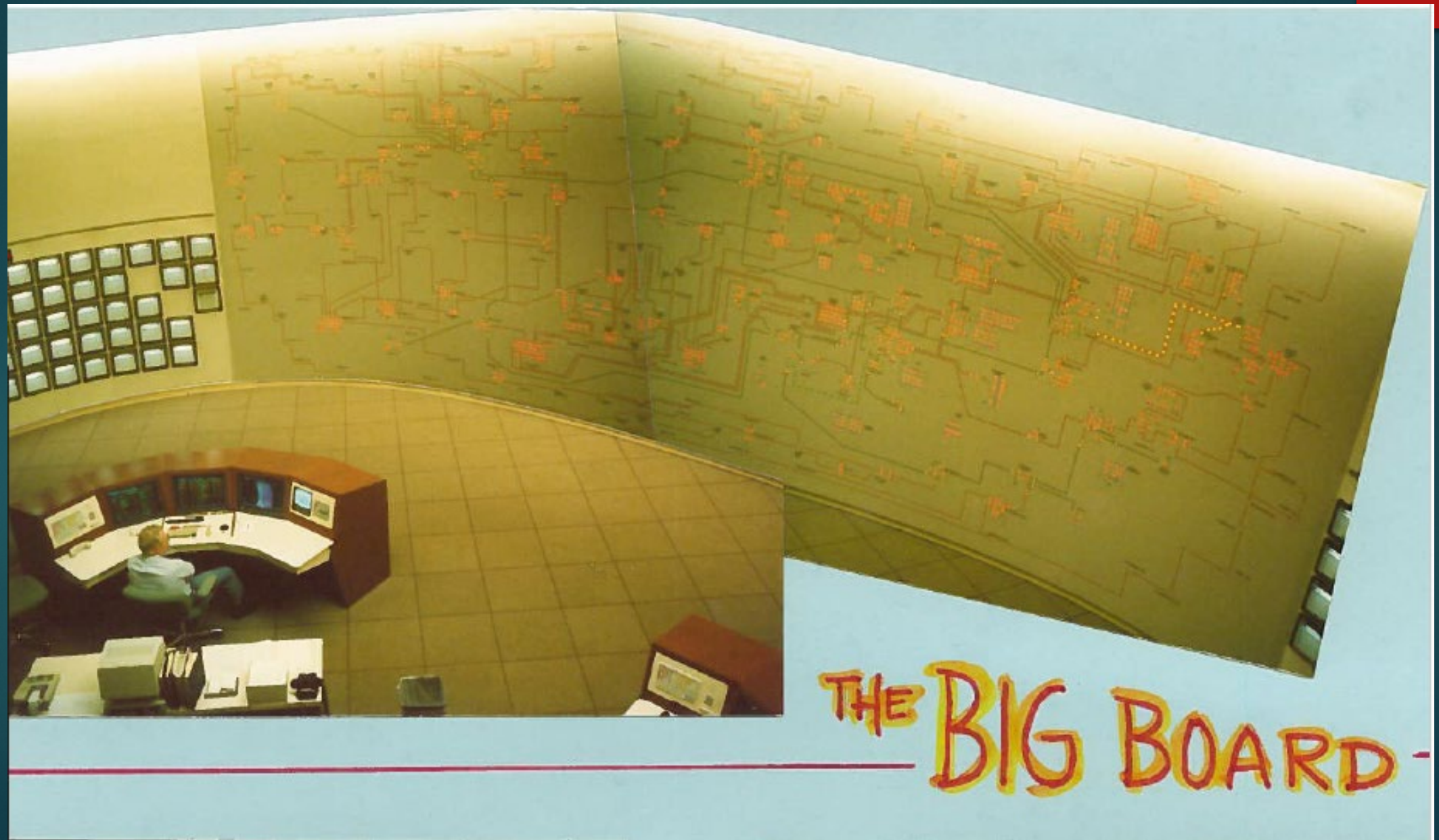
2023 NERC Monitoring and Situational Awareness Conference

The Ever-Changing Landscape of the EMS Systems

EMS Working Group

- Since 2013. 11th annual conference.
- 40+ members
- Rob Adams - *Rob.Adams@fpl.com*
- Phil Hoffer - *pehoffer@aep.com*
- Wei Qiu - *Wei.Qiu@nerc.net*

Ever Changing Landscape of the EMS



Ever Changing Landscape of the EMS

Ever Changing Landscape of the EMS

Conference Topics

1. Keynote Speech
2. Analysis of EMS Outages
3. The Future – twins, AI, clouds, sharing
4. FERC Order 881 and FAC-011 at Manitoba Hydro
5. PJM & SPP EMS Upgrades
6. Lessons Learned
7. Vendor panel – situational awareness, security, communications

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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Public

Analysis of EMS Outages

Wei Qiu, Lead Engineer of Event Analysis, NERC EA

NERC 11th Annual Monitoring and Situational Awareness Conference

October 3, 2023

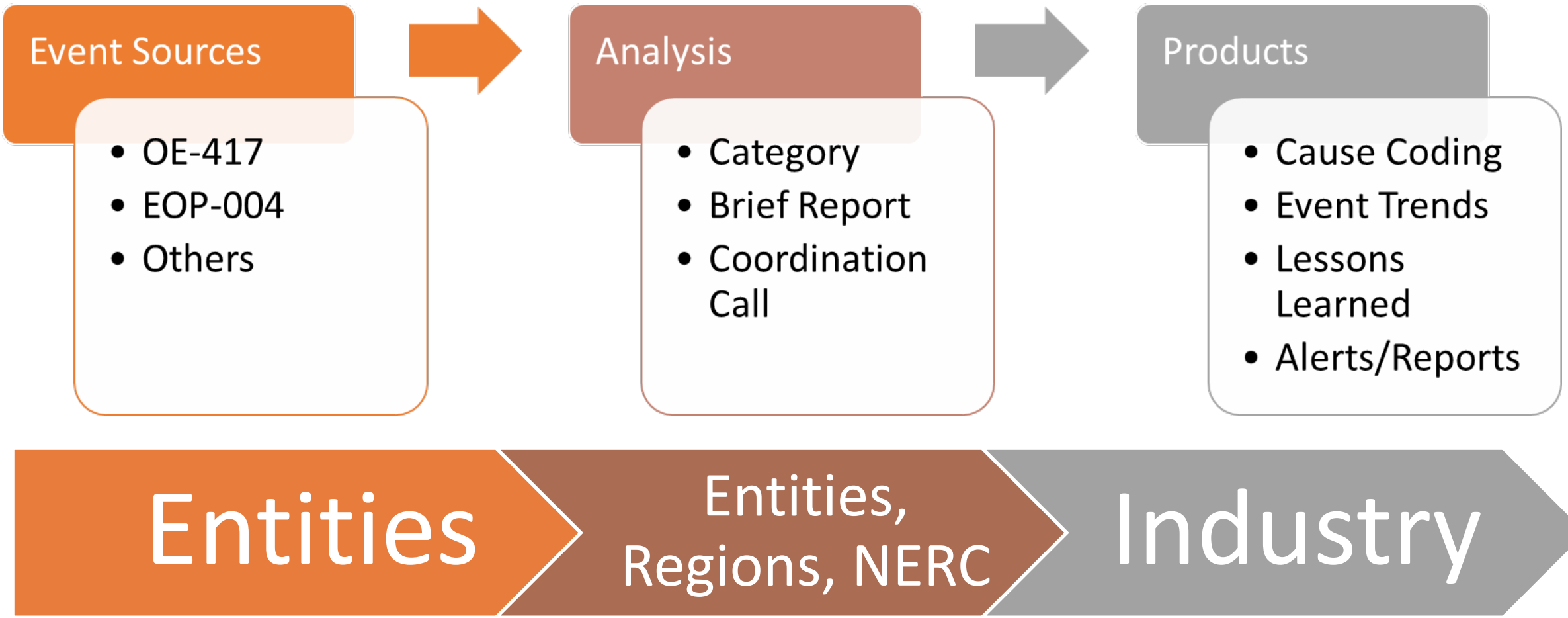
Agenda

- ERO Event Analysis Process
- Data, Analysis, and Trends
- Key Takeaways
- Q&A

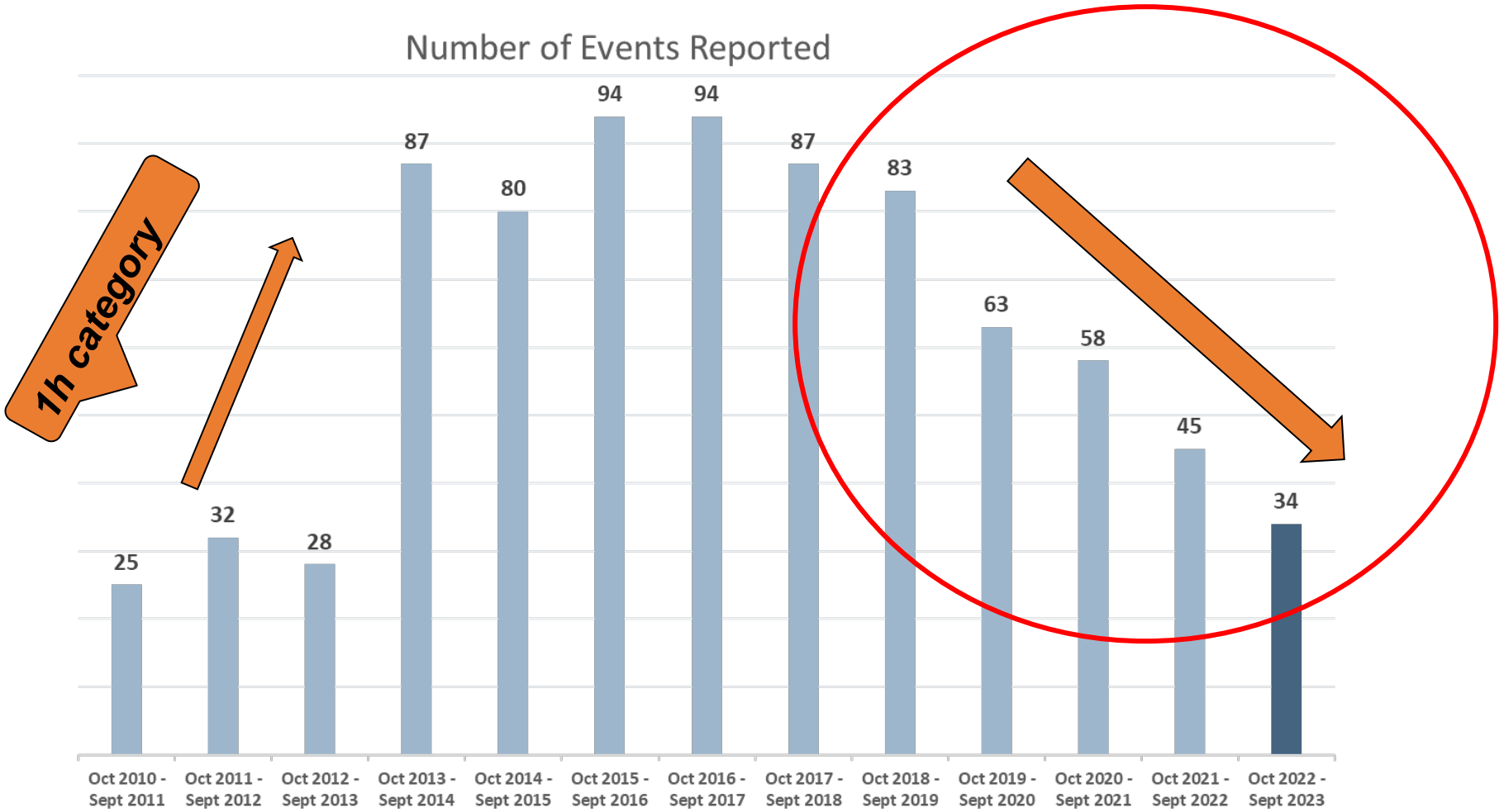
ERO Event Analysis Process

- Promote a structured and consistent approach to performing event analysis
- Values
  - ERO and industry to learn from off-normal events and to develop corrective actions to prevent recurrence.
  - Lessons to be learned and potential recommendations shared with industry to mitigate the risk of recurrence.
  - Effectiveness requires industry participation and support.
  - Continuous improvement is the mindset desired to instill in industry design and operating practices.

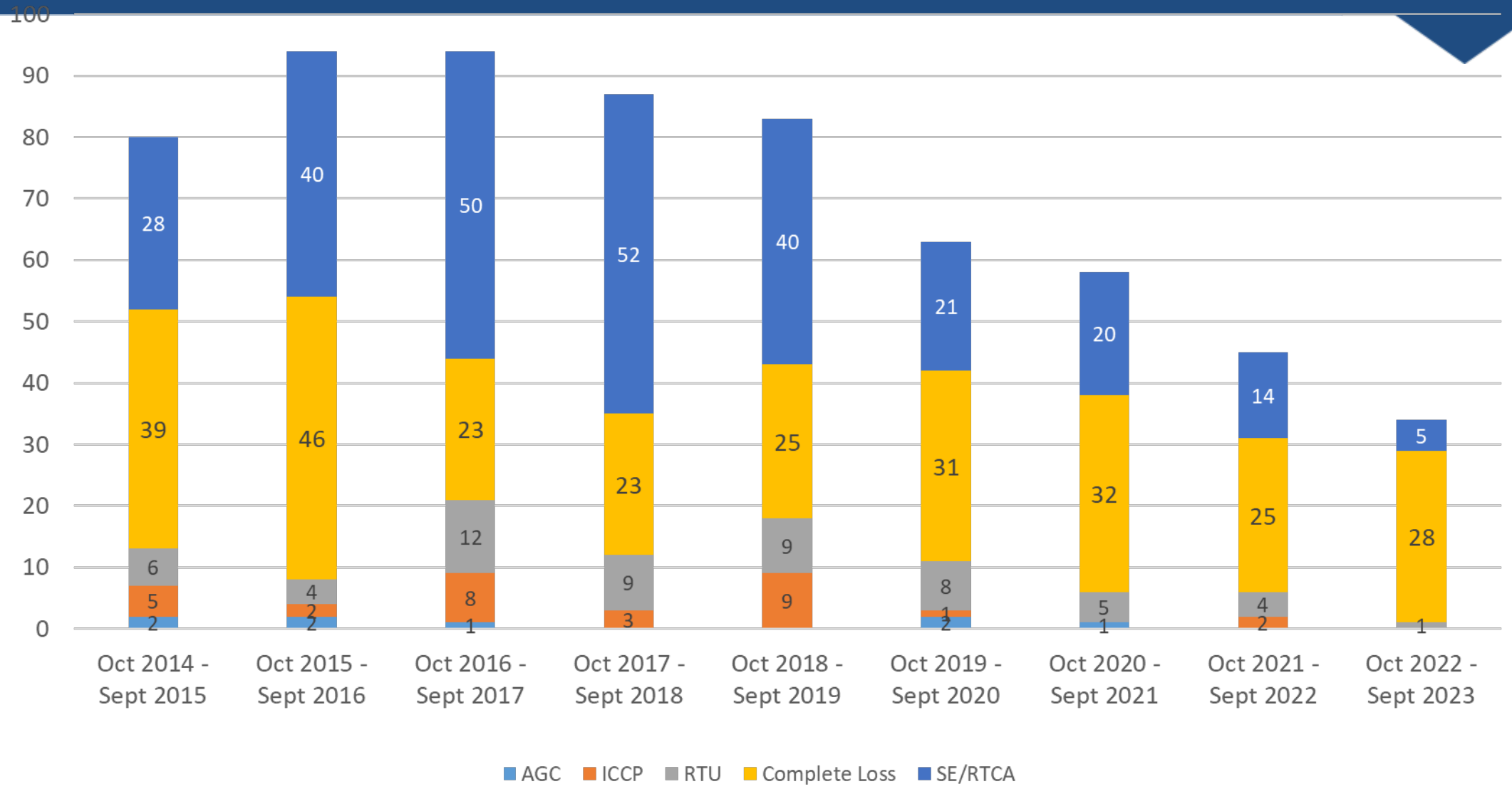
ERO Event Analysis Process



EMS Event Counts Trend



EMS Functions Trend



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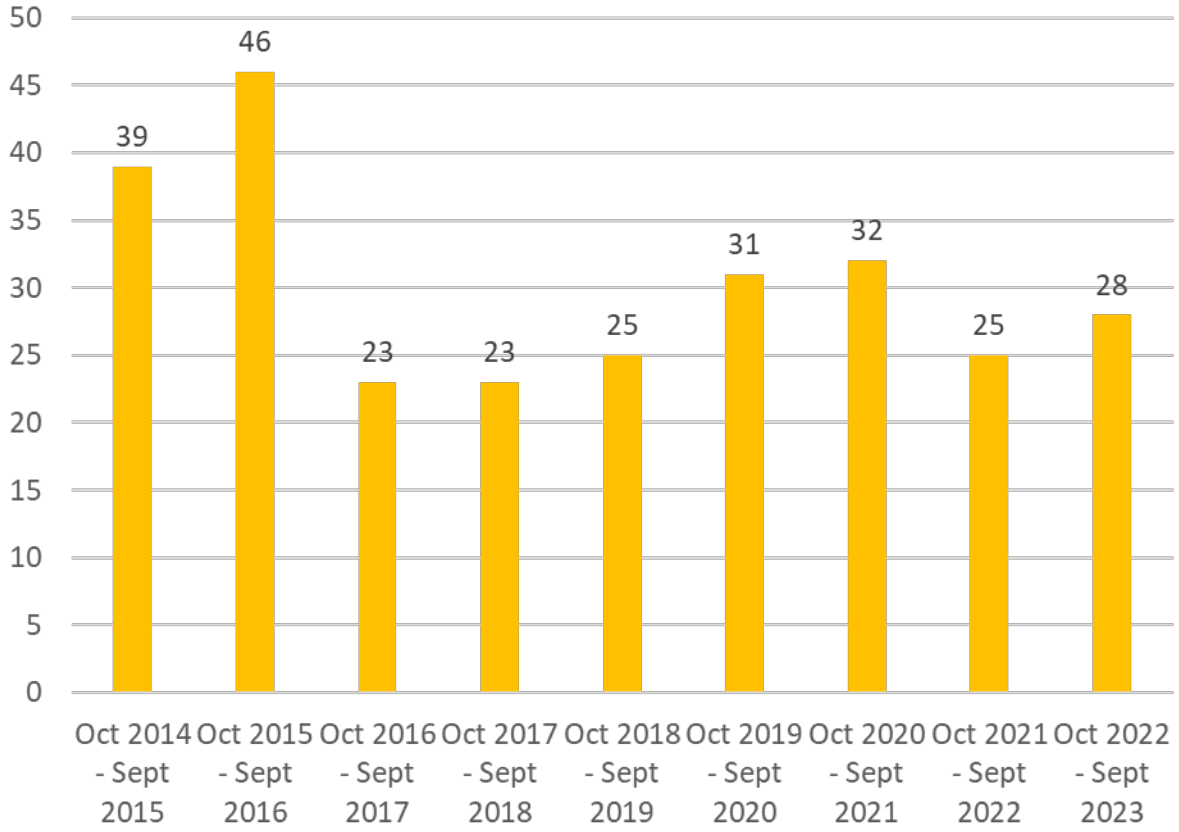
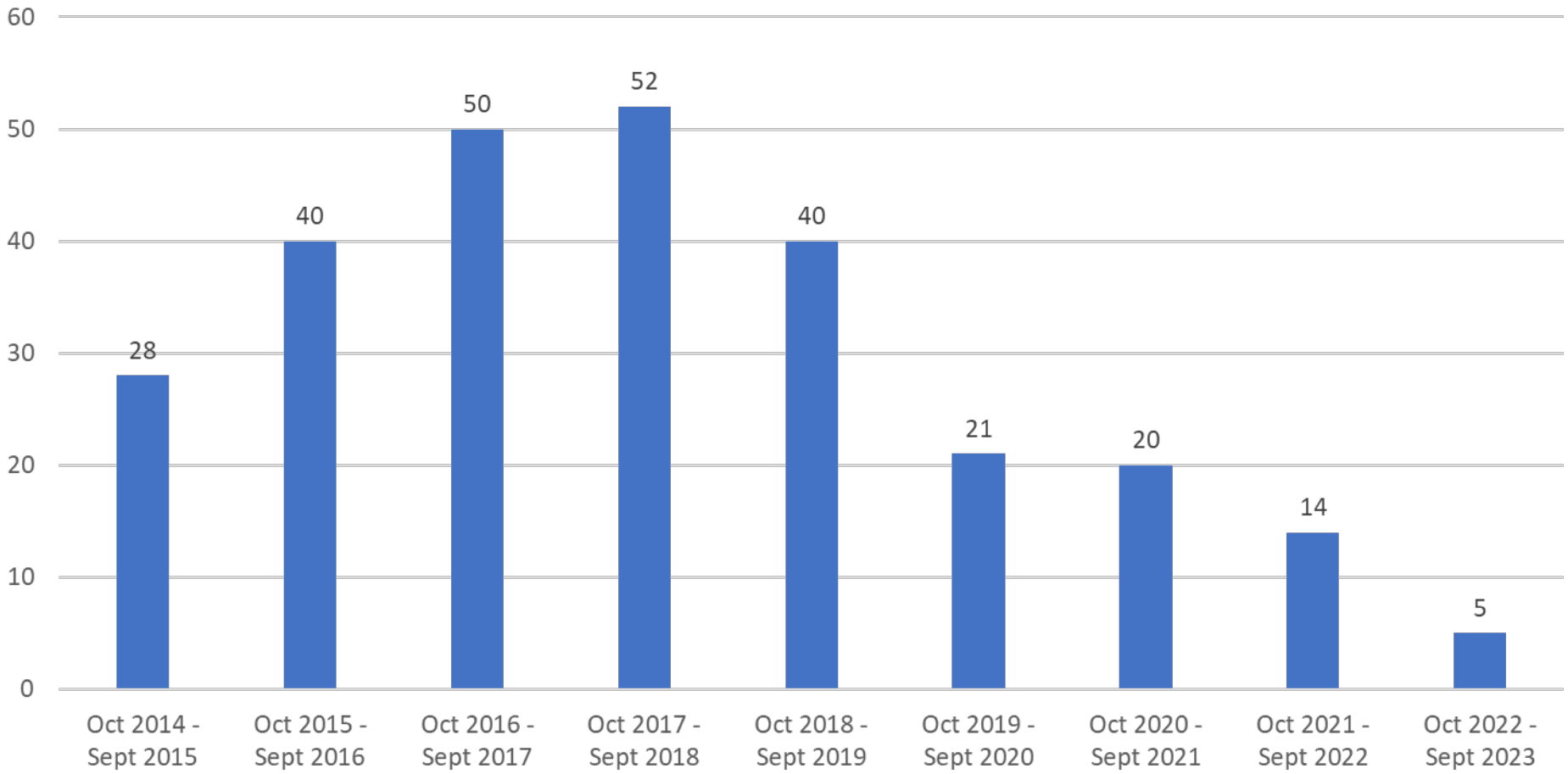
Trend of Complete Loss

- Redundancy and Diversity of Communications between PCC and BCC
  - Operators and the host EMS servers are on different physical sites
- Model update after EMS upgrade
  - Procedure
  - Testing
- EMS Health Assessment
  - Network communication (flapping)
  - Resource usage (disk, cpu, memory, etc)
  - 3rd party software (anti-virus, SQL, etc)
- Facility power
  - UPS/PDU



Trend of Loss of SE/CA



EAP 1h definition

- Original

  Loss of monitoring or control at a Control Center such that it significantly affects the entity's ability to make operating decisions for 30 continuous minutes or more.

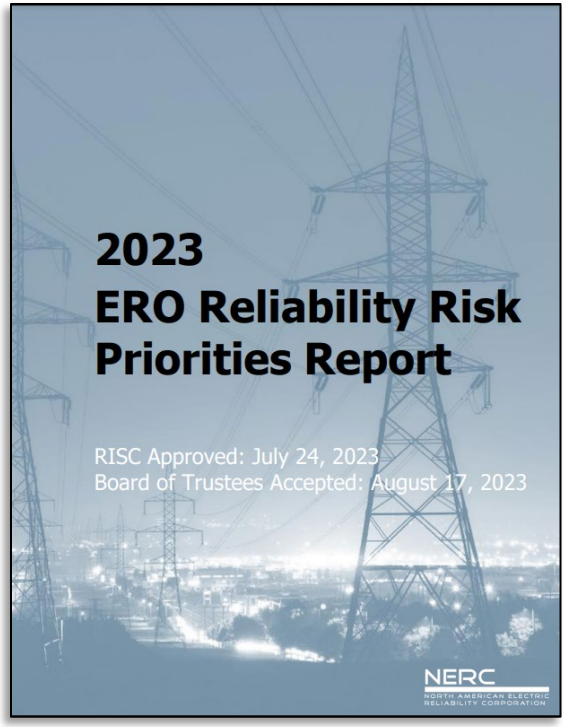
- Proposed 1h definition

  Loss of monitoring and/or control at a Control Center such that it degrades the entity's ability to make Real-time operating decisions that are necessary to maintain reliability of the BES in the entity's footprint for 30 continuous minutes or more

- "degrades" means less-than required functioning of any monitoring/control component, process, or capability.

2023 ERO Reliability Risk Priorities Report

- Loss of Situational Awareness
  - Manage (2019)
  - Monitor (2021)
  - Monitor (2023)



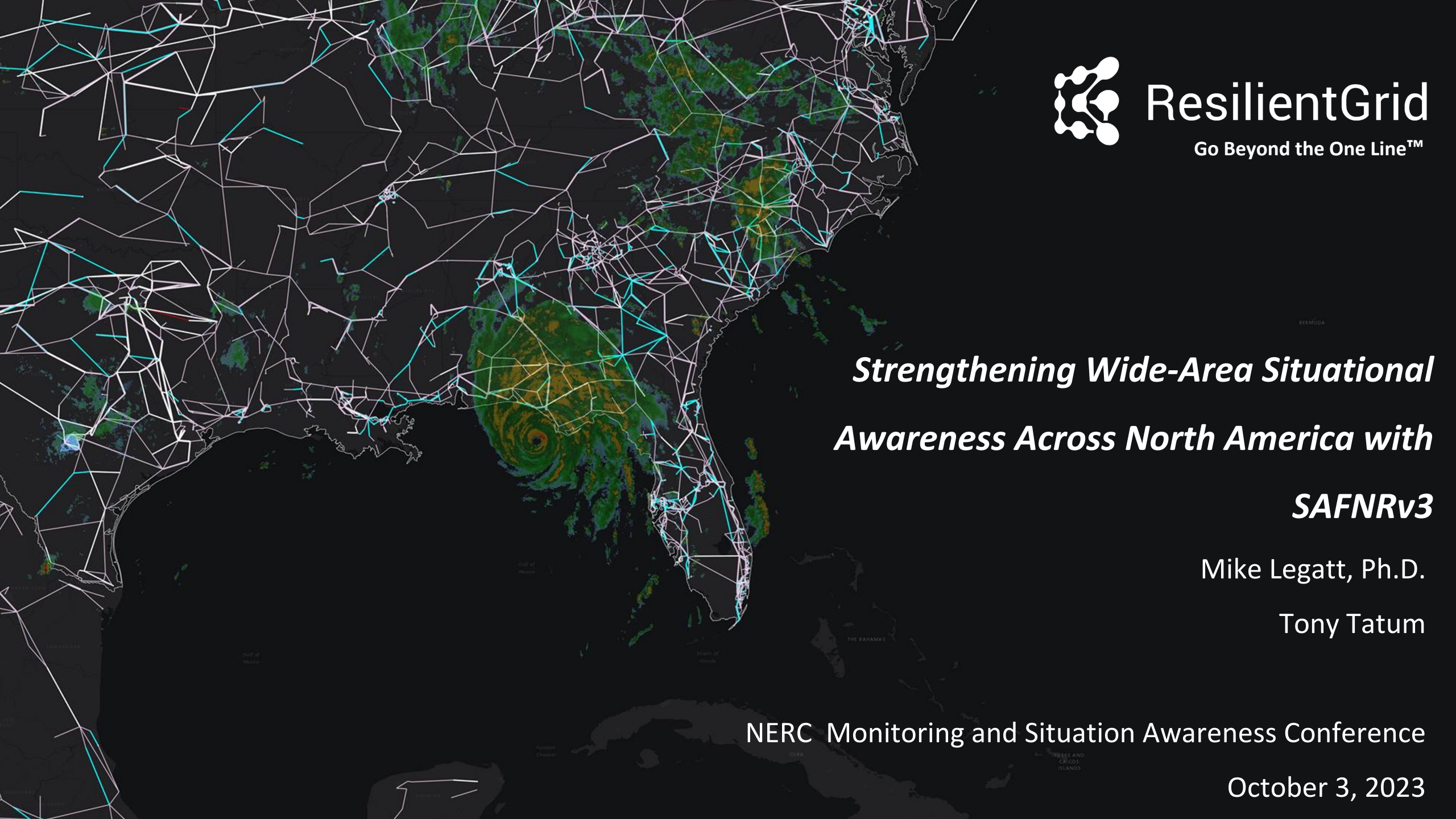
Changing Resource Mix	Manage - 2019	Manage - 2021	Manage - 2023
Resource Adequacy and Performance	Manage - 2019	Manage - 2021	Manage - 2023
Cybersecurity Vulnerabilities	Manage - 2019	Manage - 2021	Manage - 2023
Extreme Natural Events/Extreme Events	Monitor- 2019	Monitor- 2021	Monitor- 2023
Critical Infrastructure Interdependencies	Manage - 2019	Manage - 2021	Manage - 2023
Bulk Power System Planning	Manage - 2019	Monitor - 2021	Monitor - 2023
Physical Security Vulnerabilities	Monitor - 2019	Monitor - 2021	Monitor - 2023
Control and Protection Systems Complexity	Monitor- 2019	Monitor - 2021	Monitor - 2023
Loss of Situational Awareness	Manage- 2019	Monitor- 2021	Monitor - 2023
Human Performance and Skilled Workforce	Monitor - 2019	Monitor - 2021	Monitor - 2023
Electromagnetic Pulse		Monitor - 2021**	Monitor - 2023

Key Takeaways

- EMS reliability and resilience is continuously improving
- Complete loss became the most prevailing failure for the forth year in a row
- Calling for participating in the EAP
- Things we all can improve
  - Redundancy and Diversity of Communications between PCC and BCC
  - Testing and procedure of model update
  - EMS Health Assessment

Questions and Answers

Contact Information:
wei.qiu@nerc.net



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Go Beyond the One Line™

Strengthening Wide-Area Situational Awareness Across North America with SAFNRv3

Mike Legatt, Ph.D.

Tony Tatum

NERC Monitoring and Situation Awareness Conference

October 3, 2023

Core Philosophies:

"All organizations are perfectly aligned to get the results they get."
Arthur W. Jones

"For every complex human problem, there is a solution that is neat, simple, and wrong."
H.L. Mencken

Human Factors Overview

Complexity, Complicatedness, Speed and Depth

Complex: Many interdependent components

Hard to get order, control, or predictably. “Emergent system”

Complicated: Many independent components

Once you can separate components, you can deal with each of them systematically

Speed and Depth: Growth of big and fast data.

Drowning in data, thirsty for information

<u>Electric Power is increasing in all of these areas!</u>

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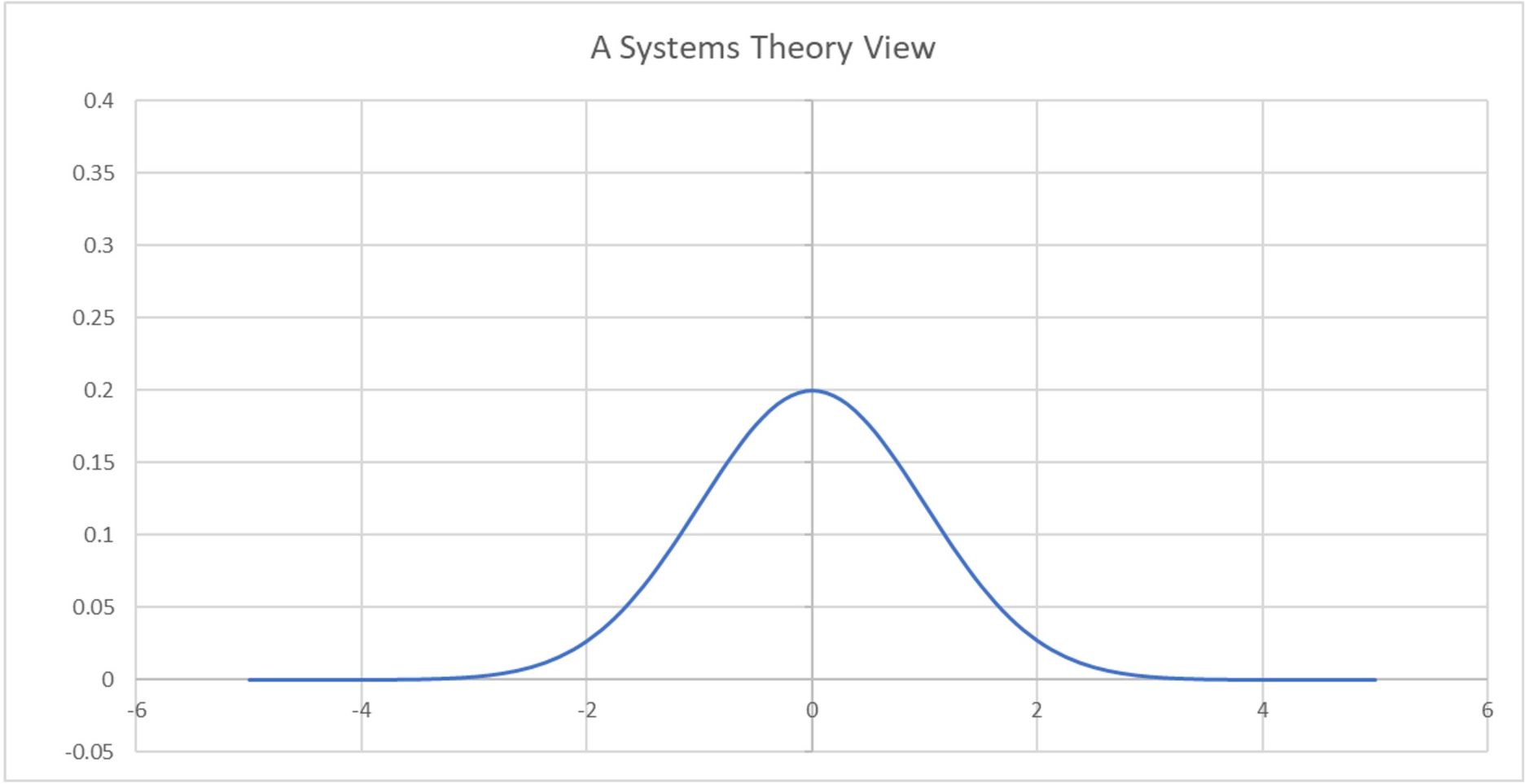
Where are we? A Systems Theory View



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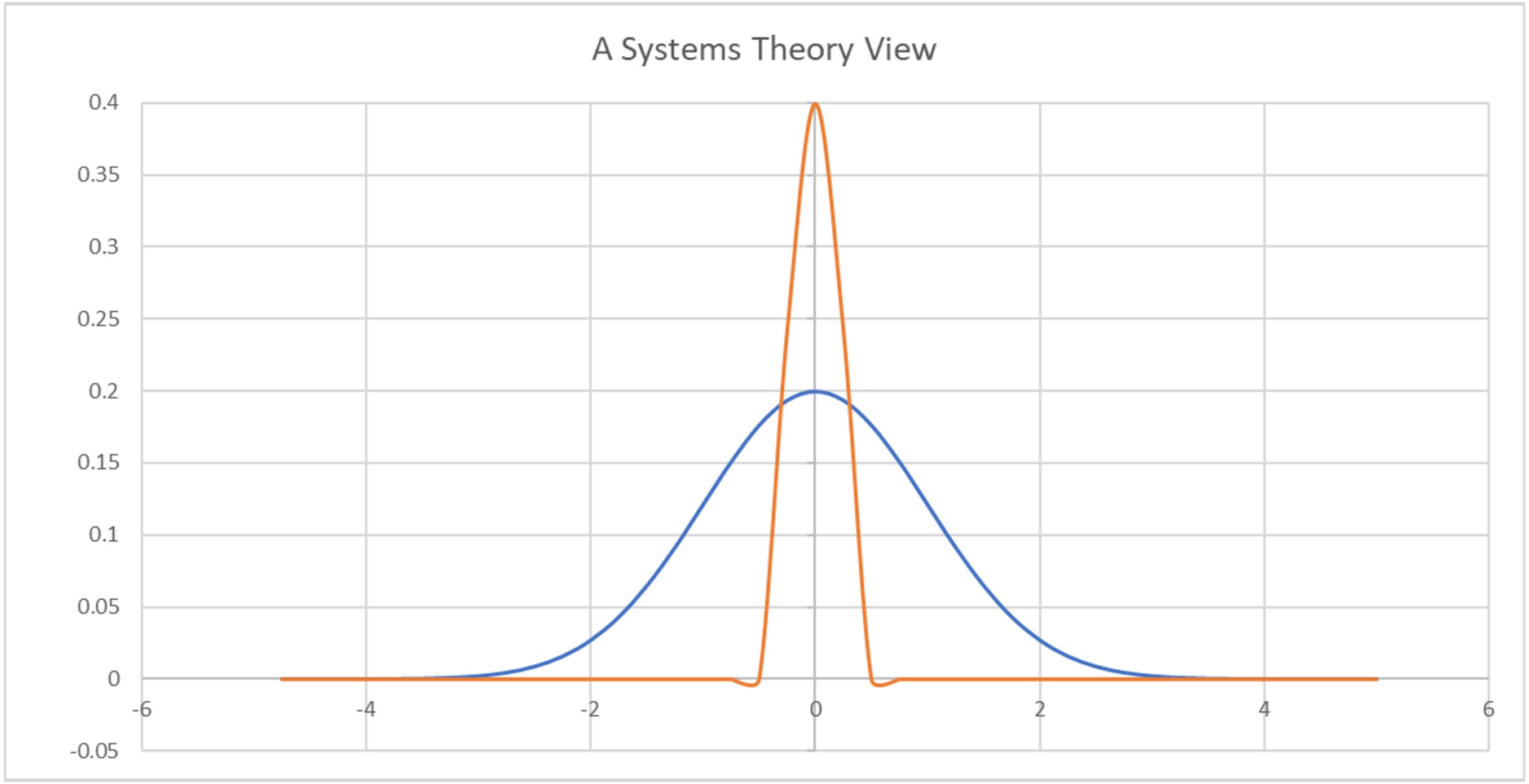

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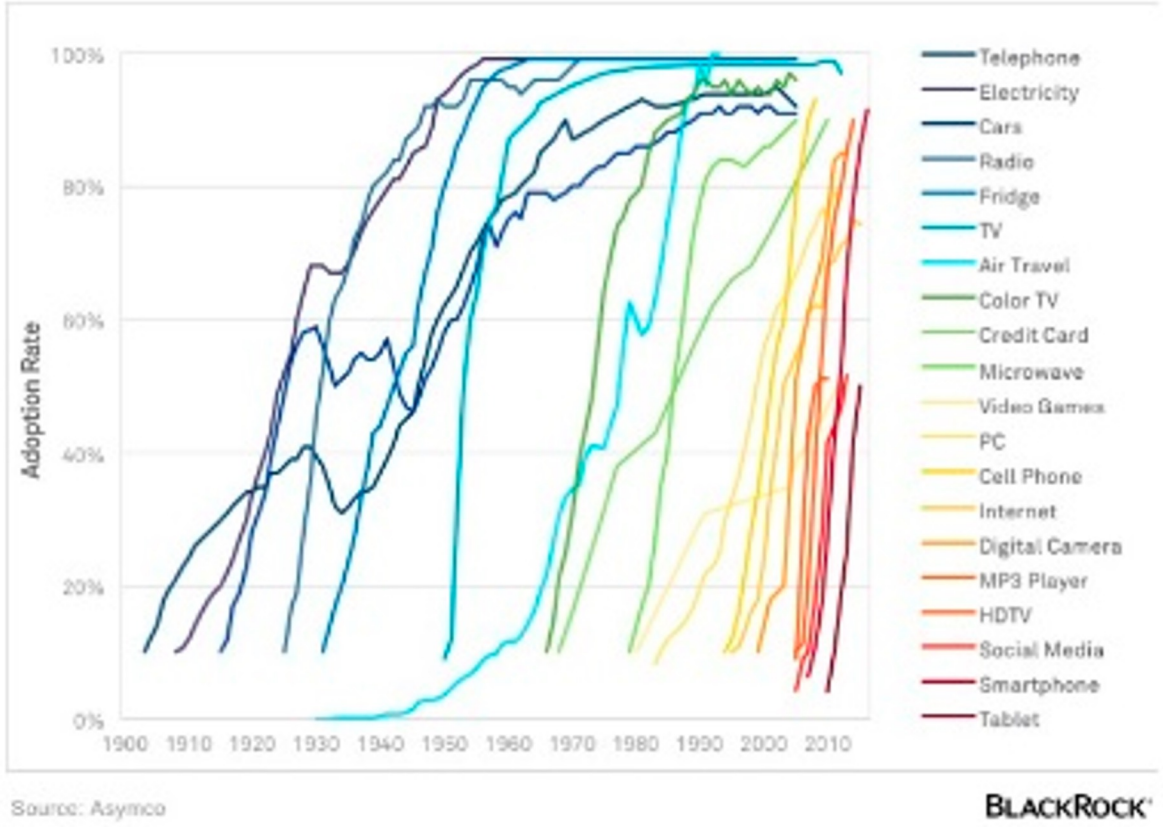
Growing Rates of Change

Yet Each Generation Keeps Coming on Faster Than the Last

Exhausting our Traditional Approach to Technology Enablement



Source: Asymco

BLACKROCK

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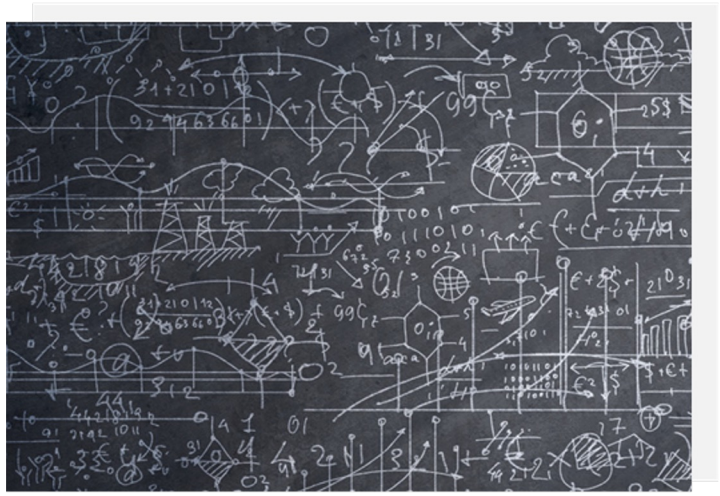
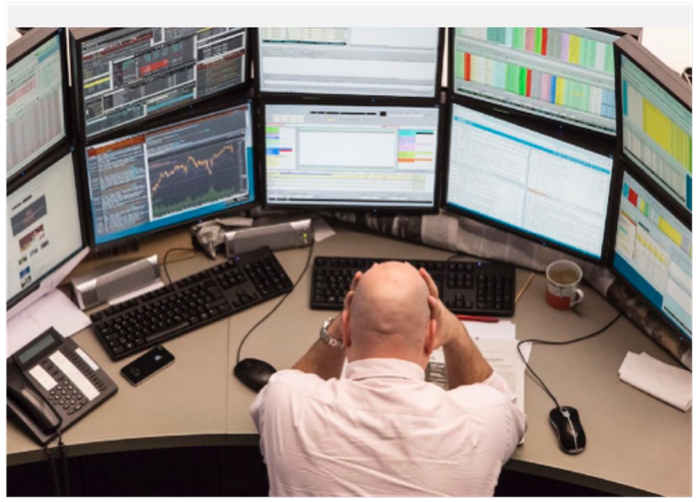
Image © Dom Hinchliffe

Increasing challenges



COMPLEXITY



STRESS

INTERDEPENDENCE

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Reliability, Robustness, Resilience

- Critical infrastructure resilience: physical and human components
- Resilience Engineering: Humans are the primary source of resiliency for an infrastructure
  - This is especially true as growing infrastructure nexus challenges occur (e.g., electric-natural gas)
- Therefore, to strengthen an organization's resiliency, you need tools to support and enhance operators'
  - Situational awareness
  - Decision-making
  - Collaboration

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Situational Awareness

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Data vs. Information

Shared SA / CROP

- **Common Relevant Operational Picture (CROP)** - Being able to share common views reduces friction and error risks. During events, ability to collaborate a critical function

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Shared SA / CROP

- **Mental Models** - How individuals internally represent the task they're performing, situation they're in, or technology they're using

- **Shared Mental Models** – team members having same understanding of
  - Team activities and task at hand
  - Team goals
  - Changing roles and responsibilities as events unfold
  - Procedures and processes

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SAFNR Overview

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SAFNRv3 Overview

- Hosted in secured data centers in Austin, Texas, and Suwanee, Georgia
- Users authenticated via NERC
- Connectivity through three MPLS networks: EIDSN, WIDSN, WAN
- Continuous work with RCs to maintain reliability as their systems and models change
- Updated network model:
  - EMS Network Models
  - ICCP Connectivity
  - Geospatial information for transmission infrastructure

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SAFNRv3 Overview

- Integrated situational awareness for NERC, FERC, REs and RCs
  - Supports timely communications and collaboration with key stakeholders
- Model and real-time data across the continental US for
  - Lines ≥ 200 kV
  - Units ≥ 500 MW
  - One bus per substation ≥ 200 kV
- Meteorological and Weather Data
- Weather alerts (e.g., flood warnings)
- External sources (e.g., wildfires)

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SAFNRv3 Status

- SAFNR Network Model in continuous improvement process
  - Integrated model built and updated from RC data (network model, geospatial, and ICCP data)
  - Ensuring the SAFNR model stays up-to-date is critical for shared situational awareness
    - Equipment within each RC territory, and the ties between the RCs
- Forced Oscillation Detection in SAFNR
  - UTK FNET to bring detected forced oscillation alerts into the RMS

FNET Overview

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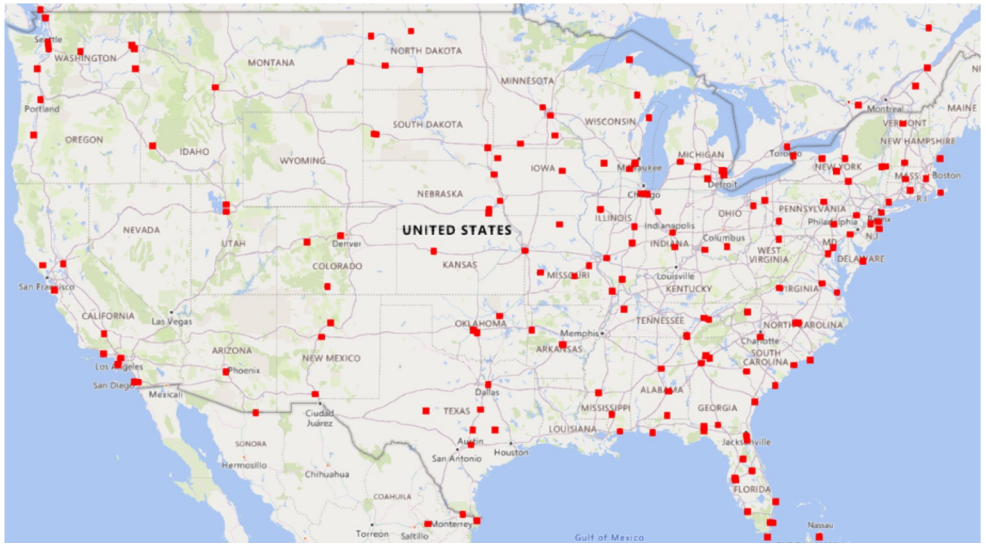
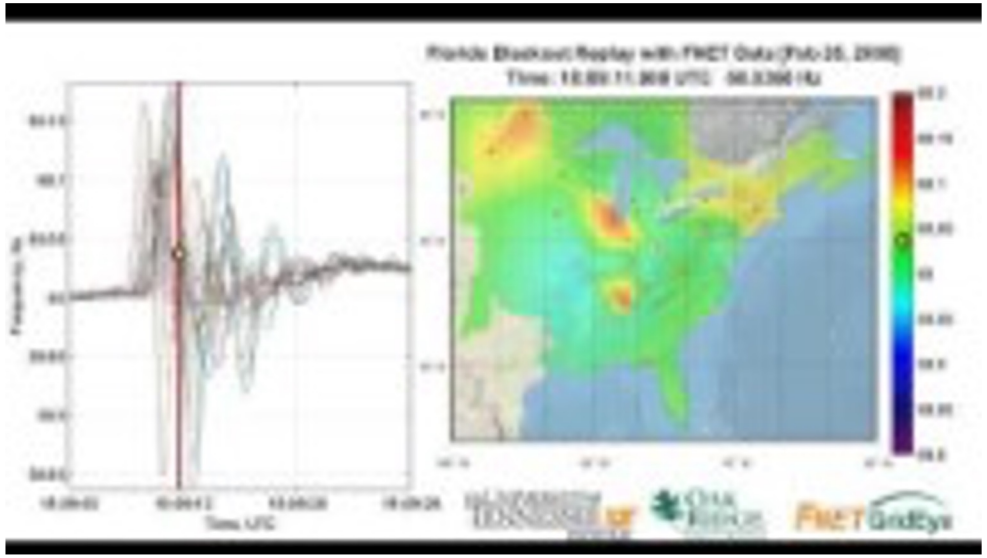
FNET Overview

- Developed at University of Tennessee, Knoxville
- Deployment of Frequency Disturbance Recorder (FDR) units around the US (and world)
- Location and triangulation of grid events, such as
  - Oscillations
  - Inter-area oscillations
  - Large unit and load changes





Source: UTK-FNET

Continuous Improvement

Continuous Improvement

- September 28, 2023: Synchronized Measurement Working Group (SMWG) presentation
  - Identifying oscillation modes and sources
  - Identifying use cases for different SAFNR users
  - Identifying opportunities to decrease user activation energy on post-forced oscillation activities
- Ongoing feedback from SANFR User Groups, and SAFNR users overall

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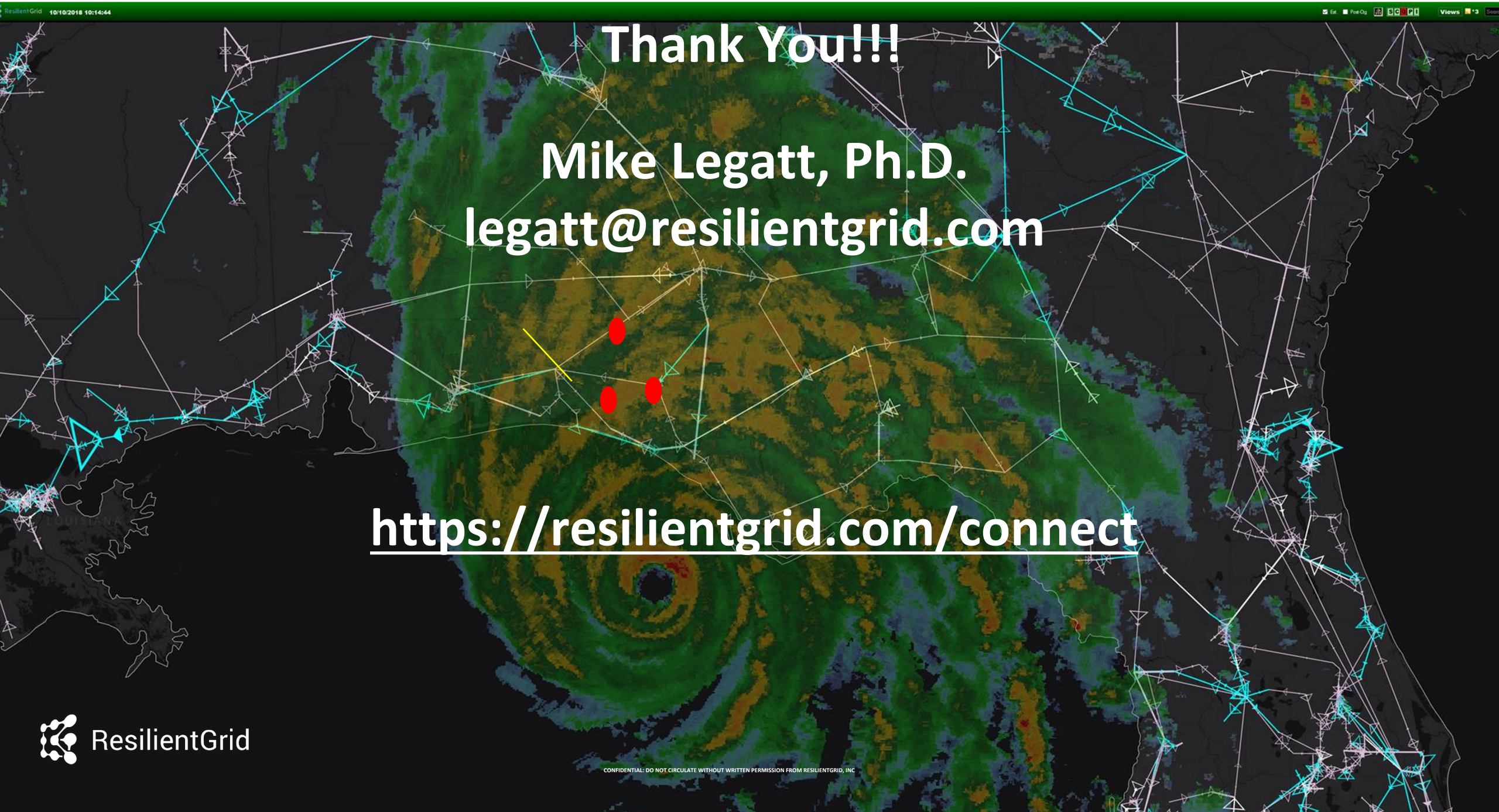

Thank You!!!

Mike Legatt, Ph.D.
legatt@resilientgrid.com

https://resilientgrid.com/connect

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FERC Order 881 and FAC-011 Implementation at Manitoba Hydro

NERC Monitoring and Situational Awareness

October 2023

Kristy Prystay – Power System Applications Lead Engineer
kprystay@hydro.mb.ca
Brent Schellenberg – EMS Applications Engineer
bschellen@hydro.mb.ca

Manitoba Hydro

Content

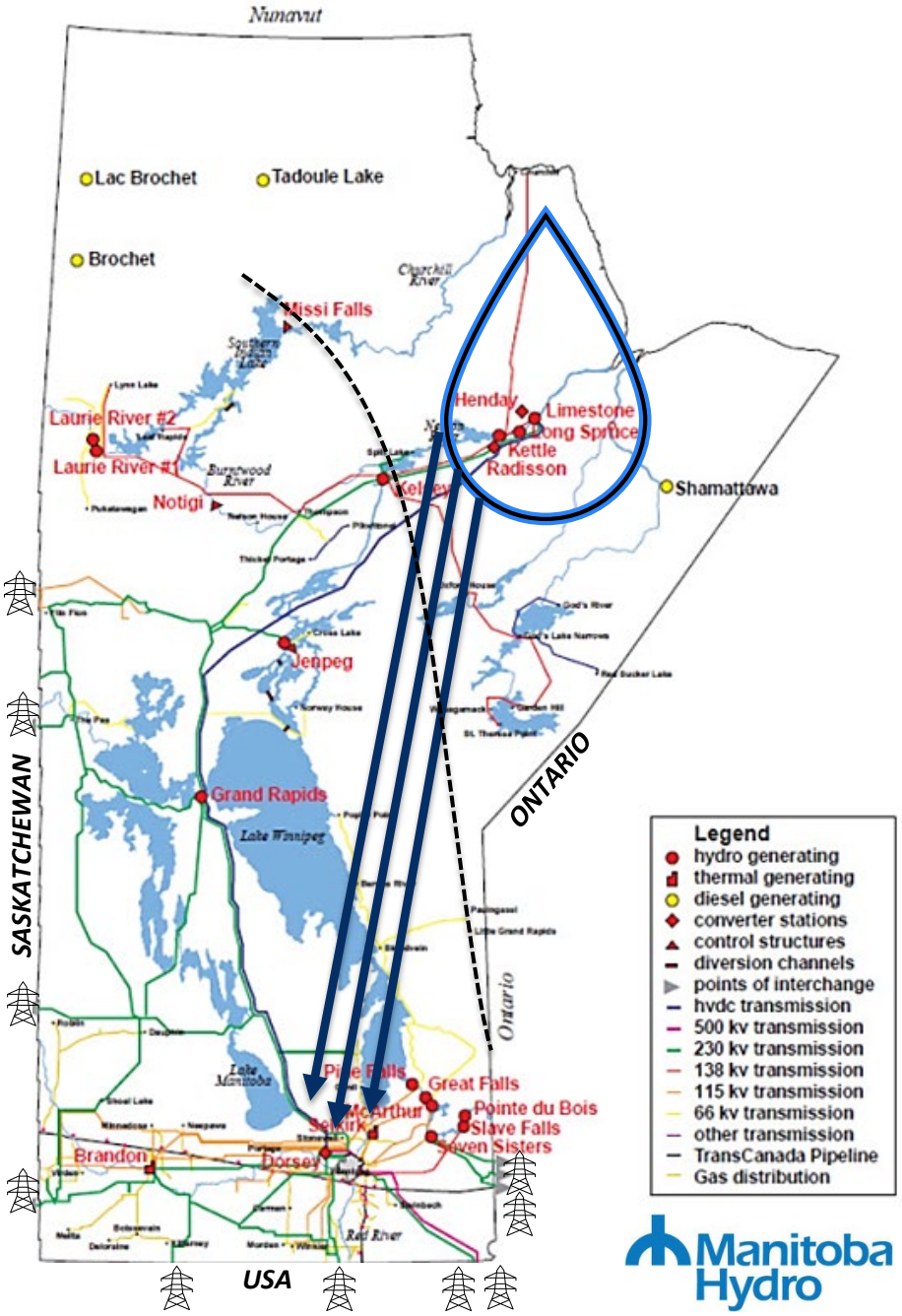
- Introduction
- FERC 881
- FAC-011-4
- Implementation
- Q&A

Manitoba Hydro

Manitoba Hydro is a vertically integrated utility; responsible for power generation, transmission, and distribution in the Canadian province of Manitoba

System features:

- ~6200 MW Gen and ~5000 MW Peak Load
- ~95% Hydro and ~11,000 km of Transmission Lines
- Asynchronous Norther Collector system island connected by 3 HVDC Bipoles
- Tie lines to SaskPower, MISO, Hydro One
- Variety of SPS/RAS, 2 SVCs, Phase Shifters on the interface and internally, fast switching capacitors



Where does Manitoba Hydro fit into the big picture?

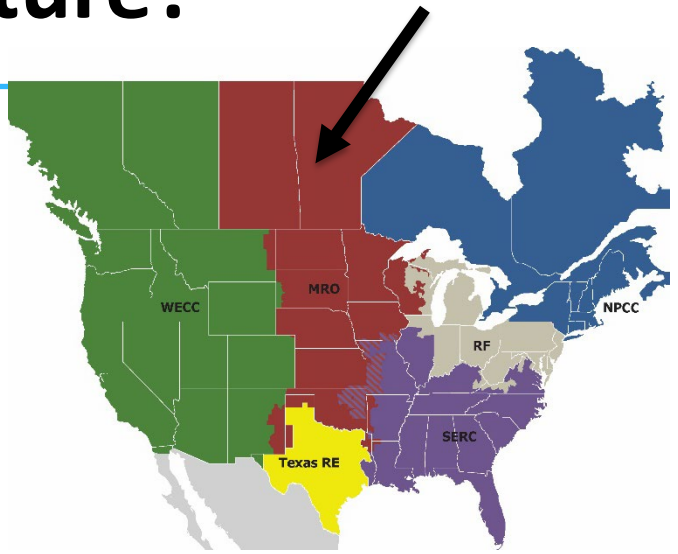
MH is part of the Midwest Reliability Organization (MRO)

-is a regional electric reliability council under North American Electric Reliability Corporation authority (NERC)

-ensures entities are in compliance with mandatory reliability standards

-conducts assessments of the grid's ability to meet electric power demand

-analyzes regional system events



MH is part of Midcontinent Independent System Operator (MISO)

- MH is a coordinating member of the MISO organization

- MH has very strong interconnection with MISO
  Export capacity 3100 MW
  Import Capacity 1400 MW

- MISO serves as MH Reliability Coordinator

Significant Changes

MH System Operations will experience significant changes:

- **FERC order 881**
  - July 2025
- **FAC-011-4**
  - April 1, 2024 (USA)
  - July 1, 2025 (Manitoba)
- **GE EMP 3.4 upgrade**
  - Q3 2024

Manitoba Hydro

FERC 881

FERC issued order 881 requesting entities to implement the following by July 2025:

- Implement Ambient Adjusted Rating (AAR)s for real-time operations and forecasted hourly for the next 10 days
- Implement seasonal ratings beyond day 10 (minimum 4 seasons)
- Develop a methodology for emergency ratings for AAR
- Use AAR/seasonal rating in Transmission Service Request (TSR) evaluations
- Implement necessary tariff changes

Update Facility Rating Methodology and Applications

- Define four seasons and associated ratings

Manitoba Hydro

FERC 881 Tasks

Implementing AAR in the MH System Control Center

- Divide province into temperature zones and identify BES Facilities in each zone
- Transfer ambient ratings from Facility Ratings System (FRS) to EMS
- Bring temperature measurements and forecasts into EMS for each zone
- Integrate the RTDYN application into EMS for both real-time and forecast instances
- Update operating instructions and operator training
- Transfer current and future ratings to MISO via Limit Exchange Portal (LEP)

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FERC 881 Jurisdiction

- MH is Not Under FERC Jurisdiction
- MH is voluntarily implementing these recommendations

Why?

- Maximize our system usage
- Use current capacity more effectively
- Make better informed decisions regarding system expansion
- Reduce alarms by using ambient ratings compared to a conservative seasonal fixed limit rating
- Will (hopefully) reduce the number of SOL exceedances
  - Reduce impact on operators
  - Reduce compliance burden

Manitoba Hydro

FERC 881 - MH AAR Methodology

Day/Night Ratings

- Analysis on day-night ratings has been completed
- Night: no solar radiation, less wind (negates the cooling affect)
- Day: solar radiation, more wind (increases cooling affect)
- Our studies concluded there is no advantage for individual day and night ratings at the same ambient temperatures

Manitoba Hydro

FERC 881 - Seasonal Facility Ratings

- Developed 4 seasonal ratings for use in seasonal study analysis
- MH network model based on the following:

Season	Ambient Temperature [°C]	Solar Altitude Assumption	Soil Temperature °C (Southern Manitoba)	Soil Temperature °C (Northern Manitoba)
Spring April 01- May 31	20	May 31 high noon	5	0
Summer June 01 – Aug. 31	40	June 21 at high noon	20	20
Fall Sept. 01- Oct. 31	20	September 01 at high noon	20	20
Winter Nov. 01– March 31	0	March 31 high noon	5	0

- MH determined air temperature and soil temperature will be treated independently
- Underground cables will require seasonal rating for only winter and summer.

Manitoba Hydro

FAC-011-04

- FAC-011-4 standard now requires that RTCA violations are reported as SOL exceedances based on associated timer logic
- May identify where system improvements are required
- Requires multiple EMS application enhancements
- RTCA will be used to report steady-state alarming instead of, or in conjunction with SCADA
- Operating procedures will change due to SOL timing requirements
- DSA Tools (VSAT and TSAT) implementation in real-time

Manitoba Hydro

FERC 881/FAC-11 EMS Changes

	Now	In 2025
Number of Seasons	2	4
Real-time System operation	Seasonal Ratings are used. Apply Ambient rating by exception	AAR will be used full time
Applying AAR	Manual override by operators when needed	Automatic by dedicated EMS application (RTDYN)
Change of rating	Twice a year	Every hour
Emergency Rating for AAR	No	Two emergency Ratings
Monitoring of timer logic and SOL Exceedance Communication with MISO	No	Yes

Manitoba Hydro

EMS - Implementation

Expected to be implemented in a two phase EMP Upgrade project:

- Base product upgrade from EMP 3.2 to EMP 3.4
- RTCA:
  - Support for FAC-11
  - Any number of limits and individual timer logic per violation
  - Recording and reporting of SOL's
- RTDYN:
  - Support for Ambient Adjusted Ratings in real-time and 240 hour forecast
  - Modeling RT AARs in ICCP from RTDYN
  - New RTDYN Forecast tool for lookahead ratings
- Limit Exchange Portal
  - WebAPI will be used to exchange hourly ratings for next 10 days with MISO
  - Container-based implementation

Manitoba Hydro

EMS – Facility Ratings System

BES Facility Ratings are now ambient determined at the following levels:

- Normal, E1, E2, LDSH

The Facility Ratings System is being updated to support:

- Additional emergency ratings
- 4 seasons
- AAR -50 to 50°C (58 to 122°F)

Sample: Seasonal ratings

Season	Normal Rating	Emergency Rating I	Emergency Rating II	Emergency Rating III
Season I				
Season II				
Season III				
Season IV				

Sample: AAR ratings

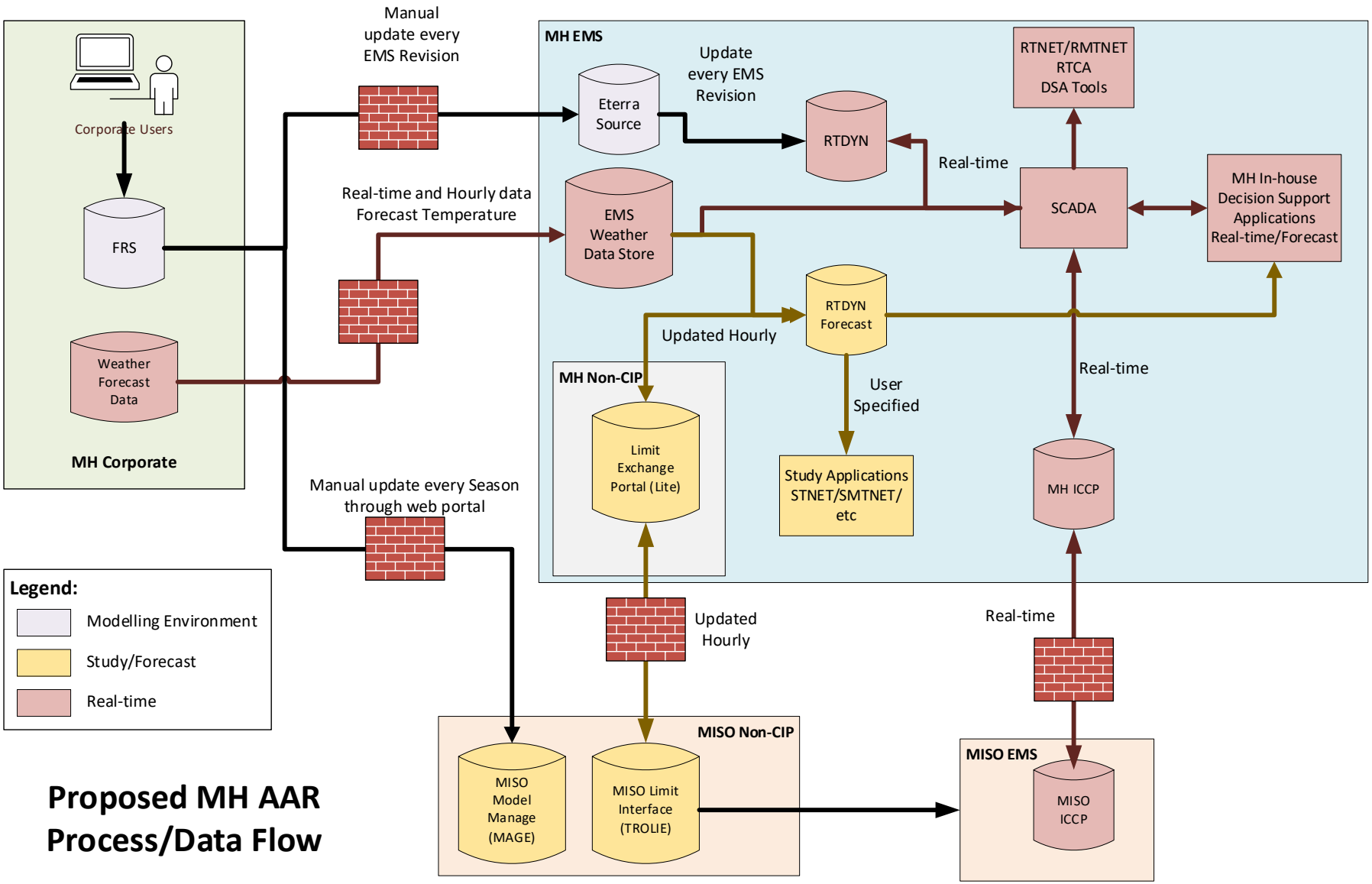
Temp. (°C)	Rating			
	Normal	Emer. I	Emer II	Emer III
-50				
-45				
-40				
⋮				
40				
45				
50				

EMS - Transferring Ratings to MISO

- Seasonal rating: Using MAGE modeling system
- Real-time AAR: Using ICCP
- Forecasted AAR: GE Limit Exchange Portal
  - MISO will act as clearing house when facilities have multiple owners
  - MH will get final rating for tie lines from MISO
  - MISO to store rating history
  - One can query the real-time rating for a line on a given date and time for the last 5 years

Manitoba Hydro

Proposed MH AAR Process/Data Flow



Proposed MH AAR Process/Data Flow

Some Notable Experiences

- FERC 881 forces us to look at different in-house applications which use ratings and combine logic
  - GLAP (Load Forecast), ADHAP (HVDC Limits)
  - RTDYN becomes the single system-of-record
- The requirement for topology driven limits adds another layer of complexity
- This project opened lines of communication between different groups allowing
  - Improvement of FRS methodology
  - The discovery of incorrect assumptions (e.g. cable subcomponents are subject to AAR)
  - Improved collaboration between Asset owners and Operations groups

Manitoba Hydro

Questions?

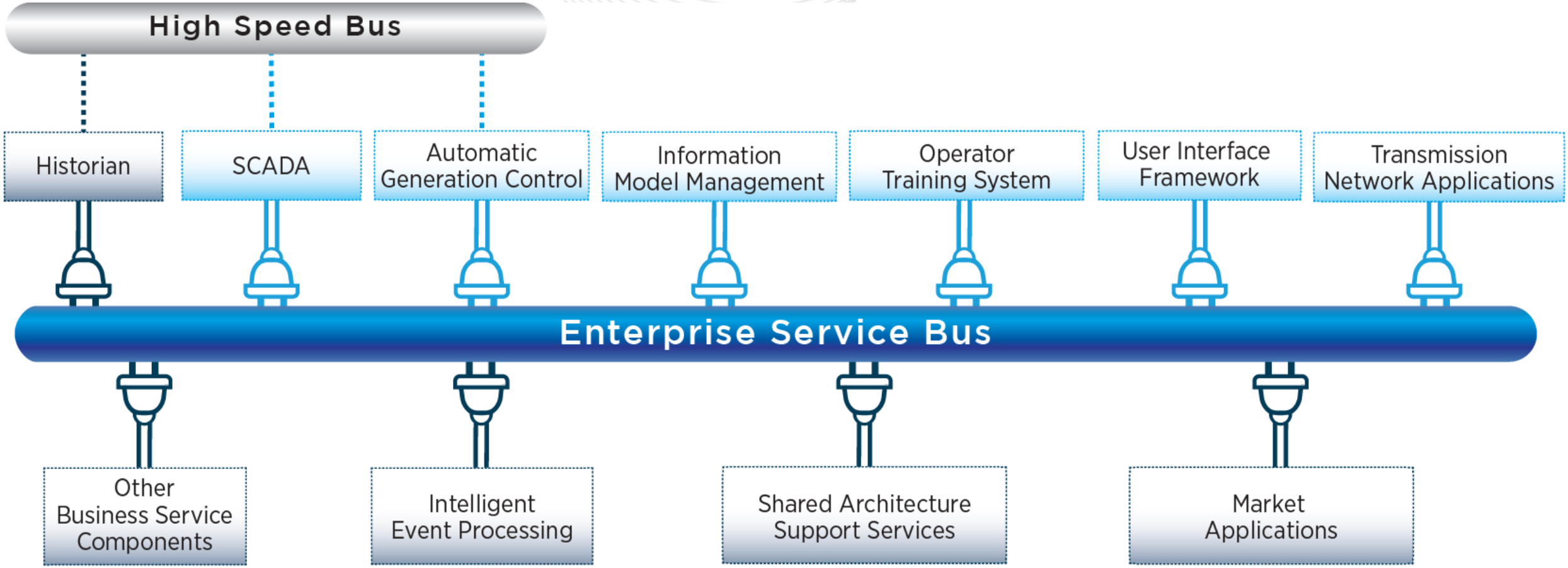
Manitoba Hydro

PJM EMS Upgrade and Cutover Practice

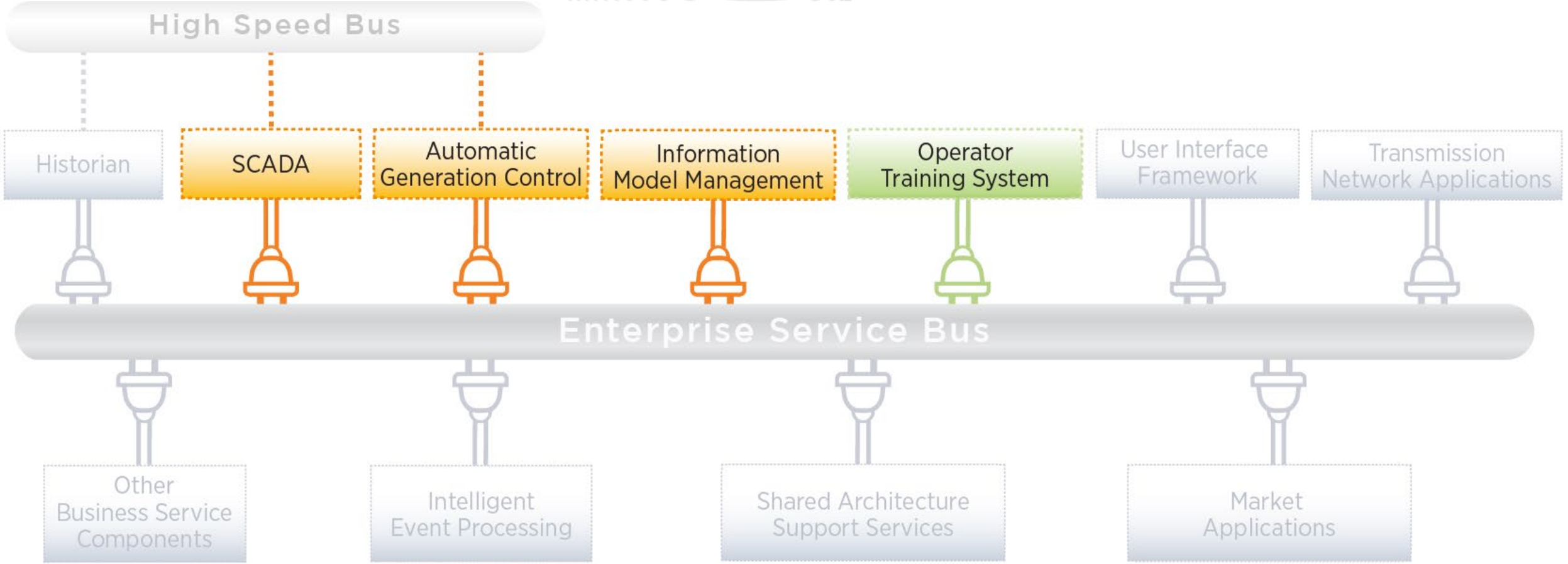
Adamy Garcia
Manager, EMS Technologies
Jeff Tiemann,
Sr. Manager, EMS Technologies

EMS Upgrade Overview

PJM's Service Oriented Architecture (SOA) Implementation



EMS Upgrade Scope



Dual Primary Control Centers

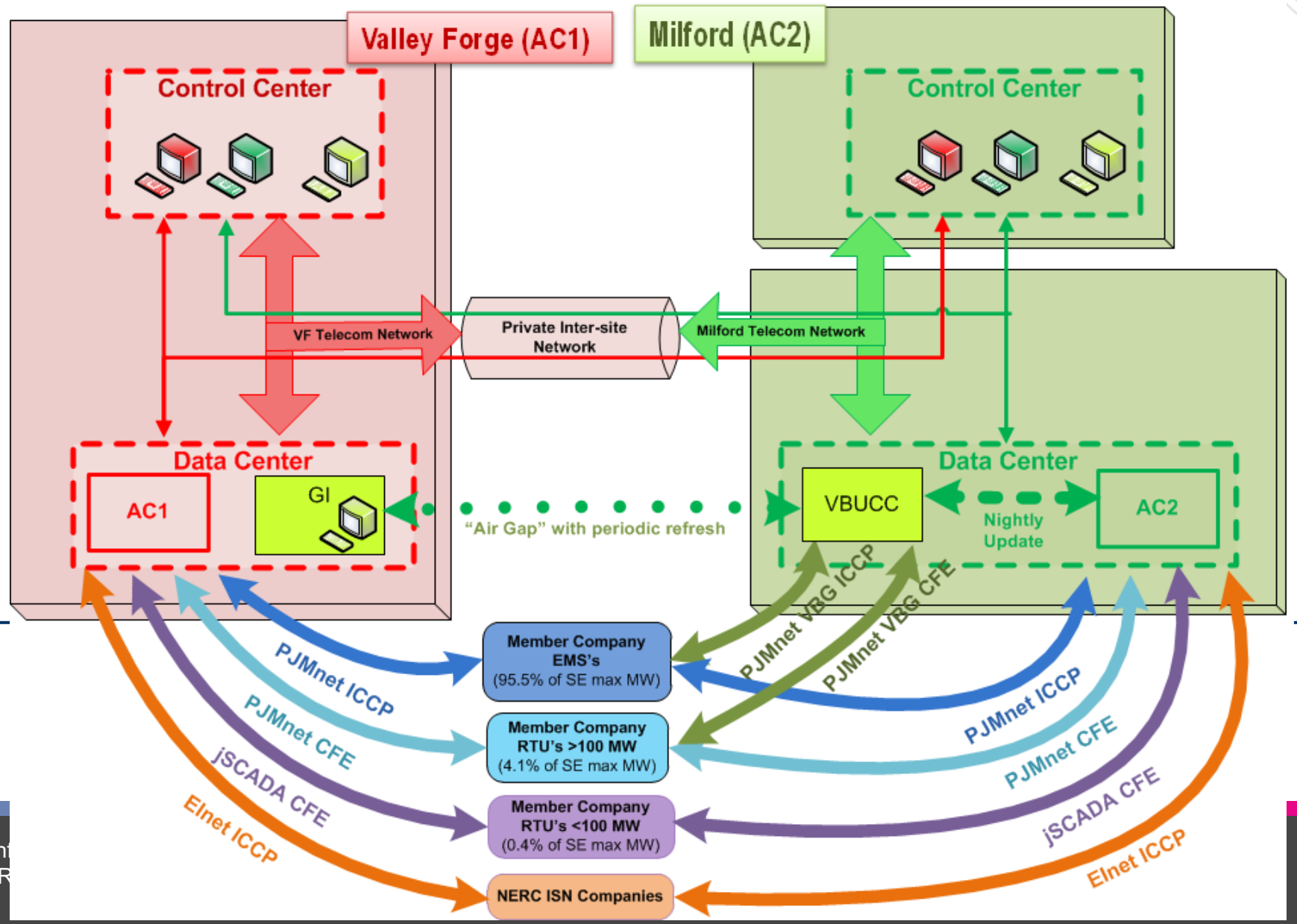


Illustration of PJM's redundant communication between AC1 and AC2 and continuous communication, operational awareness of our Member Companies

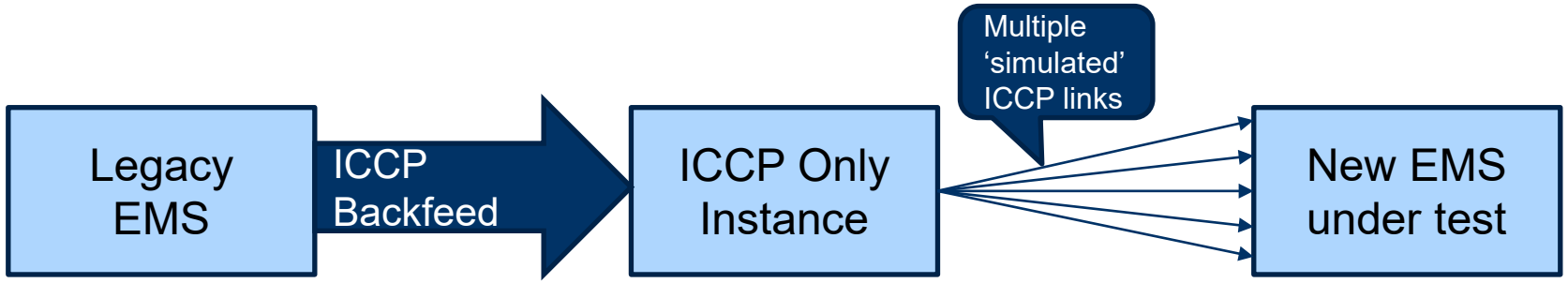
PJM

PJM Member Companies

EMS Upgrade
Testing and Mock Cutovers

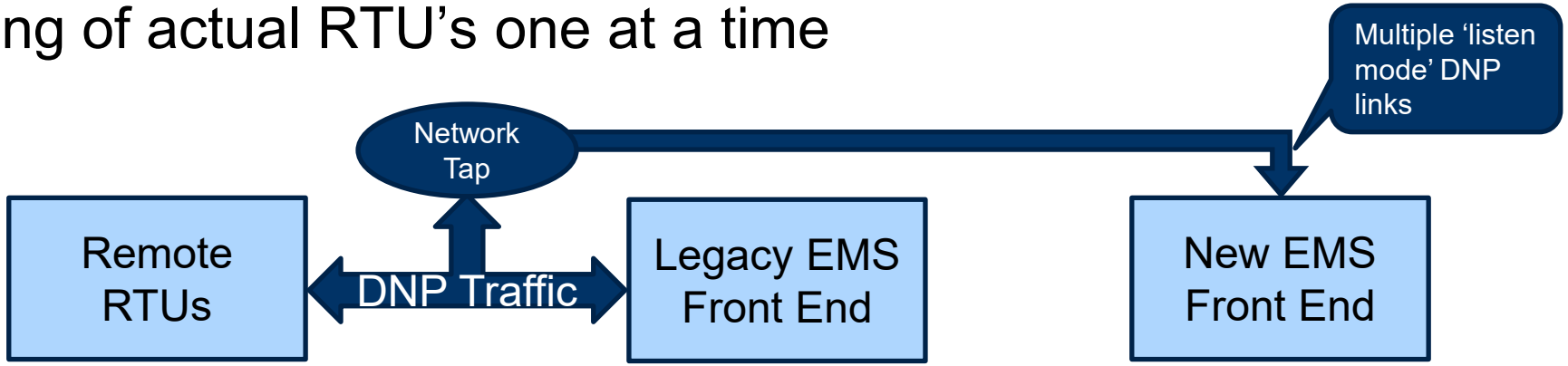
ICCP Testing Approach

- Used ‘backfeed’ ICCP link with all incoming data from ‘legacy’ EMS
- Used intermediate ‘ICCP only’ instance to act as ‘remote’ feeds
  - Flipped client and server points from production definitions
  - Allowed for override data testing without impacting production data
  - Allowed for ‘alarm flood’ testing by toggling breakers on intermediate system
- Direct testing of actual ICCP links to remote EMS systems one at a time



RTU Testing Approach

- Use of test RTU to simulate specific RTU configurations
  - RTU was able to simulate multiple RTU configurations
  - Testing manual overrides to values and qualities with no production data impacts
  - Use of ESP8266 Microcontroller (MCU) for continuous ‘closed-loop’ and performance testing
- Tested RTU’s in ‘listen’ mode
  - Allowed testing of incoming data on all RTU’s in parallel
  - Used existing network monitoring taps to forward DNP traffic
- Direct testing of actual RTU’s one at a time



Automated Tests

- Automated Daily Health Checks
- Alarm Comparison Checks
  - Alarm consistency between new EMS sites
  - Alarm consistency between new and old EMS
- Data Consistency Checks
  - Both value and quality code exceptions
- Alarm Flood Testing
  - Breaker toggles by volume and time

- Tests client SSO login for each domains

- Tests if any processes are dead
- Tests if any processes restarted in a 3 minute window
- Checks if the failover health of every monarch node is healthy
- Queries the alarm historian for any alarms within a configured period
- Checks a list of configured system values

- Checks that the analog, status, accumulator, station, units, plants, tie lines, and setpoint counts are the same across domains

- Checks if a configured ICCP import point has not updated within a configured time period
- Check if a configured ICCP export point has not sent within a configured time period

- Tests if a configured synchronization health metric for the measurement sync is healthy

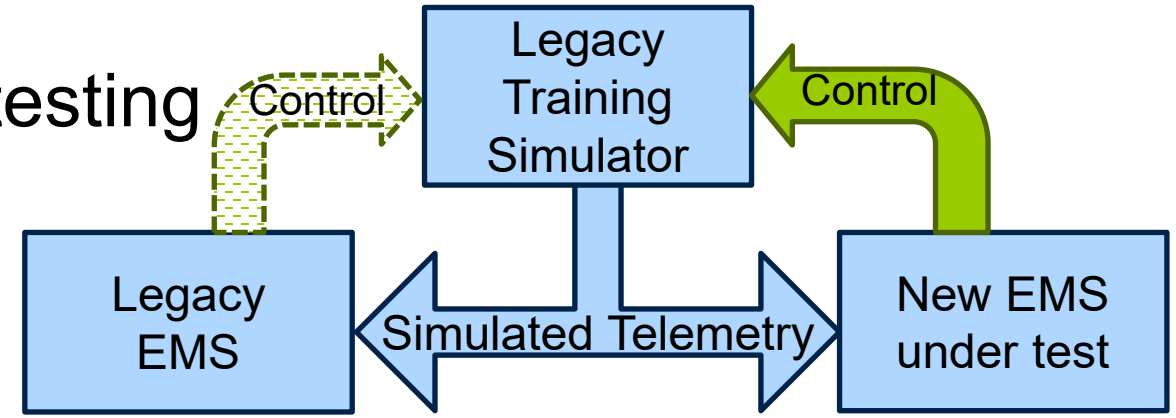
- Warn for any SOA task that has more than a configured number of failures
- Warn for any SOA task that has not run within a configured time period

- Tests that the state of each GPS clock is 'ONLINE'
- Warns if the GPS clocks timestamp hasn't updated within a configured time period

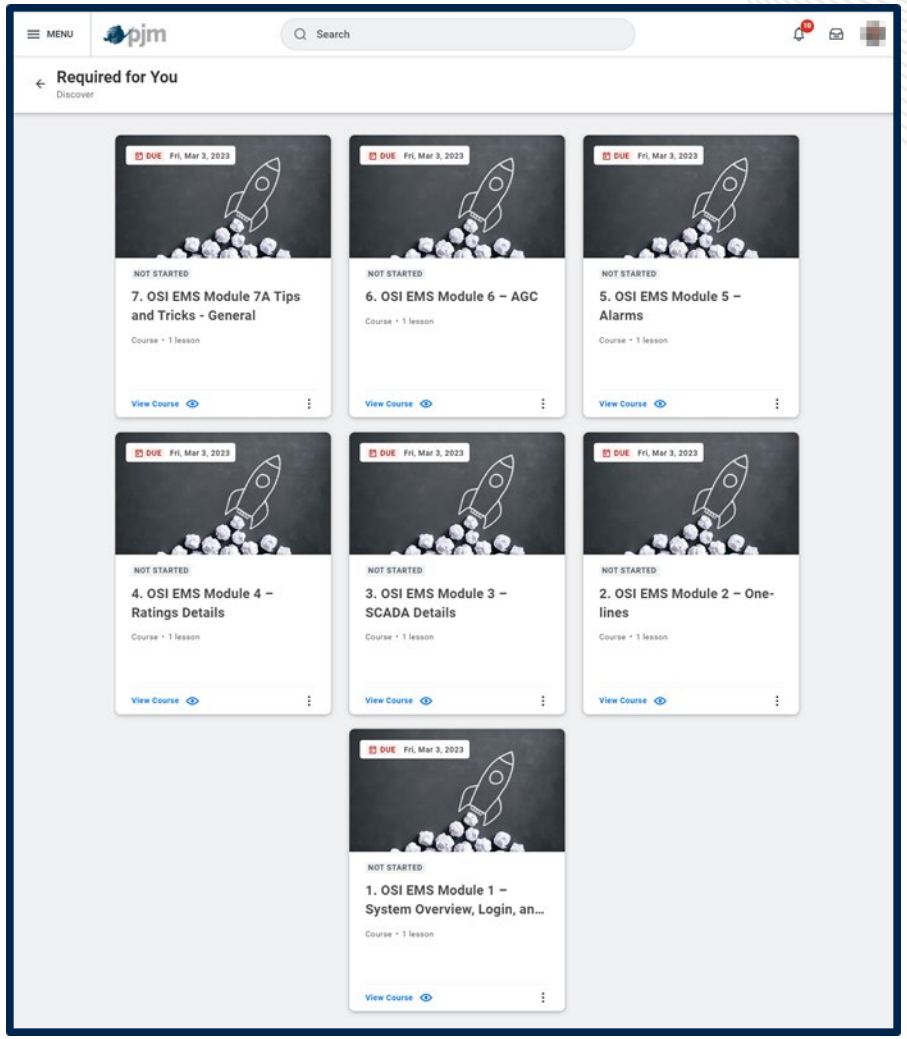
- Tests that each configured calculation formula record is 'ON'
- Checks that the state of each formula record is 'ACTIVE'
- Warns if the calculation formula has not run within a configured time period

Training Simulator

- Existing simulator was updated to feed multiple EMS instances
  - One in ‘listen’, one in ‘control’
  - Able to configure either ‘new’ or ‘old’ in ‘control
- Used for operator training
- Used for ‘side by side’ application testing
- Used for ‘island mode’ testing



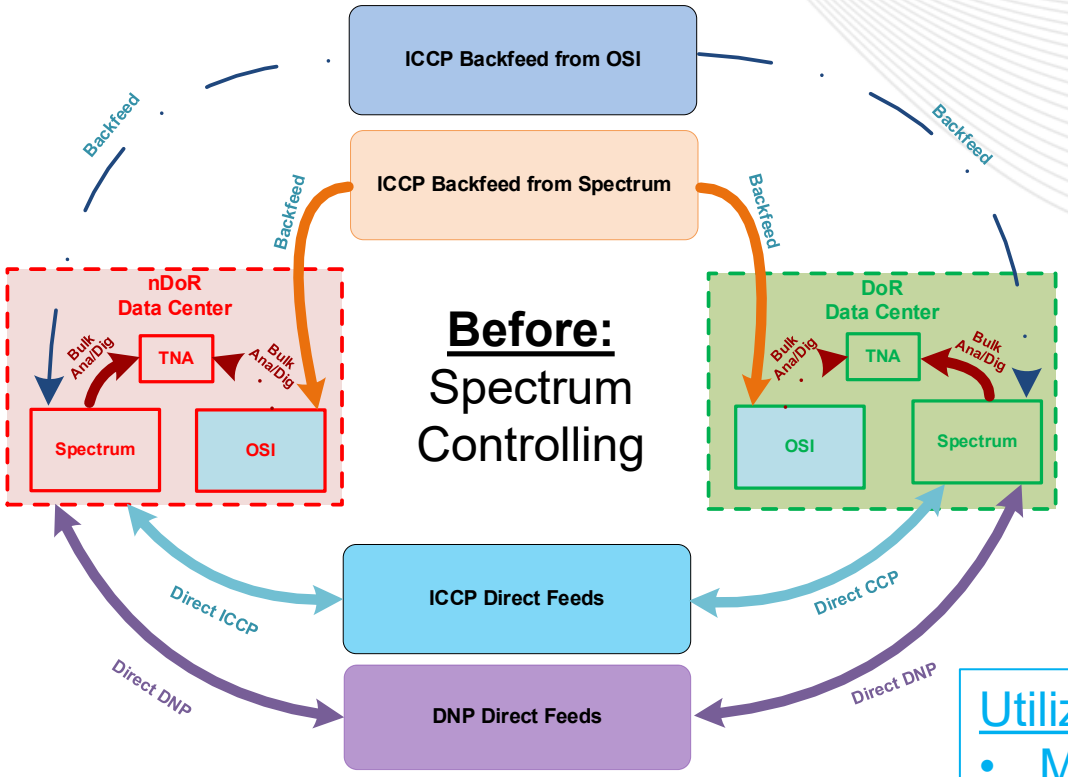
On-line Training Module Example

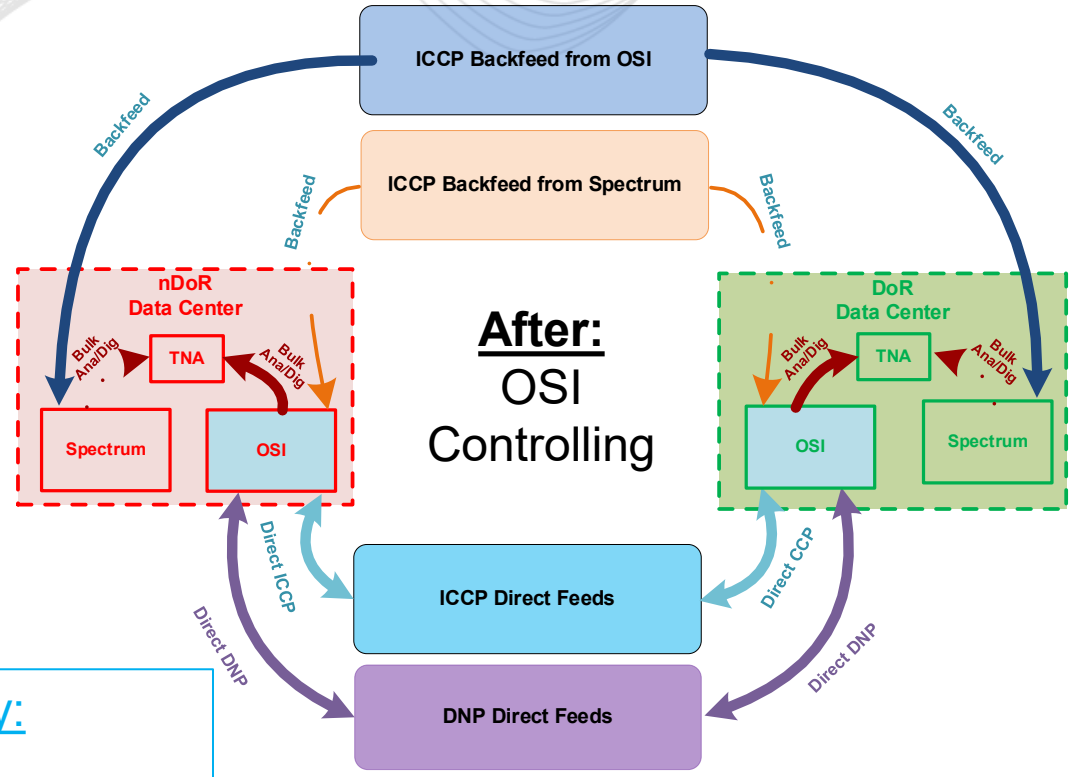


SCADA/AGC Systems		
Current		*New*
SIEMENS Spectrum		OSI Monarch
✓	Connect to PJM members	✓
✓	Collect incoming data	✓
✓	Send outgoing PJM data	✓
✓	Send/receive data via SOA	✓
✗	EITK handles SOA data	✓

Spectrum	Monarch		
AC1 PC	EMS1	Production	
AC2 PC	EMS2		
AC1 PCT	QAS1		
AC2 PCT	QAS2		
VBUCC	VBG2		
AC1 PC	SEMS1	Stage	Used to test software updates and integrations with other PJM systems
AC2 PC	SEMS2		
AC1 PCT	SQAS1		
AC2 PCT	SQAS2		

System Cutover Configuration

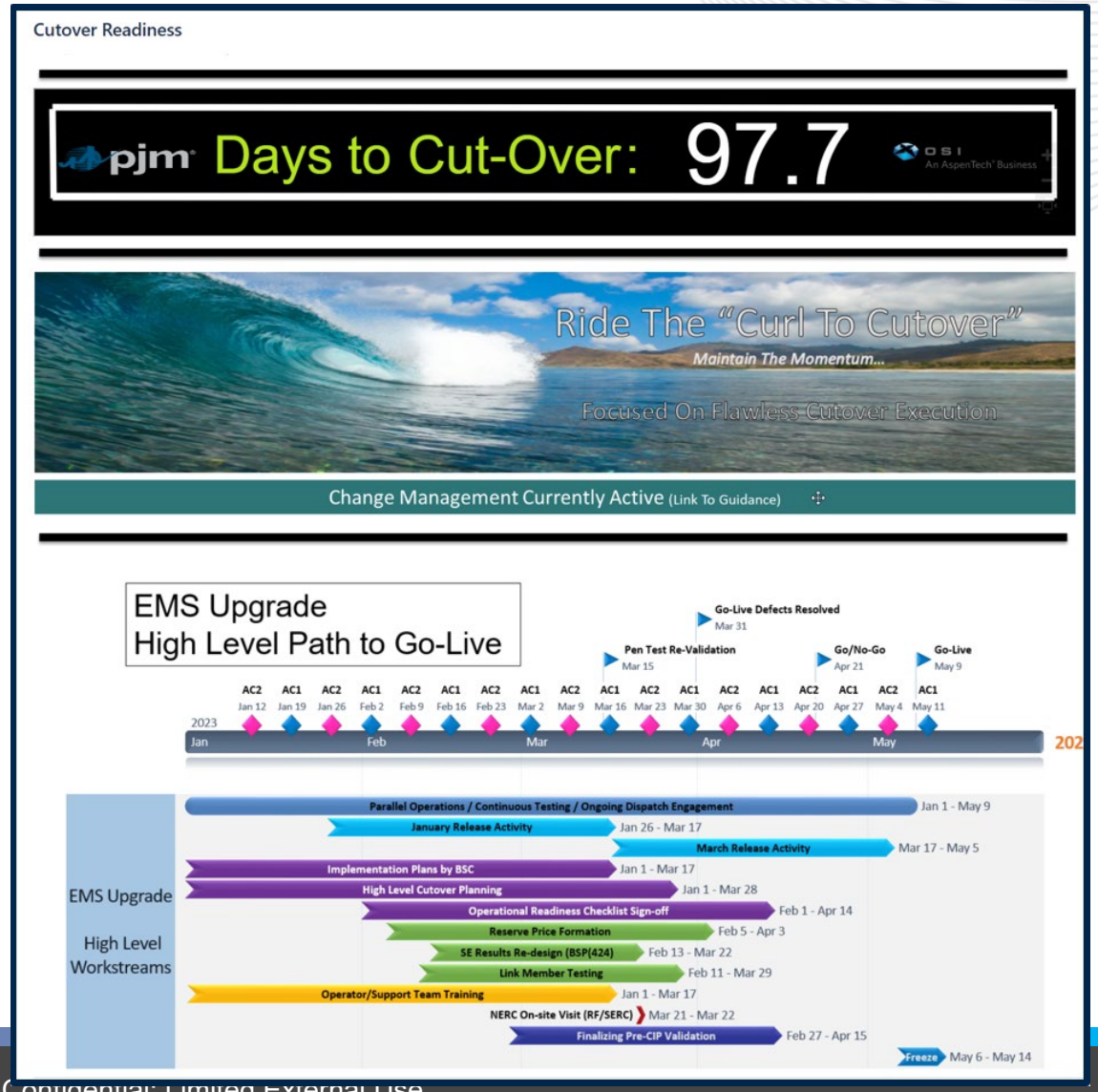


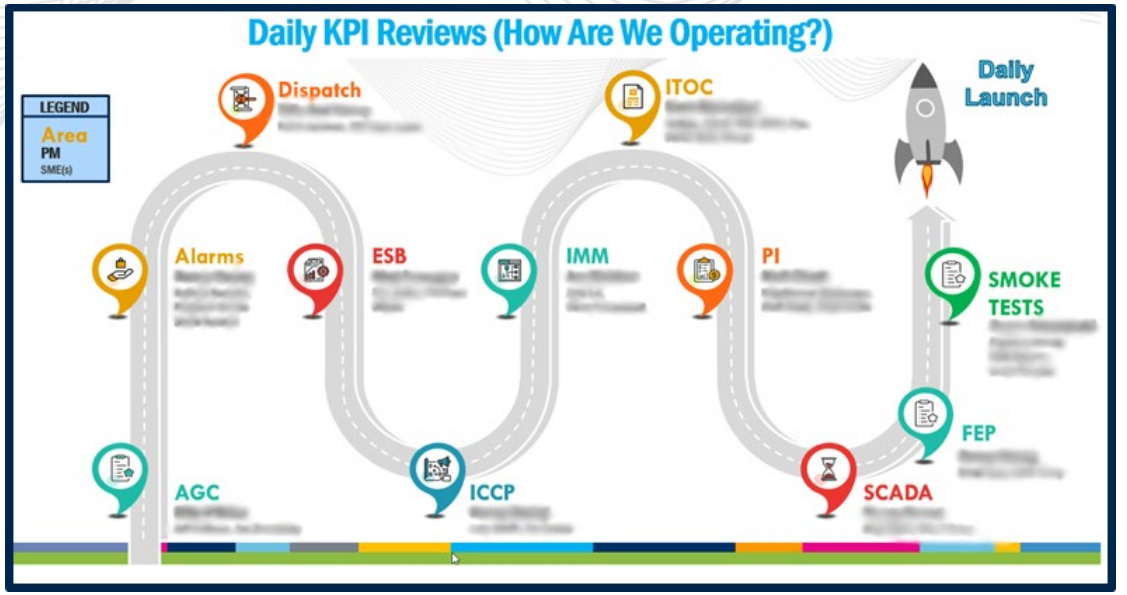


Utilizing Redundancy:

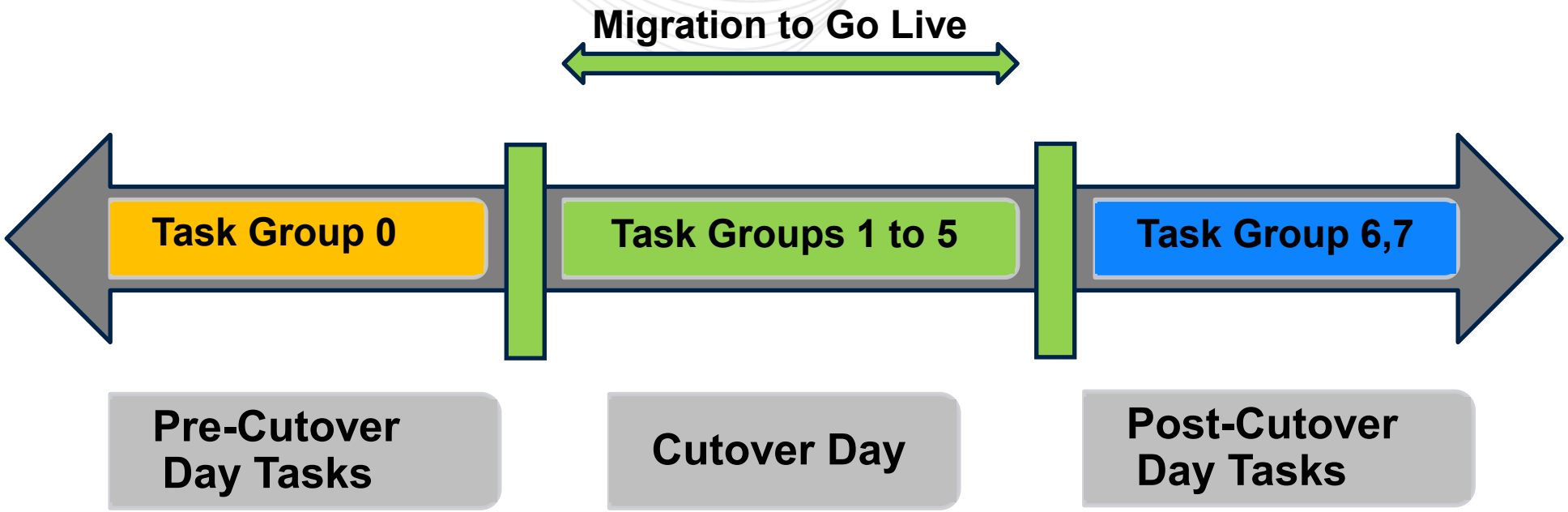
- Multi-Site Sync
- Redundant Member Links
- Primary/Backup Feeds
- Redundant ICCP Servers

Cutover Readiness Reviews





Migration Day Task Structure



Lessons Learned

- Use of ‘Control Room Coordinators’ helped operator readiness
  - SME’s on-shift with operators during parallel ops to answer questions and document issues
  - Also 7x24 post-cutover support as new dispatch teams came on-shift
- Multiple ‘mock’ cutovers helped refine final cutover process
  - PJM cutover the ‘non-data of record’ to the new EMS multiple times as part of ‘mock’ cutovers
  - Legacy EMS was backfed by ‘new’ EMS to keep it available
- Early availability of simulator helped both training, and application testing
- Leveraged ‘hot-hot’ configuration so both Legacy and new EMS never lost data during cutover
- Leveraged automated test scripts during cutover and in post-production monitoring
- Leveraged KPI’s and Splunk log collections for performance monitoring (rather than periodic performance test)

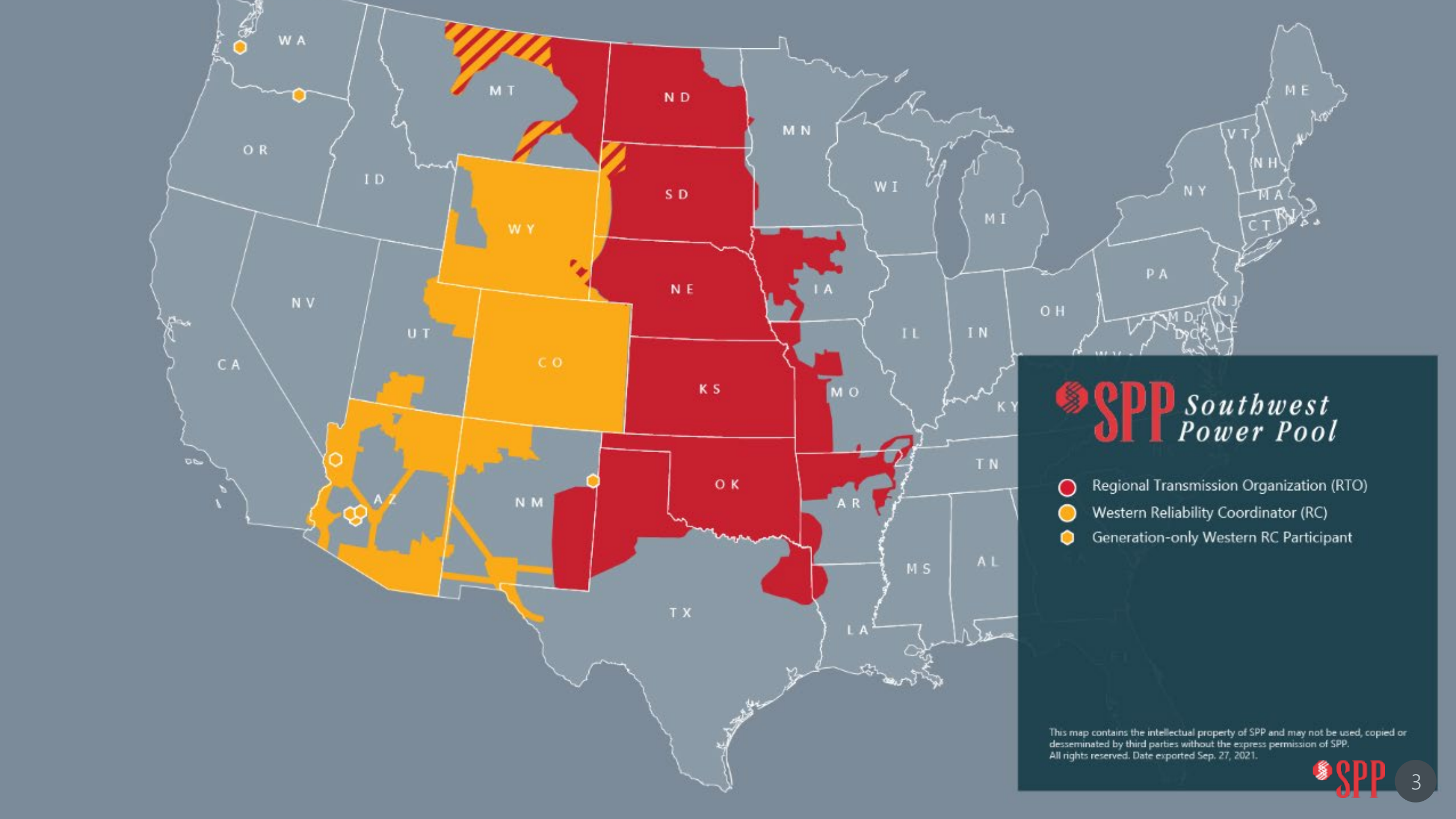
Lessons Learned Cont.

- Link data testing ensured data quality, but network and protocol configuration details still needed to be adjusted on some links during testing with remote connections
- On-site coordinated testing is the best approach
- Control Room shift team and supervisor came off normal shift 1 month before cutover
- Leveraged 3 Part Communication during all mock cut-overs
  - Gave practice for cutover day
- Timing for CIP designation was about a month before cutover

QUALITY CONTROL OF SETTINGS & EMS UPGRADE CUTOVER PROCESSES

2023 NERC SITUATIONAL AWARENESS CONFERENCE
WECC OFFICE - SALT LAKE CITY, UTAH

@hopefulromntic21


WA
OR
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WI
IL
MS
MI
IN
KY
TN
AL
OH
NY
PA
WV
MD
DE
NJ
CT
RI
MA
VT
NH
ME
SPP Southwest Power Pool
Regional Transmission Organization (RTO)
Western Reliability Coordinator (RC)
Generation-only Western RC Participant
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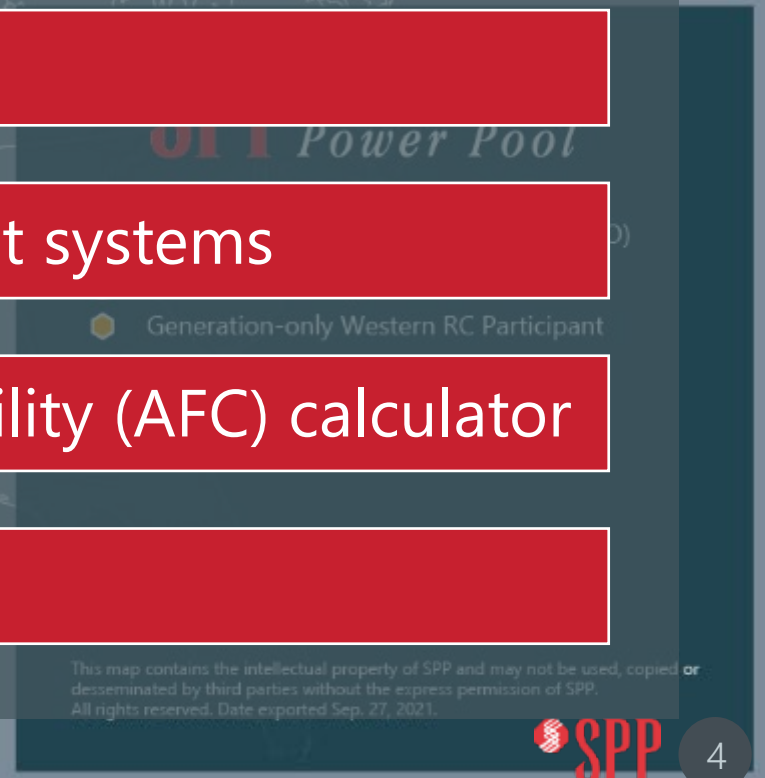
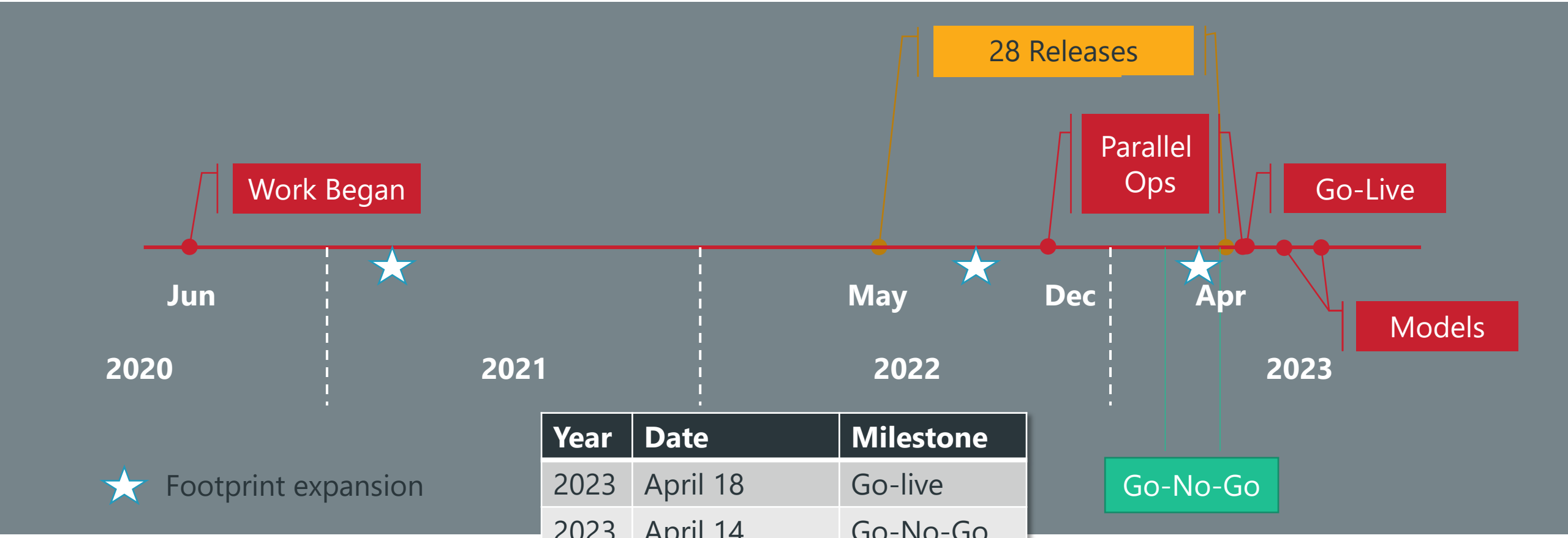
- New hardware & operating system
- New software & user interface
- Updated modeling tool
- Updated Dispatch Training Simulator
- Updated interface between EMS and market systems
- New Tariff Services Available Flowgate Capability (AFC) calculator
- New flowgate management tool



SPP EMS UPGRADE TIMELINE



Year	Date	Milestone
2023	April 18	Go-live
2023	April 14	Go-No-Go
2023	April 4	QA Go-live
2023	February 16	Go-No-Go

UPGRADE BY THE NUMBERS

- 55 core team members over 3+ years
- 28+ software releases
- 300+ tracked issues (defects, enhancements, etc.)
- 76 updated procedure documents
- 72 operators trained
- 140 high impact application settings
- 11 teams with tasks during the 4-hour cutover

THE MORE EYES, EARLIER, THE BETTER

- Identified that database pointer method changed
- Appropriate focus on settings and configurations throughout
- Contingencies were inserting, not removing equipment
- Model quality validated by multiple personnel
- Early exposure led to consensus for go-no-go decisions
- Could have identified issues earlier in exported case formats earlier

CHECK SETTINGS ON ALL SYSTEMS

- Found that software settings in the virtual machines were missing on one server
- Assigned personnel responsible for the settings of each application in the EMS
- Checked that settings persisted over the course of failovers, model loads, study solutions, and other maintenance tasks
- Signed off on settings at the beginning of parallel operations, again throughout it, and finally prior to cutovers in both the QA and in PROD environments

DOCUMENTATION OF SETTINGS

- List the following
  - Setting name, application name
  - Location of setting in user interface
  - Description of the setting's purpose (may need to supplement the vendor's description)
  - Vendor's recommended setting value
  - SPP's normal setting value
  - Reasons a user might adjust the setting
  - Any related NERC Standards related to the setting
- Document in a place that is linked/searchable/version tracked

EXAMPLE OF A DOCUMENTED SETTING

Application	Display	Name	Value	Description
RTNET	Real-Time Network Process Parameters (SE_PARAMETERS)	Maximum Iterations Voltage Convergence	100	Limits the number of REPEAT, REFACTOR, and FACTOR iterations. Maximum number of iterations allowed in one voltage convergence cycle. GE recommends a value of 18. See our analysis here: Analysis of Voltage Convergence Maximum Iterations limits

QUESTION ASSUMPTIONS

- Schema names might not change, but data type might
- Vendor may develop on a different operating system
  - Windows – filenames case insensitive
  - Unix – filenames case sensitive
  - Not reproducible at vendor

VALIDATIONS CAN GIVE A FALSE SENSE OF SECURITY

- Verify out-of-the-box validations
- Check results in every situation you can imagine
  - At initial model export
  - At manual model update by users
  - Before and after solutions run
  - Over time after operator input and study solutions
- Things that surprised us
  - Validations checked subsets of records in the database
  - Important new fields are not captured by validations

OPERATE IN PARALLEL AS LONG AS POSSIBLE

- Run all EMS applications in parallel with production systems
- Upload models to the new systems
- Perform system maintenance on the new systems
- Get operators' eyes on the system (all functions)
- Give yourself enough time to catch issues you didn't imagine
- Know what you can and cannot exercise in parallel operations
  - Market interface, data historian, situational awareness tools

MODELS & CIM SETTINGS

- Approach modeling as a conversion process to avoid dual modeling
  - Test ability to model apart from conversion process
- Go all-in on the conversion process. Don't settle for manual adjustments after each conversion
- Remember these are also risky cutovers
  - First model migration after the application cutover
  - First model w/o the conversion process

APRIL 18, 2023 – SUCCESS!

- Developed script and rehearsed it with support and operator teams that would conduct the work
- Operators and all support teams provided input
- Dress rehearsal held with the Operator crew
- Cutover successful
- Follow-up model uploads on 5/1 and 6/1 also successful

RECUPERATION

- 17% of PTO used 55% of the way through the year
- 4 cancelled vacations
- Little Rock tornado
- Plan rest
  - Discuss it in meetings,
  - Promote it to leadership
  - Stage upcoming work

SETTINGS QC CHECKLIST

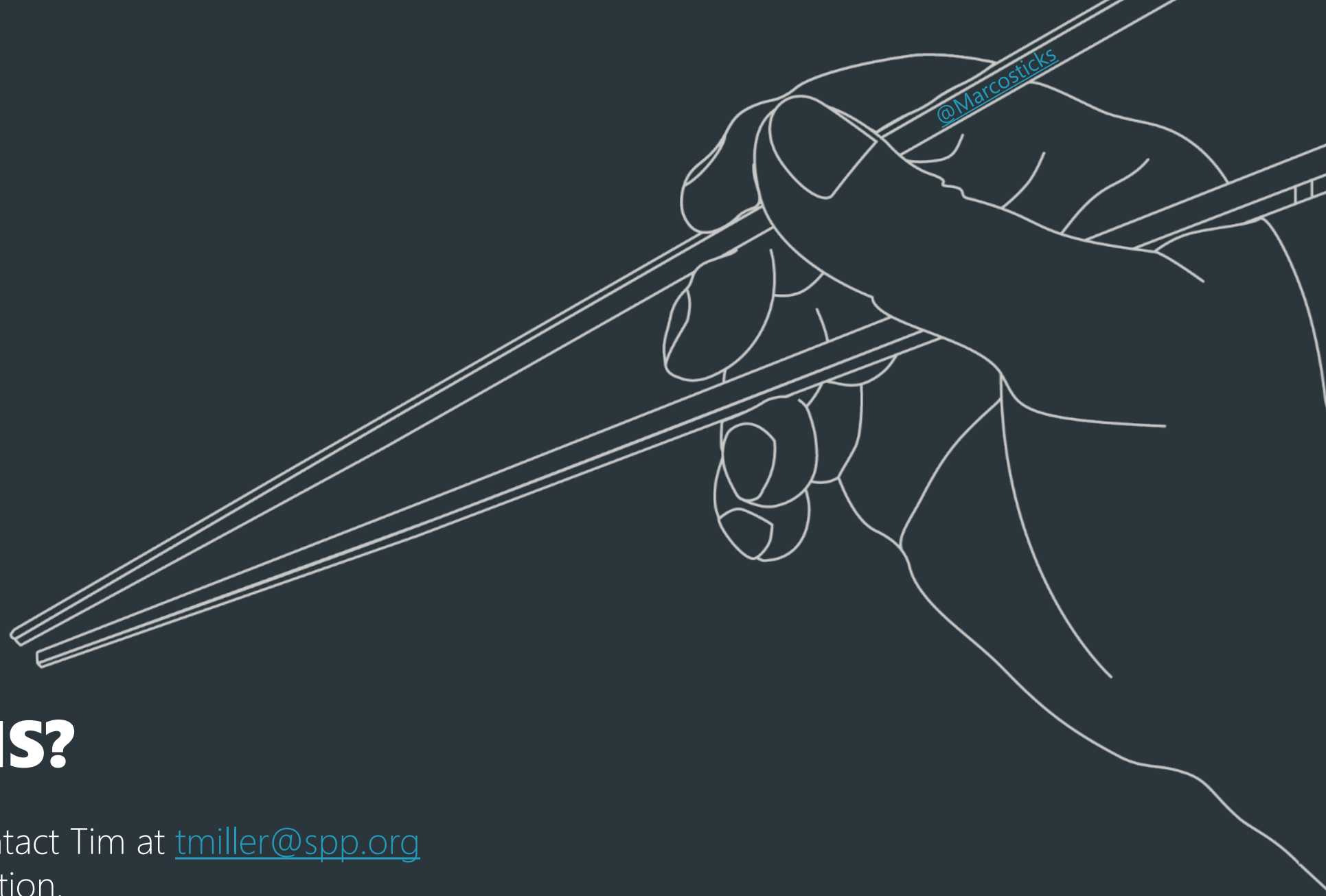
- ✓Ask Vendor for a list of new settings
- ✓Compare the database schema of new to old systems
- ✓Give your team ample time to monitor the systems in a production or production-like environment 24x7
- ✓Give built-in software validations low trust
- ✓Get as many eyes on your new system as early as possible
- ✓Document settings and establish controls

CUTOVER QC CHECKLIST

- ✓Develop a high-level cutover script
- ✓Develop detailed task-level cutover scripts
- ✓Exercise the scripts in a lower environment
- ✓Include end users in the walkthrough exercise
- ✓Learn from the exercise and make adjustments
- ✓Schedule the same users & support staff for the walkthrough exercise and the production cutover

DESIGN CHECKLIST

- Simplify interfaces
- Streamline validations
- Reduce critical settings
- Specify one way to
  - Navigate to displays and menus
  - Run a study or kick off a process
  - Perform a validation



QUESTIONS?

Please feel free to contact Tim at tmiller@spp.org
for additional information.

Architecting for Cloud Integration and Migration

MISO Model Manager Case Study

October 3, 2023

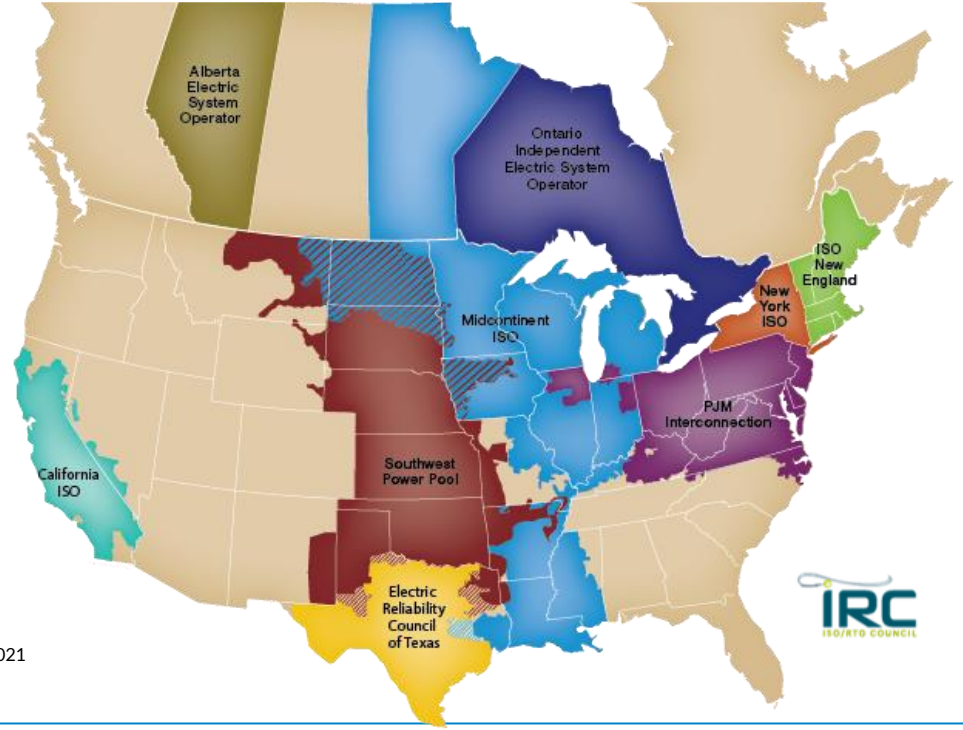
Topics

- Project background
- Cloud aspects of project

Geographically, MISO is the largest regional transmission and independent system operator in North America

KEY FACTS ABOUT MISO
15 states + Manitoba
42 million customers
$22 billion market
> 6,700 generation units with 184,000 MW capacity
65,800 miles of high voltage transmission lines
> 180 member utilities
> 470 market participants

ISO FOOTPRINTS



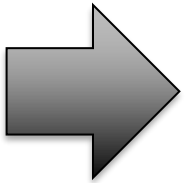
As of 01/2021

MISO

Model Manager Project Background

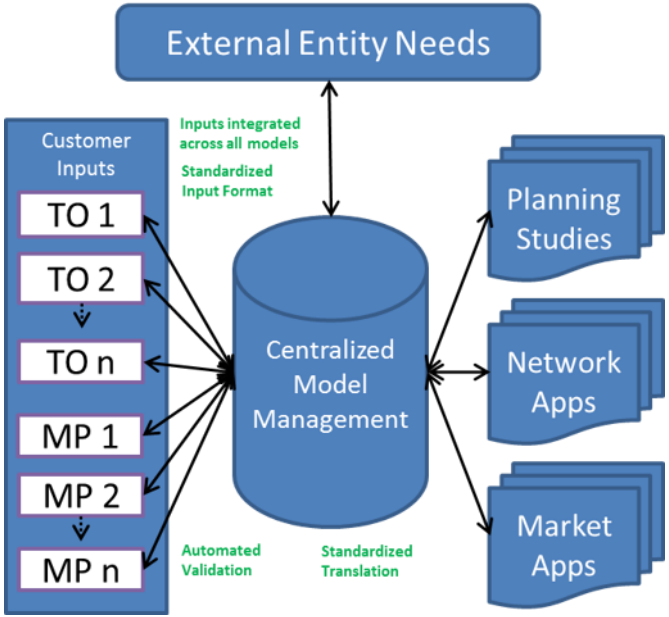
Current modeling challenges drive future opportunities addressed by MISO Model Manager project

Challenges	Opportunities
▪ Infrequent bulk updates ▪ Multiple disjointed customer touch points ▪ Multiple, non-standard sources of information ▪ Home grown system, difficult to support	▪ Frequent Δ updates ▪ Enhanced Customer Experience ▪ Industry standard data exchange formats ▪ Modern scalable, system with reduced support needs



MISO Model Manager project near-term vision

- Provide improved modeling tools for Network, Commercial, and Planning
- Improve validation with timely feedback to data submitters
- Improve visualization of existing data and future changes for submitters and reviewers
- Improve data exchange using Common Information Model (CIM)
- Synchronized source of power system modeling data in MISO



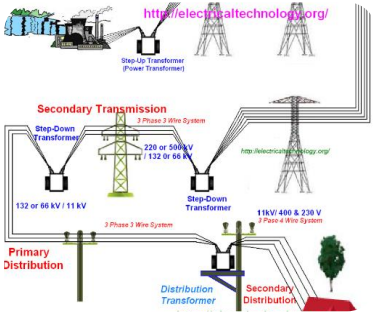
MISO Model Manager project long-term vision

Collaboration / Collection

Member sourced & reviewed model data

- Validation & visualization
- Workflow automation
- Single consistent user experience
- Data issue tracking & resolution
- Chat bot assistants

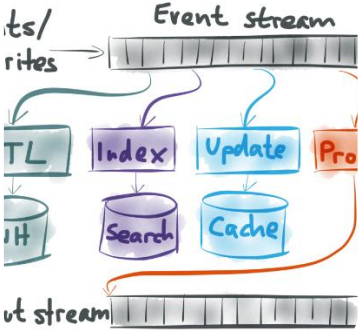
Curation



Organize & present data

Translate and transform data
Integrated and mapped data
Data change management
Model production and validation
Data transparency

Synchronization



Model update propagation

- Accurate data exchange, CIM XML
- Application Programming Interfaces
- Event-based message stream
- Incremental updates availably frequently

Customer Experience | **Model Data Source** | **Application Integration**

Cloud Architecture Aspects

Why did we choose a cloud hosted solution?

- Business value of cloud resources
  - A cloud hosted Software as a Service (SaaS) solution would reduce number of systems MISO IT staff is required to support
- Performance for large power system model
- Scalability of cloud to maintain performance as business needs grow
- Security – Cloud vendors must provide secure environment that keeps up with changing threat environment

Architecture collaboration & engagement

Architecture Services

Realize business strategy and achieve measurable business outcomes by leading best-in-class architecture principles, standards & practices.

Key Architecture Initiatives

- Enable consistent standards-based access for all users & APIs
- Real-time cloud access and service level monitoring
- Refinement of Prototype to Phase 1 integration components
- Refine flexible API & messaging for phase 1 and phase 2 downstream model ingestion

What is different from on premises?

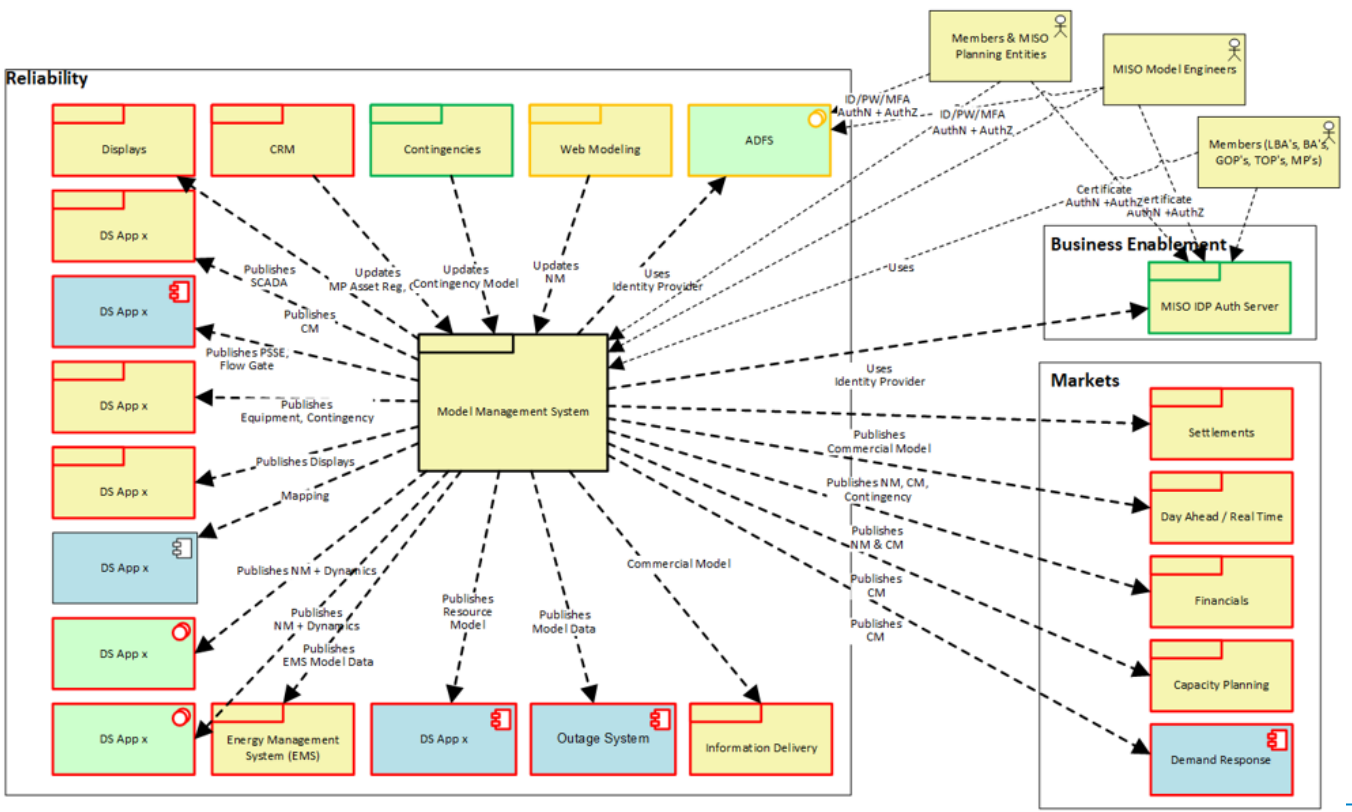
- Provisioning and configuration is dynamic, not physical, and it can be done quickly w/o purchase orders
- Infrastructure is defined with code and easily managed and visualized
- Auto-scaling can be built-in to expand and contract as needed
- Rich automatic data retention and management
- Integrated set of services, proprietary and standards based

Architecture Design – Context Diagram

20+ System Integrations

10+ Unique Model Types

Internal, External, and Programmatic User Access

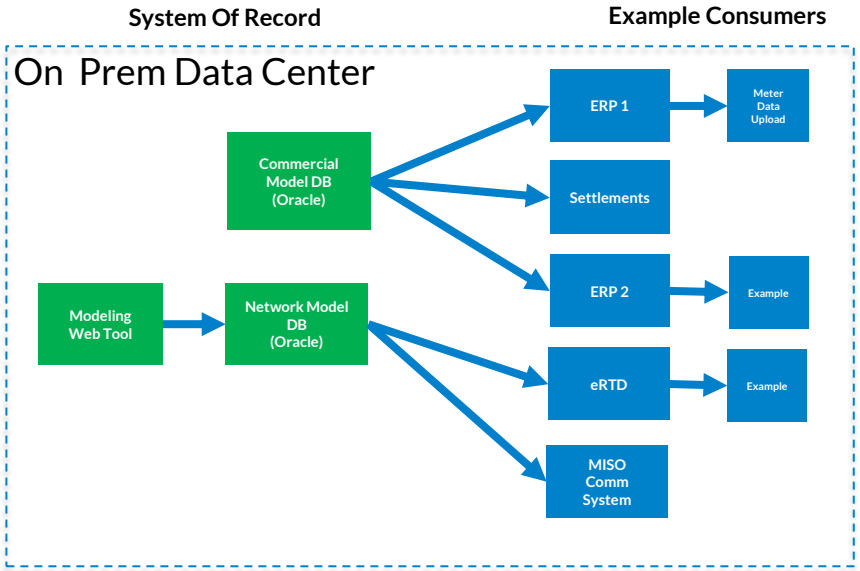


12 Obfuscated representation

LEGEND

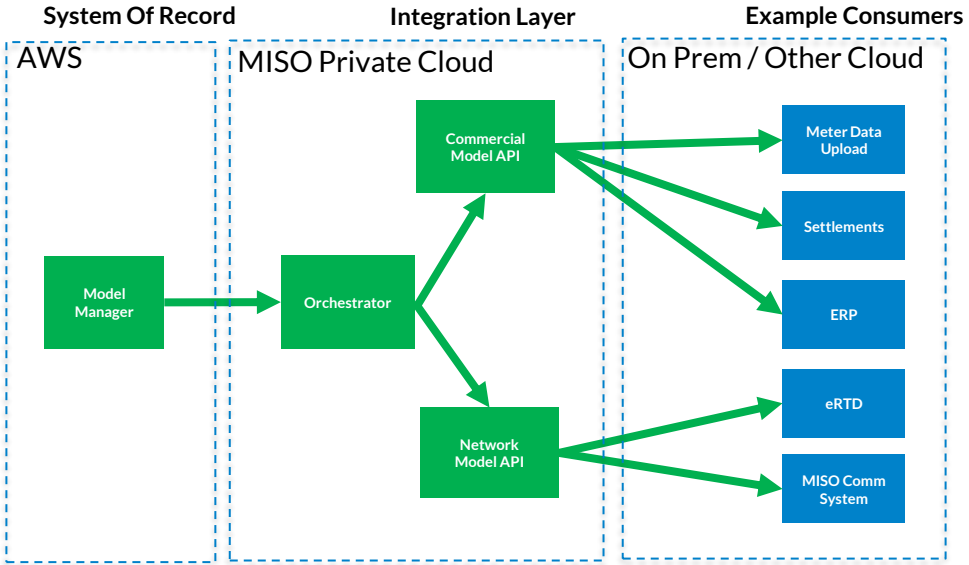
Architecture Design – Integration Path

Legacy State



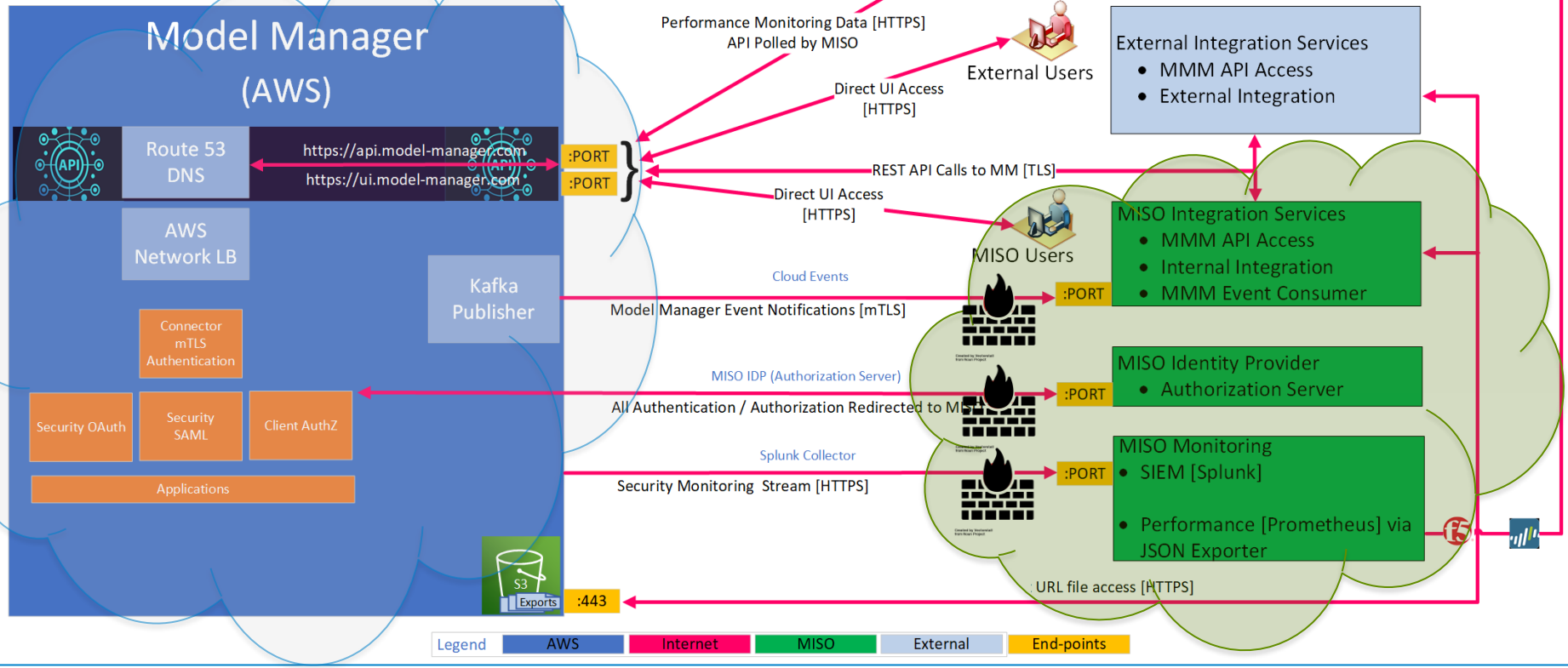
Key:

Target State



Obfuscated representation

Architecture Design – Components & Communication



Obfuscated representation

Architecture Concepts and Realization

Concept	Realization
Event-driven Architecture	• Kafka Publisher (AWS, using claim check pattern) • Kafka Cluster/Topics (MISO Private Cloud) • Kafka Mirror Maker (propagate messages to other env.)
Cloud Environments Integration	• Model Manager REST API Layer (AWS) • Firewall Ingress/Egress • Strimzi Kafka Bridge (HTTP to Kafka) • Ambassador (API Gateway)
Services	• Kubernetes Cluster (MPC) • MISO-side Model Manager Orchestrator & Integration Services (Kafka & REST API) • AWS-side service integration via REST APIs with Kafka eventing

Architecture Concepts and Realization - continued

Concept	Realization
Security Architecture	• Firewall secured Virtual IPs • Mutual TLS (client + server trust validation, encryption) • OAuth2/OIDC Consistent UI & API AuthN/AuthZ) • x.509 public CA certificates for identity (users and APIs)
Object Store	• AWS S3 (System of Record Model Exports) • MinIO (S3 Compliant Object Store on MPC) • WinZip compatible archives • Storing models in XML/RDF CIM 16 w/MISO extensions
Observability	• Streaming SIEM data from AWS to MISO Splunk via Firehose • Vendor-created REST API consumed at MISO with Prometheus JSON exporter, visualized in Grafana

Cross cloud observability

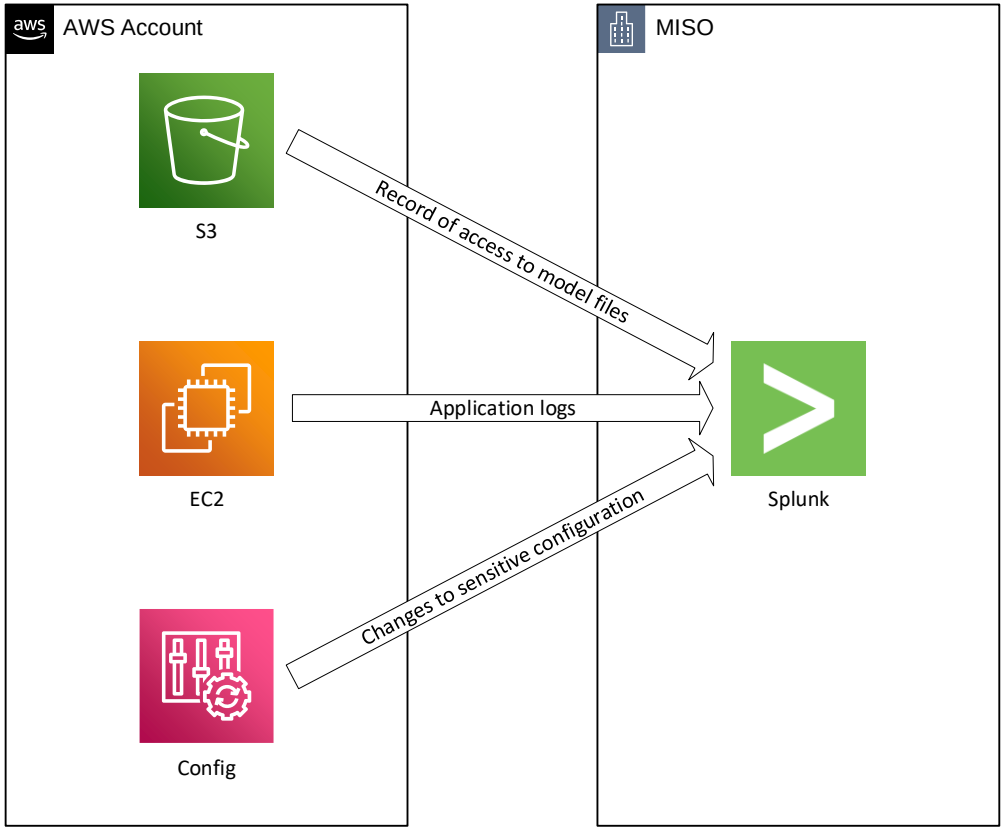
> File access

> Application access

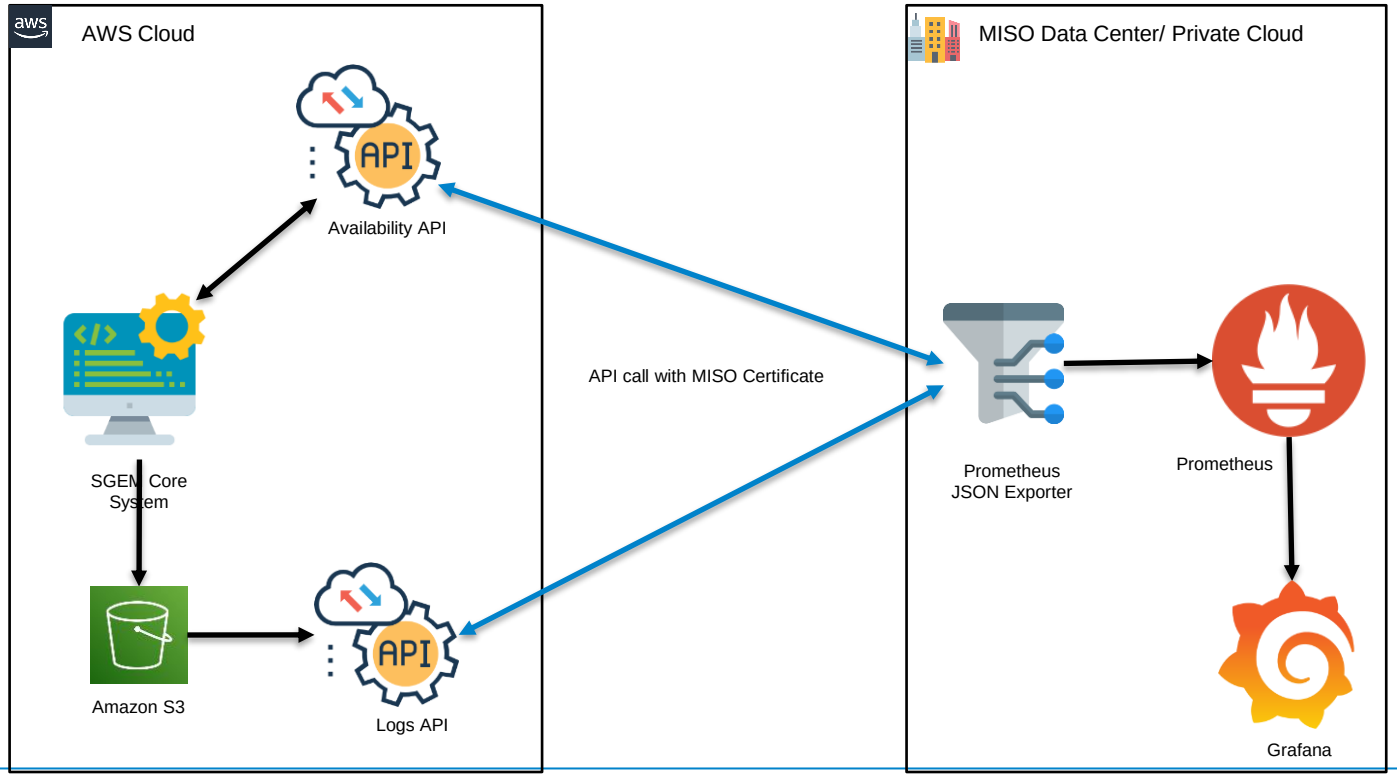
> Configuration changes

> Service Levels

- Availability
- Performance

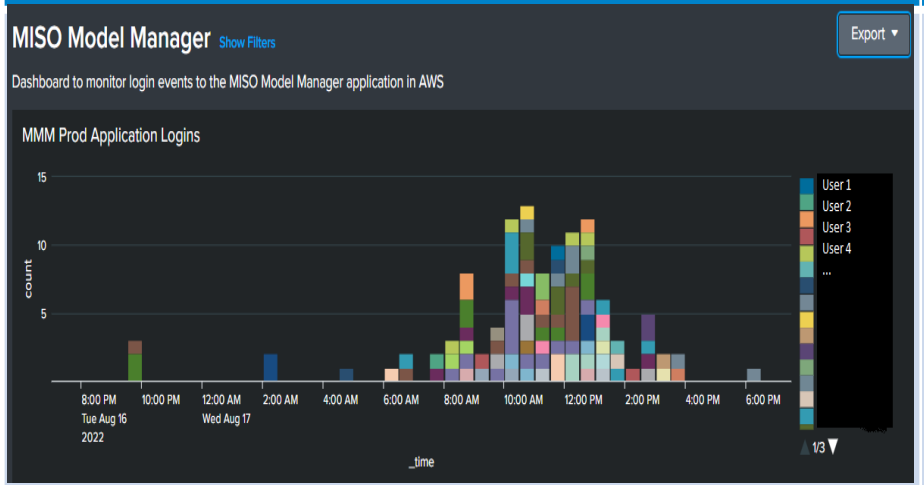


Cross cloud observability – Service Levels



Cross cloud observability - Dashboards

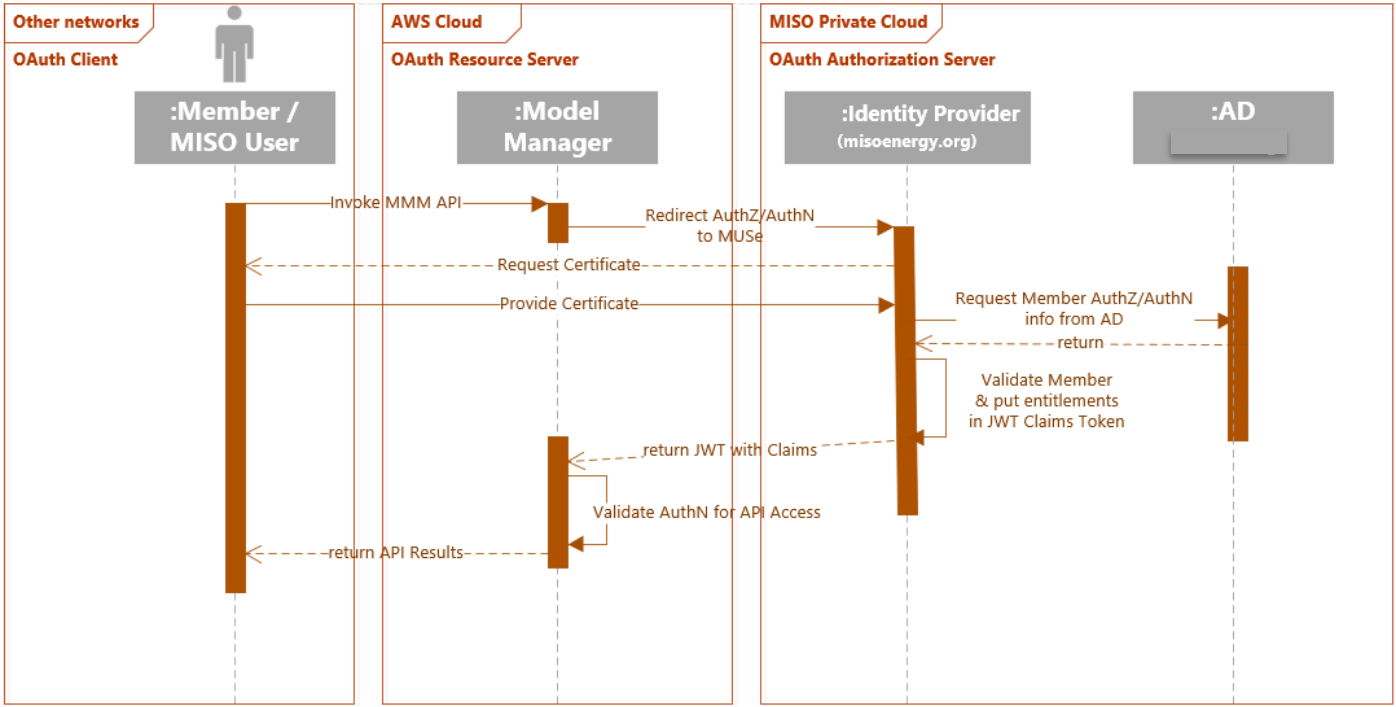
Security Information Event Management
(Splunk via Kinesis Firehose)



Service Level Objectives
(Prometheus / Grafana via REST API)

Securing application on cloud hybrid solution

- Mutual TLS
- x.509 certificates
- OAuth2 / OIDC Protocol
- IAM managed by MISO Auth Server



Cloud implementation challenges and benefits

Challenges	Benefits
First cloud-hosted solution	Easy provisioning of new environments
Extensive system security planning	FedRAMP compliant services
How to secure CEII classified data and meet ~80 FedRAMP security reqs.	Secure, built-in data retention & life-cycle services
Cross-platform networking & access	Scalable with flexible costs
Event-driven messaging design	De facto standards such as S3
Integration with other MISO systems	Rich set of available services
Troubleshooting across platforms	Enables us to let the vendor address issues if system is not performing

Adjustments for SaaS in the Cloud

- SaaS in the Cloud requires the vendor to address issues if system is not performing
  - Support staff must redirect support issues to vendor
- Data is in the cloud and must be downloaded
  - Large model to download – zipped file 300 MB
- SaaS in the Cloud does not allow MISO staff direct database access for this solution
  - Must use ad hoc query environment in application
  - API access provided by vendor for downsteam MISO integrations

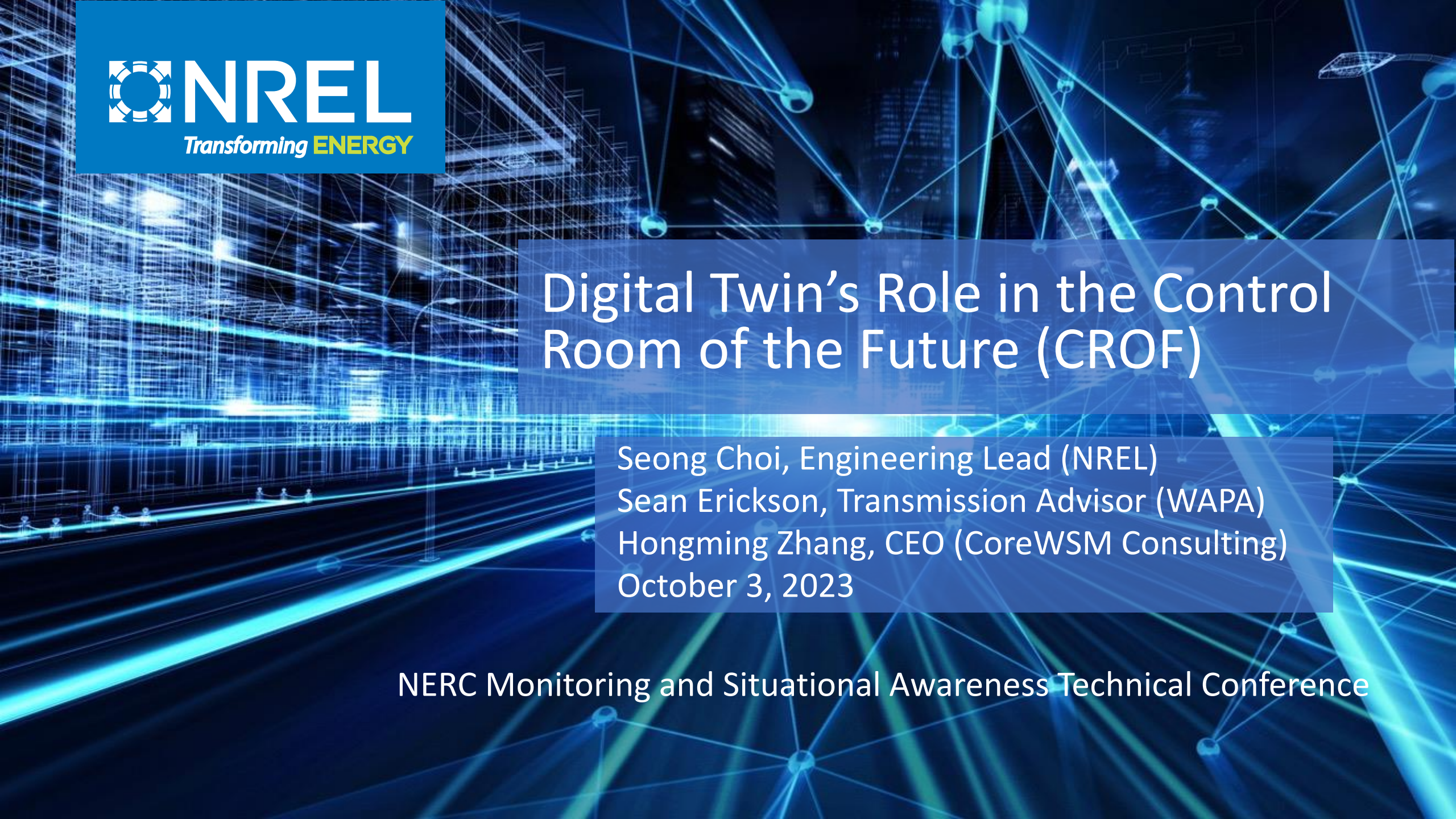
Conclusions on SaaS in the Cloud

- Pleased with performance on large power system model
- Much of our vision has been achieved
- Vendor has been responsive to issues
- Architecture provides consistent access and visibility across environments
- Architecture allowed efficient migration of services from MISO private cloud to both Azure and on prem

Questions?

Contact Information

- Joseph Brennan, Director, Architecture Services
  jobrennan@misoenergy.org

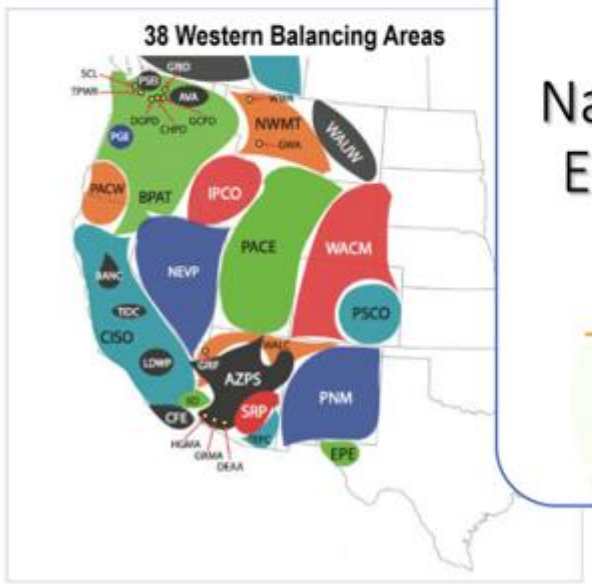


Digital Twin's Role in the Control Room of the Future (CROF)

Seong Choi, Engineering Lead (NREL)
Sean Erickson, Transmission Advisor (WAPA)
Hongming Zhang, CEO (CoreWSM Consulting)
October 3, 2023

NERC Monitoring and Situational Awareness Technical Conference

Speakers



Seong Choi,
Engineer Lead
National Renewable
Energy Laboratory

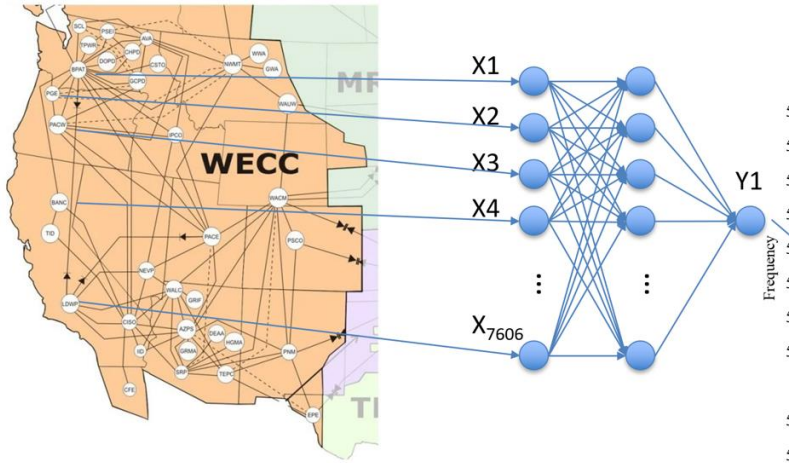
Sean Erickson,
Transmission
Advisor

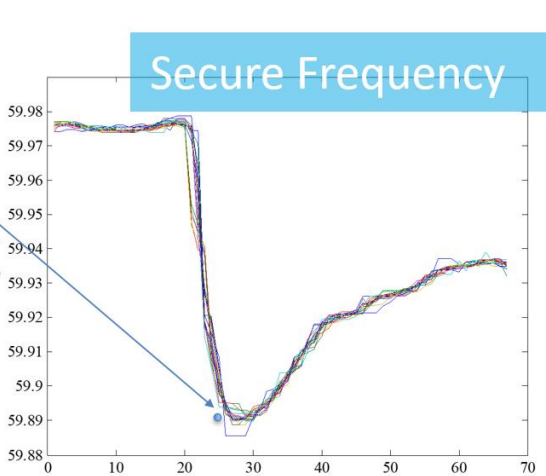
Western
Area Power
Administration

Hongming Zhang,
CEO

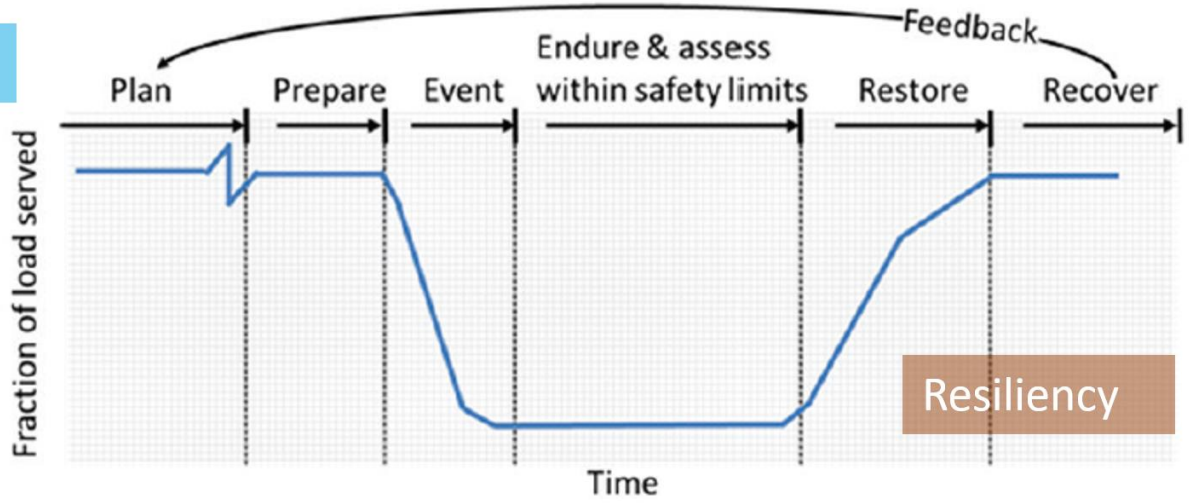
CoreWSM Consulting

U.S. Department of Energy Goal: Toward a Secure, Reliable, and Resilient Grid

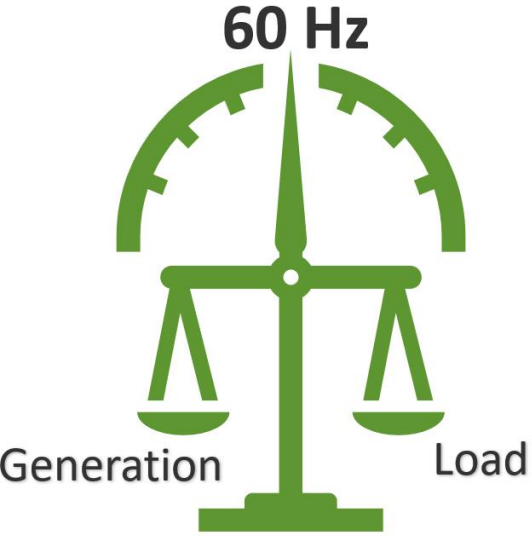




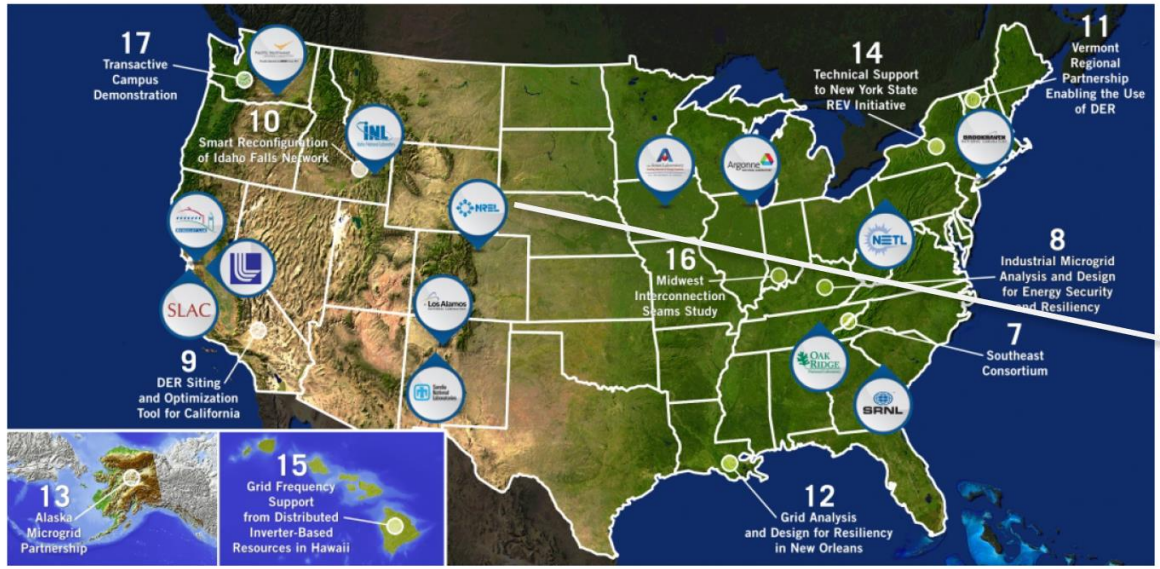
Secure Frequency



Resiliency



Reliable Operation



U.S. DEPARTMENT OF ENERGY | OFFICE OF ELECTRICITY

Today's Agenda

Exploring Energy Transition Challenges in the Control Room Operation

Why System Operators Are Critical in the Clean Energy Transition?

Can Advanced Technologies Support System Operators?

AI/ML, Digital Twin & Dynamic Dashboard

NREL R&D Initiatives in Advanced Technology

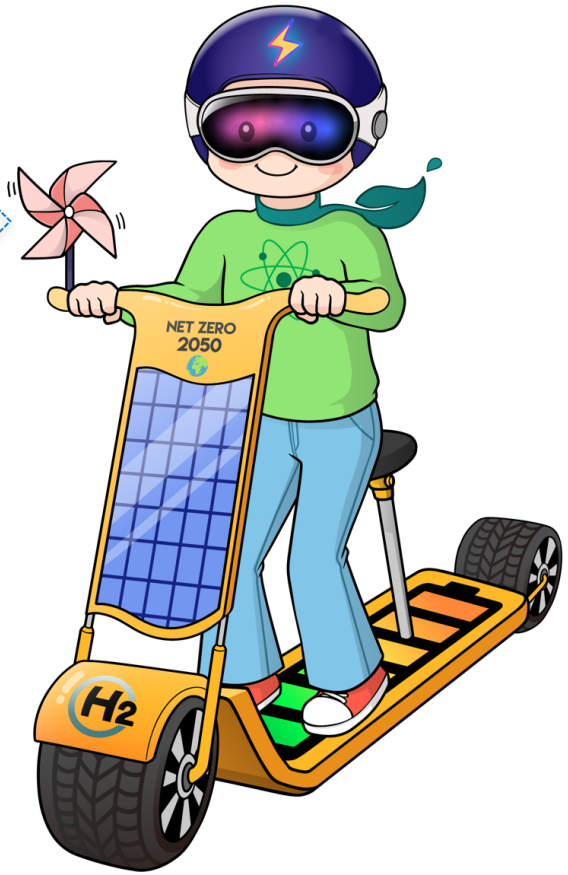
SONAR
(System Operator Network Analysis for Renewables)

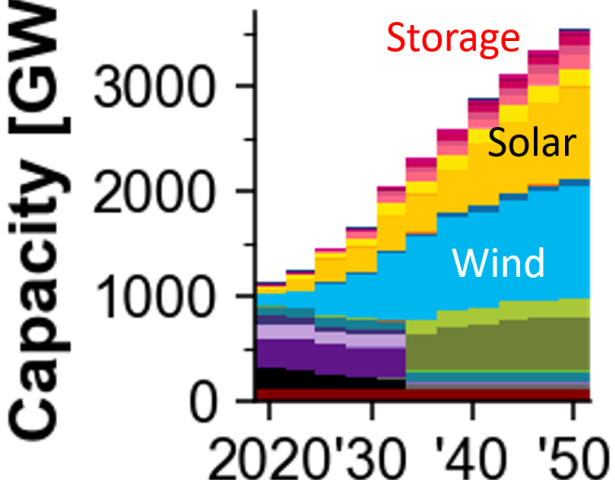
Current Energy Transition Challenges in the Control Room

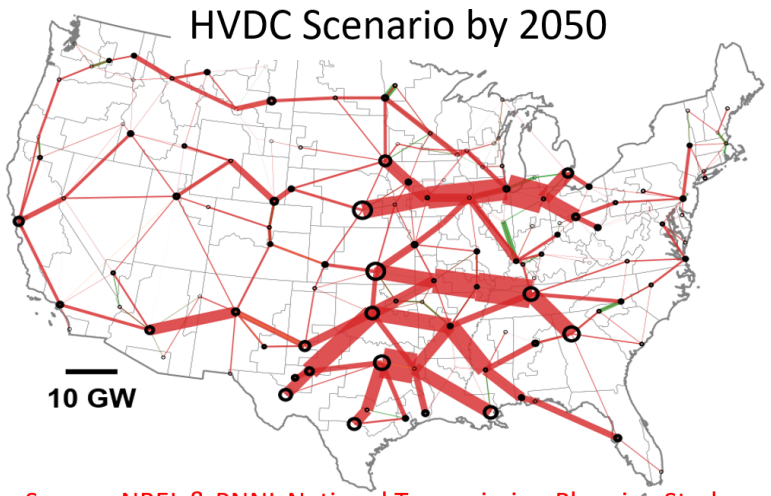
Operation & Planning	Unpredictable load and generation, load growth by electrification, new way of assessing resource adequacy
Data & Architecture	Complex, fast, and high-volume data, many communication protocols and standards
✓ Advanced Technologies	Digital transformation, AI/ML, new tools & visualization, the clouds
Natural Disaster & Pandemic	Increasing trend of high-impact low-frequency (HILF) events
✓ Cyber & Physical Threats	Bypassing the current mitigation by leveraging new technologies and slow regulatory adoption
Supply Chain Risk	Vendor S/W, original equipment manufacturer, H/W risk, logistics
Regulatory Impact	FERC 2222, NERC CIPS, Bipartisan Infrastructure Law
Workforce Shortage	Fewer engineers and less attractive field

✓ Today's discussion R&D topic

Future Clean Energy Transition



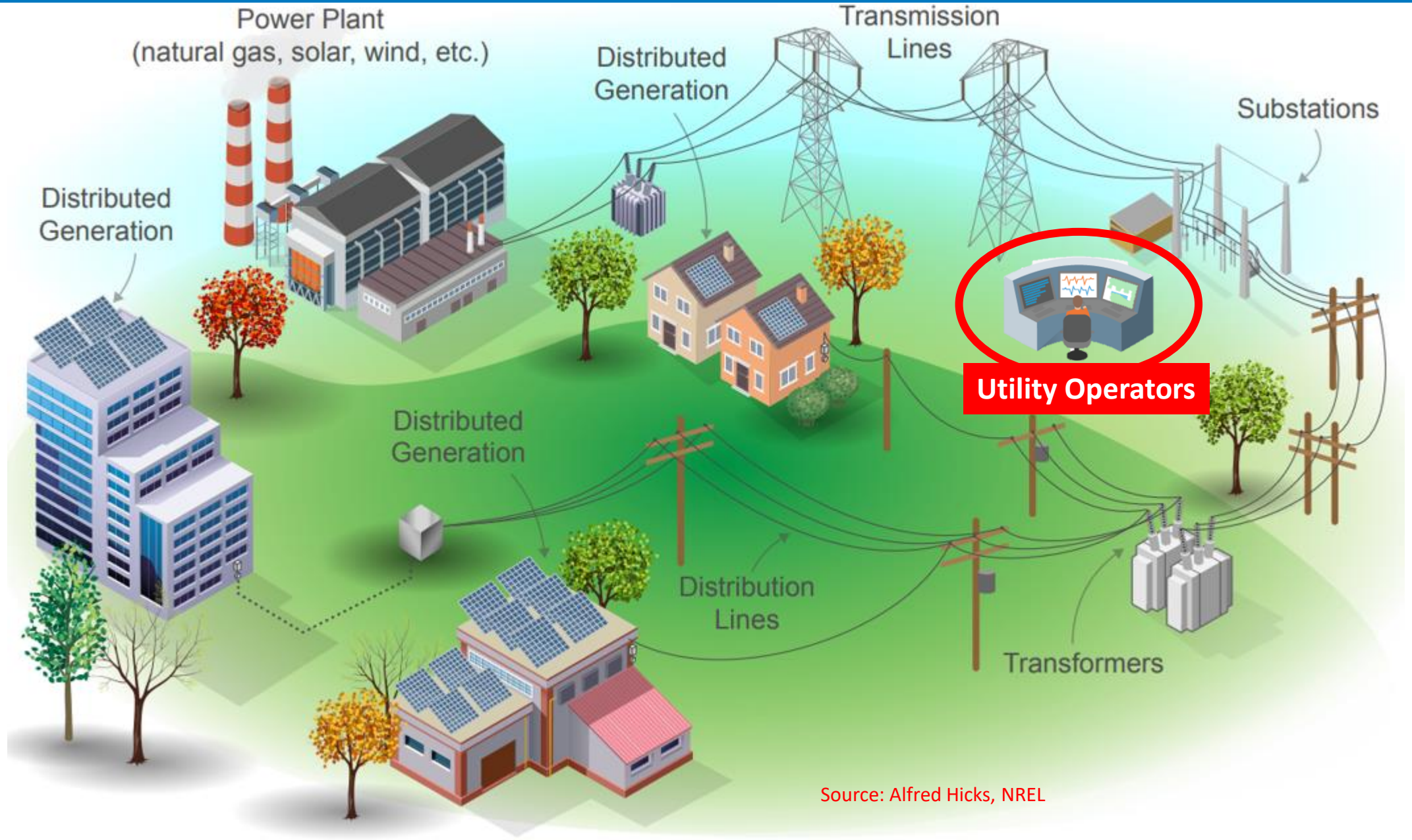




Source: NREL & PNNL National Transmission Planning Study

Illustration by SY Choi

Operator: Brain of the Grid



Source: Alfred Hicks, NREL

Why System Operators Are Key to the Clean Energy Transition?

System operators are one of the parties responsible for **implementing the power system transformation**

Policymakers and other stakeholders listen to system operators, which can **help increase confidence and ambition**

System operators must transform procedures and grids to integrate high levels of clean energy

System operators best **learn from and are inspired by their peers**, including those at the forefront of integrating renewable energy

System operators have an **emerging role in cross-sector electrification and end-use efficiency efforts**

GLOBAL PST CONSORTIUM

The Global Power System Transformation Consortium (G-PST)

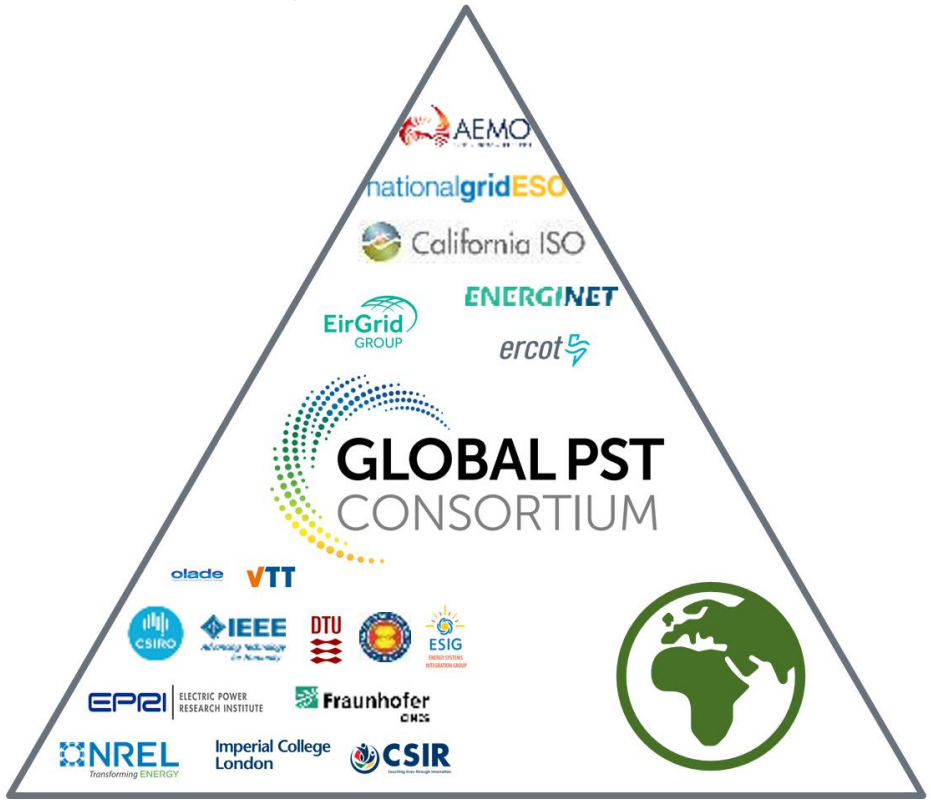
Global Power System Transformation (G-PST) Consortium

What?

A global **consortium** focused on support to **power system operators with advanced, low-emission solutions**

Who?

Founding System Operators (FSOs)



Core Team Technical Institutes

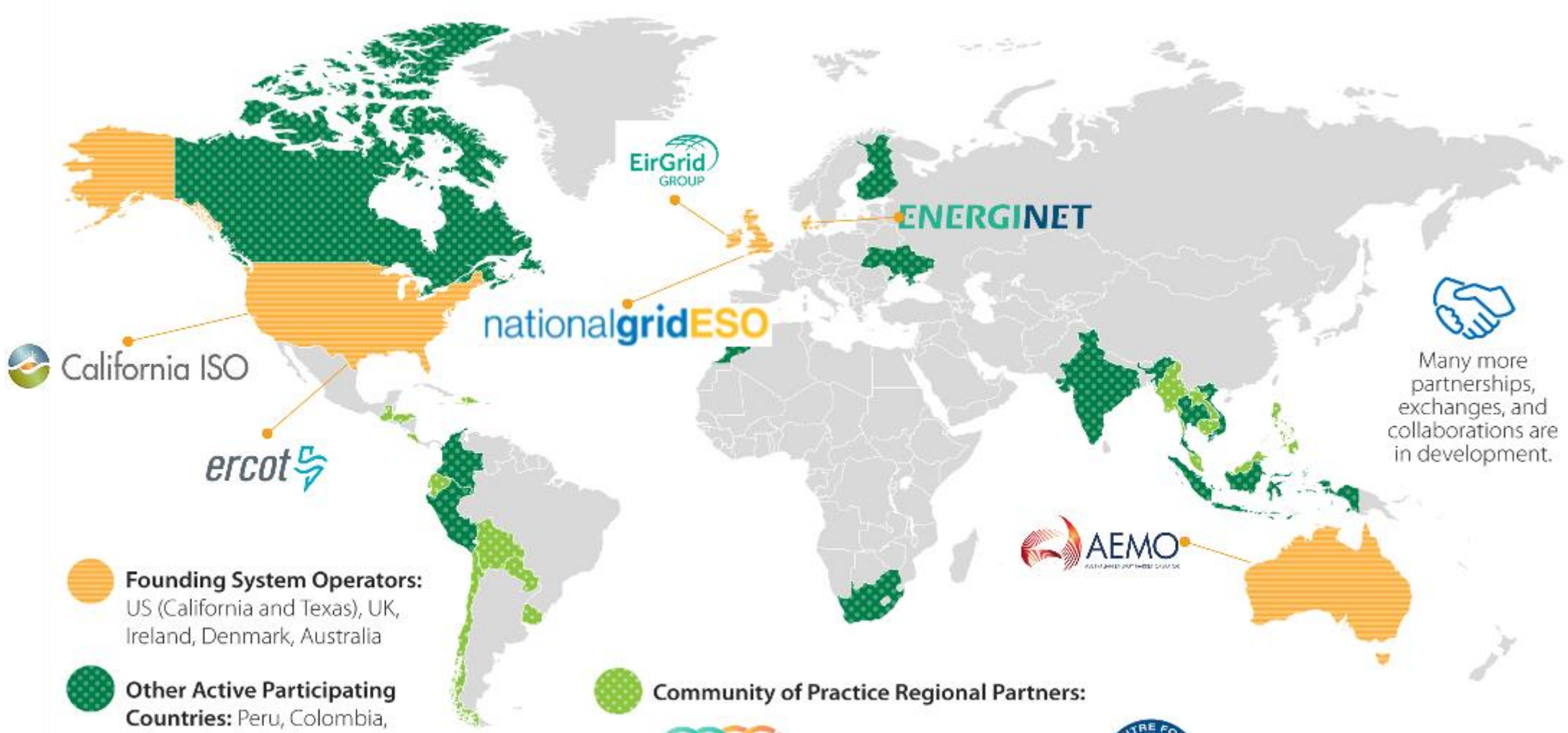
Developing Country System Operators

Indonesia, Ukraine, Vietnam, India, South Africa, Tanzania, Morocco, Peru, Colombia, WAPP and others

Why?

To drive the development and transfer of the **technical and engineering knowledge** necessary for power system operators at the **speed and scale required** to support the global energy transition

Who are G-PST Control Room Operators?

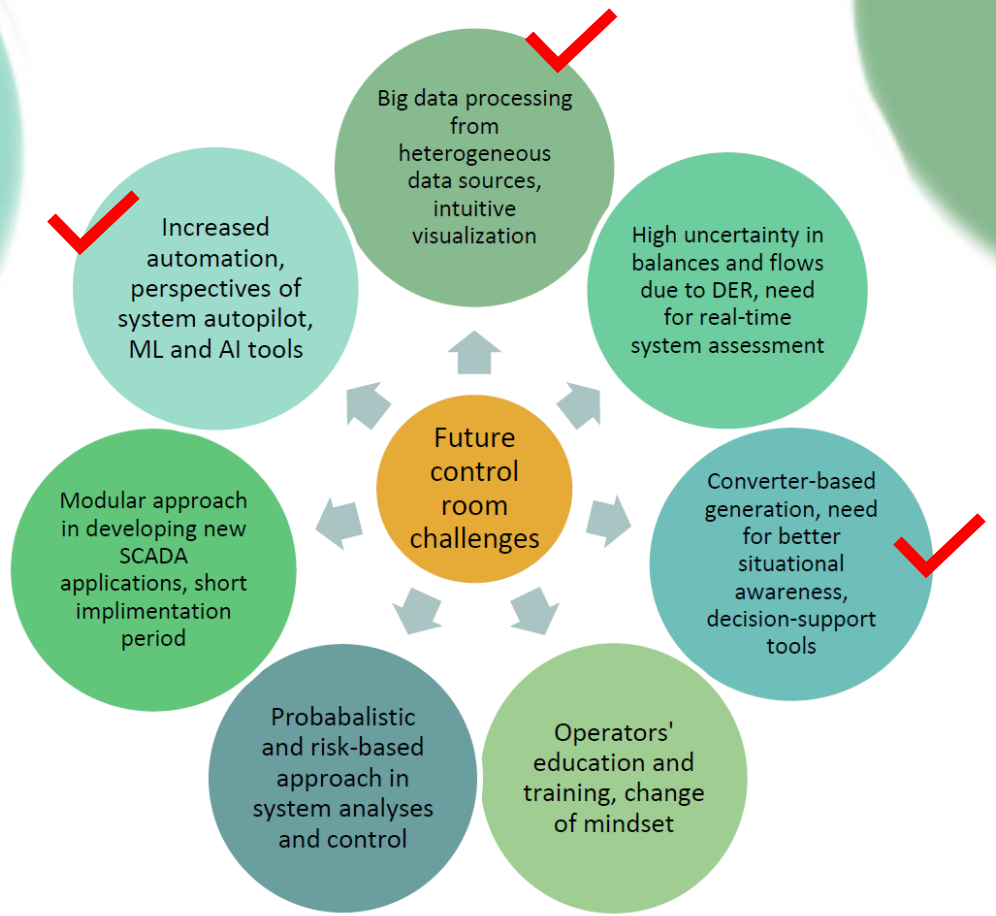


GLOBAL PST CONSORTIUM

From G-PST Control Room Operator's Interview on CROF Challenge

Increased automation, perspectives of system autopilot, ML and AI tools

Big data processing from heterogeneous data sources, intuitive visualization

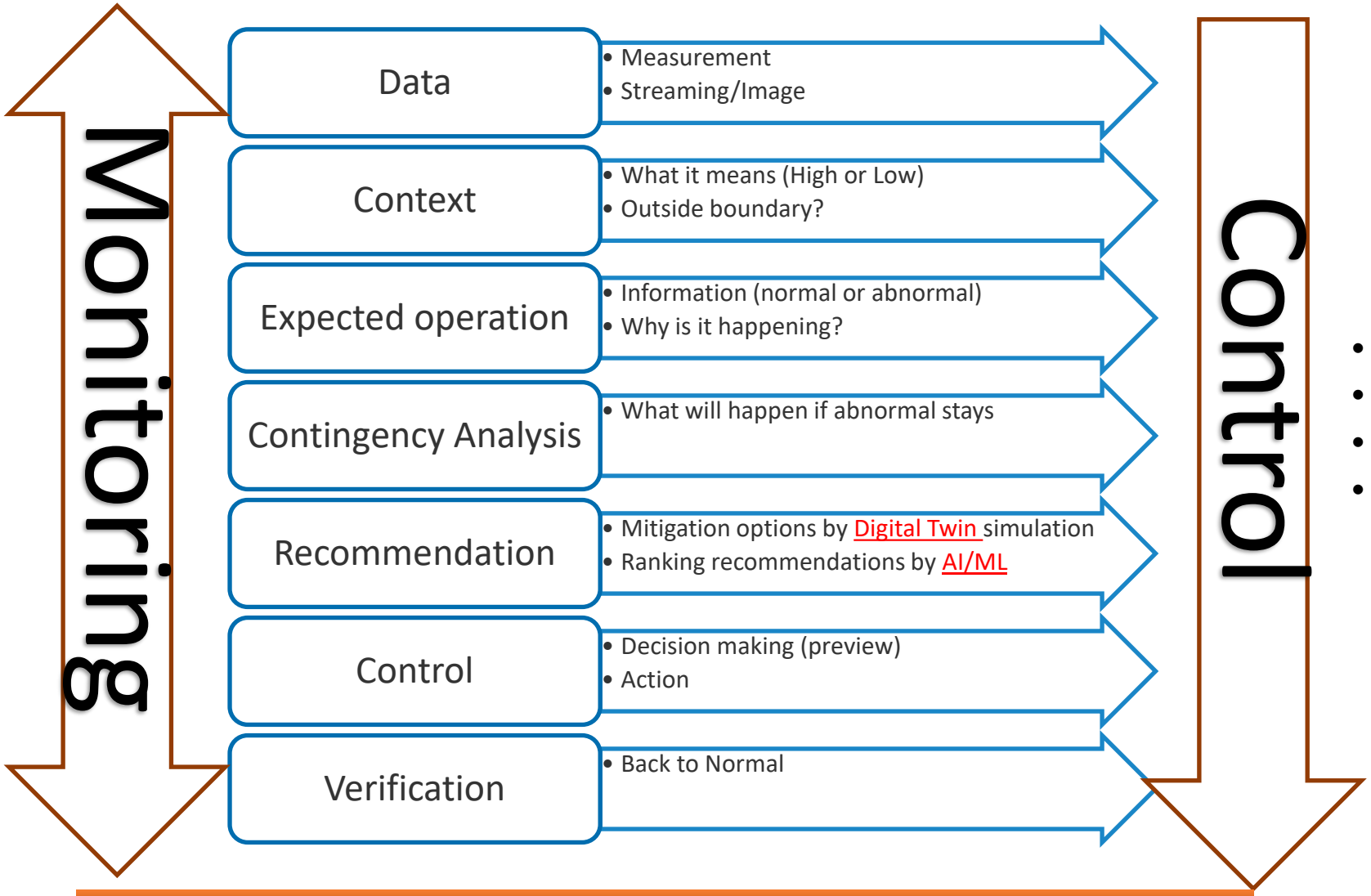


Converter-based generation, need for better situational awareness, decision-support tools

✓ Today's discussion R&D topic

Control Room Decision-Making Flow

- Visualization
- Alarms
- State estimator
- Contingencies
- Security alerts



- Frequency Control
- Voltage Control
- Protection
- Stability Control

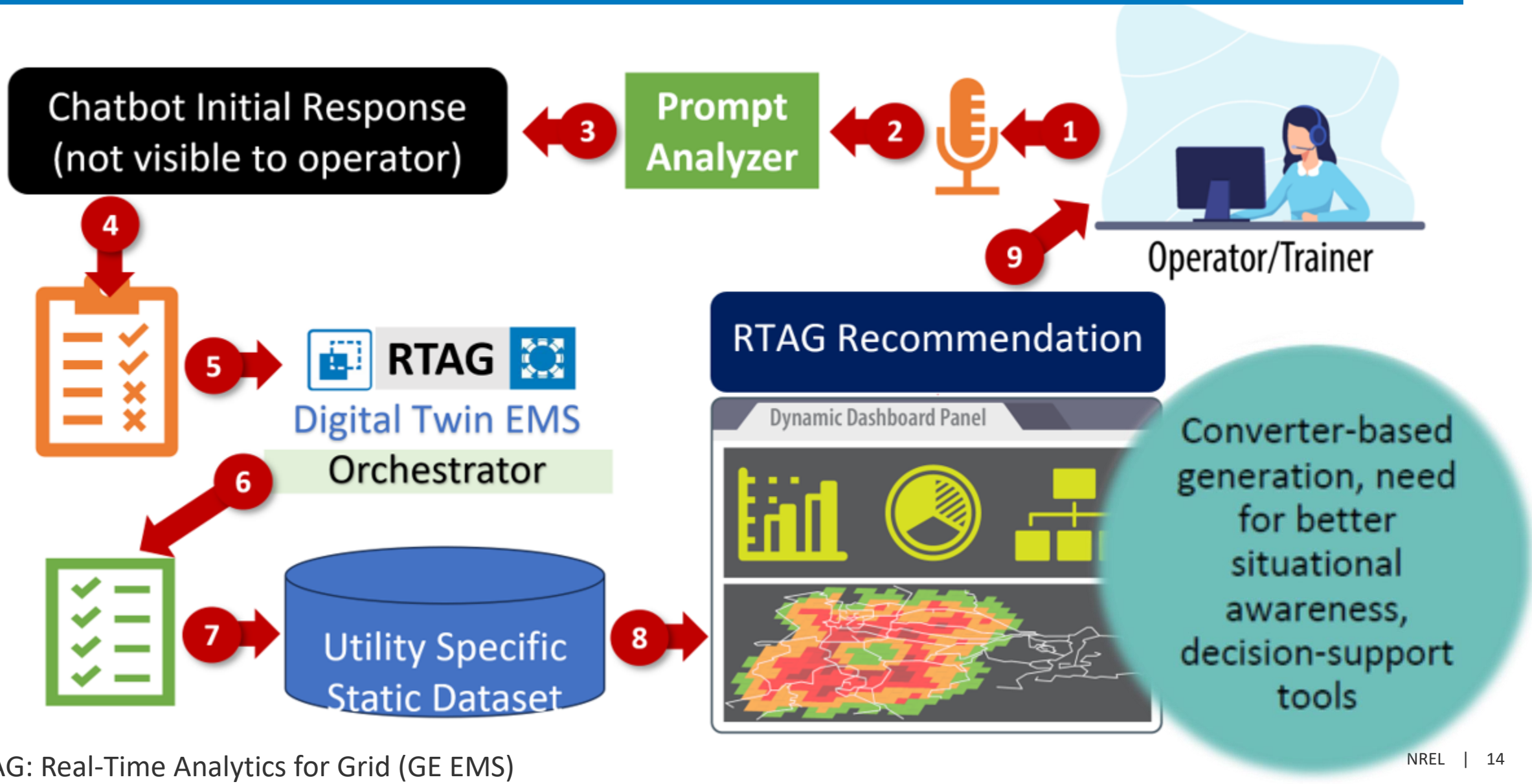
Can AI/ML or Digital Twin Support System Operator's Decision-making?

NREL Control Room of the Future

R&D Topics

- System Operator Decision-Making Platform
- Automated Digital Twin Simulation
- Dynamic Dashboard
- Tertiary Virtual Resilient Center
- OT Cybersecurity

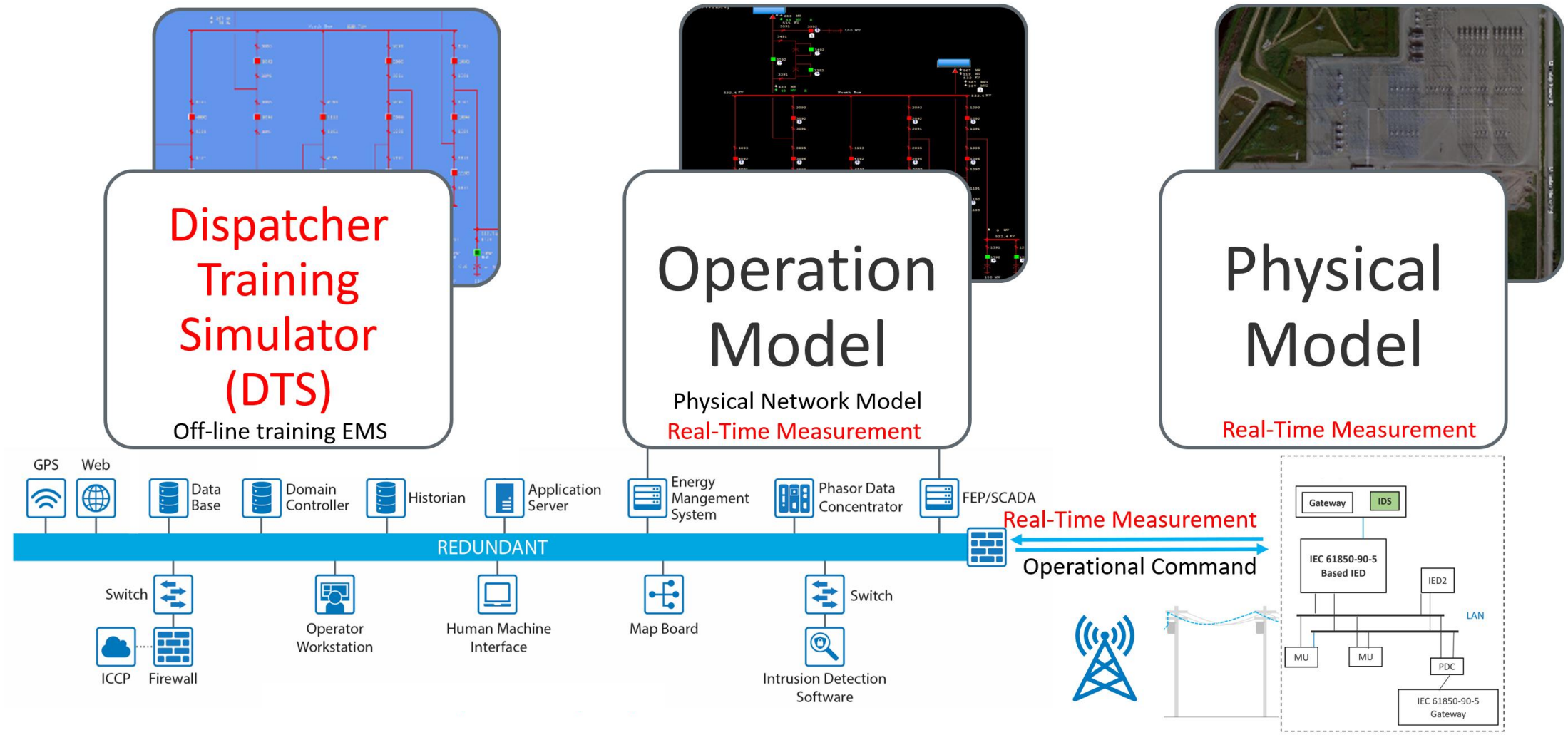
NREL RTAG Decision-Making Platform(On-Premise)



RTAG: Real-Time Analytics for Grid (GE EMS)

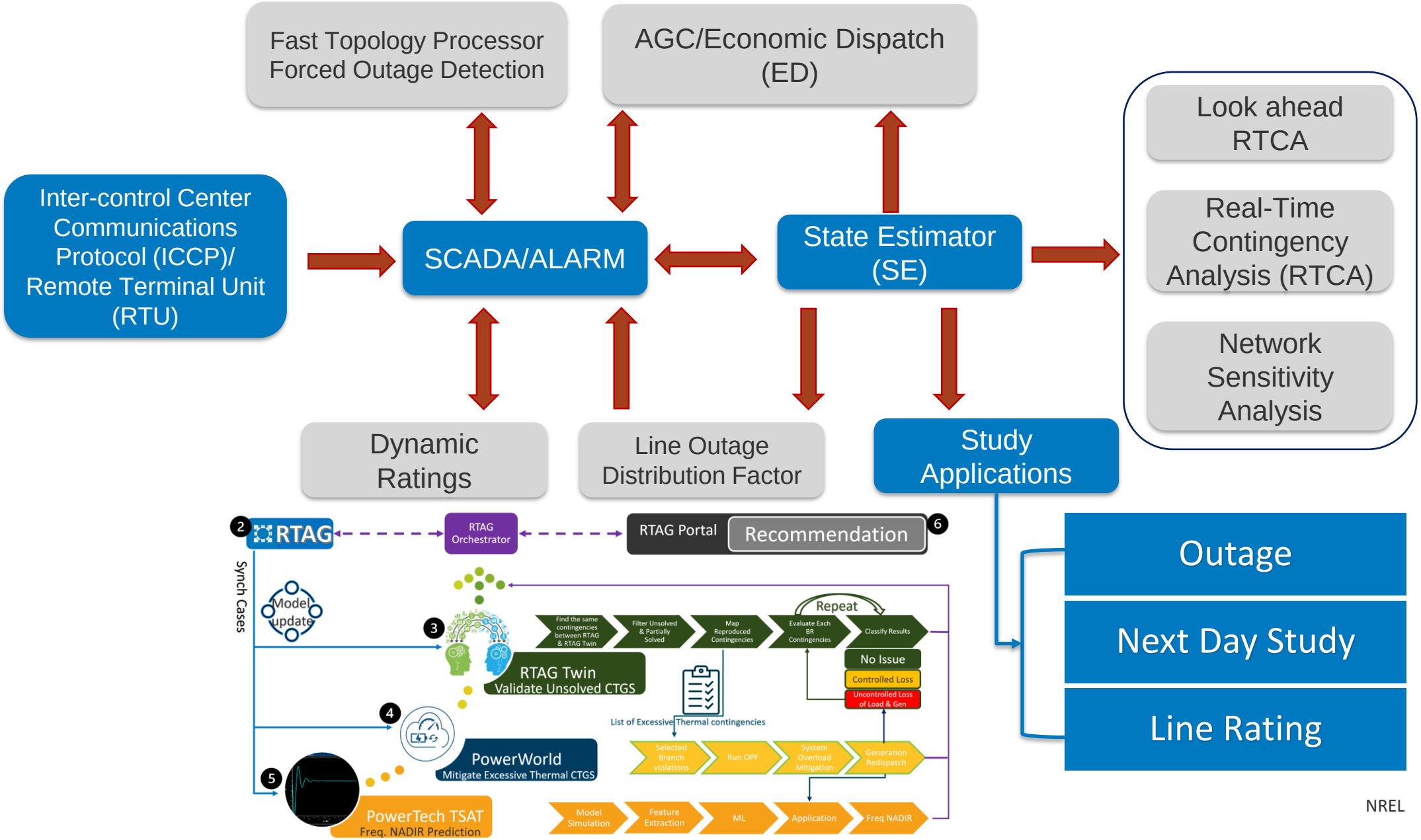
Digital Twin: Is This New? Not Really

For decades, EMS and DTS have been integrated into sizable control rooms, serving as both real-time operational tools and offline training aids

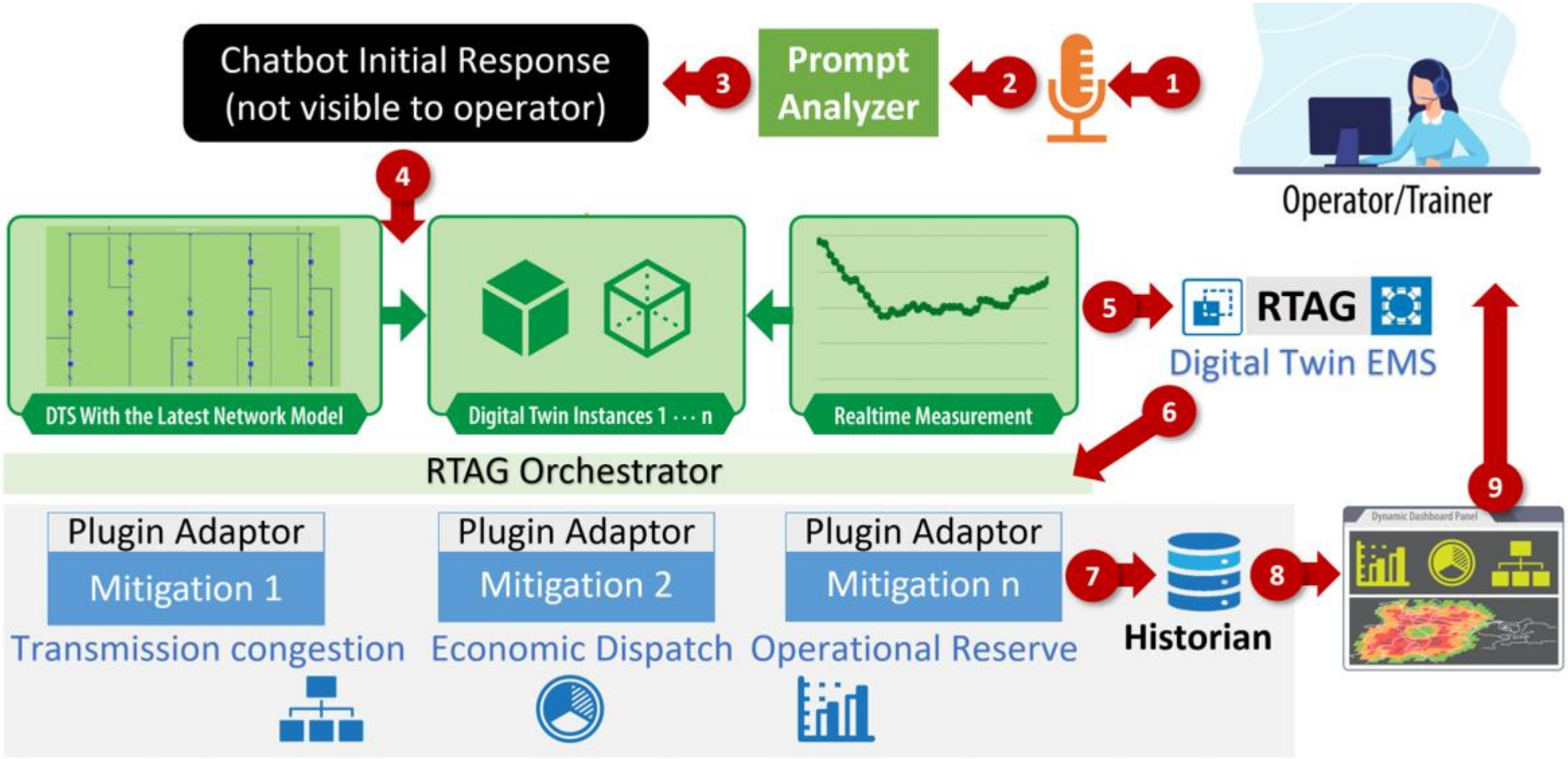


FEP: Front-End Processor, ICCP: Inter-control Center Communications Protocol, IDS: Intrusion Detection System , IED: Intelligent Electronic Device, MU: Merging Unit, PDC: Phasor Data Concentrator

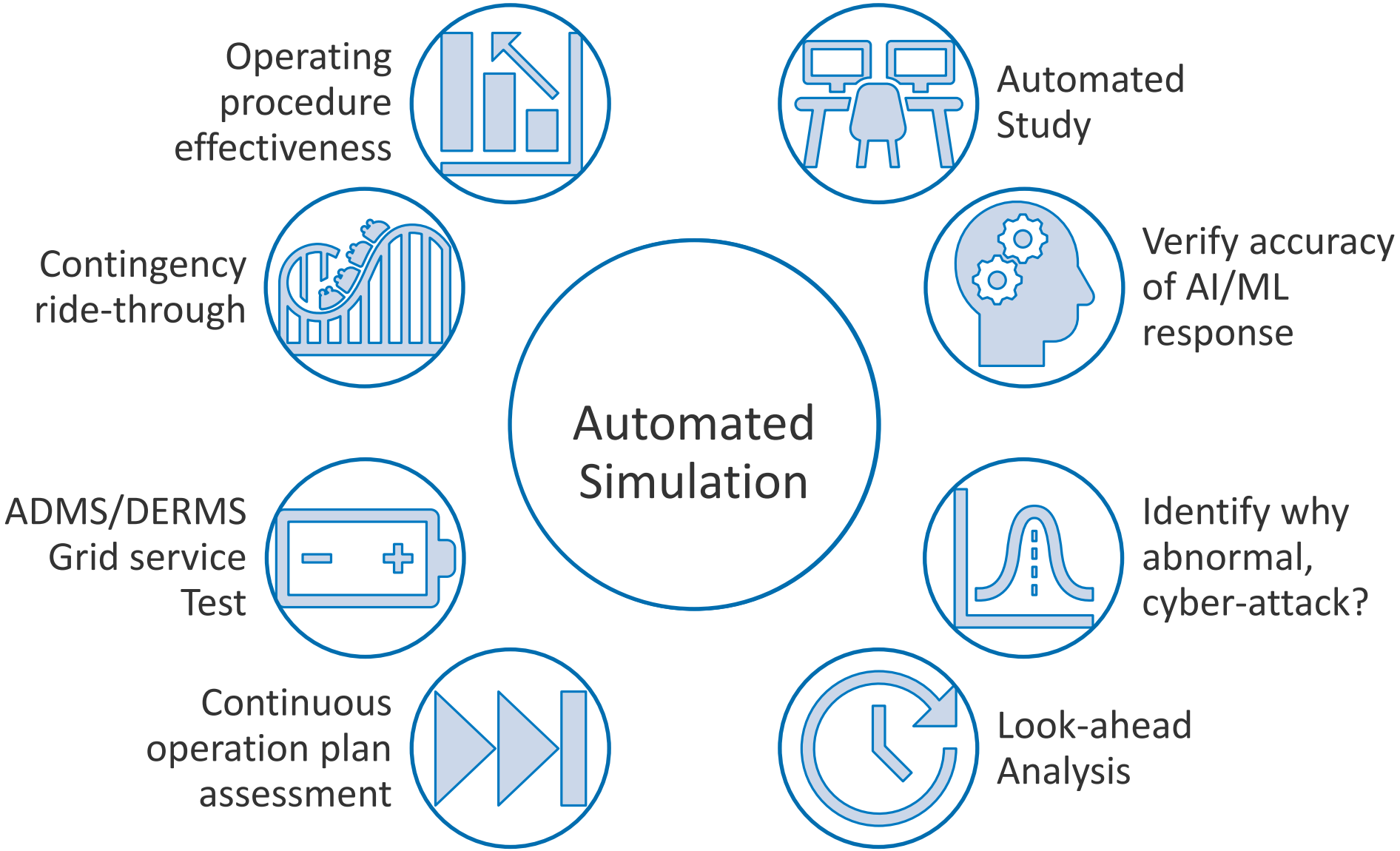
Control Room Digital Twin



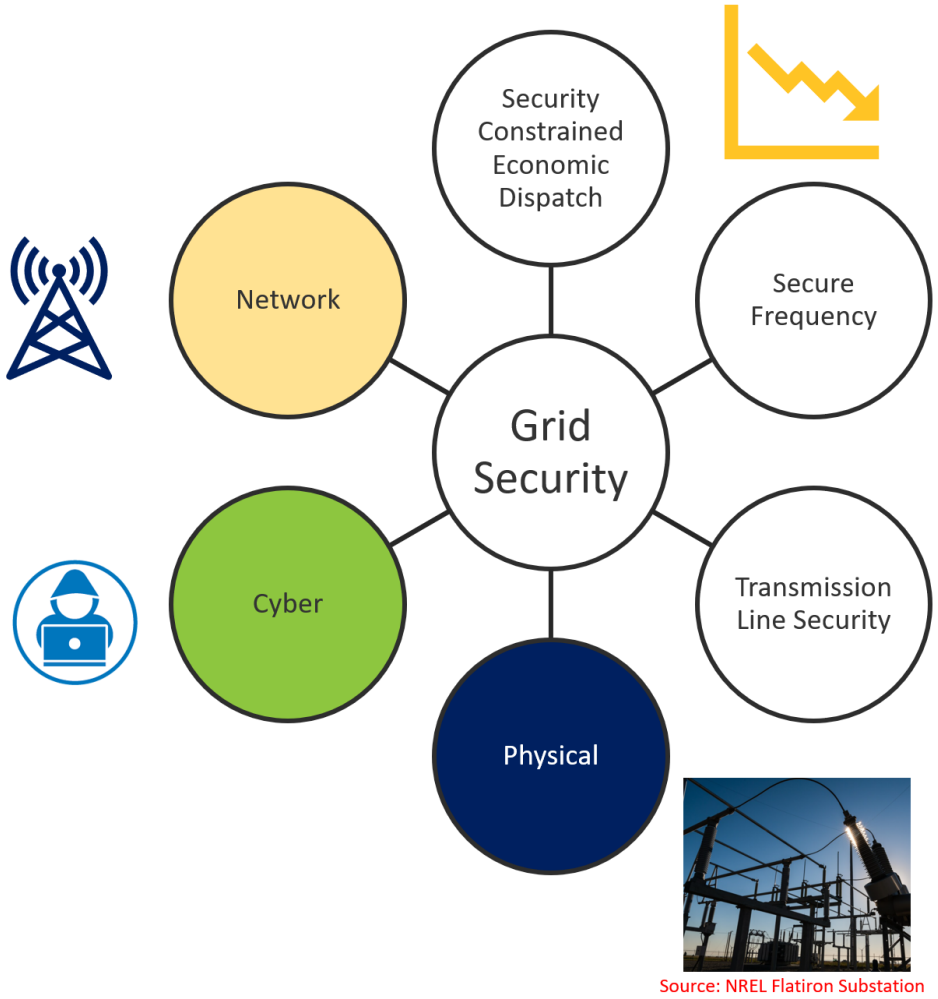
Digital Twin: How to Assist Operators?

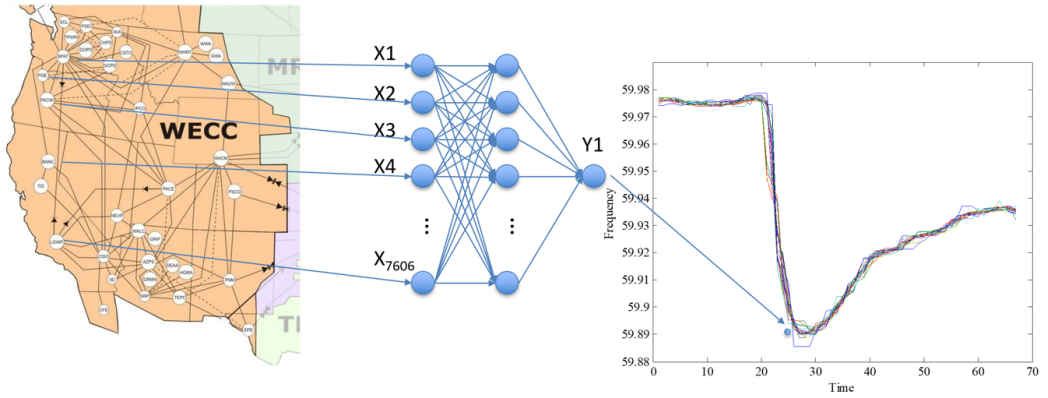


What Do We Do With Digital Twin?



What Does ‘Security’ Mean in the Electric Grid?





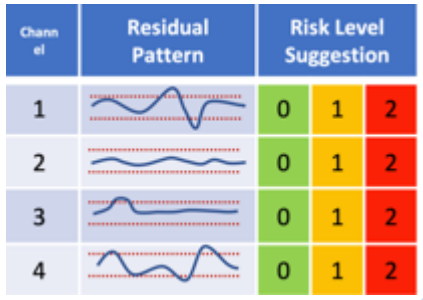
Source: NREL Flatiron Substation

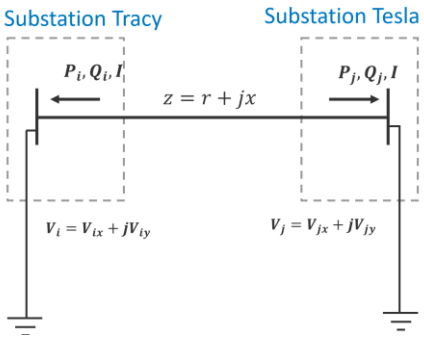
In the electric industry, ‘grid security’ relates to:

- **Grid operating conditions: balancing generation and load**
- **Cyber: data**
- **Network: data relay**
- Physical: equipment to support power delivery, including protection

OT Measurement + OT Cyber Check

- Local, regional & system Level
  - State Estimator + Real-Time Contingency Analysis
  - Integrate historical event PMU data for cybersecurity threats detection into the VT algorithm
  - State Prediction with future-hour forecasted data (Load, Generation, Interchange Schedule, and Outage)



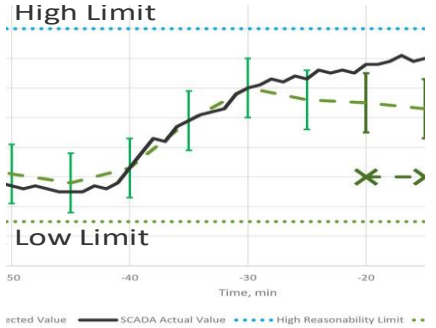


AI/ML Powerflow Trend Prediction in multi-time & space

Operationally Predicted Future Powerflow at a system level

Physics of Law at a regional level by sampling neighboring substations

Physics of Law at a local substation



Circuit Law	OADS RULES
KCL	$\lvert\sum I_{exit} - \sum I_{enter}\rvert \le k_{cer1}\lvert i_i\rvert + k_{cern}\lvert i_n\rvert$
KVL	$\lvert v_1 + \cdots + v_n\rvert \le k_{ver1}\lvert v_i\rvert + k_{vern}\lvert v_n\rvert$
Ohm's Law	$\lvert v_j - v_k - i_{jk}Z_{line}\rvert \le MAX\{k_{verj}\lvert v_j\rvert, k_{verk}\lvert v_k\rvert, k_{cerjk}\lvert i_{jk}Z_{line}\rvert\}$

OT Cyber Defense

- Asset Inventory and Device Authorization
- Protocol Anomaly Detection
- OT Network Monitoring and Anomaly Detection
- Protocol Threshold Check
- OT Measurement Signature-Based AI/ML Anomaly Detection
- ⋮

- DNP3 Protocol Packet Analysis
- Kirchhoff's and Ohm's Laws

Takeaway

R&D of advanced technologies, such as digital twin, dynamic dashboard, or AI/ML analytics in the control room

Testbed for integrating T&D with DERs + cybersecurity in mind

Work with NREL

Research platform for evaluating DERs to essential grid service operation

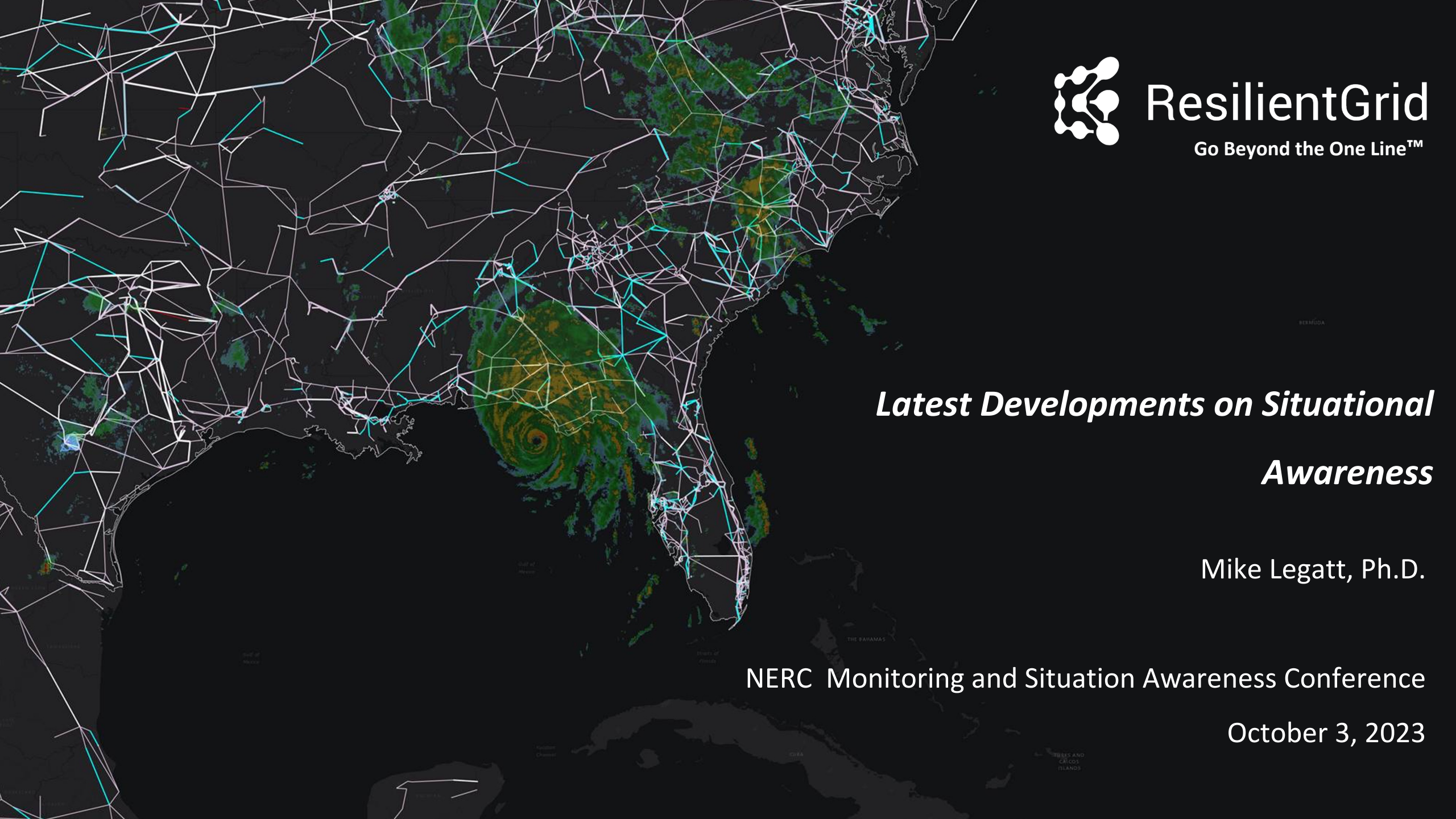
Global network of the control room operators

Thank You.

www.nrel.gov

NREL/PR-5B00-86101

This work was authored in part by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the U.S. Department of Energy Office of Electricity. The views expressed in the article do not necessarily represent the views of the DOE or the U.S. Government. The U.S. Government retains and the publisher, by accepting the article for publication, acknowledges that the U.S. Government retains a nonexclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published form of this work, or allow others to do so, for U.S. Government purposes.



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Go Beyond the One Line™

Latest Developments on Situational Awareness

Mike Legatt, Ph.D.

NERC Monitoring and Situation Awareness Conference

October 3, 2023

Core Philosophies:

"All organizations are perfectly aligned to get the results they get."
Arthur W. Jones

"For every complex human problem, there is a solution that is neat, simple, and wrong."
H.L. Mencken

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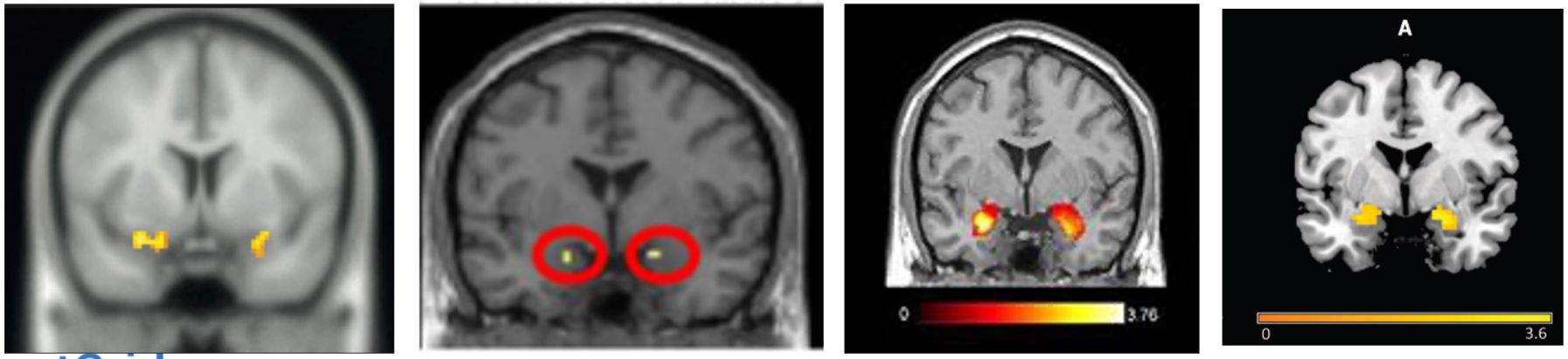
Adaptive Capacity Decreasing

- "Hours of boredom to moments of terror"
  - –Humans make 3–7 mistakes per hour awake, 11–17 under extreme stress (Muschara, 2014)
  - –Working memory decreases under stress (from 7±2 chunks to 3–5 or lower, with long term damage from prolonged stress)



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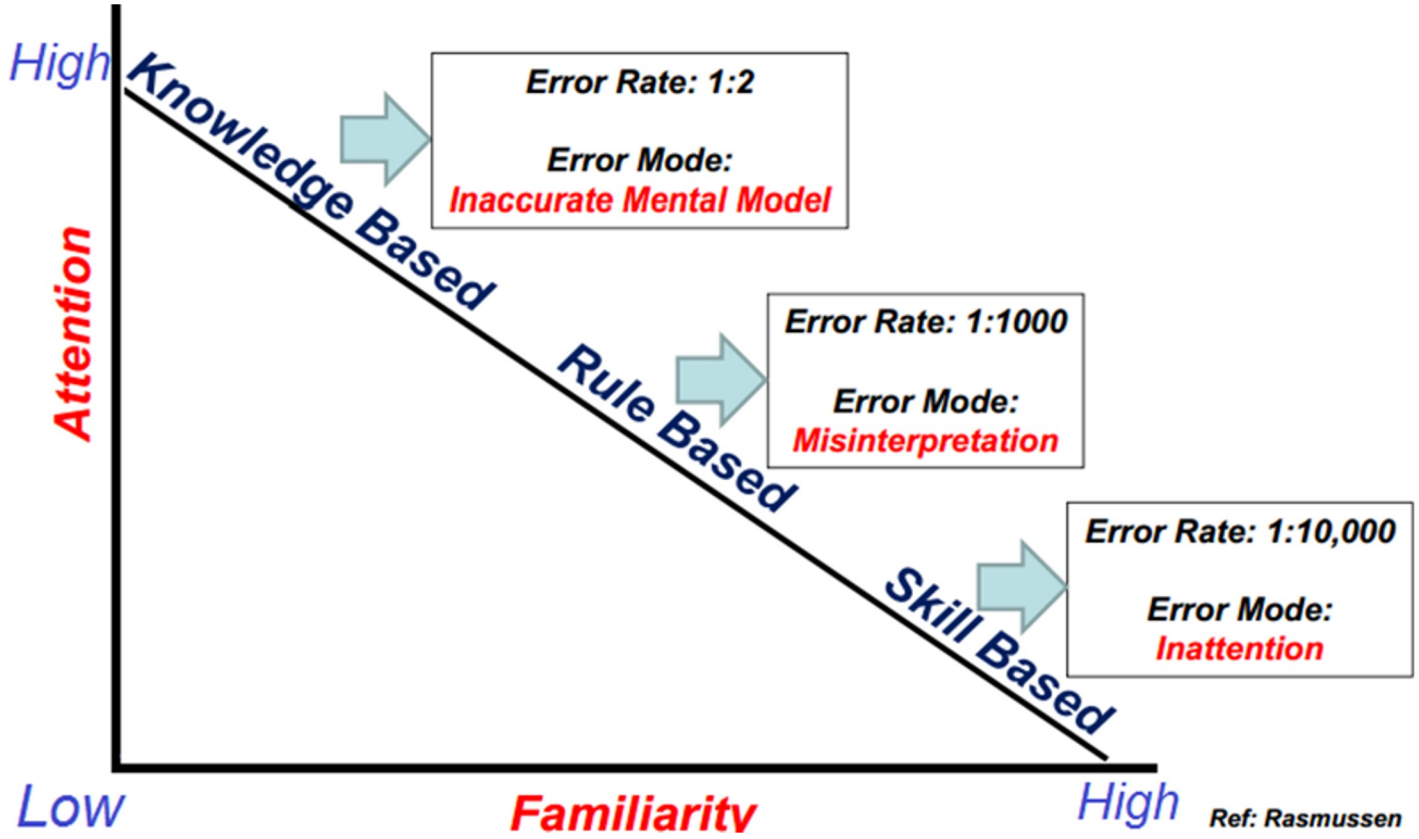
Human Performance Under Stress



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Complexity and Complicatedness

- **Complex:** Many interdependent components
  - Hard to get order, control, or predictably. “Emergent system”
- **Complicated:** Many independent components
  - Once you can separate components, you can deal with each of them systematically
- **Chaotic**
- **Clear**

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Learning Environments

- **Kind:**
  - Rapid and accurate feedback of whether a decision is correct or not
  - Limited number of variables and choices
  - Information easily available
  - Tight feedback loops
  - Simple games (tic-tac-toe) to harder games (chess)
  - People (and computers) that can handle the appropriate number of variables can learn
    - Pattern recognition and reinforcement / reinforcement learning

Hogarth, Lejarraga & Soyer, 2015

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Learning Environments

- **Wicked:**
  - Feedback inconsistent
  - Feedback not always accurate
  - Feedback delayed in time and/or space
  - Feedback not always given
  - Other variables are hidden
  - Tremendous amount of variables
- **Fiendish**
  - Not even sure what success looks like

Hogarth, Lejarraga & Soyer, 2015

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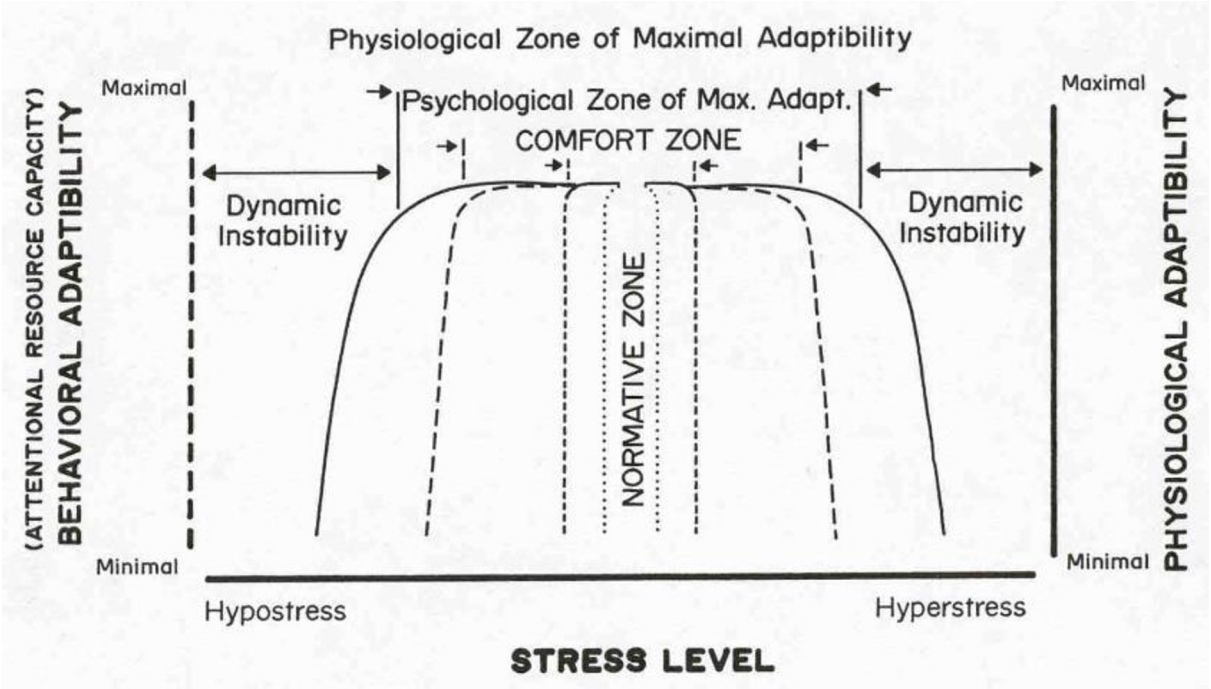
Interconnected Critical Systems

- Modes of operation:
  - Compliance
  - Reliability
  - Resilience
  - Robustness
- Stress?
  - Distress
  - Eustress
- Cascades in human error



A Dynamic Model of Stress and Attention, from Hancock & Warm (1989)

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Complex Sociotechnical Systems

- Fishbowl industry
- Depends heavily on public trust and participation
- Exceptionally dangerous for workers and consumers
- Increasing in both complexity and complicatedness

- Growth of Joint Cognitive Systems: People and technology working and communicating together
    - Agreement to work together
    - Predictable in behavior
    - Can receive and respond to instructions
    - Maintain shared mental models

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Complex Sociotechnical Systems

- Fishbowl industry
- Depends heavily
- Exceptionally dan
- Increasing in both

- Growth of Joint C ology working and communicating t
  - Agreement to
  - Predictable in
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  - Maintain share

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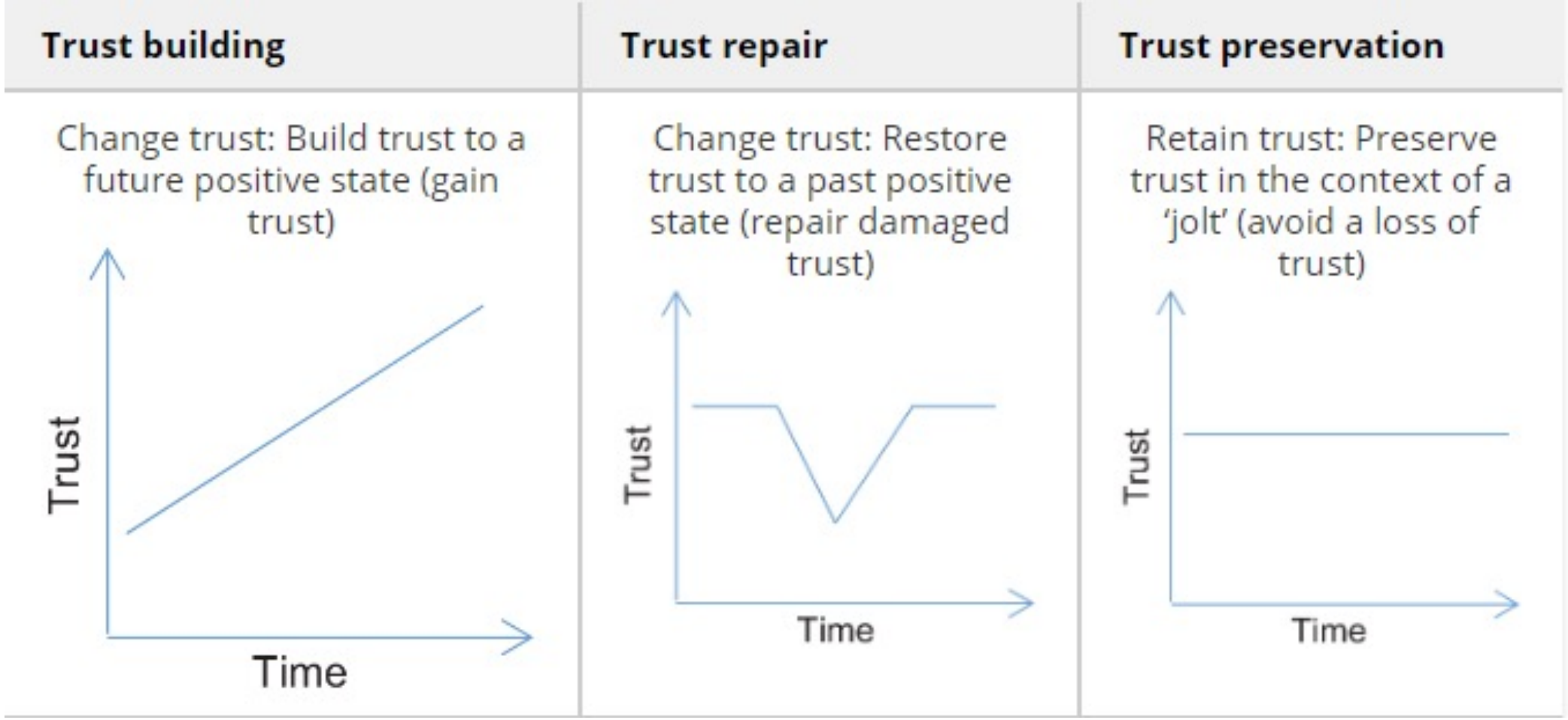
Trust in Organizations



Gustafsson, S., Gillespie, N., Searle, R., Hope Hailey, V., & Dietz, G. (2021)

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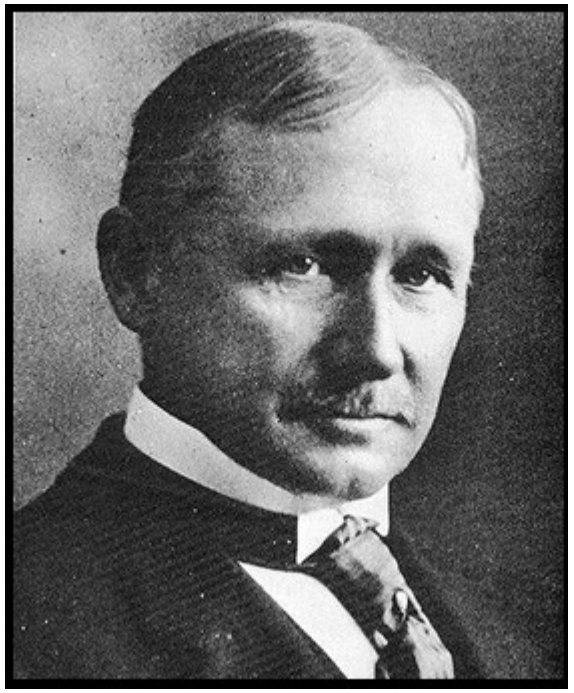
How We Work

- F.W. Taylor – The Principles of Scientific Management
  - Moved from skilled individuals doing many things to less skilled individuals following procedures over and over
  - Motivating them simple: financial awards can make them work faster



McChrystal, S. (2015). Team of Teams.
Duhigg, C. (2016). Smarter, Faster, Better.

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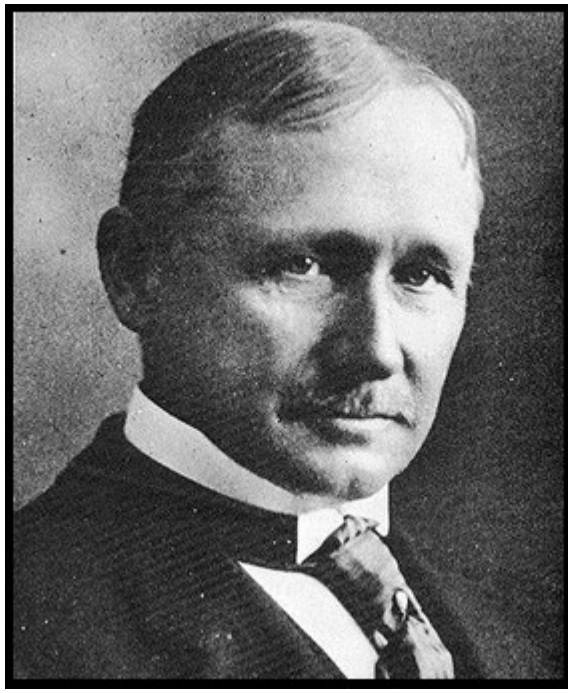
How We Work

- F.W. Taylor – The Principles of Scientific Management
  - Much of what we do is now on **thought** not repetitive, automatic actions.
  - Financial bonuses now **decrease** performance and **increase** error rates.
  - Many employees now searching for more **meaning** in their work; cultural and short term KPI misalignments.



McChrystal, S. (2015). Team of Teams.
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Back to culture

- User-centered design
- Design for performance under stress
- Expansive collaborative simulations
- Holistic view of the system operator
- Fitness for Duty
- New approach to leadership
  - High Reliability Organizational culture
  - Just culture
  - Lessons learned from projects such as Google Oxygen

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What exactly is Culture?

- Industrial-Organizational Psychology
  - “Organizational culture refers to a system of shared assumptions, values, and beliefs that show people what is appropriate and inappropriate behavior. These values have a strong influence on employee behavior as well as organizational performance.” (Powers, 2019)

What exactly is Culture?

- The brain, as a pattern-recognition machine, is primarily making predictions (e.g., Hawkins, 2004)
  - So, culture can be seen as the patterns that we expect, in terms of how we should act, and how others will react.
  - A person will predict what happens if they make a mistake
    - Will I be fired if my leaders find out I made a mistake? If so, should I hide it?
  - Or another example is a person predicting what is most important to an organization/leader, based on things they've observed
    - Which is more important, quick or correct?

What Makes a Good Leader? (Google Oxygen)

- Most positive (in order)
  - Being a good coach
  - Empowering / not micromanaging
  - Being interested in direct reports, success & well-being
  - Being productive and results-oriented
  - Being a good communicator and listener
  - Helping employees with career development
  - Having a clear vision and strategy for the team
  - Having technical skills that could help advise the team

What Makes a Poor Leader? (Google Oxygen)

- Most negative (in order)
  - Having trouble making a transition to management/leadership
  - Lacking a consistent approach to performance management
  - Spending too little time managing (servant leadership) and communicating.

What Makes a Good Team? (Google Aristotle)

- No significant relationships between team members' distribution of IQ, friendship, diversity alone.

- Significant relationship: Group norms
  - Most important: habits of how team members treat each other
  - Not important: dynamics of one/few leaders vs. distributed leadership (as long as everyone agrees)

Naturalistic Decision Making

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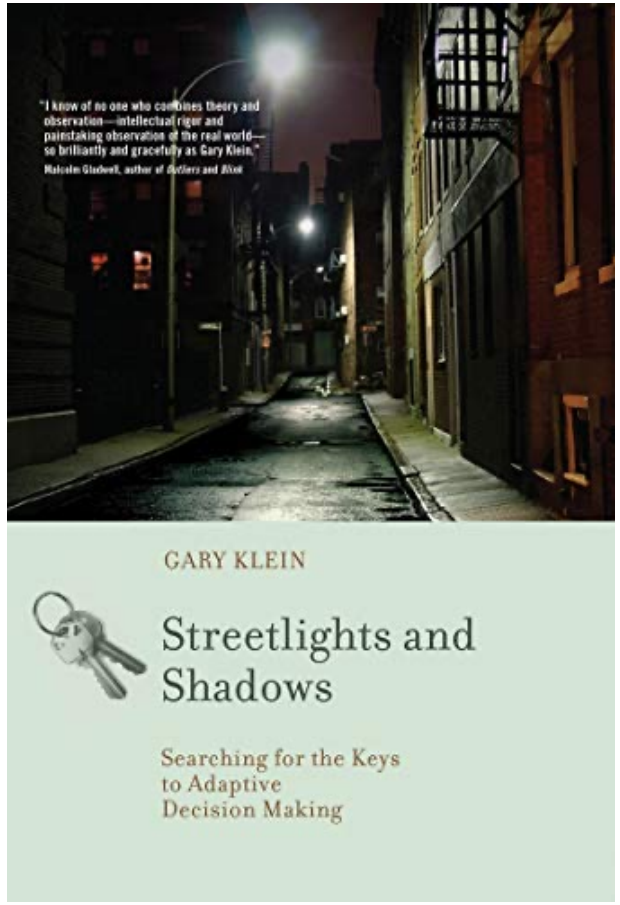
What is decision making in the wild?

How do we make decisions?

- Original research was done in research labs, under controlled conditions
- Klein et al worked with experts in real-world situations, with tremendous amounts of complexity, to determine how people actually made decisions in those real-world scenarios.

Ey, 2022



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What is decision making in the wild?

Translating experience into action focused on

- Decision making
- Sensemaking
- Adapting

It’s about how experts make decisions in the real world under conditions of stress, time pressure, dynamic conditions, ambiguous information, vague goals.

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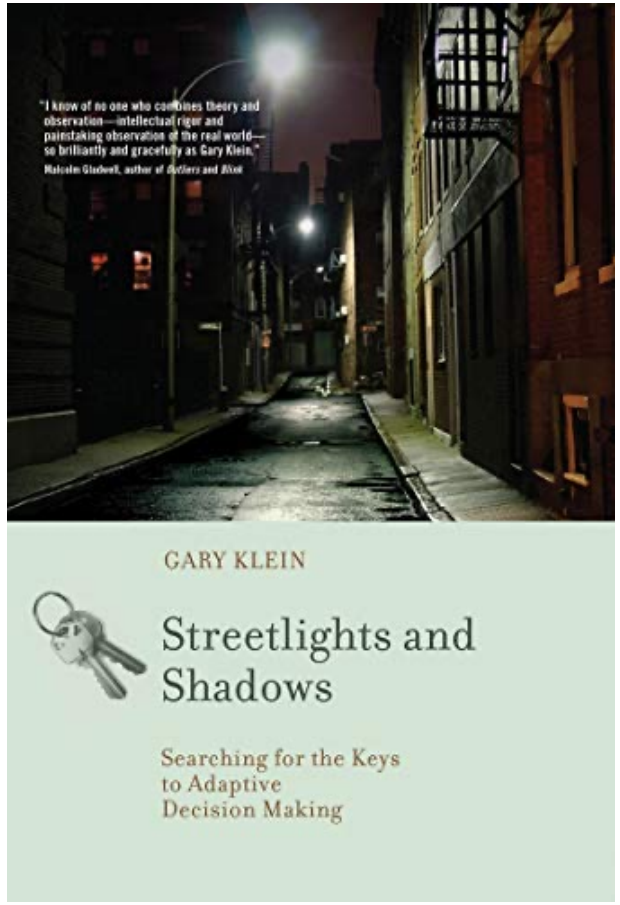

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What is decision making in the wild?

Different kinds of decisions:

- **Maximizing**: Finding the best possible outcome
- **Satisficing:** Choosing the first acceptable/workable solution
- **Optimizing**: Achieving the best possible balance among goals/choices

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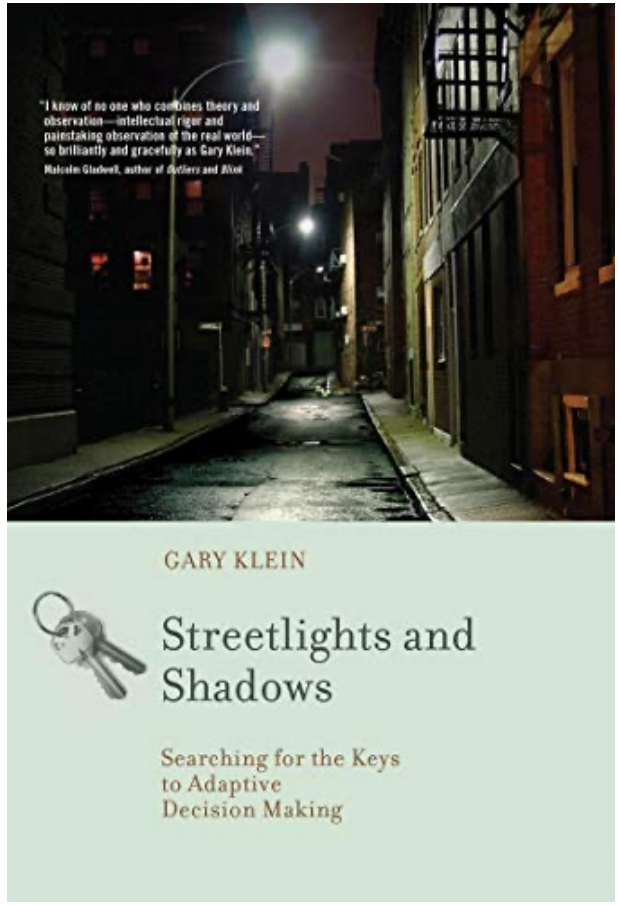

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What is decision making in the wild?

Common beliefs, but not so fast, it depends	This instead
We can reduce uncertainty by gathering more information. Too much information can get in our way.	In complex situations, what we need isn't the right information but the right way to understand the information we have. We don't need to connect all the dots but figure out what counts as a dot in the first place.
To make sense of a situation, we draw inferences from the data.	We make sense of data by fitting them into stories and other frames, but the reverse also happens: our frames determine what counts as data.
Leaders can create common ground by assigning roles and setting ground rules in advance.	All team members are responsible for continually monitoring common ground for breakdowns and repairing the breakdown when necessary.

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Naturalistic Decision Making Approaches

- Premortem – Starting with why
  - Find weakness in plan before it's implemented.
  - Reduce overconfidence.
  - Builds a culture of being open and candid. Encourages authentic dissenters. Respects people for their creative contributions.

Ey, 2023

Making Effective Premortems

- **Problem reframing** – Don't ask the group what could go wrong. it's easier to find reasons why something has happened than develop scenarios for things that might happen (Michell, Russo, & Pennington, 1989). Requires more engagement.
- **Cognitively diverse group** – individuals with similar backgrounds produce similar ideas ((Nijstad, Diehl, & Stroebe, 2010).
- **Psychological safety** – the environment needed to unfreeze thinking and reduce the social pressure to go along (Johnson, Johnson, & Smith, 2000). Leader goes first. Walk the talk.
- **Group equality** – everybody plays, and everybody's input treated as equal (Nijstad, Stroebe, & Lodewijkx, 2003). Don't ask for volunteers; one idea per person per round. Nobody dominates.
- **Go fast** – just get the ideas out there; no rambling; no editing and second guessing

Ey, 2023

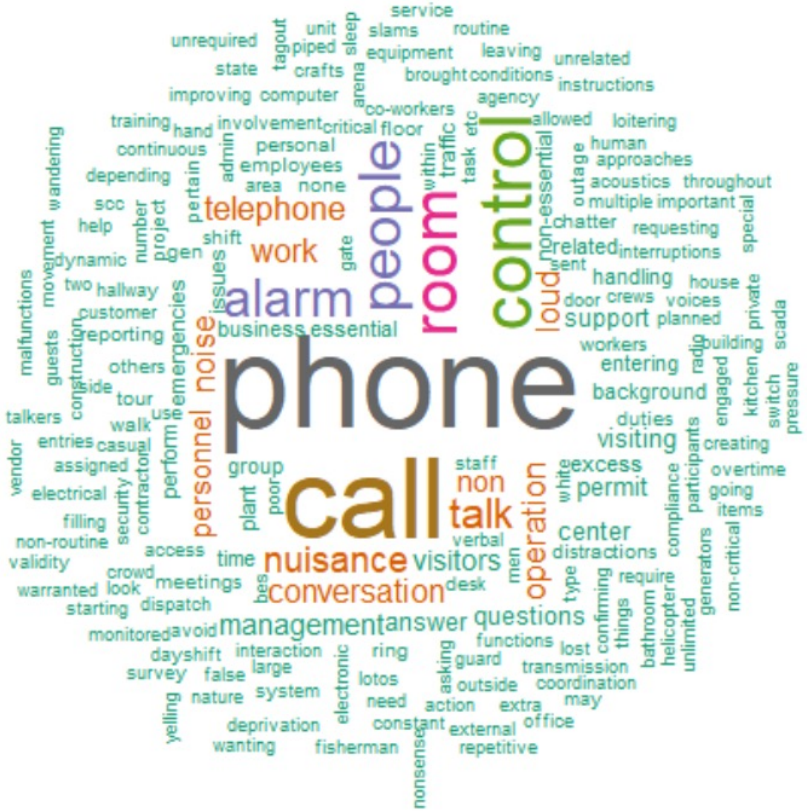
ResilientGrid

Resilience Engineering

ResilientGrid

Adaptive Capacity

- "Resilience to Perturbation" decreasing
  - Focus on maximizing efficiency at the expense of Adaptive Capacity
  - Busy people pulled into tactical or task-base thinking
  - Minimal time to reflect, integrate and consolidate information
  - Add limitations to trainability, and knowledge acquisition is reduced
  - Further ongoing distractions make higher-order thinking more challenging

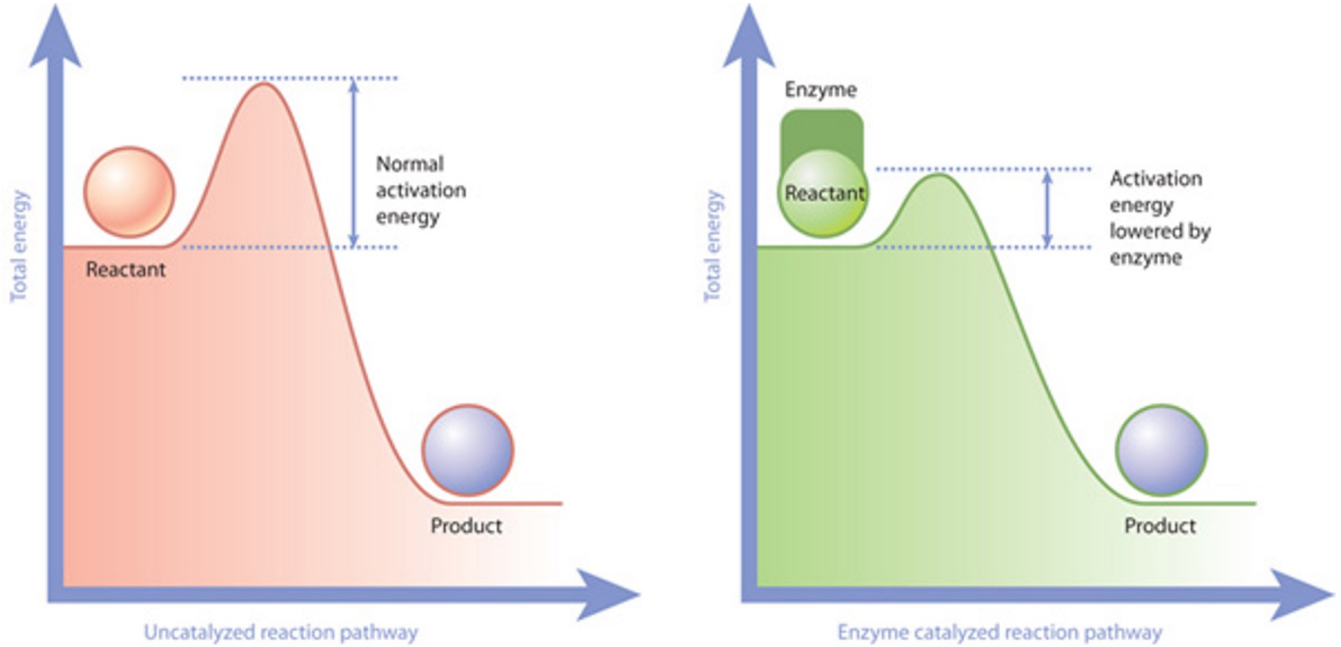


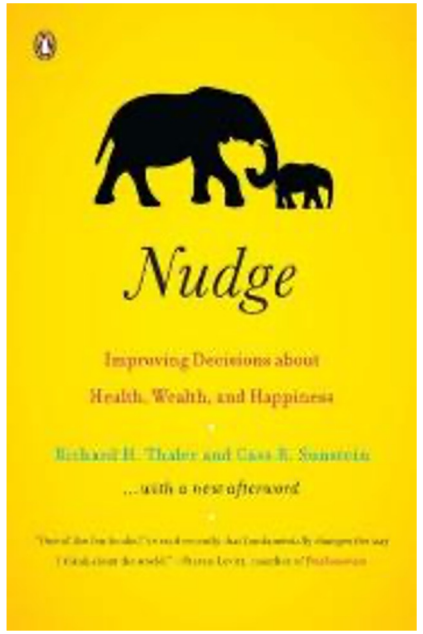
Halverson & Iversen (2018)

ResilientGrid

Activation Energy in Decisions

- In Chemistry, activation energy is what's needed to make a reaction happen; without it, the reaction won't occur.
- In Psychology, it's the motivation needed to start a task.





From http://www.nature.com/scitable/content/enzymes-and-activation-energy-14711476

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Cyber/Physical and other Nexus Events

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Research on IT/OT Nexus

- DOE-Funded research: “Geospatial Visualization to Enable Holistic Response and Situational Awareness (GeoViz)”
- ResilientGrid and Pacific Northwest National Labs
- Workers from nine utilities, across
  - IT
    - Cybersecurity Analysts
    - Cybersecurity supervisors, managers, and leadership
  - OT
    - EMS Support Personnel
    - Control Room operators
    - Control room supervisors, managers, and leadership
  - Trainers

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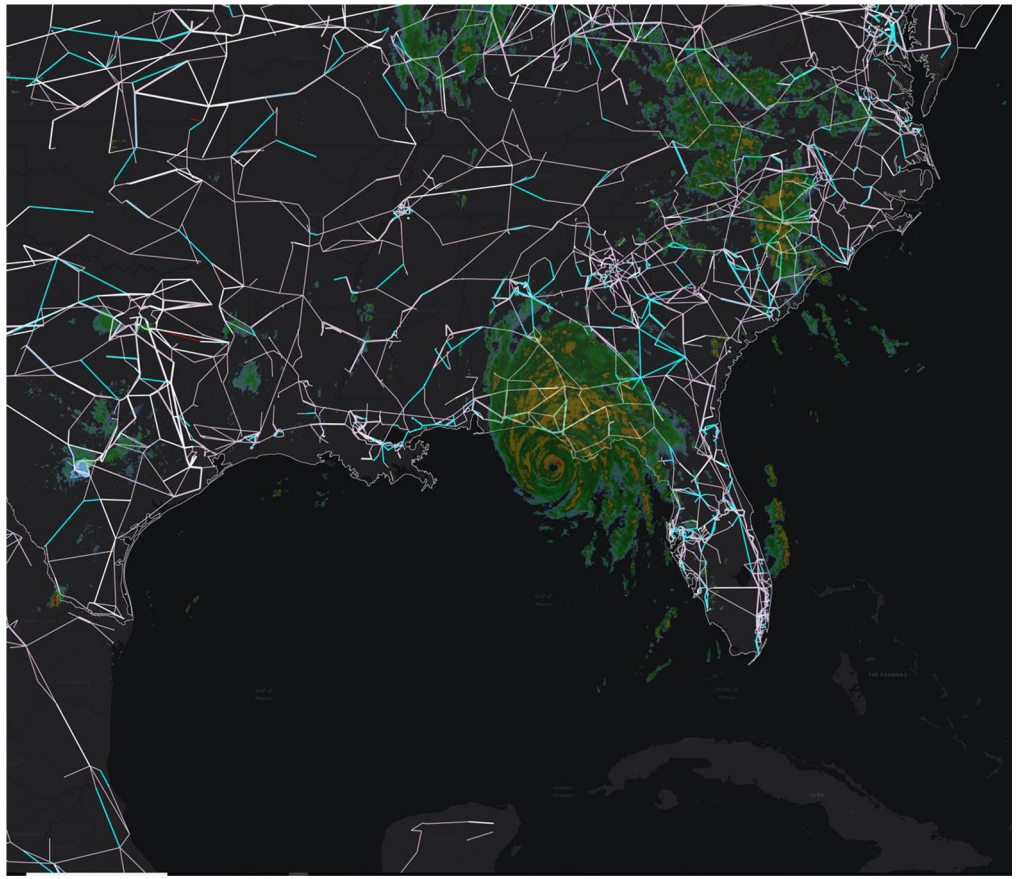
Research on IT/OT Nexus

- Goals:
  - Enhancing an integrated situational awareness tool
  - Providing a Common Relevant Operational Picture (CROP) for collaborative work between IT and OT workers around “bang”
  - Research across several utilities to understand how they would respond to a blended IT/OT event

ResilientGrid

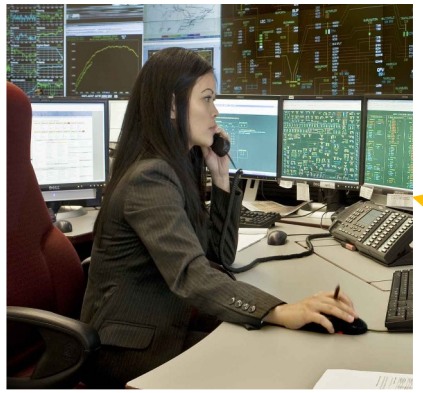
Research on IT/OT Nexus

- Resiliency Management System (RMS)
  - ResilientGrid product for integrated situational awareness (SA)
  - Originally designed for control room SA in real-time operations
  - In use in transmission operations, at the country-wide level (Situational Awareness for FERC, NERC, and the Regions; SAFNR)
- Enhancement of RMS to provide a common view for system operators, EMS support personnel, and Cybersecurity analysts around a “bang”



ResilientGrid

Bifurcation of Controls



Power System Operator

Resiliency Management System® (RMS)

Cyber Analyst

Energy Management System (EMS)

System Status and Controls

Cyber Logs and Network Traffic Analytics

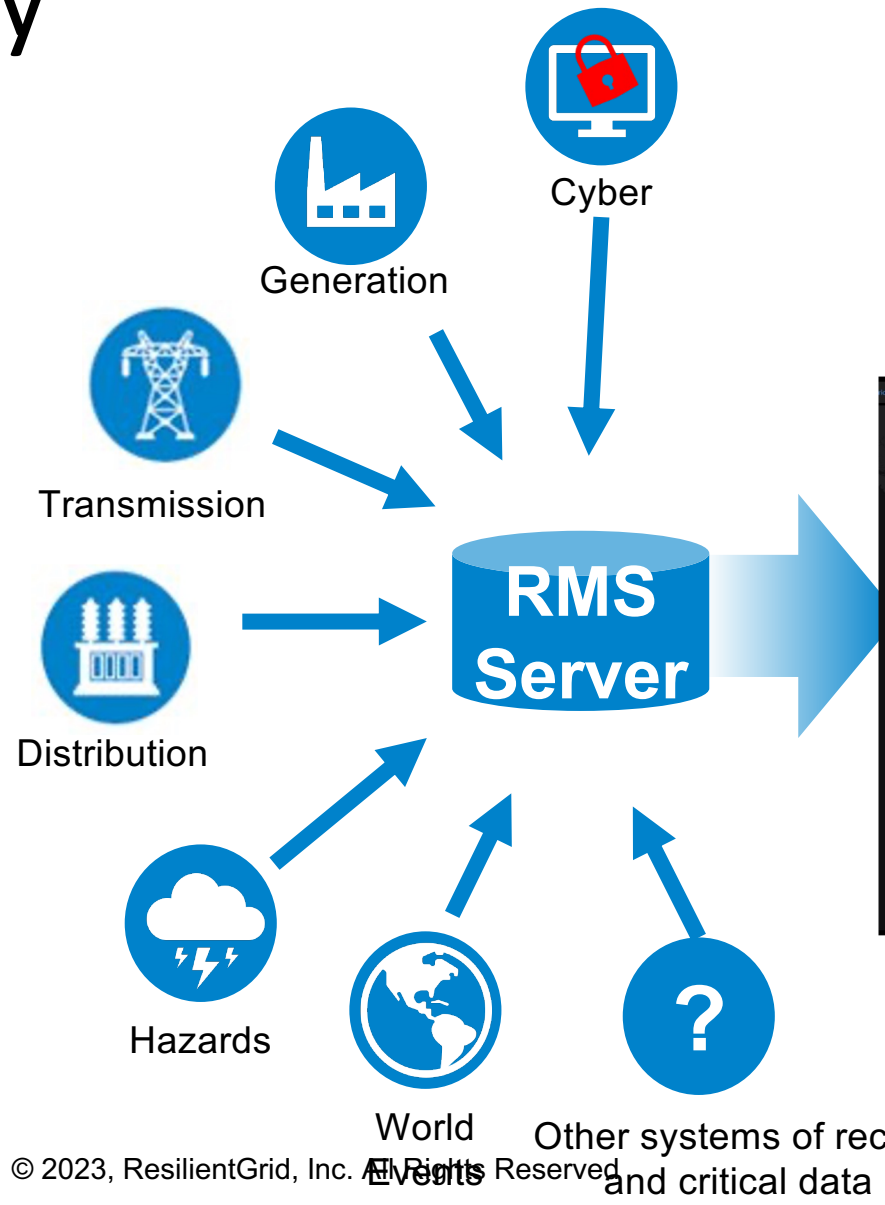
Security Information Event Manager (SIEM)

ResilientGrid

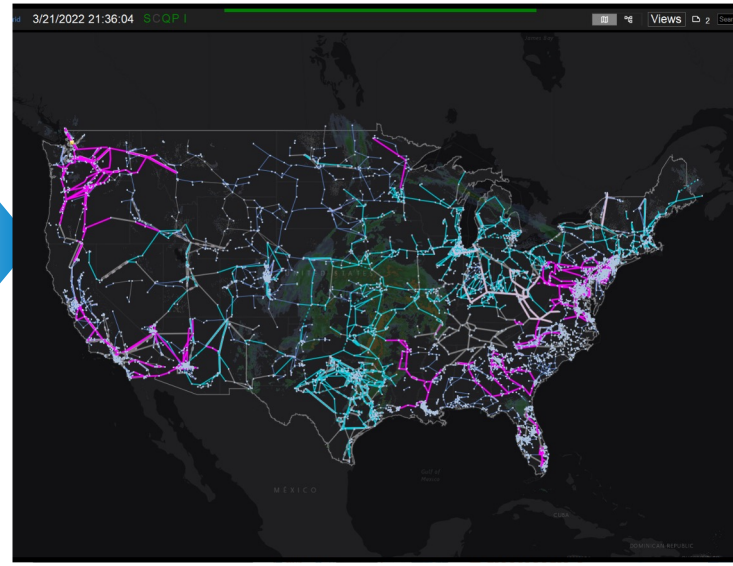
Photos © AESO and Evans Consoles

GeoViz Summary

- Problem:
  - Power system operations is dependent on cyber
  - Power system operators have limited insight into cyber
  - Cyber analysts have limited insight of power system operations
- GeoViz is a geo-spatial visualization to understand the cyberthreats and ongoing impacts to the operation of the electric grid.



IT and OT Analysts, Operators, SMEs



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Question

- What must people do well in order to maintain reliability through a blended IT/OT thread?

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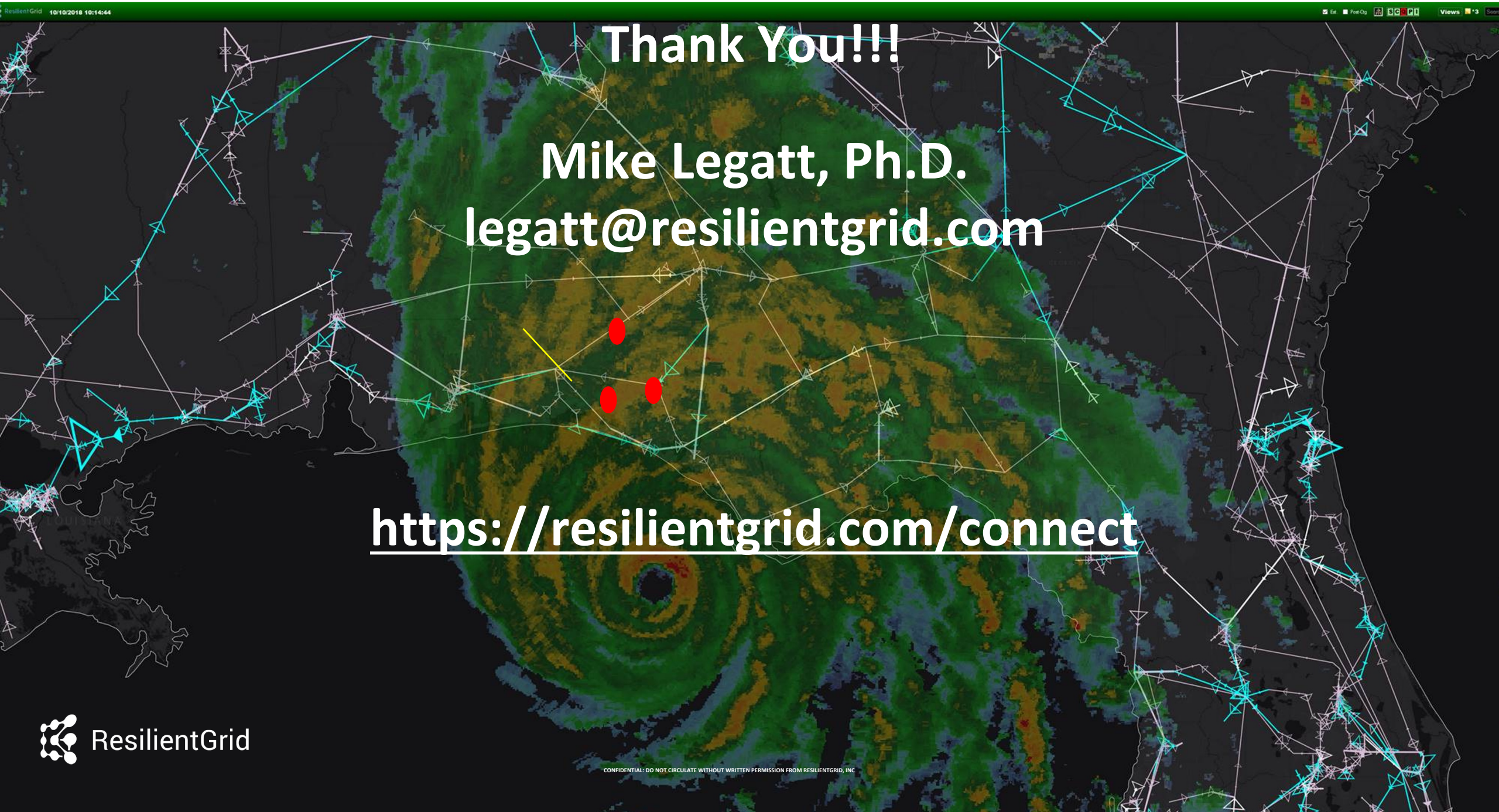
Lessons Learned

- Live-fire red-team/blue-team cyber/physical exercise
- For more information, please visit https://www.energy.gov/ceser/liberty-eclipse
- GeoVis Integrated Cyber/Physical Mapboard
  - Building a Real-Time Common Relevant Operational Picture (CROP)

ResilientGrid



Thank You!!!

Mike Legatt, Ph.D.
legatt@resilientgrid.com

https://resilientgrid.com/connect

ResilientGrid

ABNORMAL AREA CONTROL ERROR DUE TO A MODEL TRANSLATION ERROR LESSON LEARNED

Dwayne Fewless, Principal Analyst

SA & Monitoring Workshop

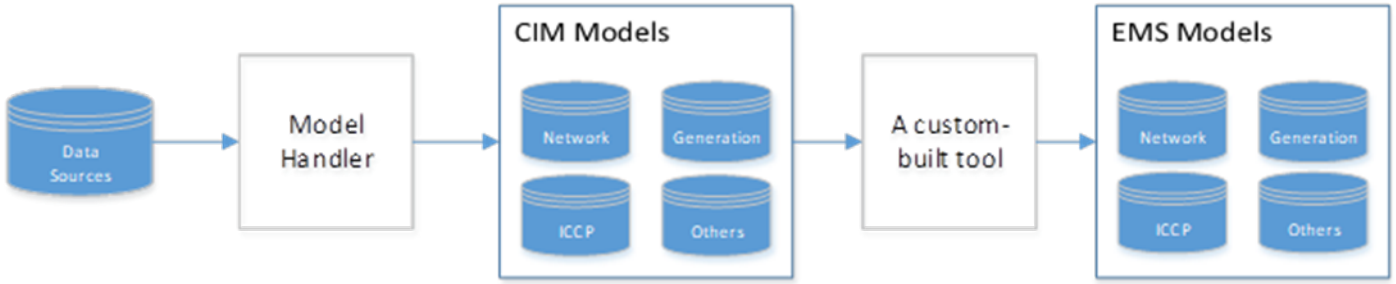
RELIABILITY FIRST

AGENDA

- DETAILS
- WHAT HAPPENED
- CORRECTIVE ACTIONS
- LESSONS LEARNED

DETAILS

- EMS upgraded to new EMS version
  - did not use the model handler and the custom-built tool to generate new EMS models during upgrade
  - directly converted the previous quarterly EMS models to the new EMS version with EMS vendor assistance



- Model Handler: Generating CIM models
- Custom-Built Tool: Translating CIM models to EMS models

DETAILS CONT'D

- Quarterly model updates occur on regular basis
- Two new fields introduced in the new EMS version
- When generating the new quarterly models
- Teams involved with model validation and cutover activities did not recognize the impact that the new fields would have on the model build process
- Data quality checks were done on AGC and generation monitoring

CORRECTIVE ACTIONS

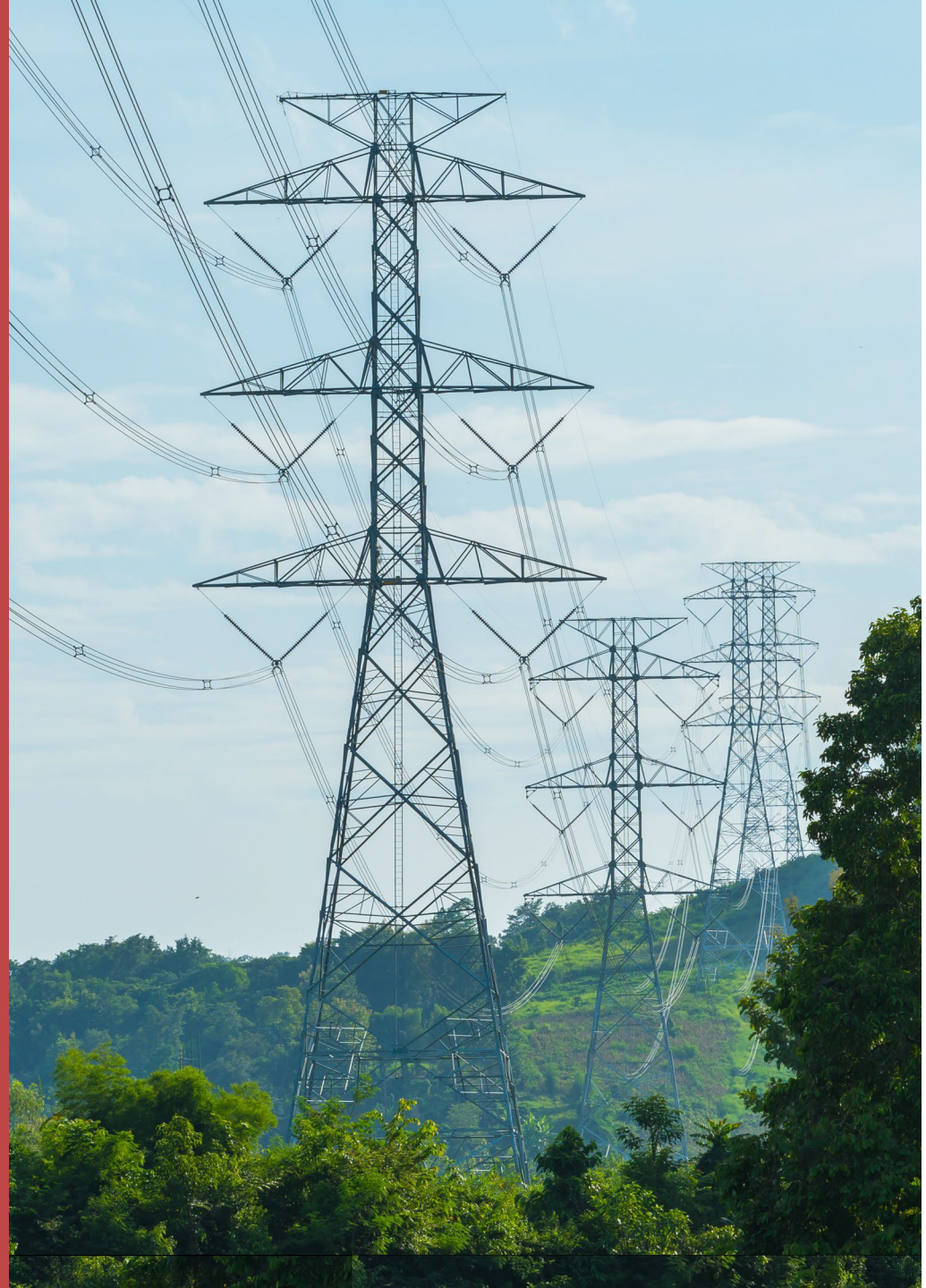
- Reverted to its previous model to manage system conditions while continuing to investigate
- Updated their neighbors about the situation and took manual actions to resolve the issue
- After identifying the modeling error, the entity developed
  - instructions to address the zero MW setpoint issue and to
  - apply a fix to AGC with the new model

LESSONS LEARNED

- The challenges that entities usually face during an EMS upgrade are primarily due to the confluence of change from the EMS upgrade and the model tool/application implementation. Entities should ensure the following actions concerning EMS upgrades:
  - Develop a more holistic approach to aligning the models with EMS revisions
  - Strengthen communications with vendors and increase knowledge transfer from vendors
  - The vendors document all new data fields in their release package, the entity understands their impacts, and modifies or creates in-house tools accordingly

LESSONS LEARNED CONT'D

- For a major model release, entities should perform front-end and back-end data validations and field-by-field comparisons of all databases that are not limited to fields or areas with previously identified issues.
- Entities should run regression testing with new models in a comprehensive test environment and ensure the applications can consume the new models and yield similar or improved results.



FORWARD TOGETHER RELIABILITYFIRST

QUESTIONS & ANSWERS

California ISO

Loss of Monitoring due to a Half Failed High Availability Switch Pair

Robert Melis
Dir. Information Security & Network Operations
California Independent System Operator

Agenda

Introduction California ISO

- History
- Mission
- NERC Registration Functions

Network Overview

- CAISO Network Design
- Hardware and Software Descriptions

Event Overview

- Sequence of Events
- Description of Impacts and Duration
- Resolution and Lessons Learned

California ISO: Introduction

California ISO: Introduction

History

- California Assembly Bill 1890 (1996)
- CA Electric Sector Restructuring (deregulation)
- CAISO assumed responsibility for 80% of the CA BES on April 1 1998

Mission

- Only independent grid operator in the western interconnect
- 26,000 miles of transmission; over 260 million megawatt-hours of electricity annually
- Facilitator of wholesale energy market for CA
- CAISO WEIM used for over 2/3 of load in western interconnect
  - $3.82 Billion in cumulative benefits through March 2023

NERC Registrations

- Balancing Area Authority (BA)
- Transmission Operator (TOP)
- Transmission Service Provider (TSP)
- Reliability Coordinator (RC)
- Planning Authority / Planning Coordinator (PA/PC)

California ISO

Network Overview

Network Overview

Physically and Logically Segmented based on system functions

- Corporate/Enterprise Systems
- Market Systems
- Real Time Systems
- IT Monitoring Systems
- Test/Development Systems

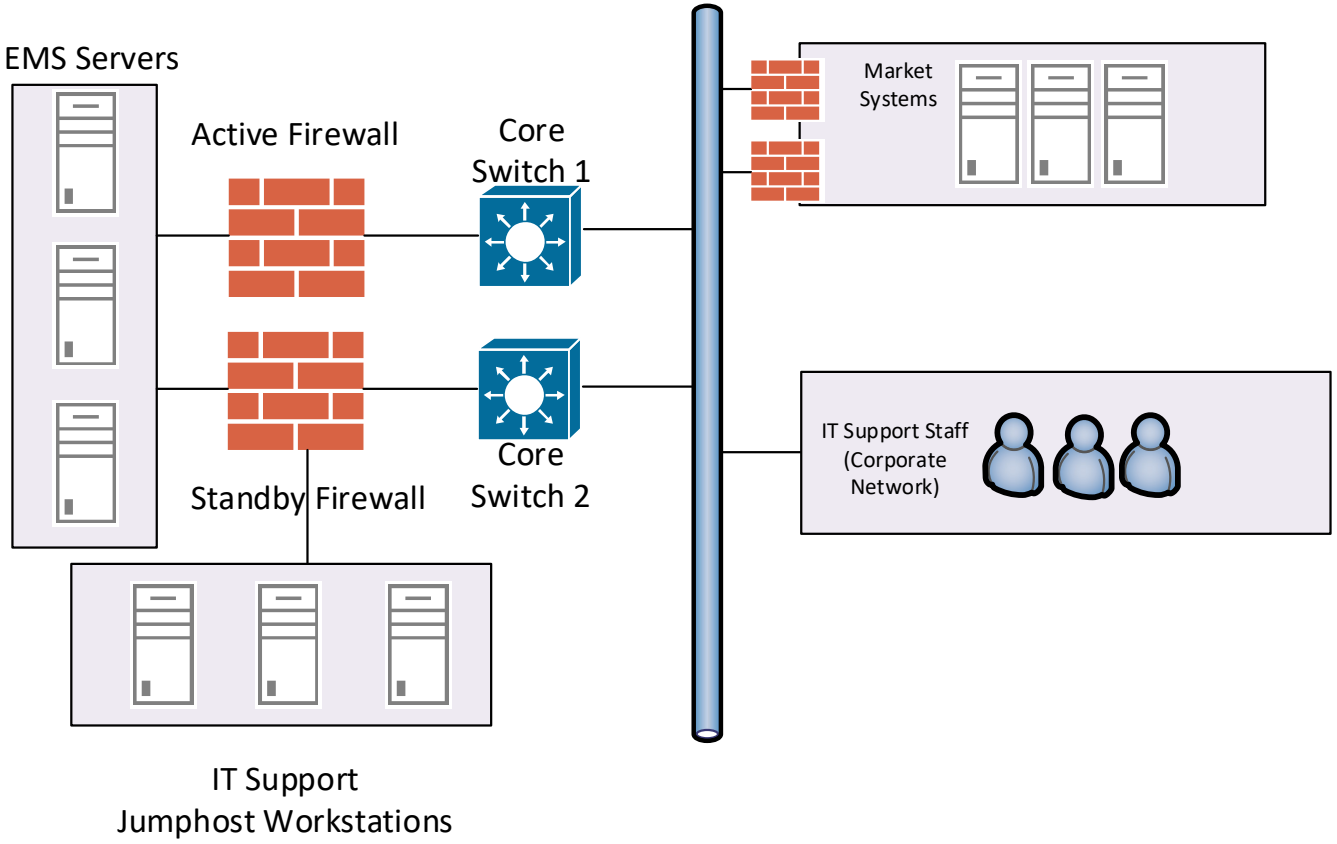
Connections to each network segment/enclave are protected via Firewalls (HA pairs)

- Connections to external networks (Internet, virtual private wide area networks) secured by Firewalls (HA pairs)

Design is same in both Primary and Alternate Data Centers

- Multiple Internet Service Providers
- Multiple metro area service providers (bandwidth between data centers)

Event Overview


EMS Servers
Active Firewall
Core Switch 1
Market Systems
Core Switch 2
IT Support Staff (Corporate Network)
Standby Firewall
IT Support Jumphost Workstations

Lessons Learned

Lessons Learned

History of hardware issues

- Previous issues with spontaneous restarts
- Challenging software upgrades
- Age of equipment (purchased in 2013); already planned for 2023 replacement

Firewall Failover Mechanics

- Firewalls were configured to failover based on firewall status
- Active firewall was still functional and communicating with standby (via 'inside' network)
- Therefore the firewalls did NOT failover automatically
- Failover configurations were updated to network track interface status (up/down)
- Also changed firewall failover configurations so an automatic failover will NOT reverse automatically when an interface comes back up

Active-Standby versus Active-Active

- Would an active-active firewall configuration made the event less impactful?
- Active/active mode requires advanced design concepts that can result in more complex networks
- Active-Active splits traffic based on a source IP, dest IP and dest port hash value
  - NOT 'load balancing' on a per packet basis
- Active/passive mode has simplicity of design; it is significantly easier to troubleshoot routing and traffic flow issues in active/passive mode
  - Seamless failover has been demonstrated countless times during both planned and unplanned events

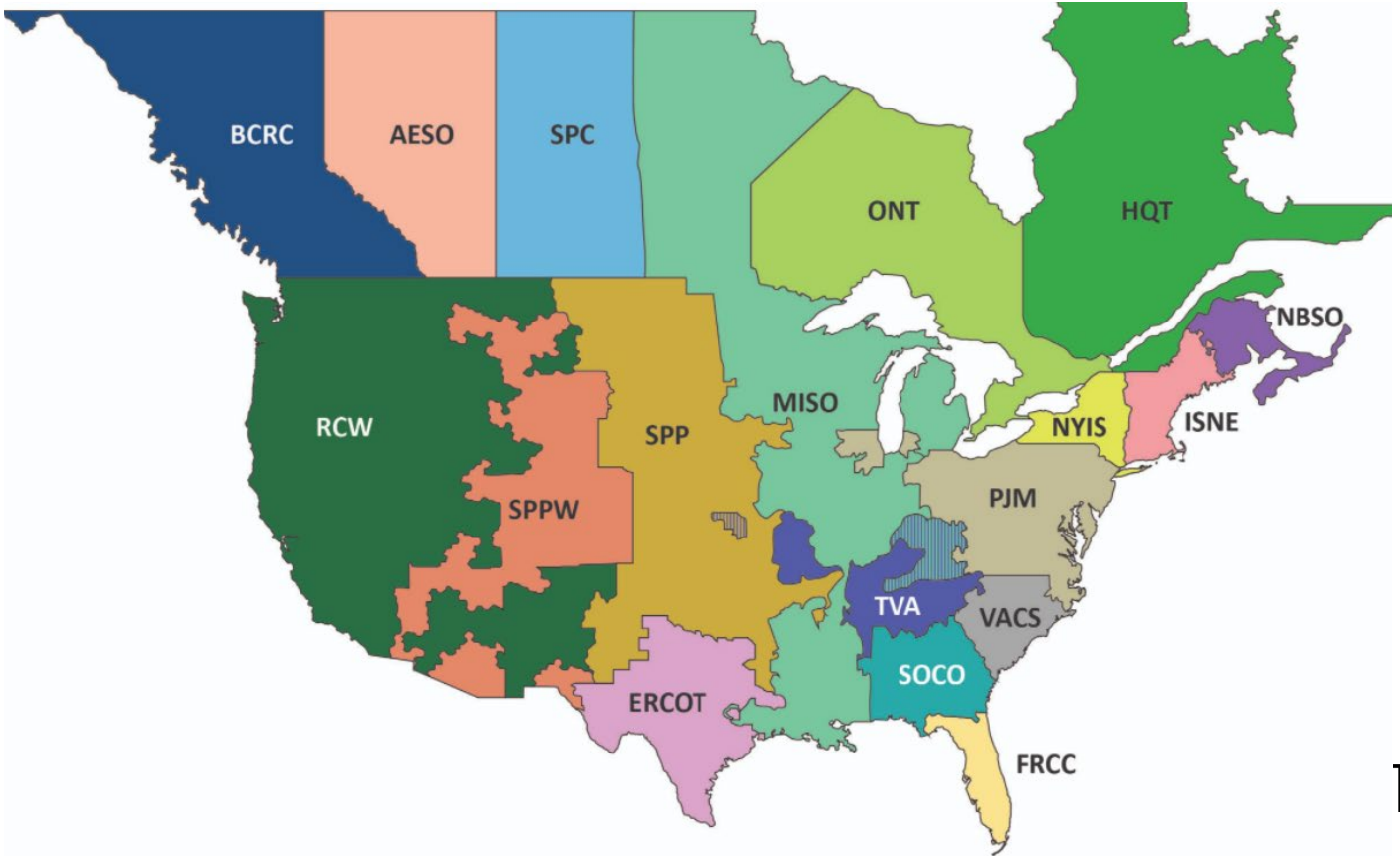
California ISO

Questions?

TVA System Operations Center Loss of Power Event

TVA TENNESSEE VALLEY AUTHORITY

TVA Reliability Coordinator



TENNESSEE VALLEY AUTHORITY

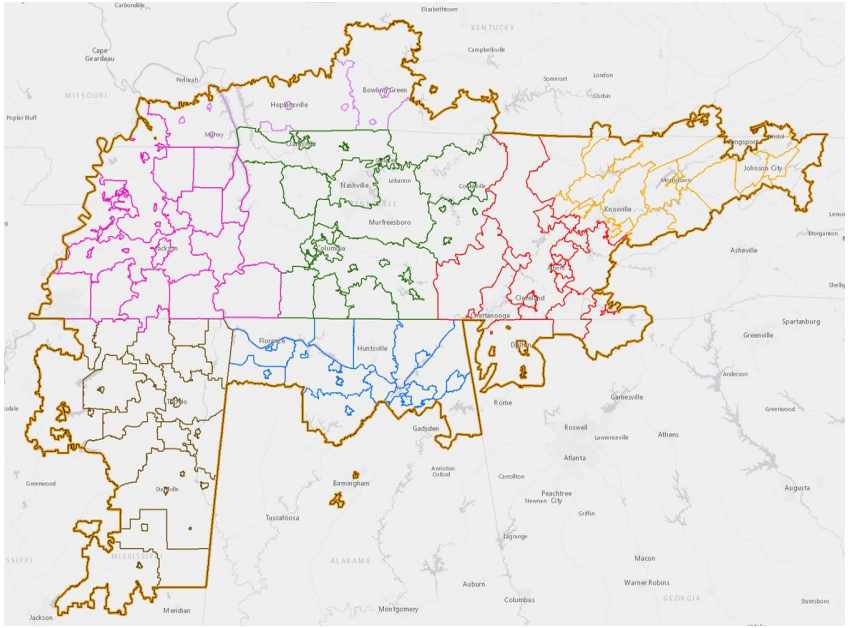
TVA RC Area

- Serving six members including AECI, LGE-KU, MLGW, OMU, SMT, & TVA
- 3 BAAs: AECI, LGE-KU, TVA
- ~ 45,000 MW Load / ~ 52,000 MW Generation
- 12 million customers spanning 11 states
- 199,000 square mile area
- 34,280 miles of transmission

TENNESSEE VALLEY AUTHORITY

Tennessee Valley Authority (TVA) at a Glance

- A federally-owned, self-financed corporation created in 1933 by the TVA Act
- Provides power to 153 local power companies, and 65 directly served industries plus federal facilities
- **Mission of Service – Serve the people of the Valley to make life better through the 3 E's Energy, Environment, and Economic Development**



80,000 SQUARE MILE SERVICE REGION

10 MILLION RESIDENTS

ROBUST TELECOMMUNICATIONS CONECTIVITY INCLUDING **LONG-HAUL FIBER OPTIC**

LOCATED IN 7 STATES

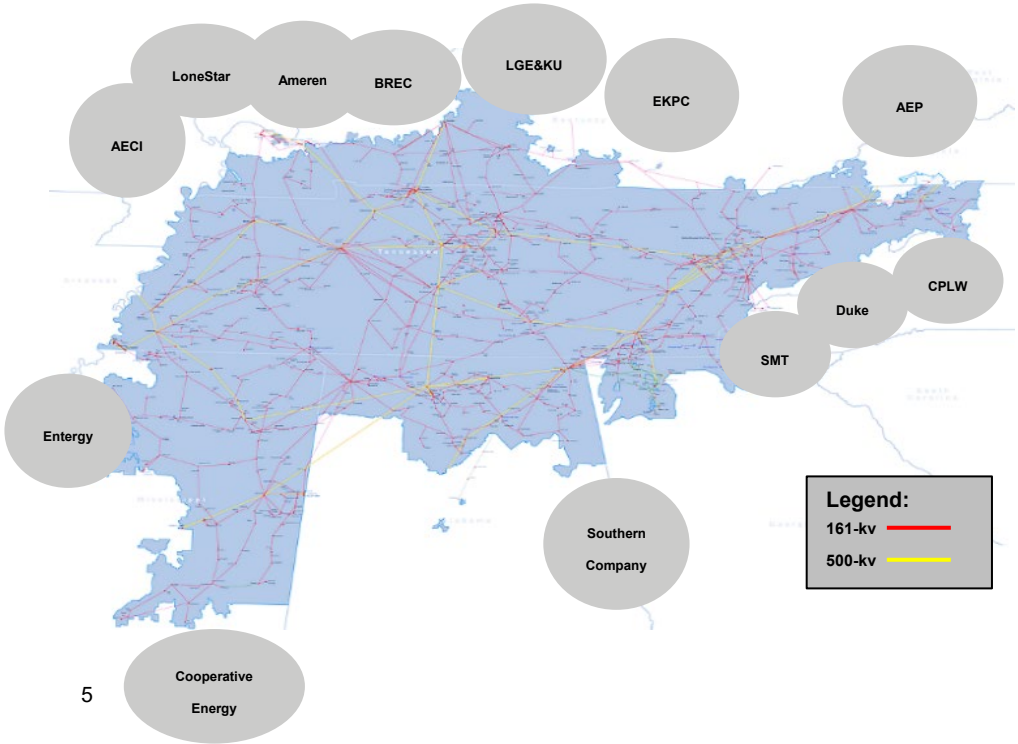
LOW BUSINESS & PERSONAL TAXATION RATES

DIVERSE GENERATION MIX

TVA TENNESSEE VALLEY AUTHORITY

TVA Transmission Overview

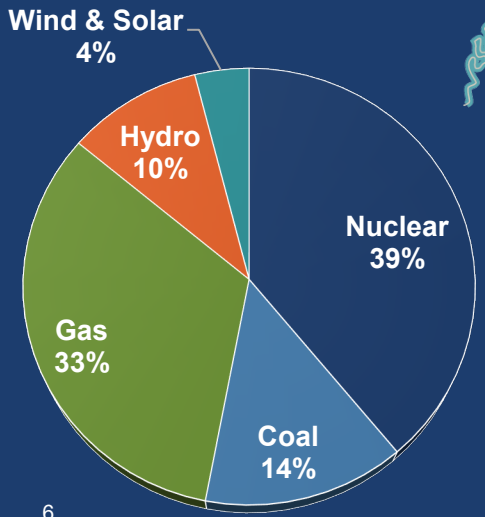
16,265 Circuit Miles | 104,865 Structures | 522 Substations | 1,325 Customer Connection Points | 239,439 Acres ROW
4,300+ miles Backbone Telecom Fiber | 69 interconnections to 13 neighboring systems | 25K Maintenance and Emergency Switching orders each year

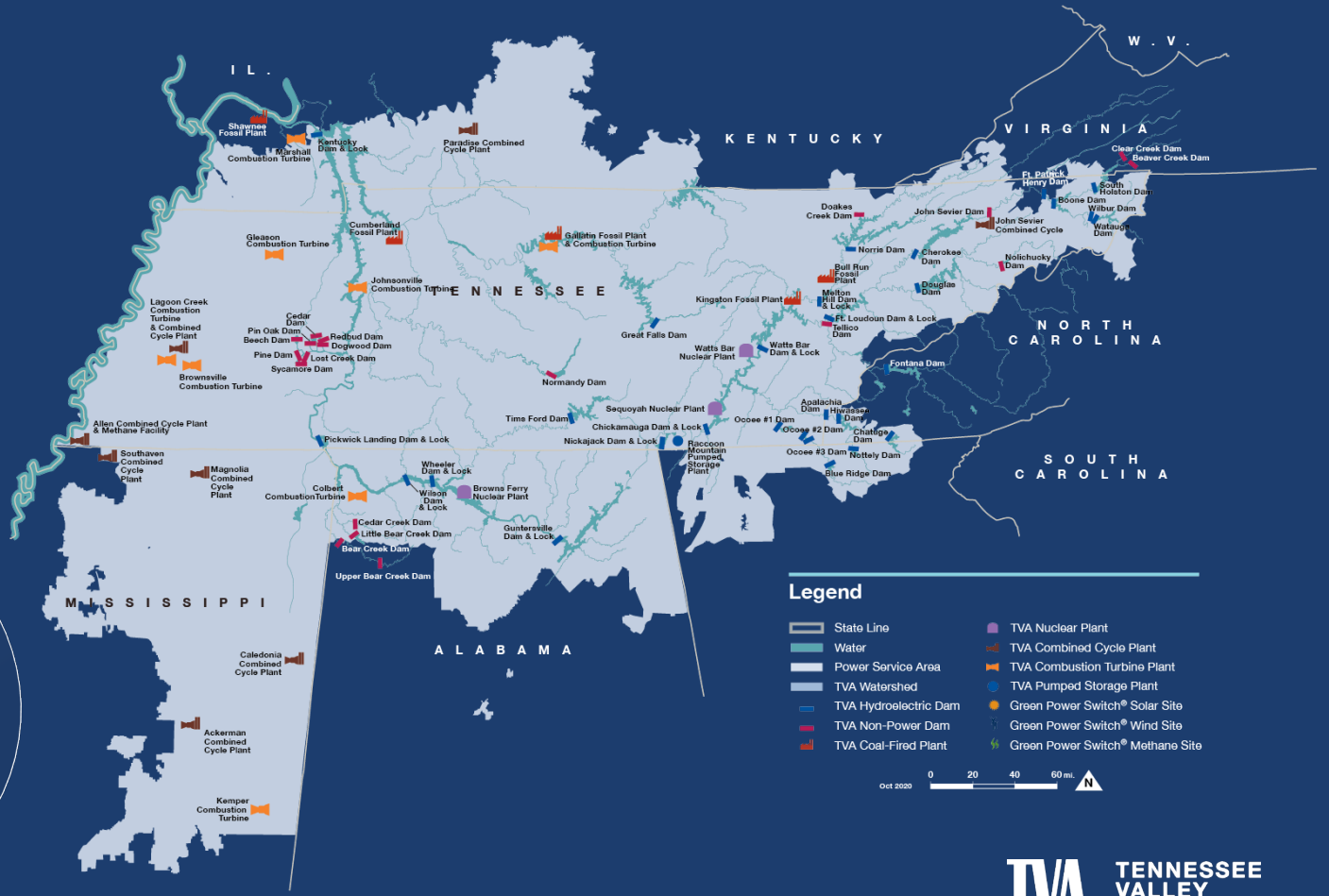


TVA TENNESSEE VALLEY AUTHORITY

The TVA Power System

FY22 Energy





TVA TENNESSEE VALLEY AUTHORITY

Control Centers

- Two fully-operational control centers
  - System Operations Center (SOC)
  - Regional Operations Center (ROC)
- Hydro Dispatch Control Center (HDCC)
- Staffed 24x7
- Data is mirrored at both in real-time
- RC and NOC use ROC as PRI
- TOp, BA, and HDCC use SOC as PRI

TVA TENNESSEE VALLEY AUTHORITY

TENNESSEE VALLEY AUTHORITY

Loss of Power “Button Day”

Friday April 21, 2023

EPO (Emergency Power Off) Switch

TENNESSEE VALLEY AUTHORITY

What's an EPO switch and why is it needed?

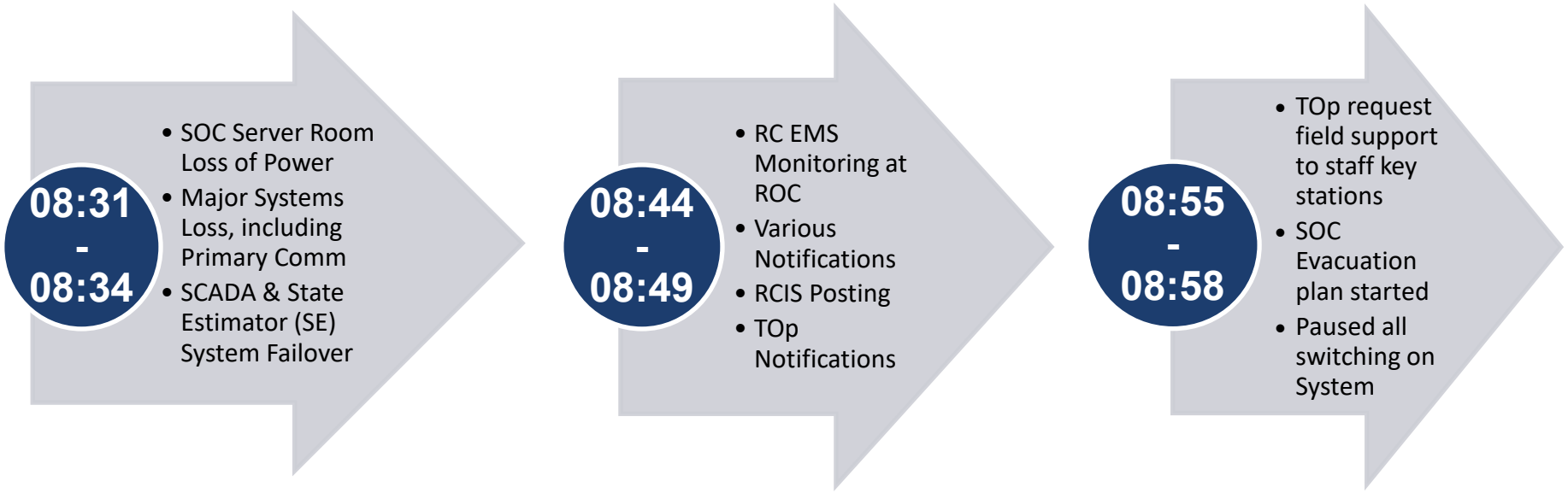
- **Code Requirements for EPOs**
  - The 2020 edition of NFPA 70, also known as the National Electric Code (NEC), states in section 645.10 that "an approved means shall be provided to disconnect power to all electronic equipment in ITE rooms, or designated zones within the room".
- **Extent of Condition**
  - 2 EPO switches with security monitoring – SOC server and telecom rooms
  - 1 EPO switch with security monitoring – ROC new server room
  - Other TVA data centers with EPO switches and no security monitoring

TVA TENNESSEE VALLEY AUTHORITY

Sequence of Events

- ***Friday*** morning, 4/21/23 - During a routine battery replacement on the alarm function of the Server Room Emergency Power Off (EPO) device, the EPO device was inadvertently activated resulting in a complete loss of power to the Server Room and prevented the start of active backup electrical supply.

Sequence of Events



All times CPT

TVA TENNESSEE VALLEY AUTHORITY

Sequence of Events

All times CPT

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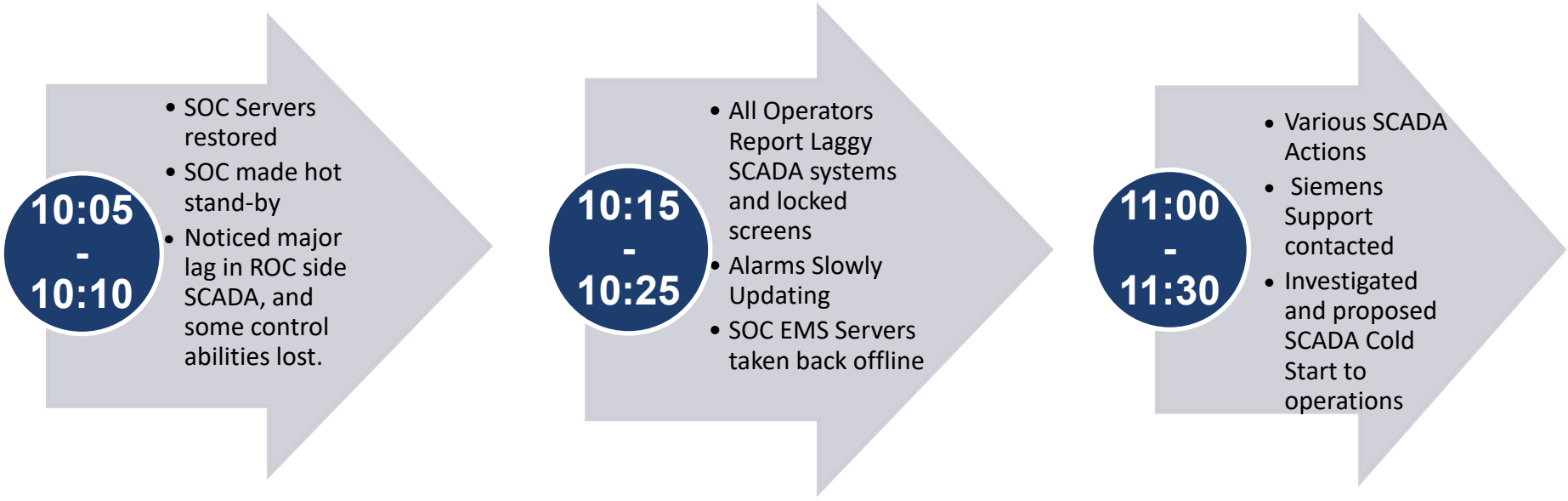
Sequence of Events



All times CPT

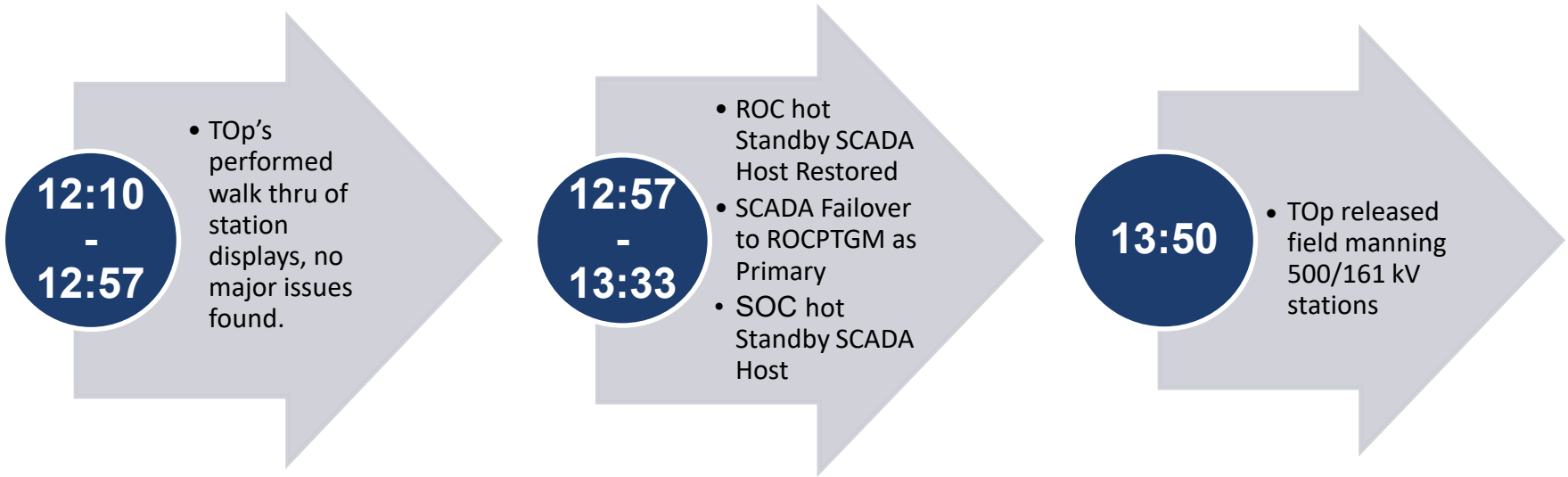
TENNESSEE VALLEY AUTHORITY

Sequence of Events

All times CPT

TVA TENNESSEE VALLEY AUTHORITY

Sequence of Events



All times CPT

TVA TENNESSEE VALLEY AUTHORITY

Questions and Considerations

- Is EPO switch cover alarming necessary, since it is not a requirement?
- Is the risk to operations fully understood by maintenance personnel when performing EPO switch maintenance?
- Do you have a solid Communication process in place for major events?
- Password Management, Hard copy locked box?
- Critical station list for manning and onsite monitoring?
- Emergency notification, stand down on all work.
- Black Start procedure for server and network infrastructure?

Questions and Considerations (Cont.)

- Any work being done in the Server room should be coordinated with supporting groups for awareness of possible risk
- Support staff should have a plan for which site to go to (especially if remote workforce)
- Consider staffing both the location with the problem and location that operators are relocating to
- Create culture of honesty and ownership
- Technician that accidently hit button was quick to identify the cause of power outage, which saved critical time to root cause event and focus on restoration
- Learning Experience


TVA
TENNESSEE
VALLEY
AUTHORITY

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Vendor Discussion Panel

Dwayne Fewless, ReliabilityFirst

11th Monitoring and Situational Awareness Technical Conference

October 4, 2023

RELIABILITY | RESILIENCE | SECURITY




Vendor Discussion Panel

- Moderator
  - Dwayne Fewless, *ReliabilityFirst*
- Panelist:
  - Manu Parashar, *GE*
  - AJ Singh, *Hitachi Energy*
  - Xin Jiang, *OSI*
  - Jason Lindquist, *Siemens*

EMS Health Assessment

- What recommendations do you have for customers to build EMS Health Assessment?
  - Network connectivity
  - Data quality
  - Solution quality

Patch and Upgrade

- Insight on reducing the need for significant software changes, version adjustments, in line with the life cycle of their applications and the supporting third-party tools their applications rely upon.

- Any plan or road map to make upgrading in place easier?

Transfer Capability Study

- Transfer Capability Study is important to support energy transformation, grid reliability, and resilience. What recommendations do you have for customers to do transfer capability study?
  - Static
  - Dynamic
  - Performance

Forecasting

- With the increasing permeability of new energy and the rising demand response load, the uncertainty on the production and load sides are both increased, bringing new challenges to the forecasting work and putting forward higher requirements to the forecasting accuracy.
  - What advances are you doing in solar, wind, and load forecasting?
  - What recommendations do you have for customers to do such forecasting?

Cloud Computing

- Can you share the roadmap to support the cloud computing?
- With cloud computing, what are some of the cyber challenges discovered and how have they been addressed?
- What measures are taken to handle Cyber Security risks.

AI & Future

- How do you envision using AI in the contingency analysis and other advanced applications?

- What are the new developments considered for the next 5 years.

Thank You and See you Next Year !