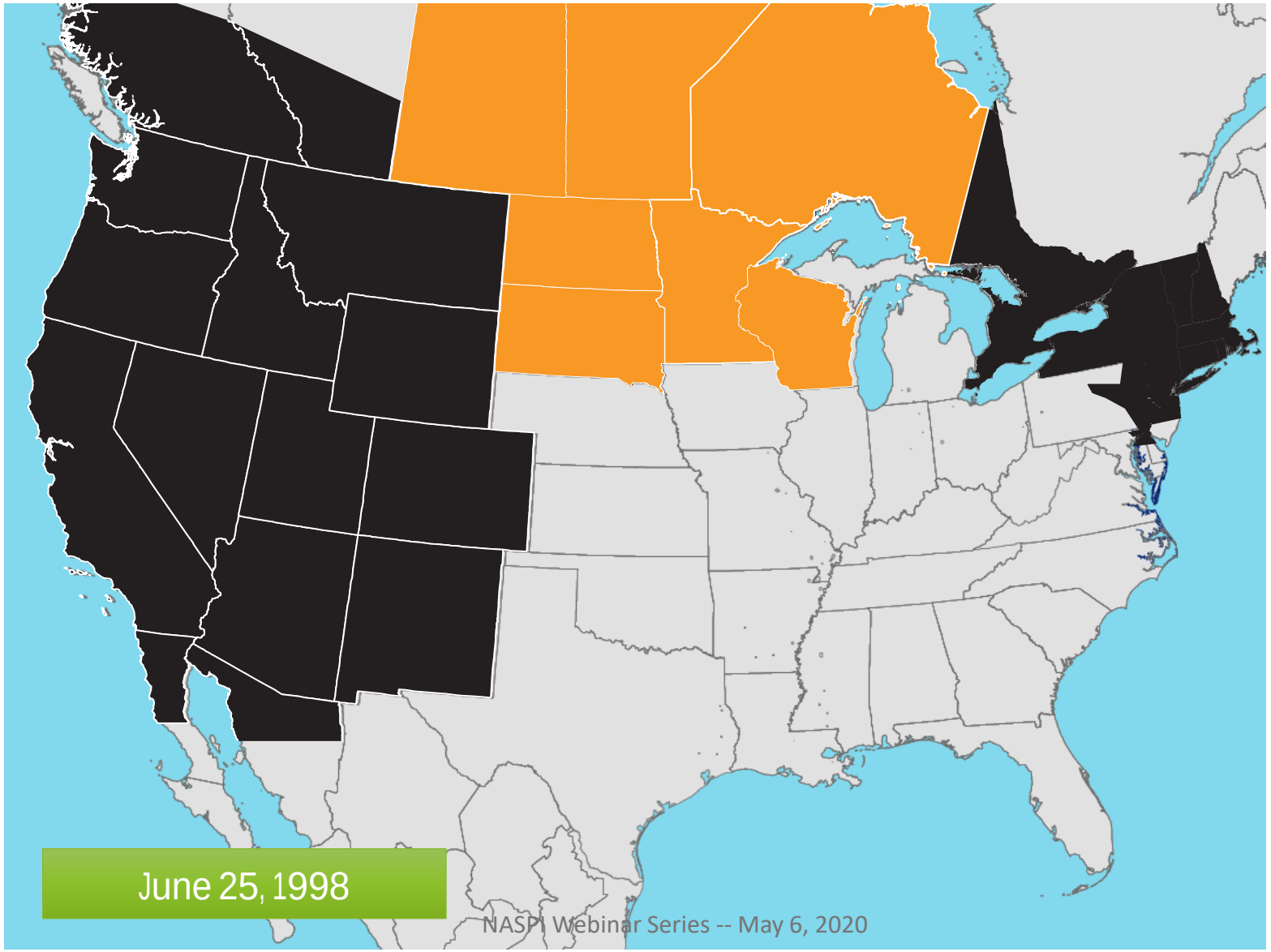
Power Disturbances – July 3, 1996



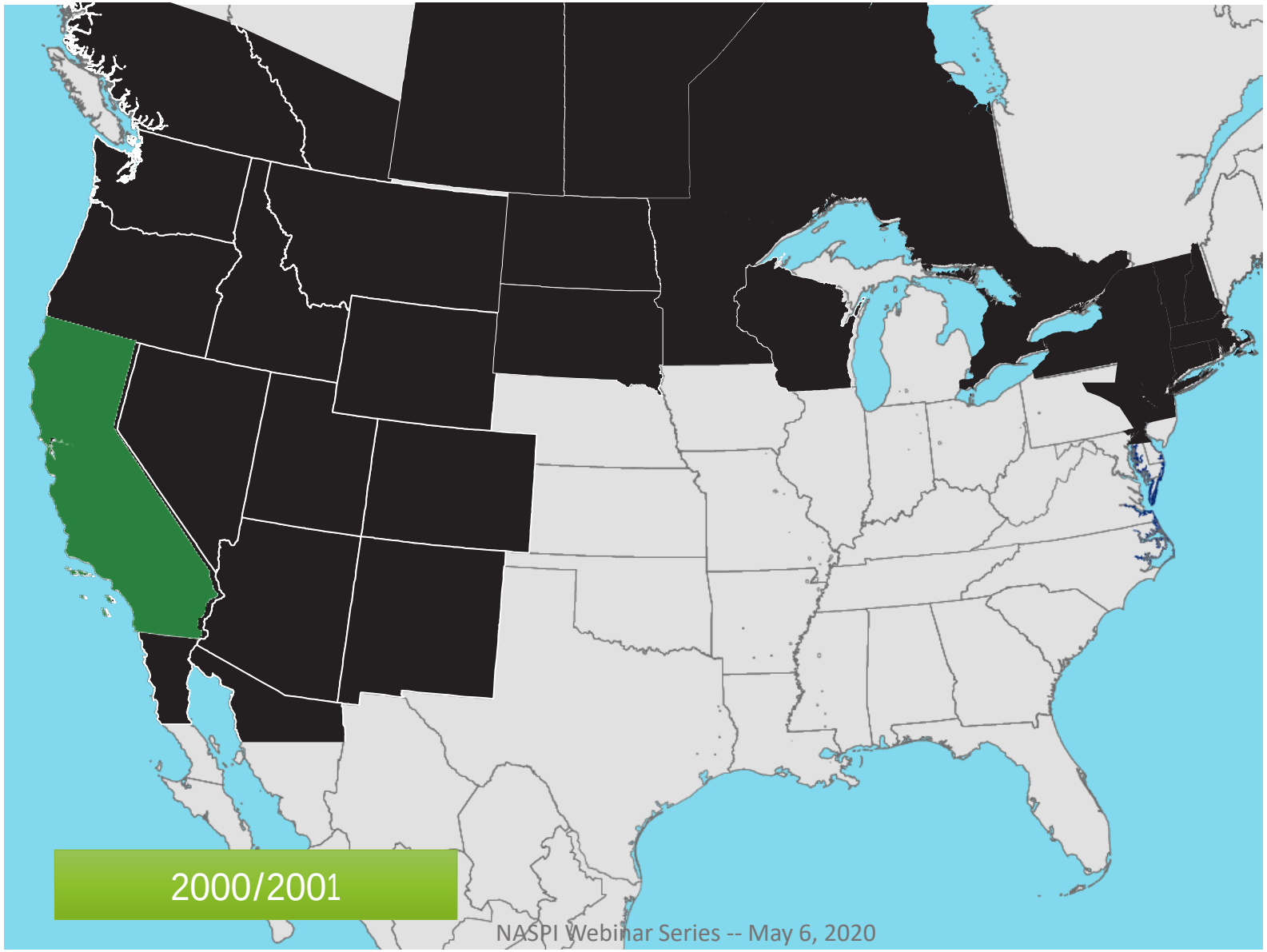
Power Disturbances – August 10, 1996



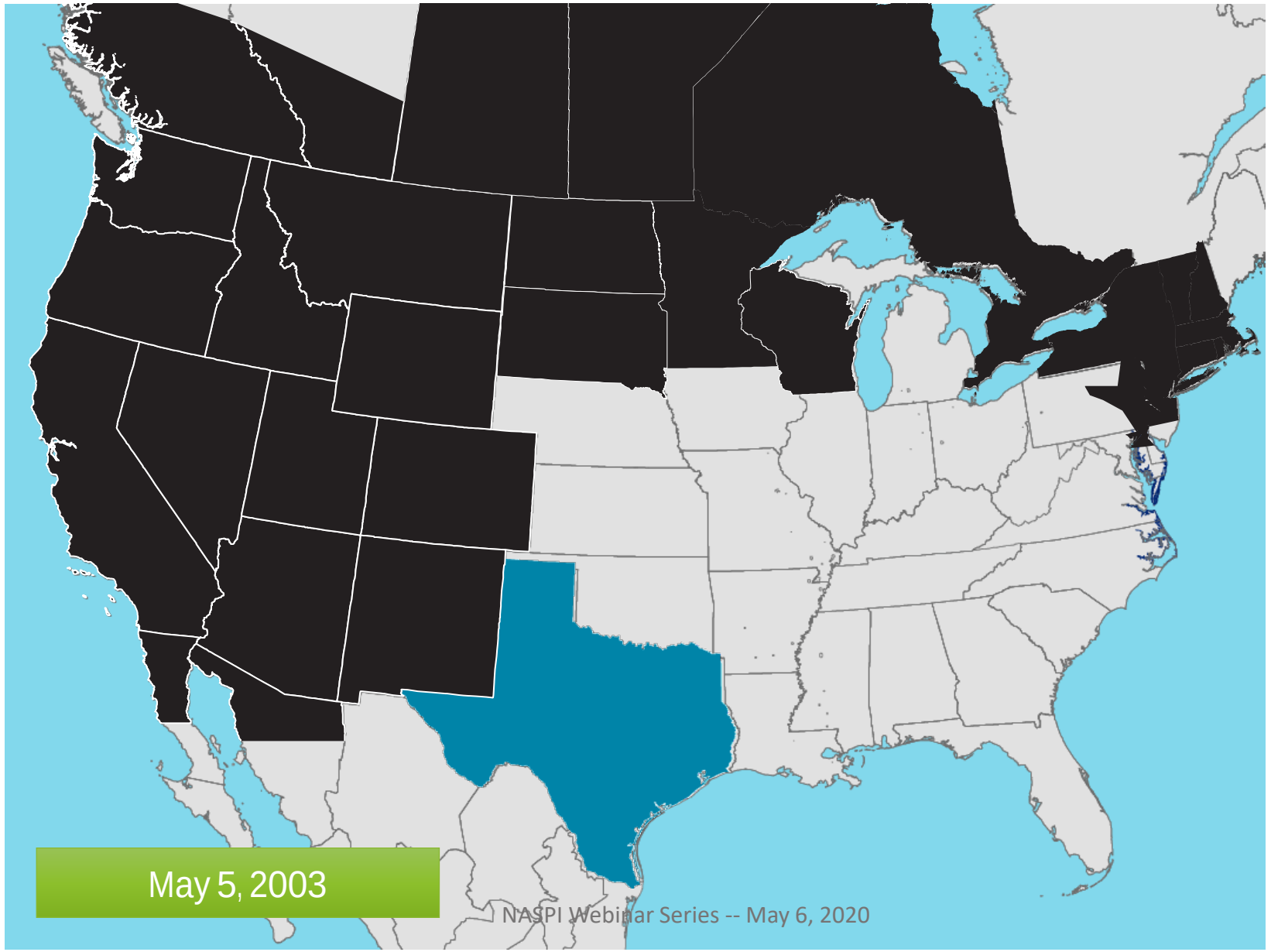
Power Disturbances – June 25, 1998



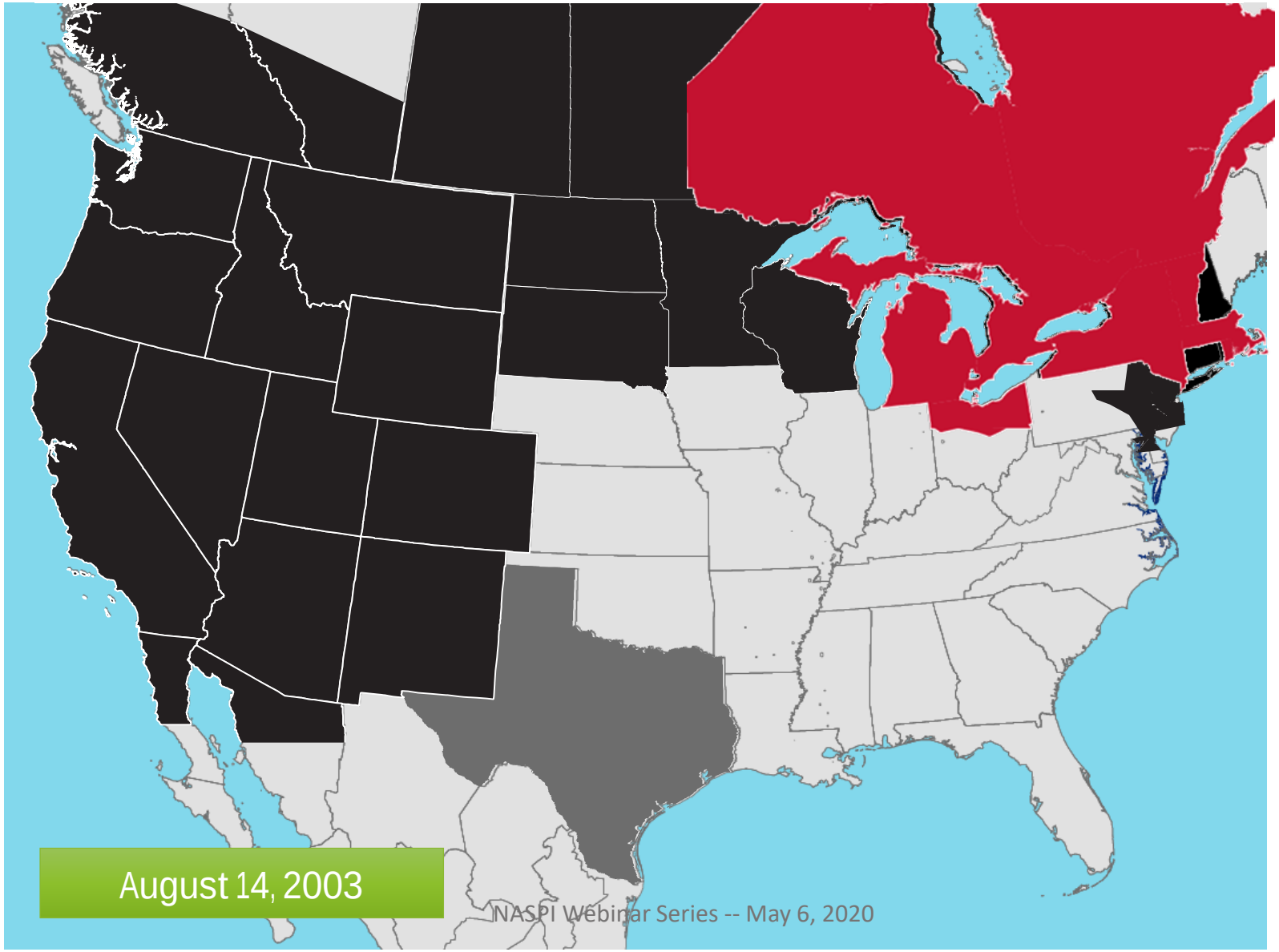
Power Disturbances – 2000/2001



Power Disturbances – May 5, 2003

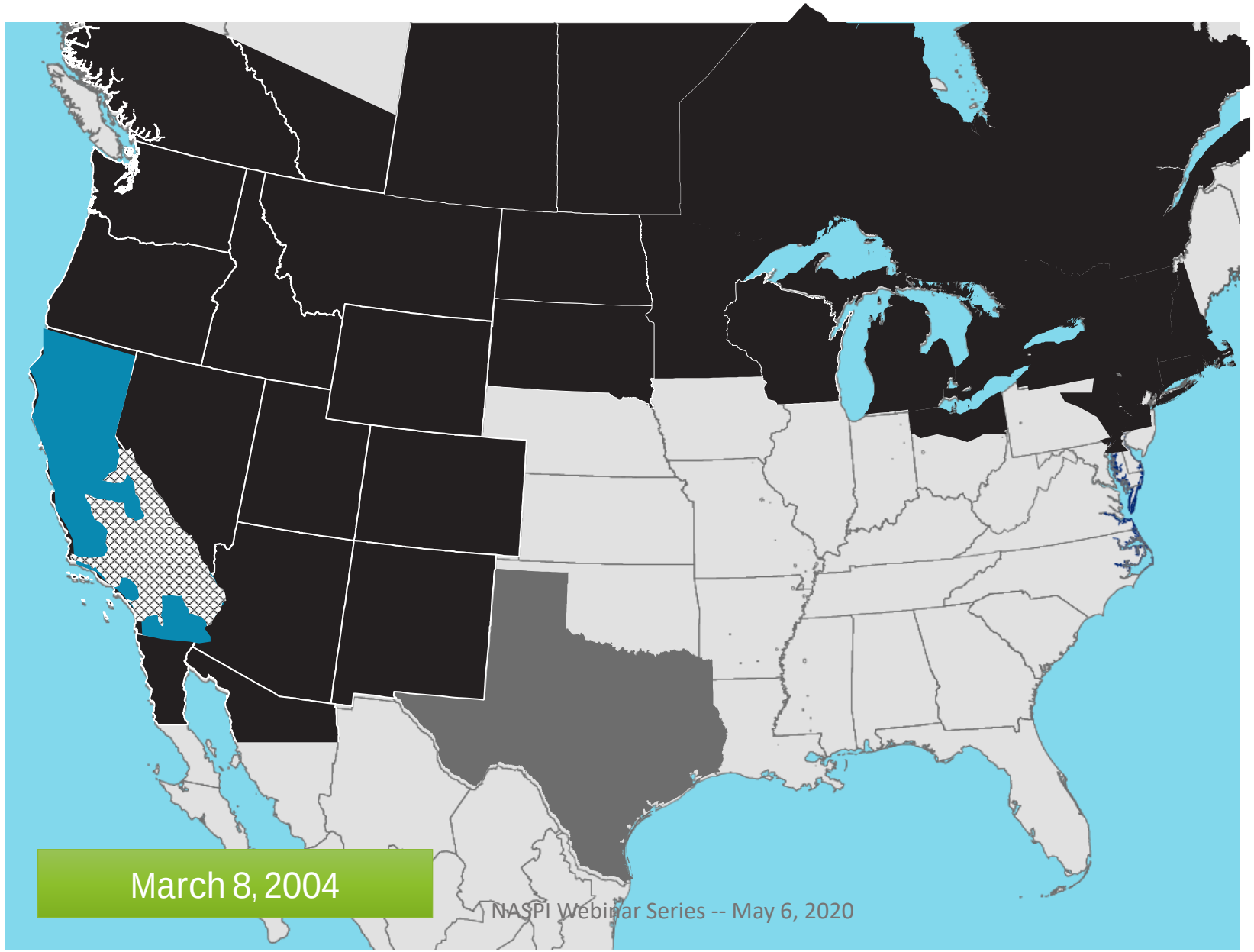


Power Disturbances – August 14, 2003

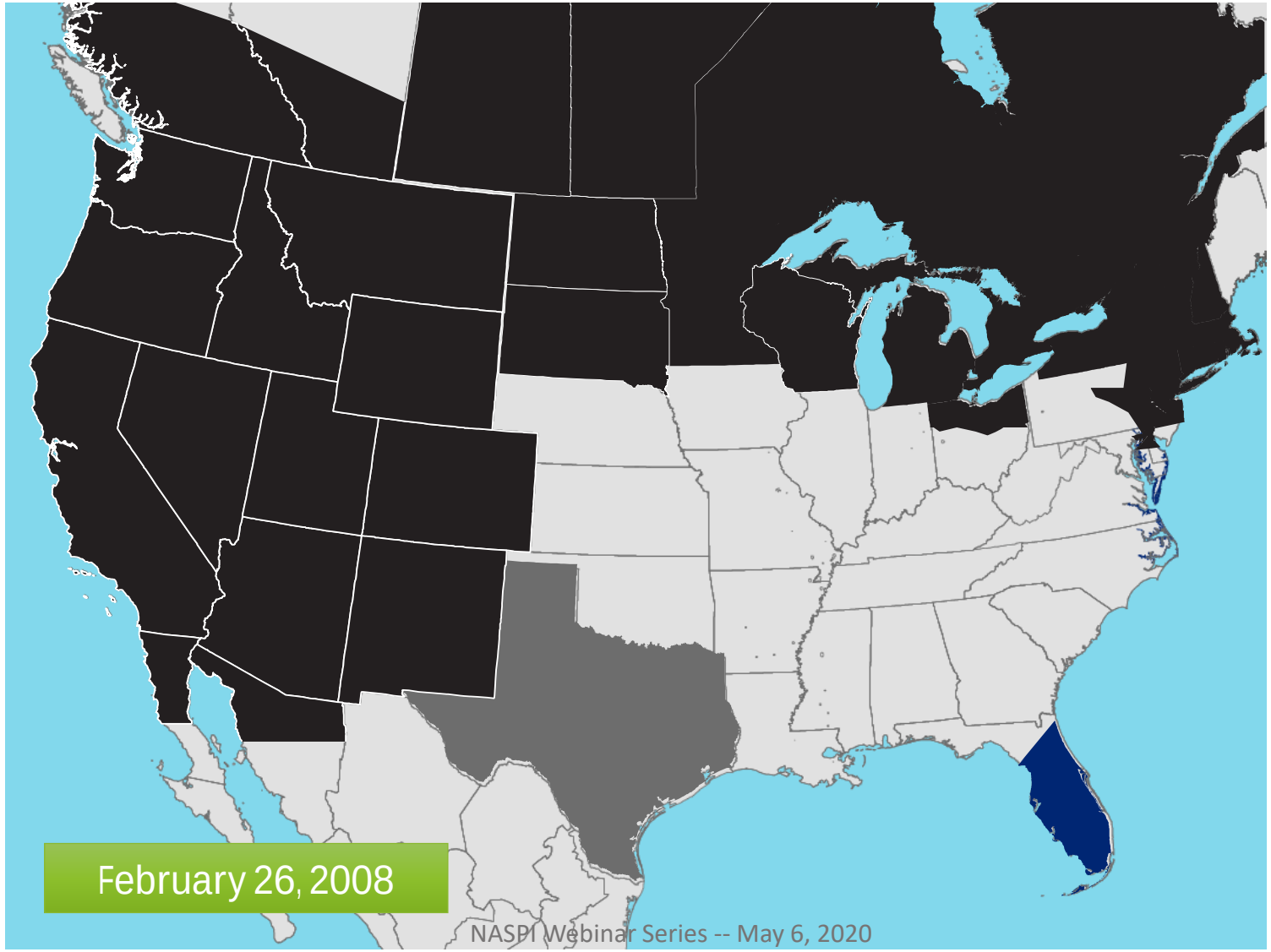


2003: Midwest/Northeast & Canada

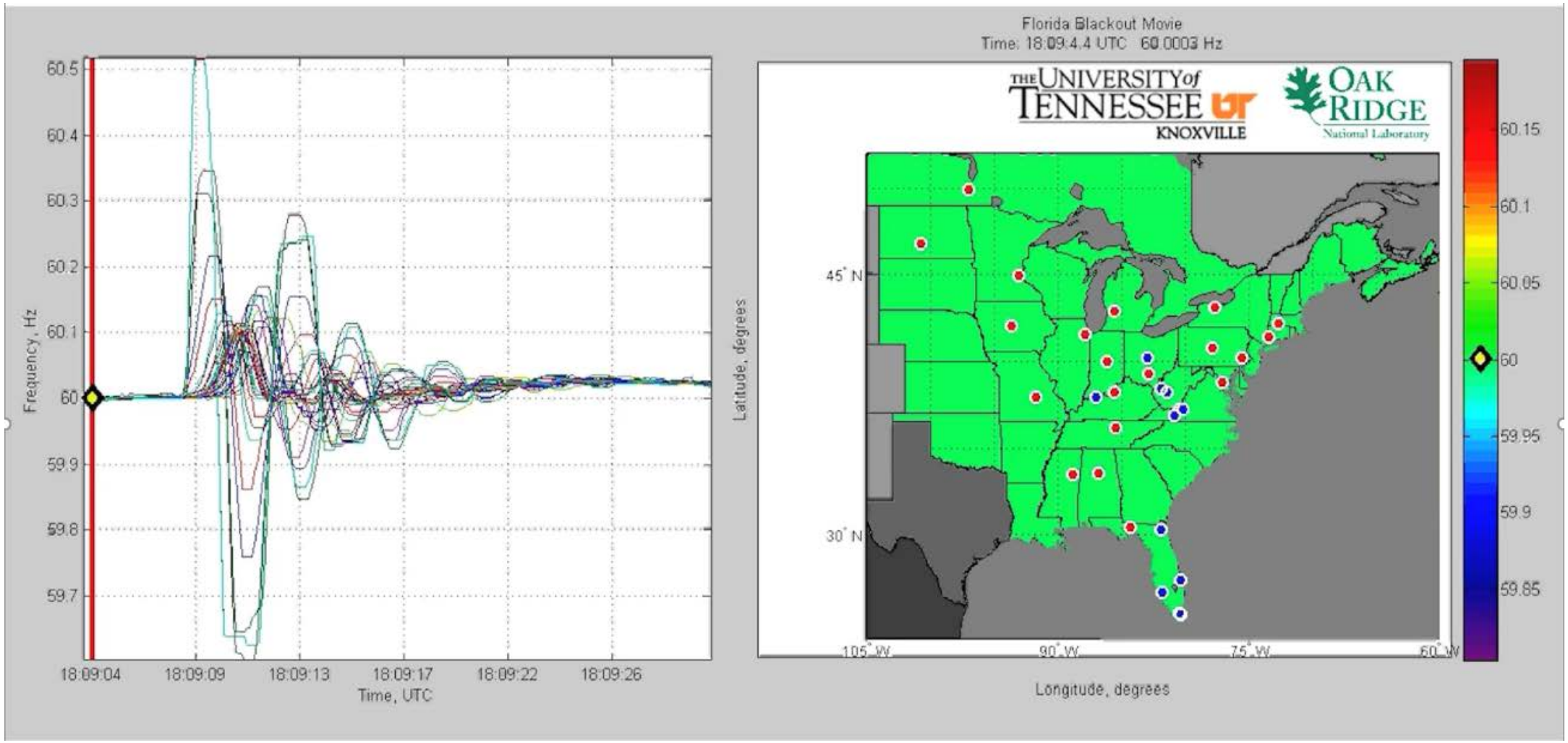
Power Disturbances – March 8, 2004



Power Disturbances – February 26, 2008



During the February 26, 2008 Transmission Forum Meeting



2 x Real Time

From Miami to Manitoba

Contact Link: http://fnetpublic.utk.edu/index.html

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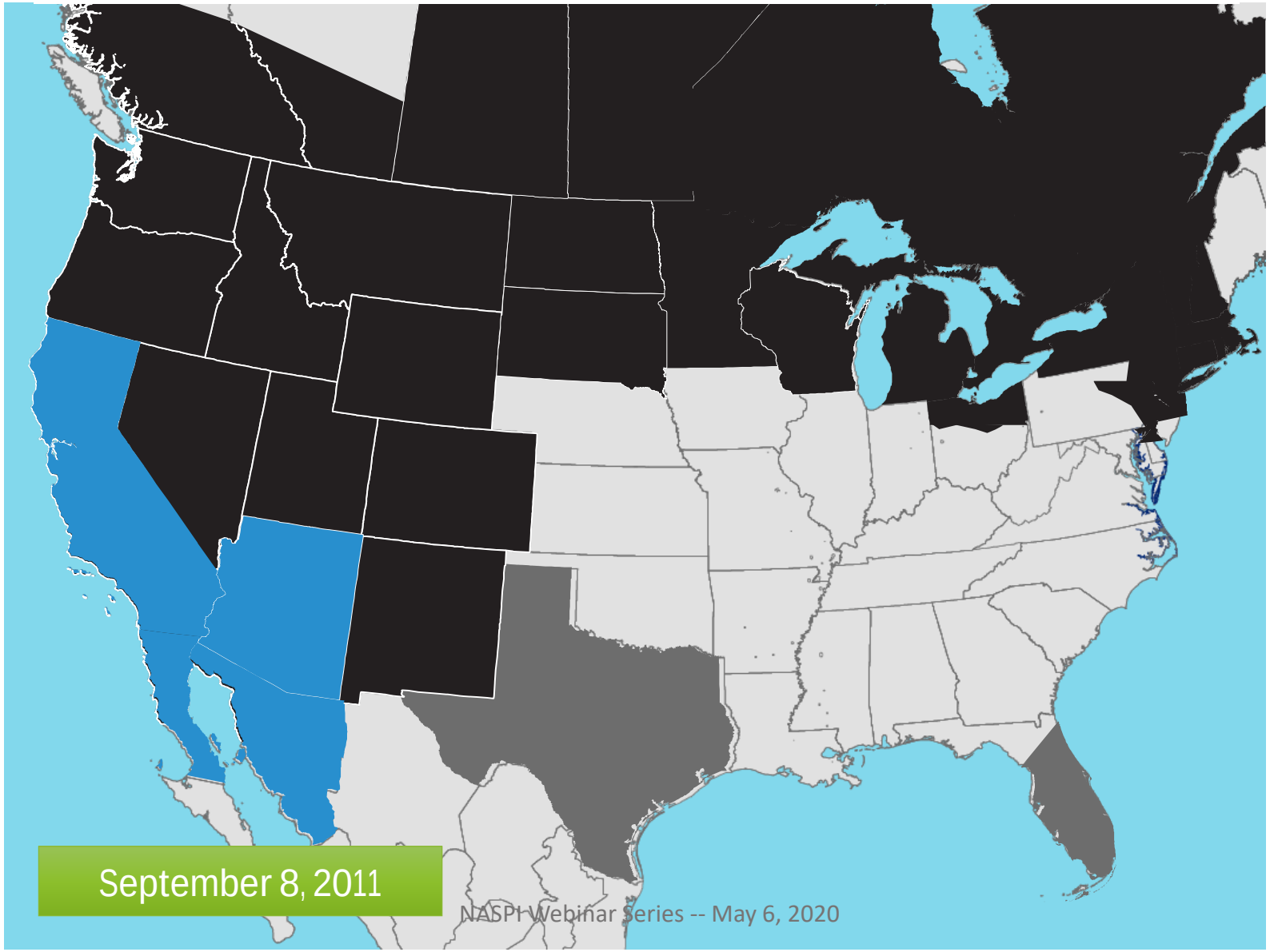
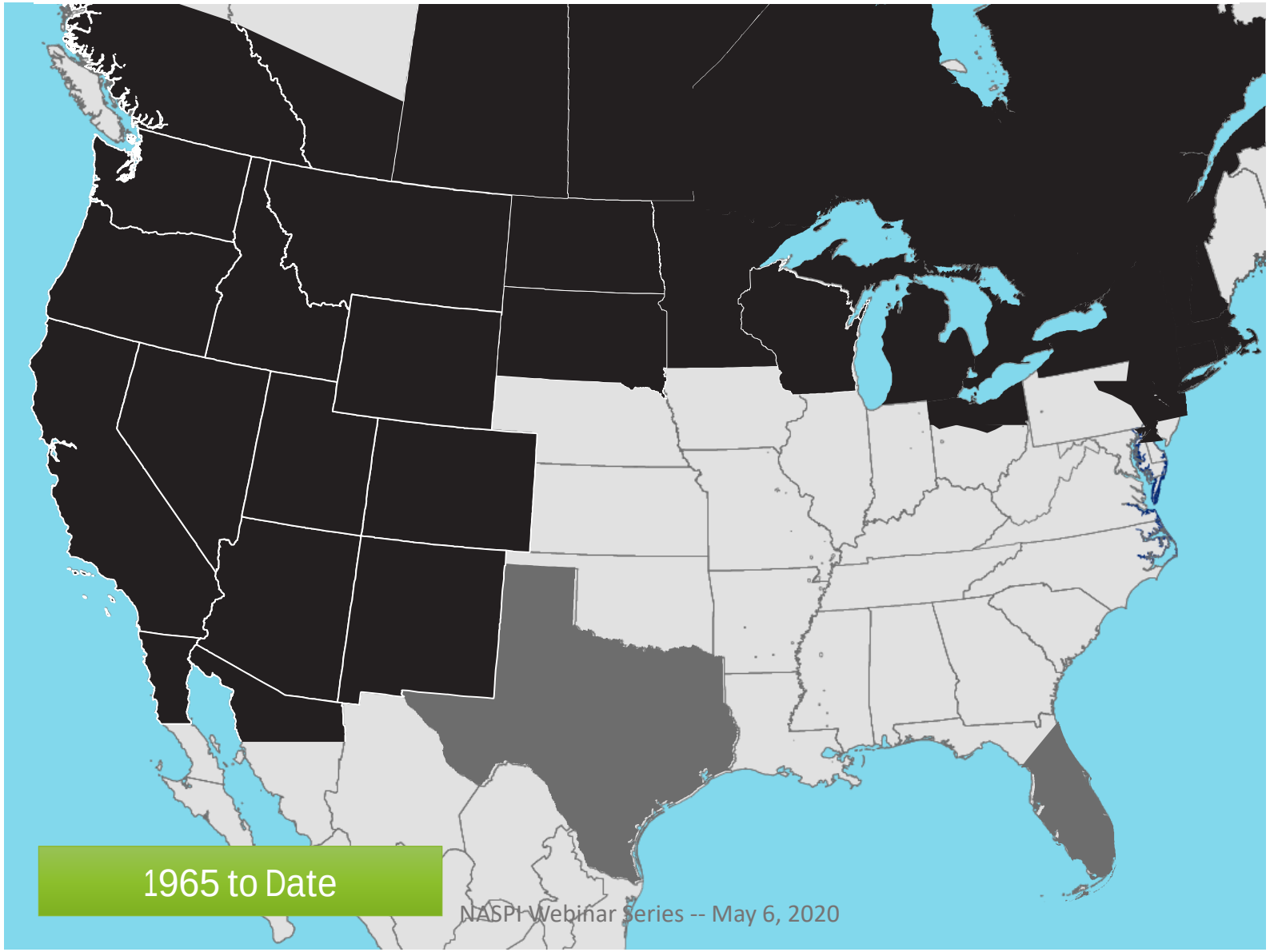
Power Disturbances – September 8, 2011

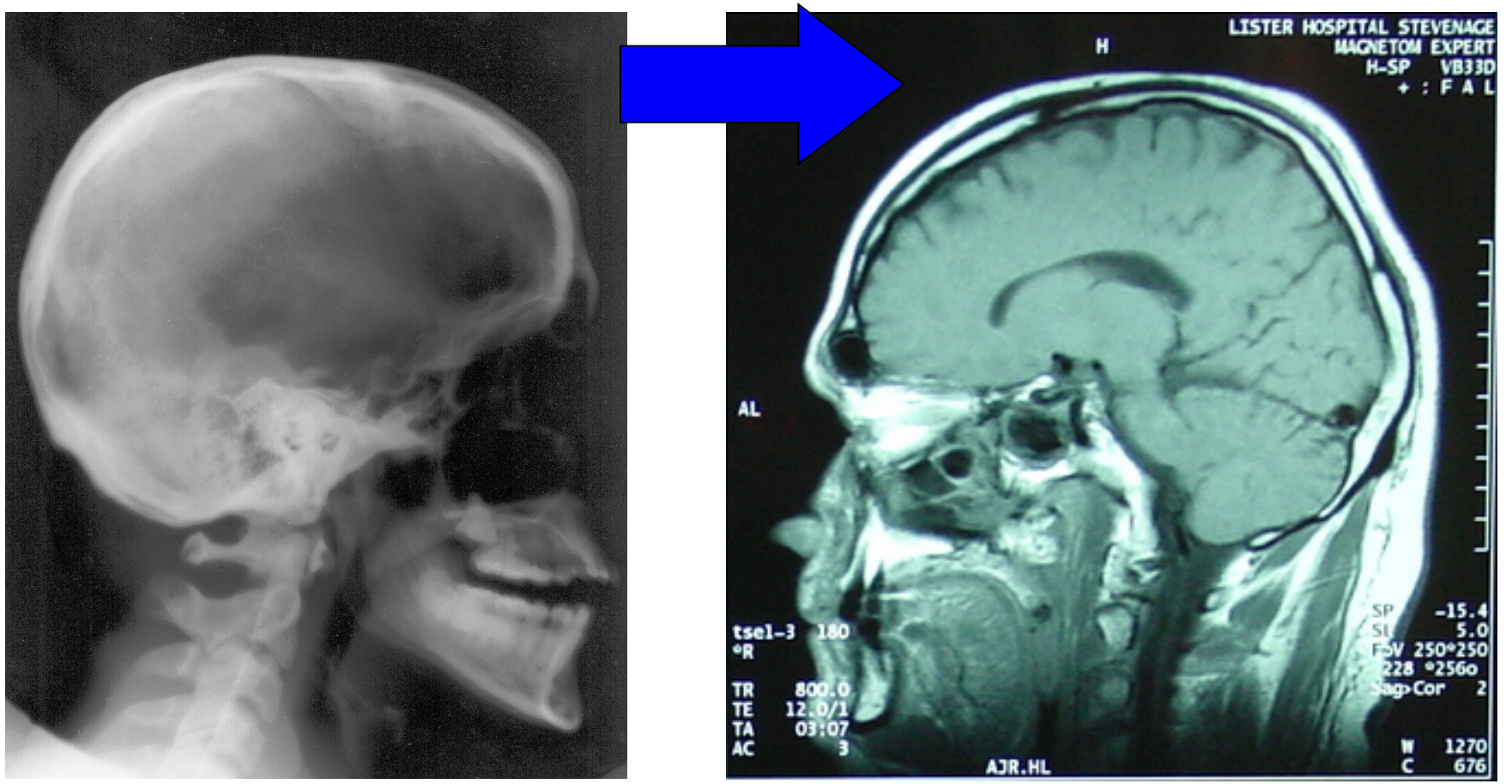


2011: San Diego

Power Disturbances – Cumulative Since 1965



PMU Moving Us From X-Rays to MRIs



1952 — **Nobel Prize**

1972 — **1ST Patent**

1977 — **1ST Human Scan**

What's new with GPA products?

Grid Protection Alliance

GRID PROTECTION ALLIANCE

GPA is a not-for-profit corporation established in 2010.

- Specializes in software and services for the electric utility industry
- All software is open-source, published under the permissive MIT license
- Focus is on a robust, reliable and resilient grid

`https://gridprotectionalliance.org`

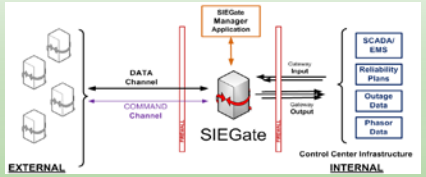
GPA's Synchrophasor Open-Source Product Suite

https://github.com/GridProtectionAlliance

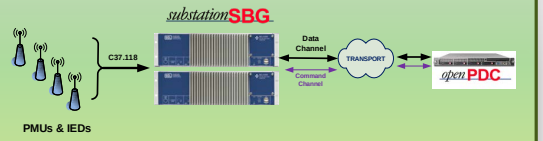
Daily updates available at https://gridprotectionalliance.org/NightlyBuilds/

Collect

openPDC



substationSBG



SIEGate

Distribute

Synchrophasor Stream Splitter

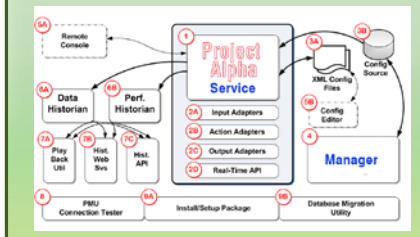
PMU Connection Tester

Gateway Exchange Protocol

sttp

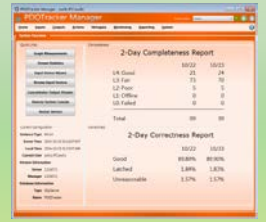
Analyze

TSL Project Alpha



DATA WALKER openHistorian

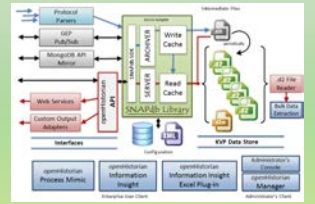
PDQ TRACKER
phasor data quality alarming & reporting



openECA
open and Extensible Control & Analytics platform for synchrophasor data

Save

openHistorian 2



Display

PLAYBACK UTILITY openHistorian

Grafana
Beautiful metric & analytic dashboards

New Protocol Needed for Large Phasor Data Streams

Advanced Synchrophasor Protocol Project

sttp

DOE FOA 1492
DE-OE0000859

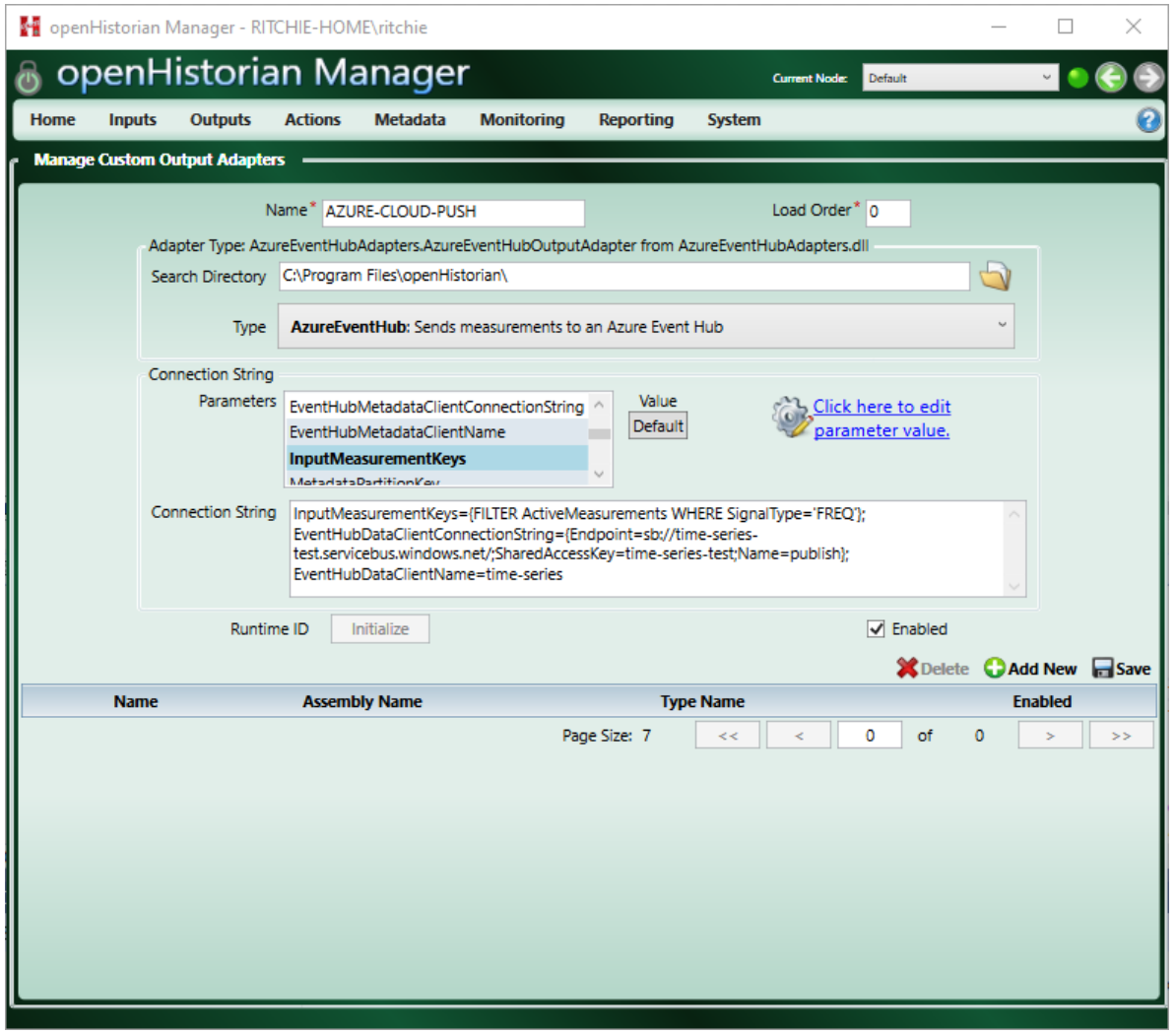
ASP

Streaming Telemetry Transport Protocol

- US DOE Project
- Intrinsically reduces losses and latency compared to frame-based protocols
- Allows the safe co-mingling of phasor data with other operational data network traffic
- Detailed metadata exchanged as part of protocol
- Includes lossless compression to reduce bandwidth utilization
- Security-first design with strong authentication and option for encryption

Time-series Application -- Cloud Adapters

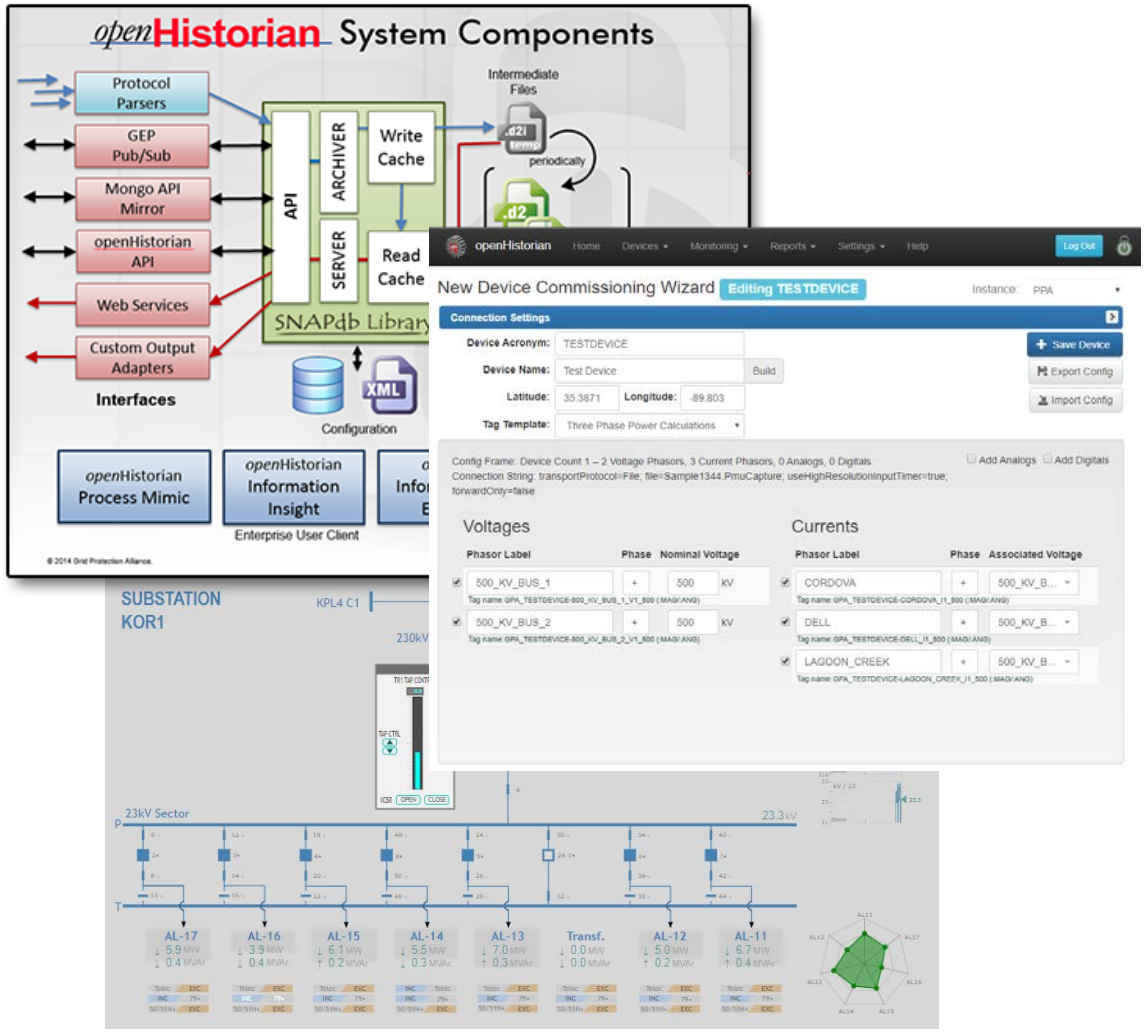
- The openPDC and openHistorian include a new adapter that can send data to a cloud repository
- In production use for the Azure Event Hub
- Other cloud data repositories are being added
  - Amazon Kinesis
  - Google Pub/Sub



Version 2.7 of the *open*Historian Now Released

New Features

- "Device Group" feature that extends into Grafana queries
- Automatic NGEN compilation for faster start-up and better performance
- Web-based Synchrophasor Device Wizard for New Devices with User-Customizable Dynamic Calculations
- Latest STTP Updates with Reverse Connection Support



Feature Improvements

- Includes Grafana server Version 6.6.2
- Includes new Geo Map and Data Export Panels and Device Filtering in Alarms
- New Signal to Noise and Unbalance Reports
- Improved WPF Synchrophasor Device Add/Update Wizards
- New default point-tag naming expression builder – that accommodates multiple utilities

https://github.com/GridProtectionAlliance/openHistorian/releases

Displaying Synchrophasor – Grafana Integration

- Grafana Integration
  - openHistorian Data
  - openHistorian Alarms
  - Device Groups
- Synchrophasor Displays
  - Geographic displays
  - PMU status Displays
  - Phase Displays

Value of Synchrophasors – SNR Reports

- Cause of growing noise – failed fuse clip

SNR of Voltage Phase Magnitude

S3: SNR of voltage phase magnitude

Unbalance and SNR Report

Instance: REP Records: 25

Report Period: Last 30 Days Start Time: 03/23/2020 18:21:41.63900 End Time: 04/22/2020 18:21:41.63900

Filter: Worst 25 Signal to Noise Ratio by Maximum Generate Report

Worst 25 SNR Report

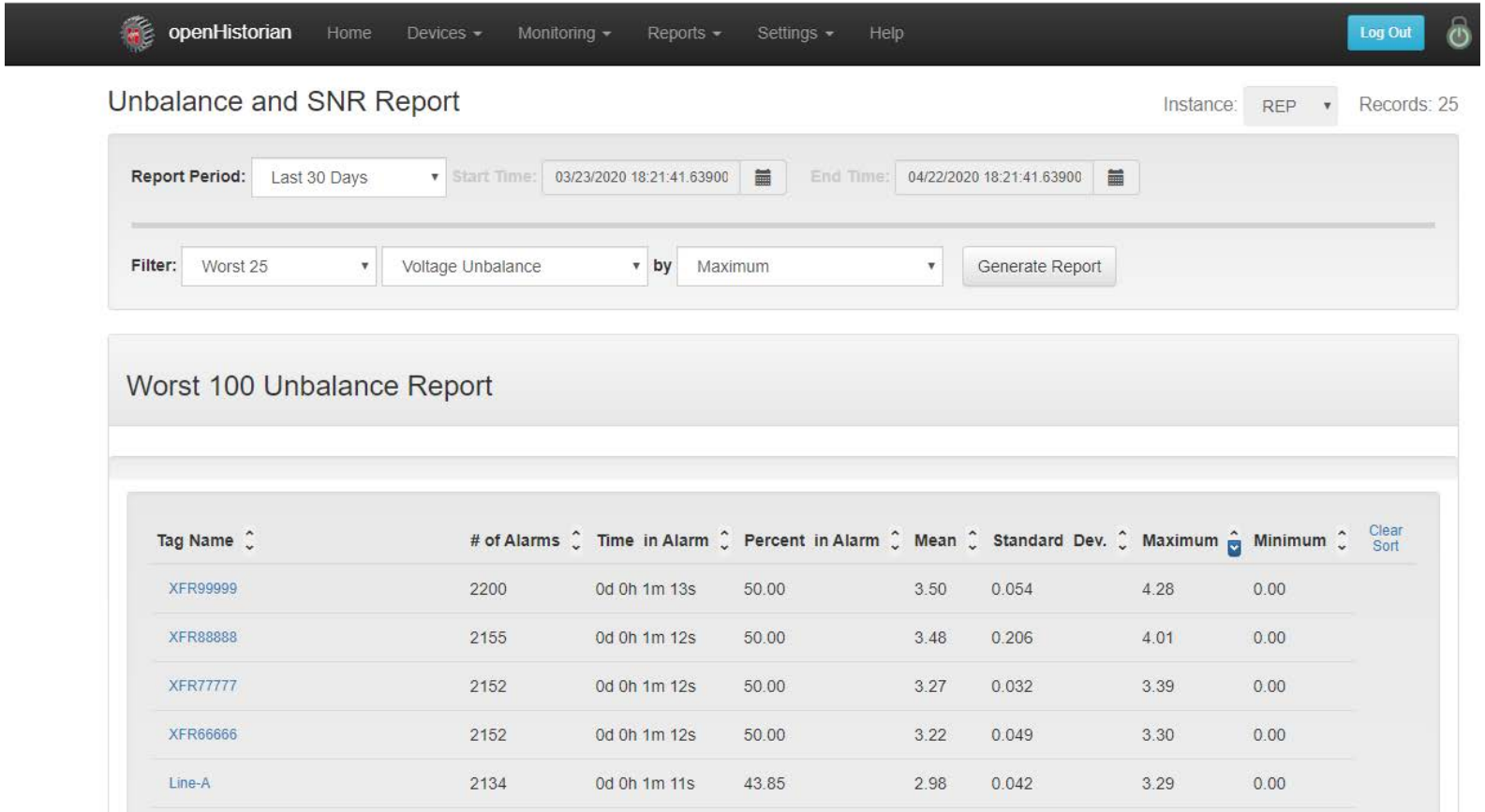
Tag Name	# of Alarms	Time in Alarm	Percent in Alarm	Mean	Standard Dev.	Maximum	Minimum
XFR99999:F	2200	0d 0h 1m 13s	50.00	53.29	2.545	60.26	40.47
XFR88888:F	2155	0d 0h 1m 12s	50.00	49.73	1.534	55.24	40.75
XFR77777:F	2152	0d 0h 1m 12s	50.00	49.72	1.532	55.24	40.76
XFR66666:F	2152	0d 0h 1m 12s	50.00	49.72	1.532	55.24	40.76
Line-A:IH	2134	0d 0h 1m 11s	43.85	41.61	7.247	48.87	-26.54
Line-B	2132	0d 0h 1m 11s	42.75	42.29	7.282	48.06	-17.63

Clear Sort

Source: Tennessee Valley Authority

Value of Synchrophasors – Unbalance Reports

- Unbalanced Operation leads to
  - Higher losses
  - Stress on transformers and generators
- Unbalance Reports
  - Identify unbalanced lines
  - Alert and notify

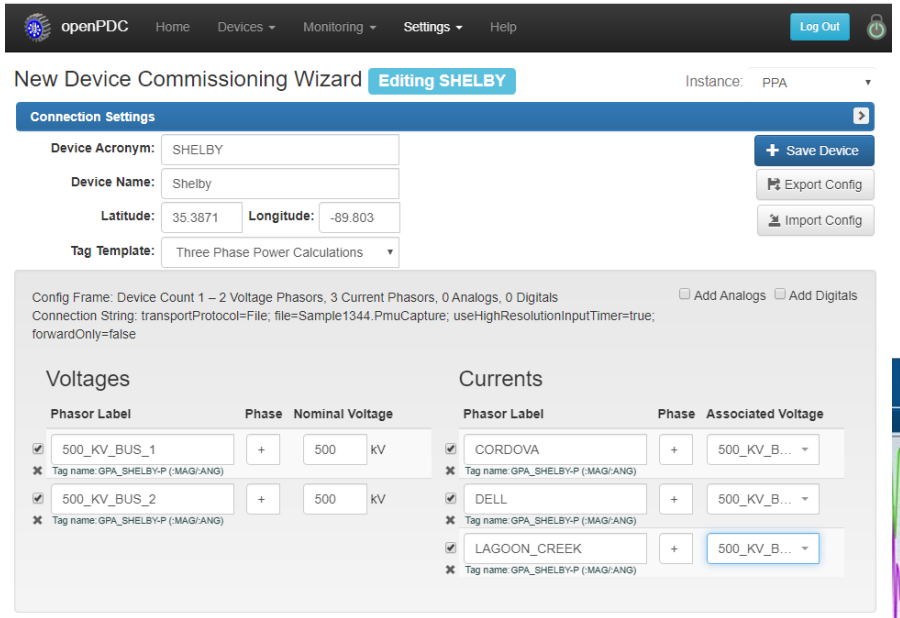


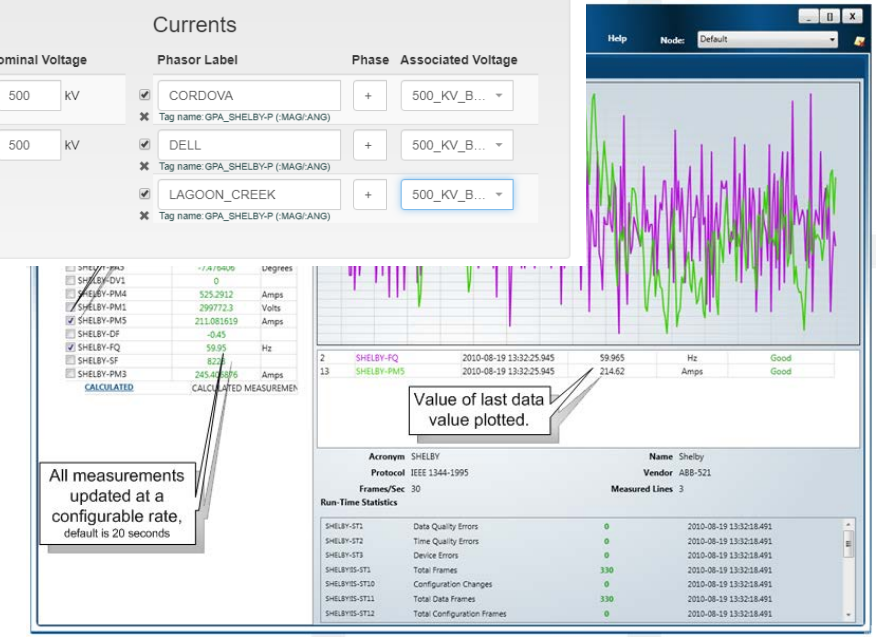
GRID PROTECTION ALLIANCE

Version 2.8 of the *open*PDC Now Released

Features

- Automatic NGEN Compilation during Install for Better Overall Performance
- New Web-based Interface with Modbus and Synchrophasor Device Wizard for New Devices with User-Customizable Dynamic Calculations
- Latest STTP Updates with Reverse Connection Support





Recent Improvements

- Improved Meta-data and IEEE C37.118 Input Operations
- Improved WPF Synchrophasor Device Add/Update Wizards
- New Default Point Tag Naming Expression
- Improved SQLite Support

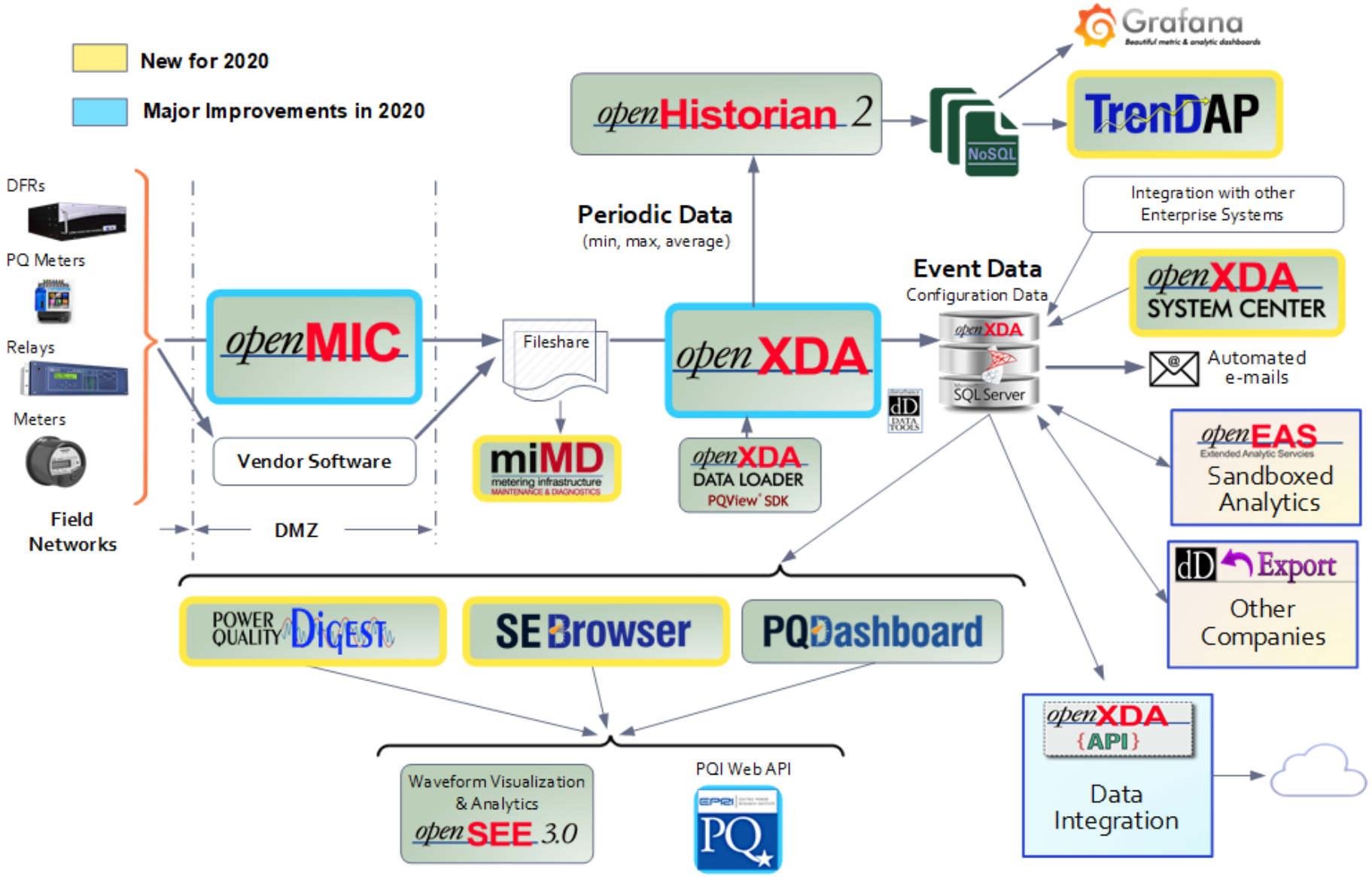
https://github.com/GridProtectionAlliance/openPDC/releases

Other Synchrophasor Product Improvements

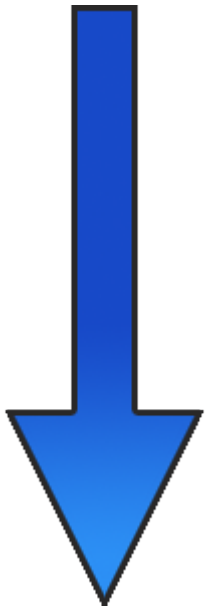
Product	Purpose	Latest Version	Recent Improvements
SIEGate	Inter-control center data exchange, including phasor data	**1.7** May 2019	• Includes STTP • Meta-data updates
substationSBG SECURE BUFFERED GATEWAY	Substation level rolling historian with gateway connectivity with automated archive restoration	**1.5** May 2019	• Includes STTP • Better certificate management
PDQ TRACKER phasor data quality alarming & reporting	Standalone data quality and availability reporting	**1.4** May 2019	• Includes STTP • Improved connect-on-demand
Synchrophasor Stream Splitter	Turns single synchrophasor inputs into multiple ones	**1.1** May 2020	• NGEN Pre-compilation • High-order ID codes
TSL Project Alpha *a complete time-series solution template*	Defines a base template for new time-series framework adapters	**0.5.4** May 2018	• Improved installer template • Includes STTP
openECA open and Extensible Control & Analytics platform for synchrophasor data	Allows for easy creation and deployment of new analytics	**1.3** May 2020	• Improved Matlab project support • Includes STTP

For more information: www.GridProtectionAlliance.org

What's New? GPA's Disturbance Tool Suite



openXDA Analytics Determining Likely Cause

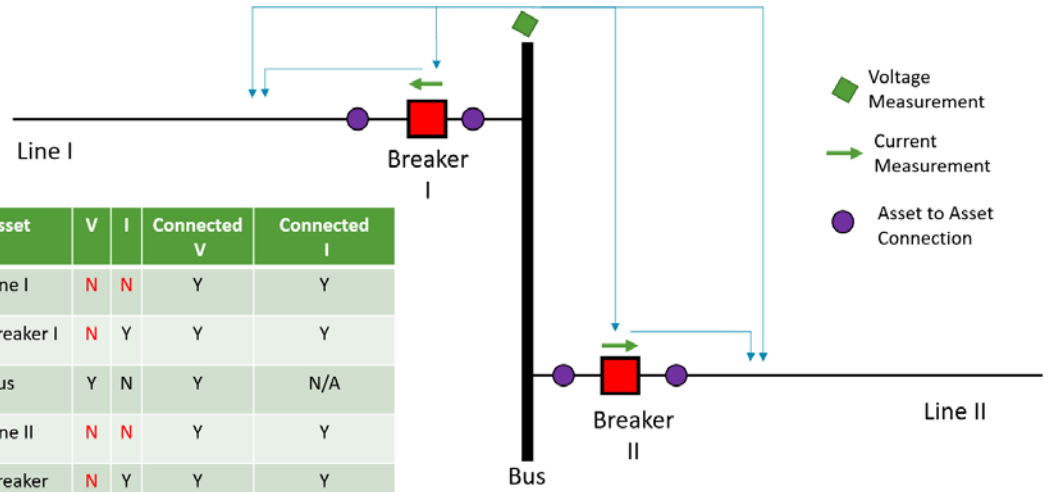


Decreasing Analytic Certainty

Cause	Prob. Levels	High Probability
Break	High, Low	Must have pre-fault current and be a L-G fault. Probably high if pre-fault current goes to zero in faulted phase
Lightning	High, Med, Low	Lightning occurs within 2 mSec of fault inception
Tree	High, Med, Low	Must be a L-G fault. "Fault resistance" is >= 20 ohms
Slap/Debris	High, Low	Must be a L-L fault. Ratio of ground current to fault current < 0.3
Arrestor	High, Low	Must have pre-fault current and be a L-G fault. R atio of third harmonic to first harmonic for pre-fault current > 10%
Insulator	High, Med, Low	Must have pre-fault current and be a L-G fault. Phase shift pre-fault to fault-inception +/- 15 degrees.

Likely cause = only one 'high probability' found → display cause
= multiple 'high probability' found → display cause with most certainty and "?"
= no 'high' and one or more 'medium' found → display cause with most certainty and "??"
ELSE display cause as "unknown"

Highlights of 2020 Changes – Automated Analytics



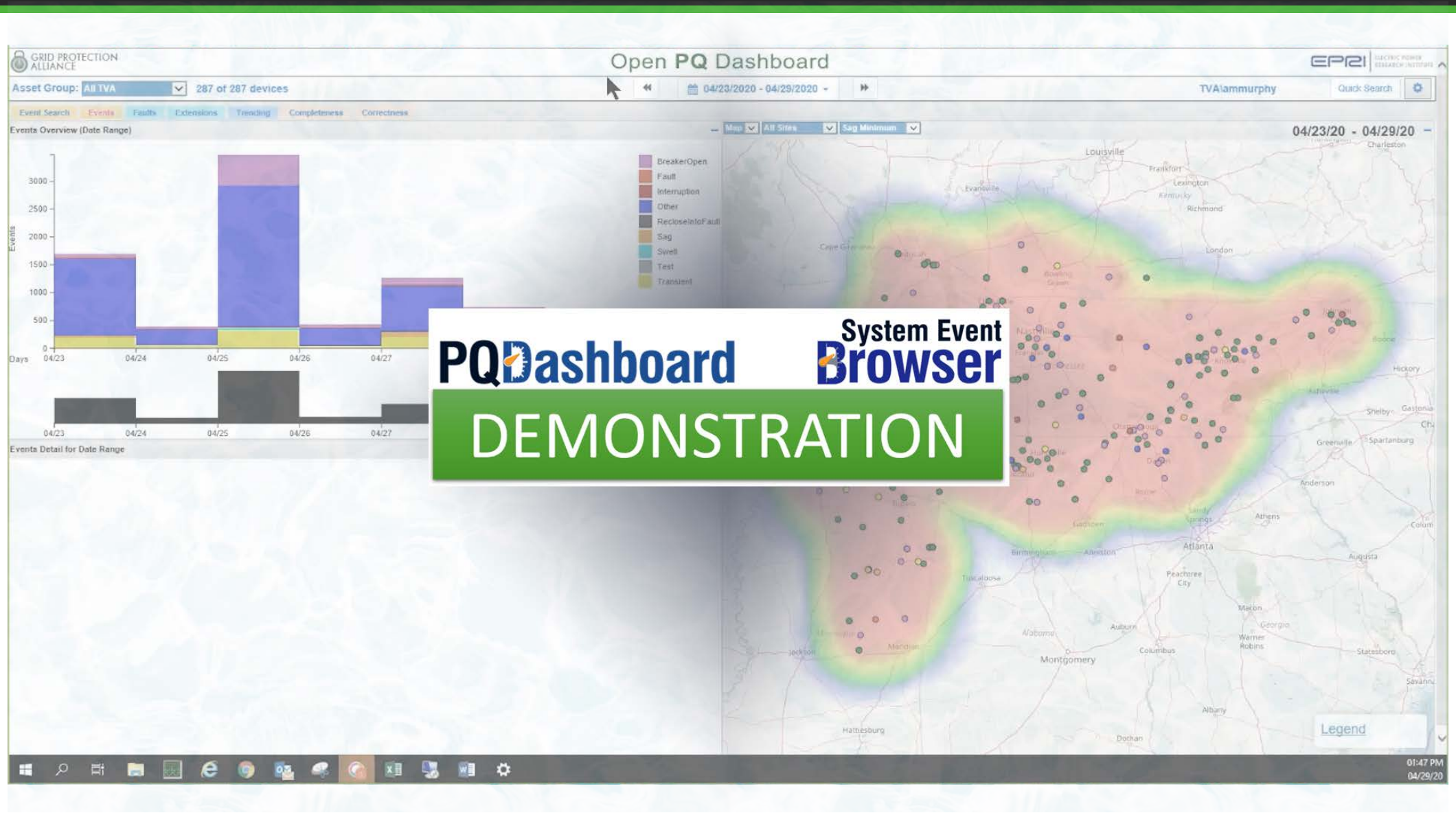
Asset	V	I	Connected V	Connected I
Line I	N	N	Y	Y
Breaker I	N	Y	Y	Y
Bus	Y	N	Y	N/A
Line II	N	N	Y	Y
Breaker II	N	Y	Y	Y

Currently, these assets can be modeled:

- Line
- Breaker
- Bus
- Transformer
- Capacitor Bank

- A new asset-centric model has been implemented in openXDA
- Can designate spare breakers and switch out breakers serving lines
- Can associate a voltage measurement with a bus
- Can model line segments – each with their individual characteristics

Open PQ Dashboard / SE Browser Demo



What's the "Next Generation"?

The Future of PMU and kHz Measurements

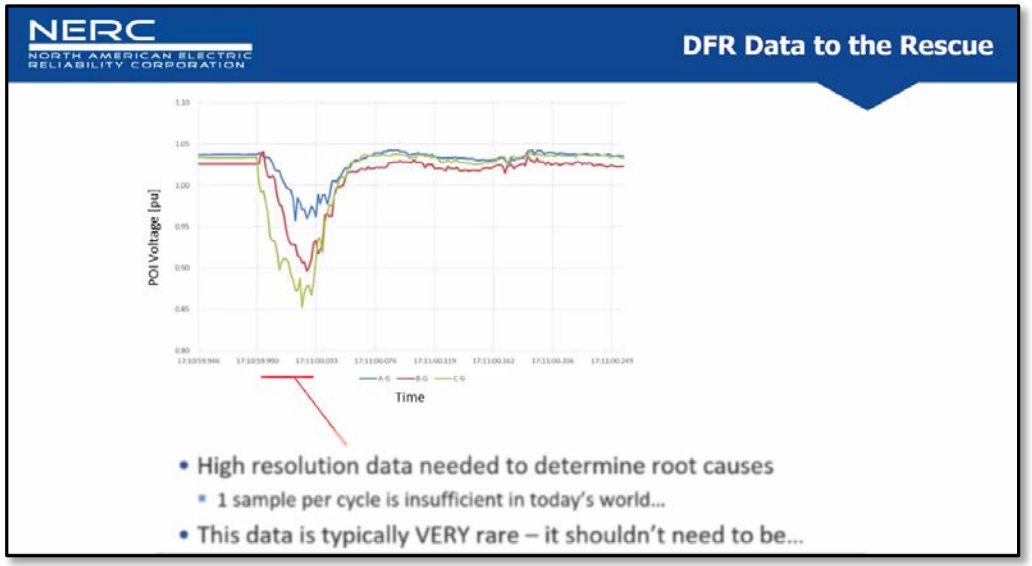
Phasors and Data
Are Here to Stay

Current Value from Synchrophasors

- Frequency monitoring and compliance (NERC BAL-003)
- Oscillation detection mode monitoring and voltage stability monitoring
- Support black-start system recovery and load restoration (EOP Standards)
- Equipment heath monitoring / Predictive maintenance (NERC PRC-004)
- Model validation – Generation, load, FACTS, HVDC; system model validation
- Forensic analysis of events (NERC PRC-002)

From the NERC Report on the last NASPI Call

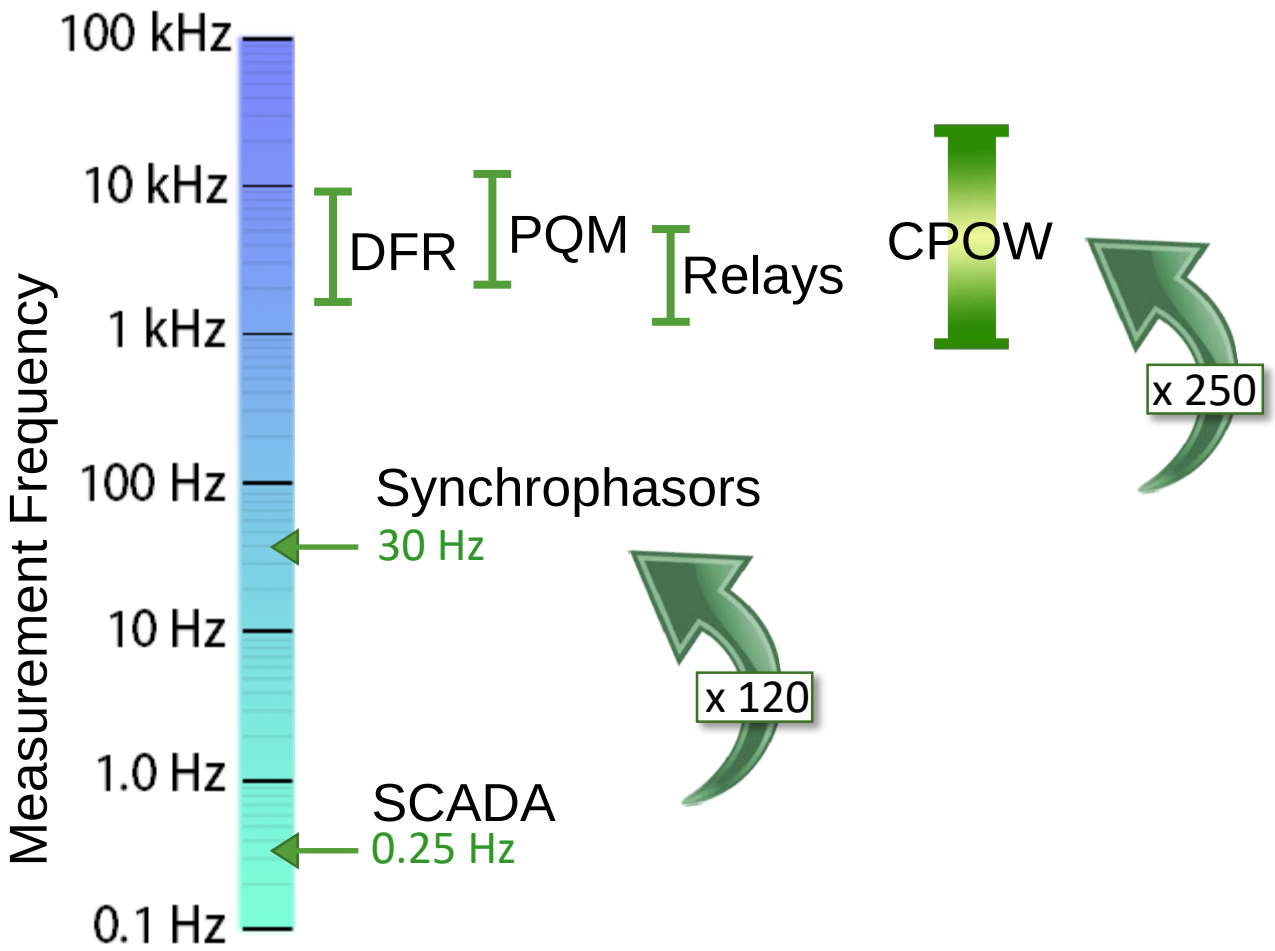
- Phasor Data -- One sample per cycle in insufficient
- High resolution data (i.e., DFR resolution data) is often required to determine root cause
- This [high resolution] data is VERY rare – and it shouldn't be.



Source: Ryan Quint, NERC

Differing Grid Measurement Fidelity

- Grid SCADA data
  0.25 Hz, protocols don't include a time stamp
- Synchrophasors
  30 to 60 Hz, GPS time
- Event-triggered Recorders
  - Digital Fault Recorders (2 to 10 kHz)
  - Power Quality Meters (2 to 30 kHz)
  - Relays (1 to 8 kHz)
- Continuous, Synchronized Point-on-Wave
  1 to 60 kHz sampling, GPS time (16 to 1,000 points per cycle)



SPOW = Synchronized Point-On-Wave

CPOW Research Opportunities

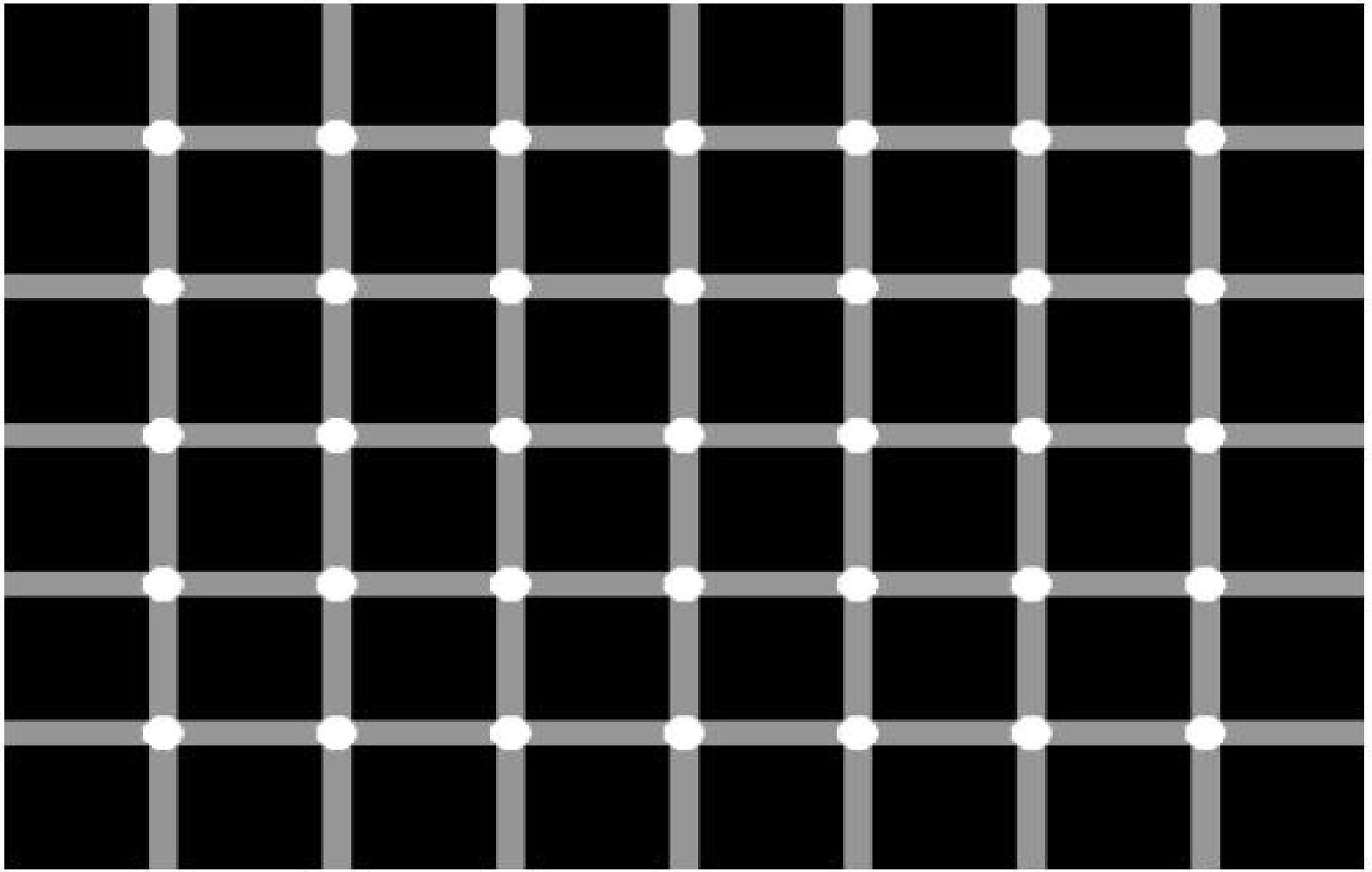
- Data Collection – Numerous vendor solutions available → **Available and improving**
- Local Analytics – Digital relays have performed POW analytics for decades → **Existing techniques need extending**
- Data Distribution – STTP, IEEE P2664 → **High volume streaming needs operational tuning**
- Short and Long-Term Storage – Velocity and Volume Issues must be addressed → **Data management techniques require validation**
- Wide-area / Centralized Analytics – New centralized analytics and decision support tools are needed → **Data integration processes and analytic techniques must be developed**

Synchrophasor Road Map to Chart the Future

- From: Blackout Investigation Forensics
  To: Blackout Prevention
- From: Back-Office Engineering Tool
  To: Real-Time Decision Support
- From: Supplemental Data
  To: Trusted SCADA Backup
- From: Reliability Coordination
  To: Preventative Maintenance
- From: One measurement per cycle
  To: DFR Fidelity – Synchronized Point-on-Wave

Blackout Prevention --Measurement and Verification

PMUs still a matter of perspective



How many black dots?

The Future of High Fidelity Grid Measurement

The best way to predict the future is to create it!

---Peter Drucker

https://GridProtectionAlliance.org