NAESB BOARD OF DIRECTORS MEETING
APRIL 10-11, 2019

GAS-ELECTRIC MODELING AND ANALYSIS FOR RESILIENT SYSTEMS

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OUTLINE

- Argonne Overview
- Interdependencies, Models, and Tools
- Projects with Industry
- Fuel Adequacy Concerns and Gas Data Collection Effort
- Questions and Discussion

- Part of the U.S. Department of Energy (DOE) laboratory complex of 17 National Laboratories
- Managed by UChicago Argonne, LLC
- Main site: 1500-acre site in Illinois, southwest of Chicago
- Diverse basic and applied research portfolio

$1B
TOTAL BUDGET IN FY2018

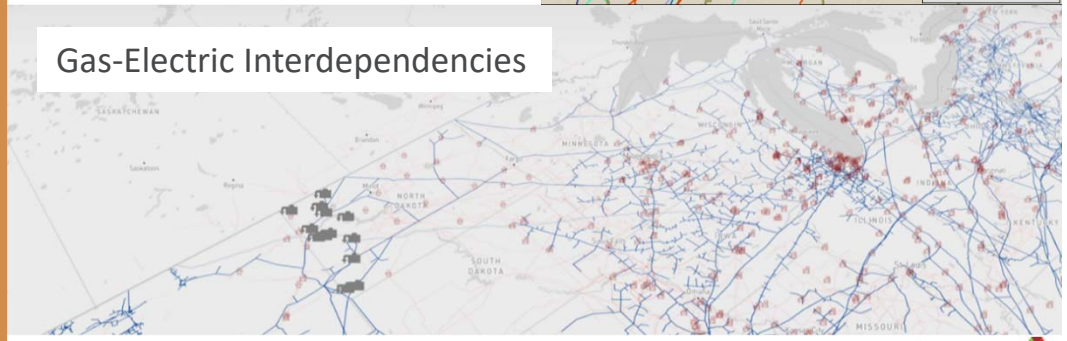
3,200+
EMPLOYEES IN 2018

8,300+
EXTERNAL USERS OF RESEARCH FACILITIES

- Initial work conducted during World War II to develop nuclear energy
- Mission to accelerate science and technology to ensure U.S. prosperity and security
- Organized into Directorates:
  - Computing, Environmental, and Life Sciences
  - Energy and Global Security
  - Photon Sciences
  - Physical Sciences and Engineering

LONG HISTORY OF INFRASTRUCTURE ASSESSMENT METHODS AND TOOLS

- Long history of natural gas and electric infrastructure assessment and modeling activities
  - DOD – Facility Isolation and Systems Analysis
  - DOE – Energy Infrastructure Assessments and Hurricane Support
  - FEMA – New Madrid Seismic Zone Study, National Level Exercise 2018
  - DHS – Regional Resiliency Assessment Program
- Extensive engagement and/or activities with electric, gas, and other cross-sector industry partners



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LIFELINES "MAKE OR BREAK" OUR LIFESTYLE

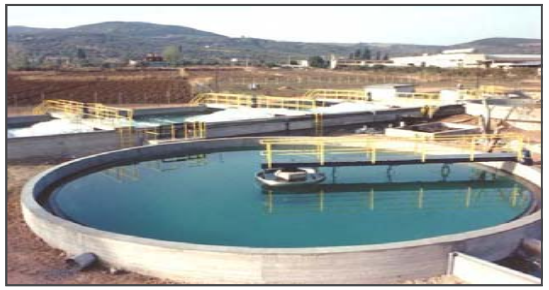
Petroleum

Electricity

Transportation

Communications

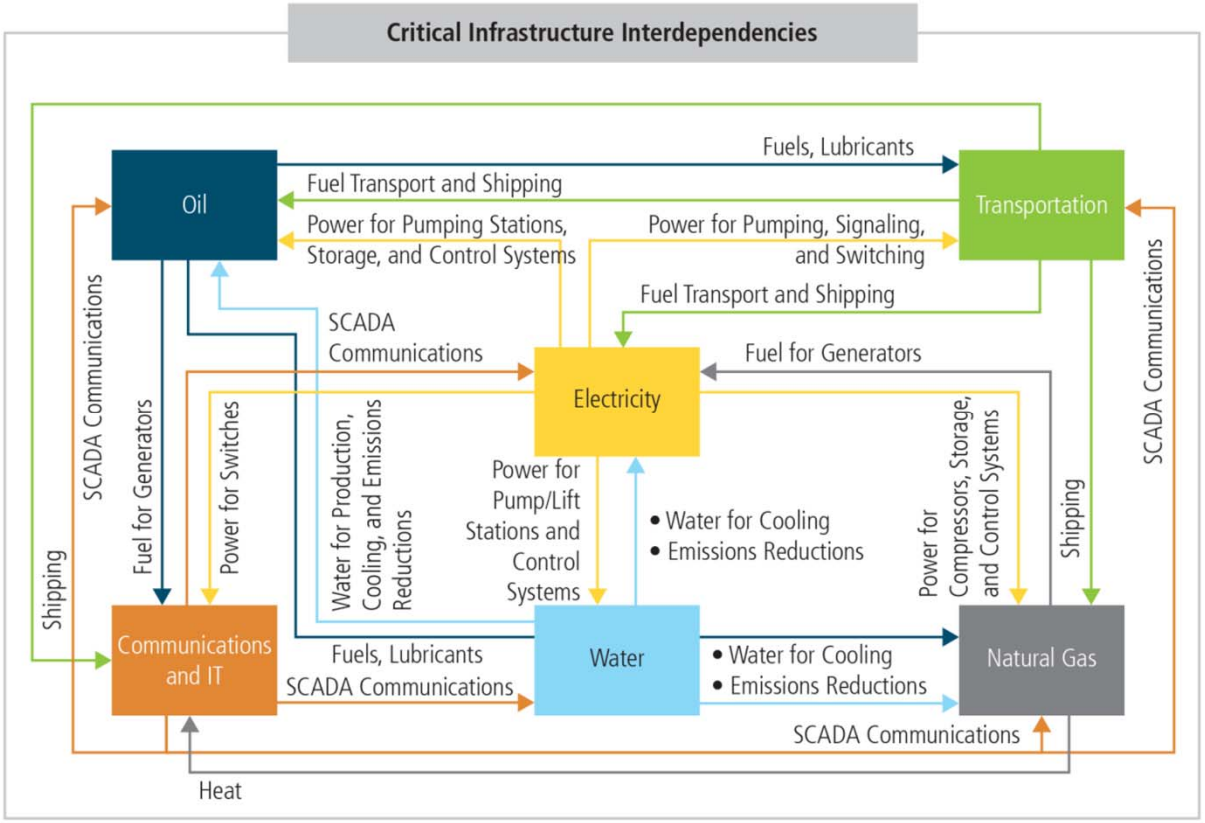
Natural Gas



Water/Wastewater

Source: Peerenboom et al. 2001

LINKAGES ARE COMPLEX AND INTERRELATED



Sources: Peerenboom et al. 2001, Argonne 2016, DOE 2017 (QER)

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INTERDEPENDENCIES ARE A "RISK MULTIPLIER"

Increase intensity and create new threats/hazards

Expand the set of vulnerabilities

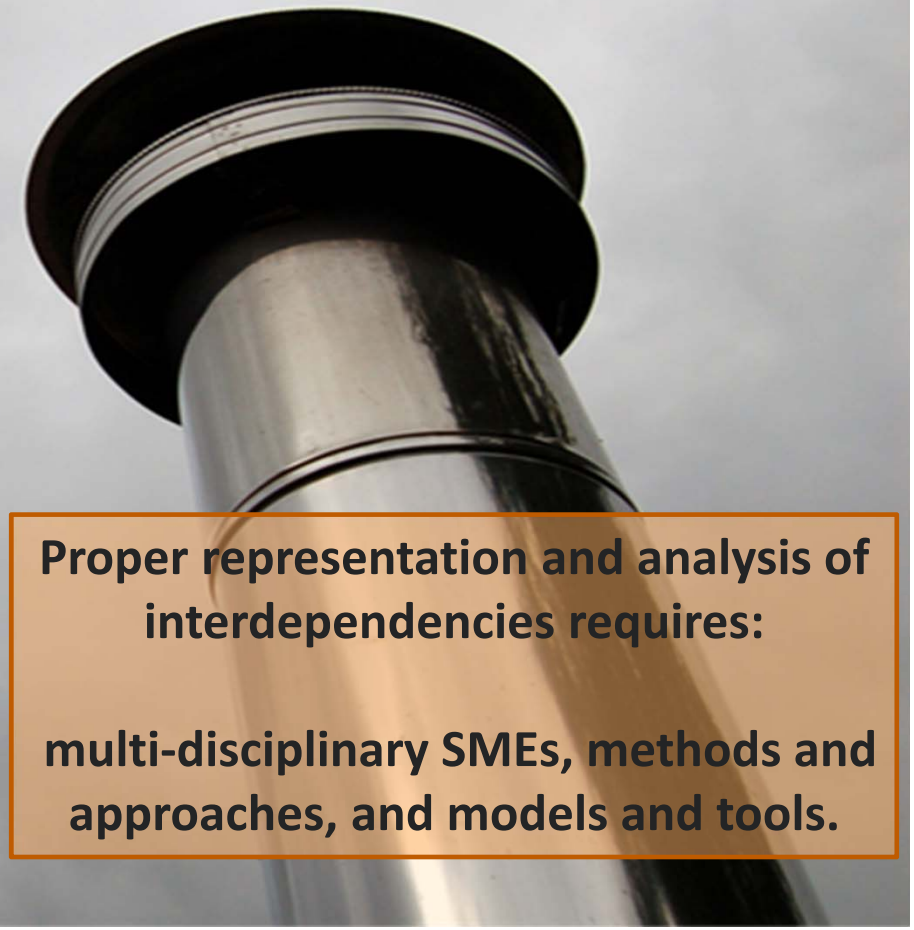
Generate cascading and escalating consequences

Expand the set of mitigation requirements

Objectives →

- Anticipate Consequences
- Decrease Vulnerabilities
- Enhance Resilience Capabilities
- Decrease Risk

WHAT IS ABSOLUTELY CLEAR…



Proper representation and analysis of interdependencies requires:

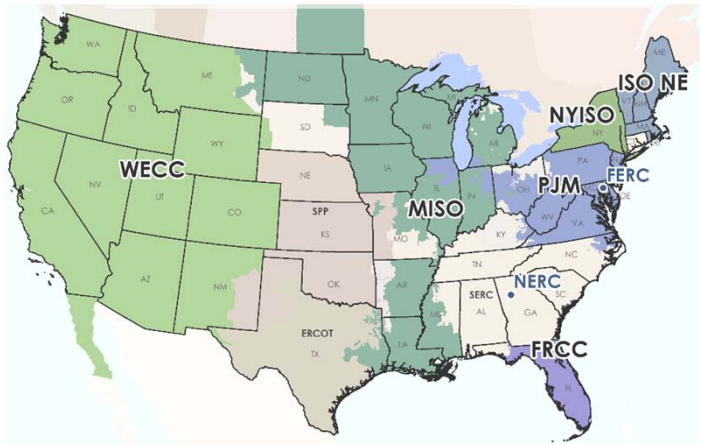
multi-disciplinary SMEs, methods and approaches, and models and tools.

ARGONNE IS ROUTINELY ENGAGED WITH DIVERSE INDUSTRY STAKEHOLDERS

- Reliability Coordinators:

pjm, MISO, FRCC Florida Reliability Coordinating Council, Inc., SERC Reliability Corporation, ISO new england 20 years, NERC North American Electric Reliability Corporation, ercot, ISO New York Independent System Operator, WECC

Active Stakeholder Engagements



Source: Platts 2018

- Electric Utilities: ComEd An Exelon Company, Exelon, PECO An Exelon Company

- Gas Industry Associations and Pipelines: INGAA, AGA American Gas Association

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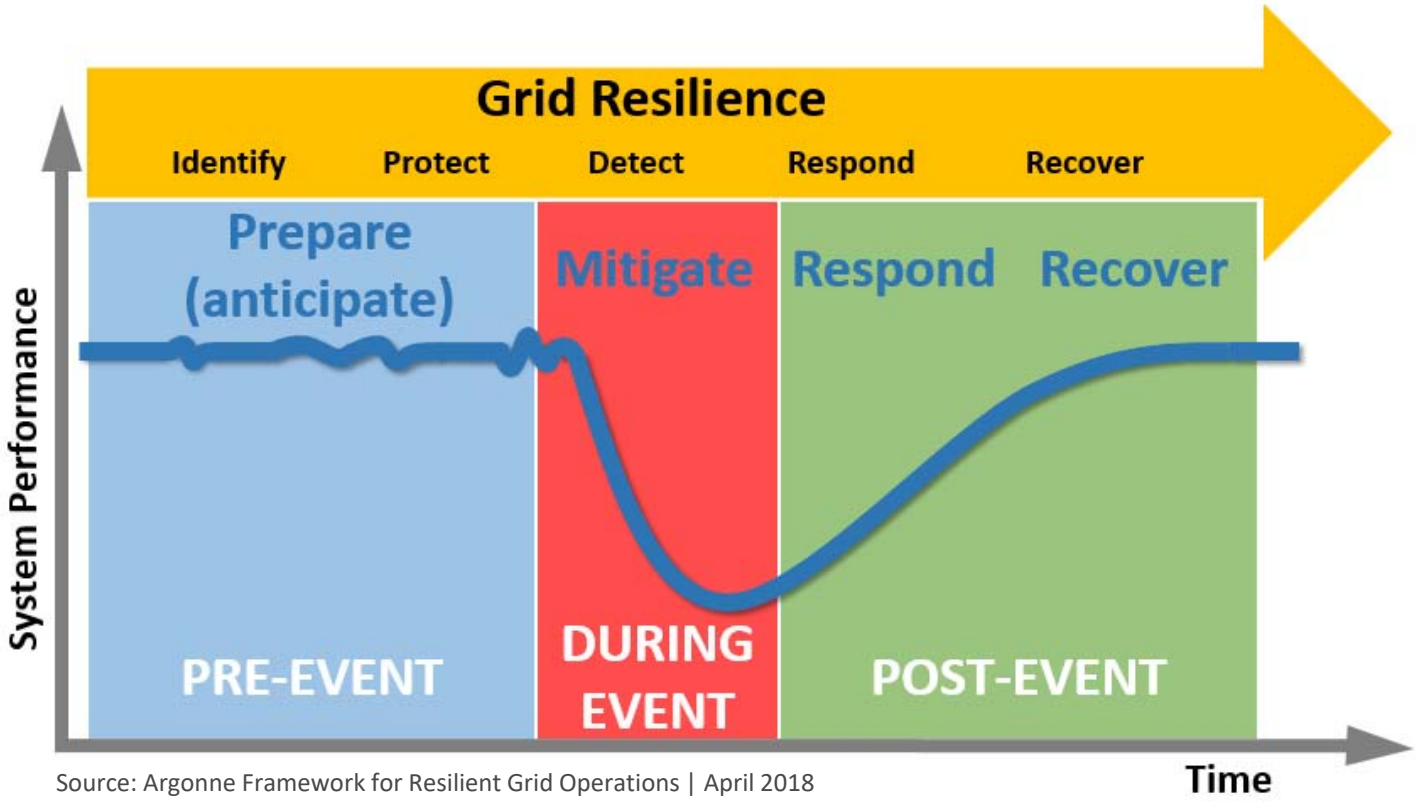
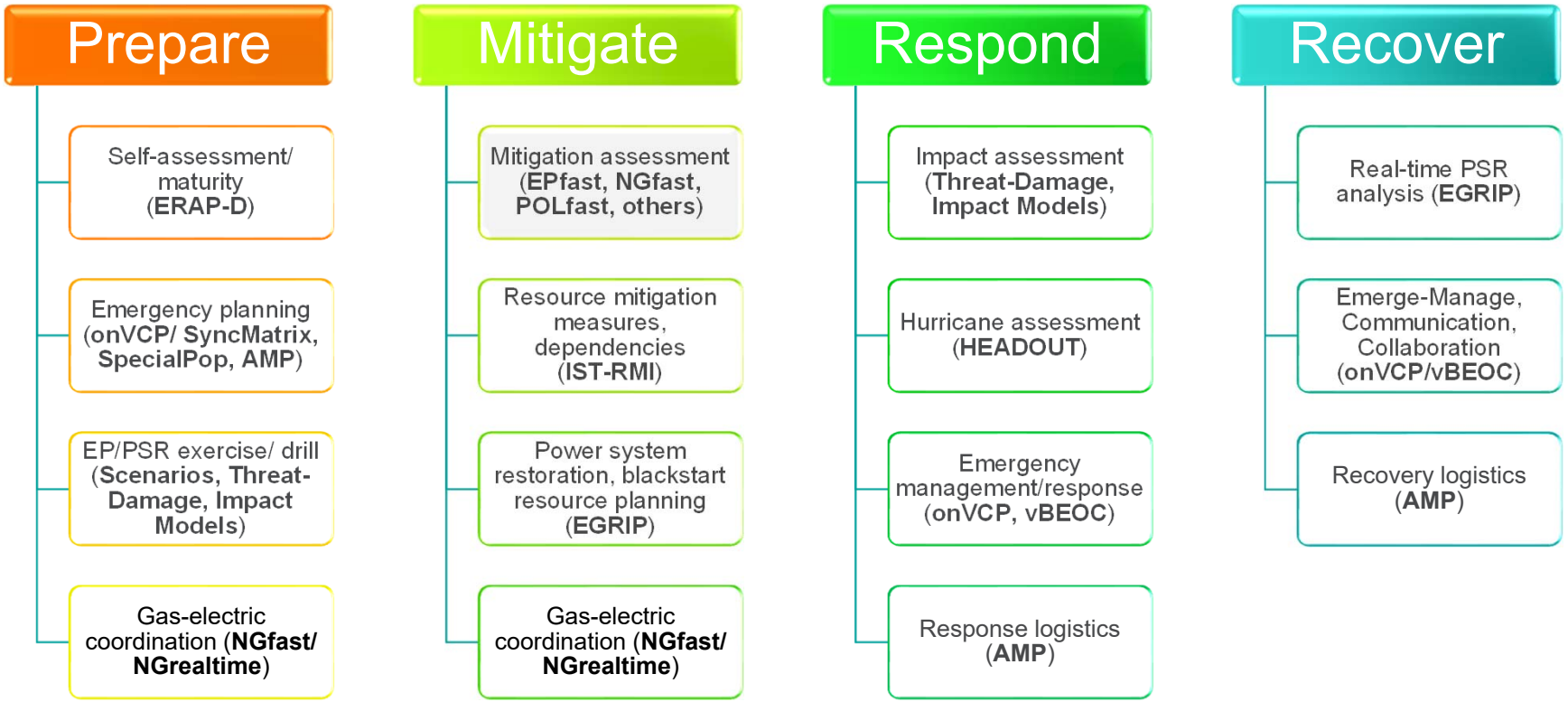
WHAT HAPPENS WHEN THINGS BREAK, AND HOW DO WE MINIMIZE IMPACTS?

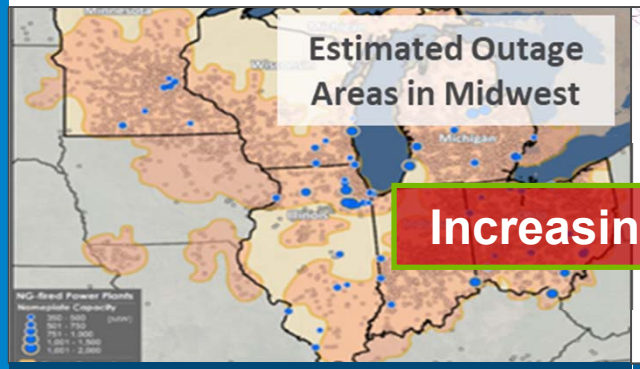


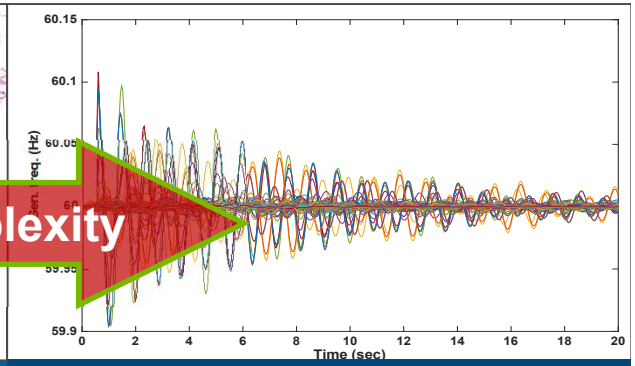
Source: Argonne Framework for Resilient Grid Operations | April 2018

ARGONNE RESILIENCE MODELING TOOLS



ARGONNE ELECTRIC MODELS IDENTIFY CRITICAL COMPONENTS AND IMPACTS OF DISRUPTIONS AT DIFFERENT LEVELS OF DETAIL





Increasing levels of detail and complexity

- **EPfast** is a linearized DC-power flow tool to rapidly study n-k scenarios and examine the impacts of natural and man-made threats/hazards on large electric grid systems
- Models the tendency of power systems to cascade or "island" after large disturbances, which can lead to regional power outages

- **EPflow** consists of multiple different power flow tools, including (1) PFLOW for AC power flow analysis, (2) OPFLOW for AC optimal power flow analysis

- **EPtransient** is a HPC/PETSc-based tool tested and validated for large-scale dynamics simulation; used for system stability assessment of large disturbances
- Enables steady-state and transient security assessment, including dynamics simulation of large-scale cascading failures and transient-security constrained dispatch

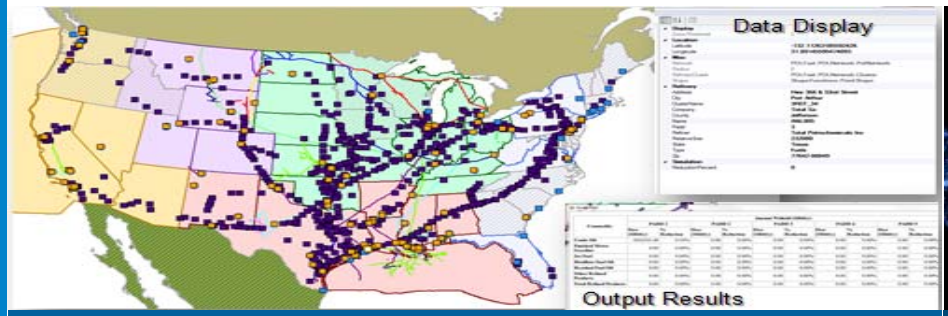
ARGONNE'S GAS MODELS IDENTIFY CRITICAL COMPONENTS AND IMPACTS OF DISRUPTIONS AT DIFFERENT LEVELS OF DETAIL

- **NGfast** is a linear, steady-state, national-level gas pipeline network model that enables rapid assessment of impacts from disruptions and flow reductions in the nation's natural gas pipeline infrastructure (pipes, compressors, storage)

- **NGflow** is a non-linear steady-state hydraulic gas network flow model to estimate pipeline flows and node pressures under various operating conditions
- Range of applications for DoD, DOE, and DHS

- **NGtransient** is a highly-detailed, non-linear, dynamic, hydraulic gas model for planning purposes and state-estimated real-time gas contingency analysis
- Prototype developed with and for PJM in 2017

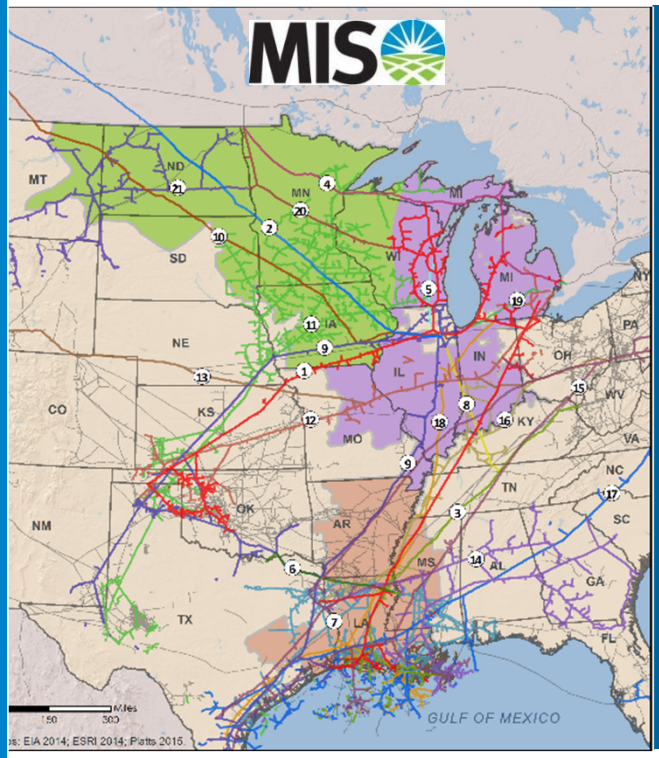
ARGONNE PETROLEUM & COMMUNICATIONS MODELS IDENTIFY CRITICAL COMPONENTS AND IMPACTS OF DISRUPTIONS



- **POLfast** is a national model that considers crude oil production, refinery production of gasoline, distillate, residual, and jet fuel; gasoline blending, transportation by pipeline, water, and rail; and storage
- Estimates impacts to petroleum sector from disruptions in production, storage, and transportation
- Range of applications for DHS and DOE

- **TELCOfast** estimates impacts to the communication sector, including wireline, wireless, and microwave communications, and interdependencies with grid
- Underlying methodologies have been applied in multiple analyses by Argonne, most recently for NLE2018 which was reviewed and generally agreed to by DHS National Coordinating Center for Communications, and in development of training scenarios for ISO-NE and NYISO in 2019

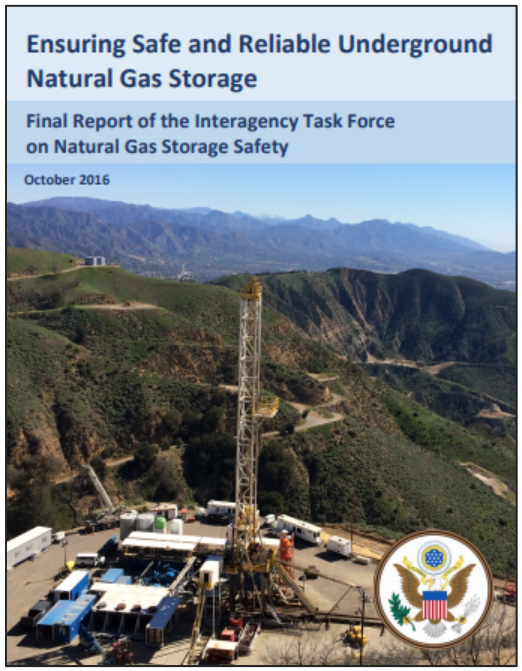
ARGONNE MODELS & ANALYTICS DRIVE OPERATOR GAS-ELECTRIC TRAINING

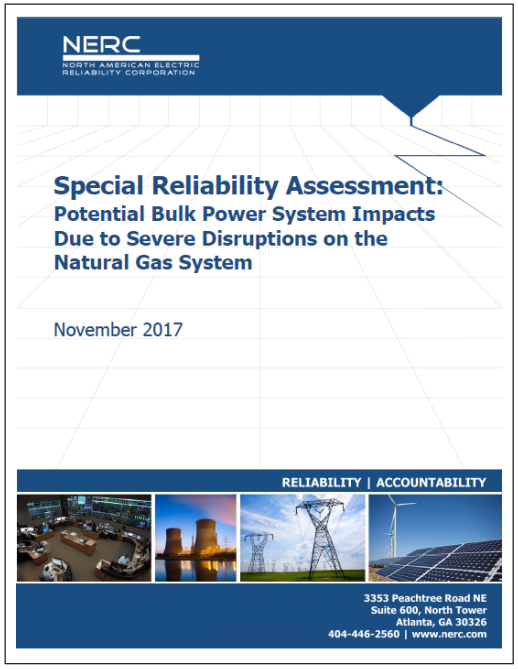


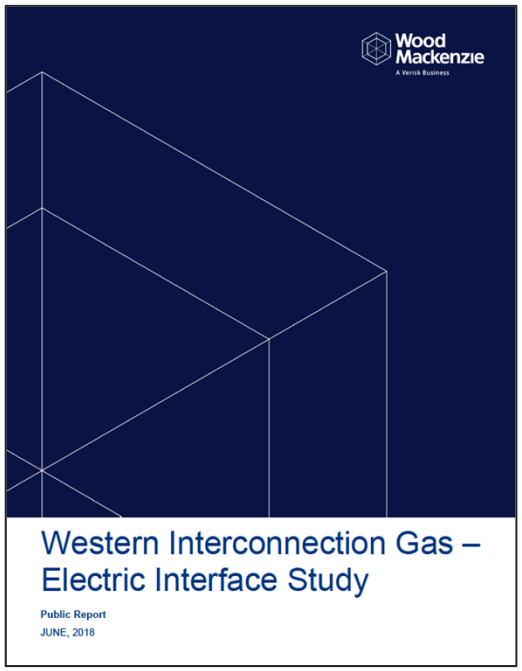
- Developed a NERC-certified training course for MISO system operators on natural gas and electric coordination
- Trained over 600 MISO grid operators on electric/gas interdependencies as part of the 2015 emergency preparedness/power system restoration training cycle
- Geared toward creating a greater awareness of electric-gas emergency scenarios, vulnerabilities, and fuel supply concerns in MISO and NERC footprint
- Revealed operational lessons learned following a gas outage scenario simulation utilizing NGfast

Inform electric operators on gas infrastructure, gas operations, and fuel adequacy concerns.

ARGONNE MODELS & ANALYTICS DRIVE GAS-ELECTRIC STUDIES AND FINDINGS







2016 **2017** **2018**

Examine gas-electric interdependencies and characterize cross-sector impacts, identify potential resilience concerns related to increased natural gas fuel utilization, and initiate cross-sector outreach.

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ARGONNE MODELS & ANALYTICS DRIVE REALISTIC OPERATOR TRAINING DRILLS

After Action Report

Argonne National Laboratory Nor'easter Simulation Exercise – Q4 2018

Report date: January 18, 2019

ISO new england

« Distributed Generation Forecast Working Group requests survey data for 2019 forecas
Main | Now online: Presentation and recording of Q4 Settlements Issues Forum webina

in Inside ISO New England

Argonne National Laboratory helps ISO-NE system operators prepare for impacts of major winter storm

WEDNESDAY, DECEMBER 12, 2018 AT 2:45PM

A "classic" Nor'easter can be anything but routine to the power grid

Nor'easters are a trademark of New England winters but the timing, intensity, and impact of such storms are far from predictable. ISO system operators must be prepared to operate the grid through a wide variety of wintertime scenarios.

This year, scientists from the Argonne National Laboratory studied previous Nor'easters and provided the ISO with a detailed analysis of the potential effects a major winter storm could have on the New England power system.

Operator Feedback **ISO-NE**

The crew members provided the following feedback:

- Simulator session seemed real – it felt like we were on watch in the real control room

MISO FEEDBACK

"I appreciate all the effort you folks provide to us to create some realism." email on 3/25/19 from Chris Kelly, MISO Senior Trainer, MISO Spring Drill 2019

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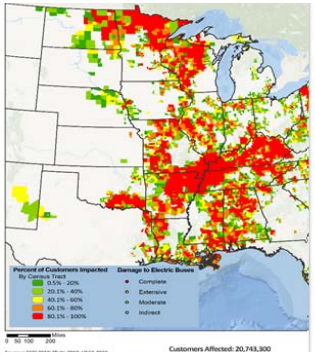
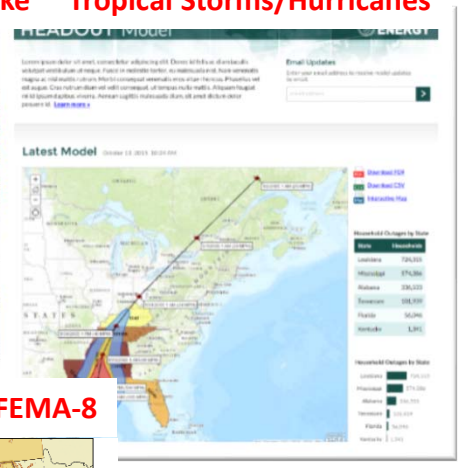
ARGONNE MODELS & ANALYTICS DRIVE REALISTIC OPERATOR TRAINING DRILLS

- HEADOUT (Hurricane Electrical Assessment Damage Outage Tool) is a quick turn-around tool to identify bulk assets at-risk and estimate customers at-risk of electric outage by census tract, county, and State
- Used for real-time support of DOE response activities during hurricane season
- Used for off-line exercise planning, operator training, TPL-001-4 planning
- Peer-reviewed as part of DOE's Grid Modernization Initiative and down-selected as DOE's ONLY hurricane impact model
- Range of threats and hazards

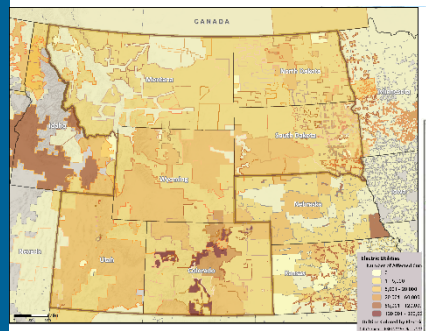
New Madrid Earthquake



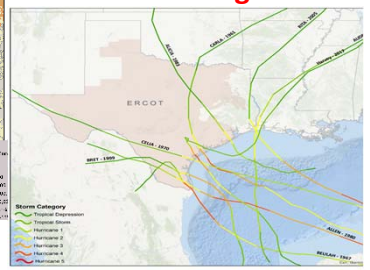
Tropical Storms/Hurricanes



Snow Storm/Blizzard FEMA-8



ERCOT Transmission Planning



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EXERCISES FACILITATE DISCOVERY AND TRANSFORM KNOWLEDGE

ComEd Operation Power Play – #POWERPLAY2019

"And to help us better simulate a real emergency, we've hired a special team of disaster experts."

Collaborate to understand interactions, identify concerns, propose lessons learned, and establish effective policies.

PREPARATION REQUIRES A BROAD RANGE OF CROSS-SECTOR MODELING AND ANALYSIS CAPABILITIES

From Scenario Definition to System Restoration

Scenario or Threat Definition

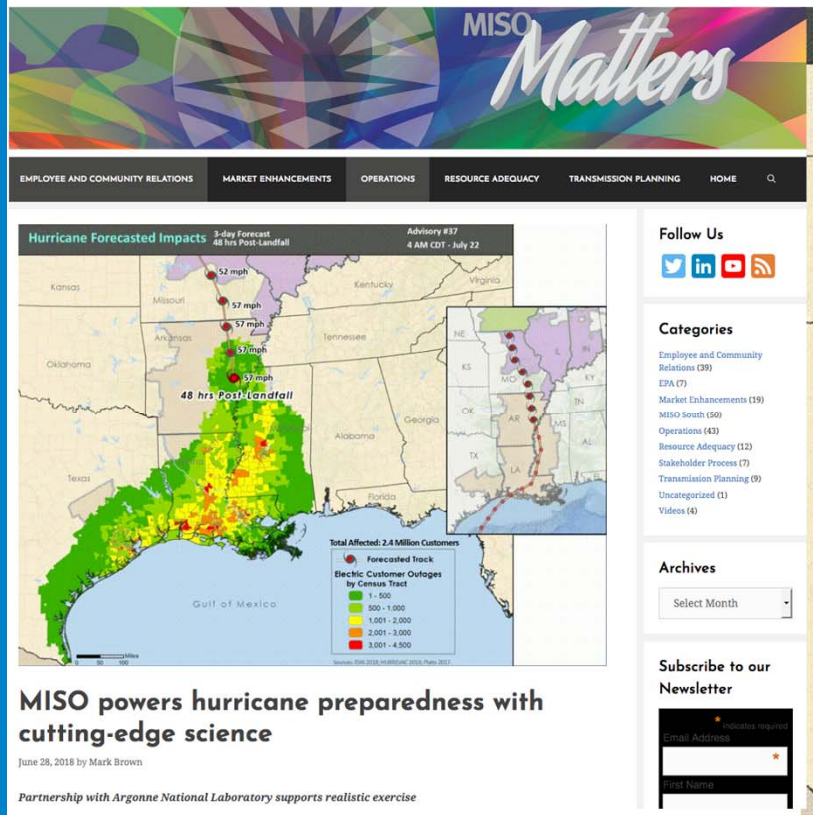
Physical Impact Assessment

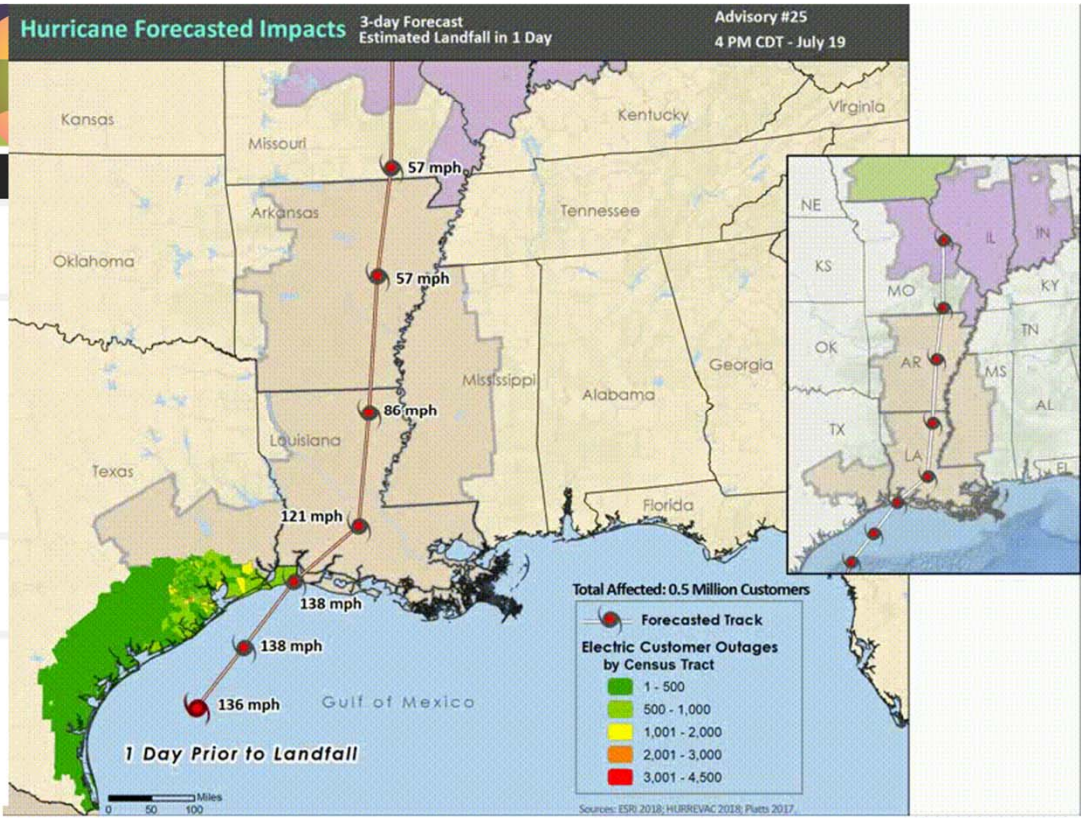
System Modeling

System Restoration and Response Modeling

The foundational basis for exercises must be defensible to ensure effective collaboration.

EXAMPLE: MISO SPRING 2018 AND SPRING 2019 HURRICANE DRILLS





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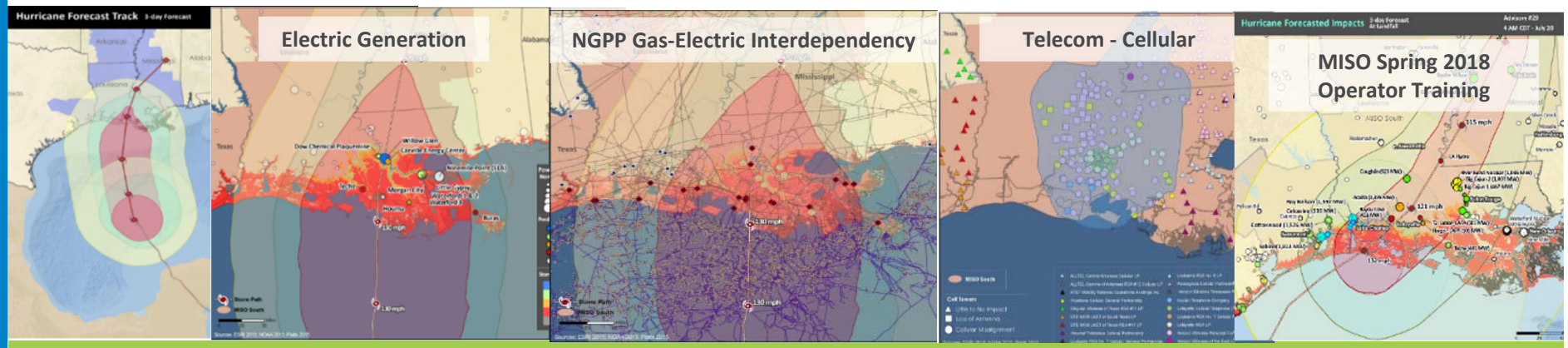
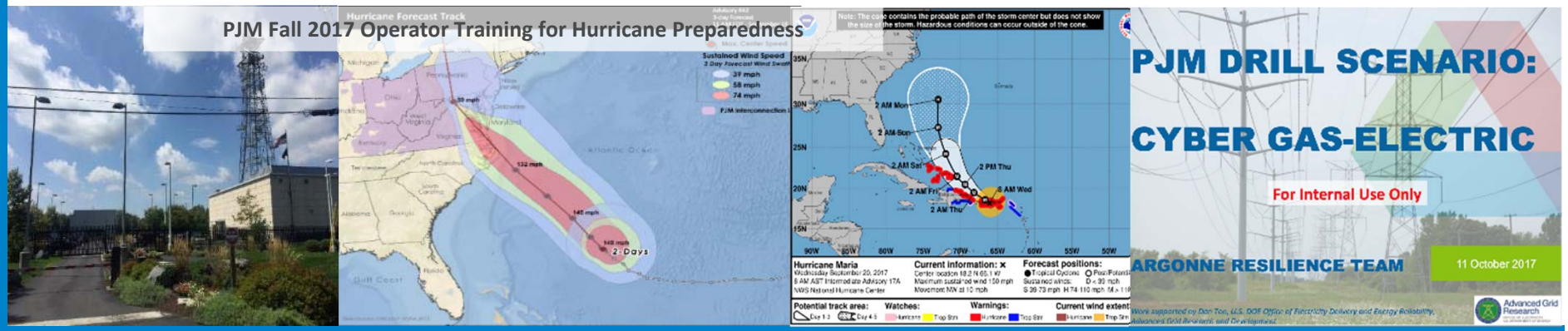
EXAMPLE: MISO SPRING 2018 AND SPRING 2019 HURRICANE DRILLS



- Argonne has supported MISO's working group for Emergency Preparedness and Power System Restoration (EP/PSR) since spring 2015 (hurricanes, gas-electric)
- Jointly prepared 2016 and 2017 spring drills on preparedness, fall drills on power system restoration
- Recently completed MISO Spring 2018 Drill (May/June) and Spring 2019 Drill with focus on hurricane scenario and impact on various assets, including power plants, substations, transmission assets, communications assets, and natural gas supply and natural gas processing plant impacts; implemented on MISO's Dispatcher Training Simulator
- ***"Your partnership with MISO on the development of the 2017 and 2016 drills were exceptional. Both in content and working with the ANL staff."*** Jerry Rusin, Sr. Advisor MISO South Region Operations

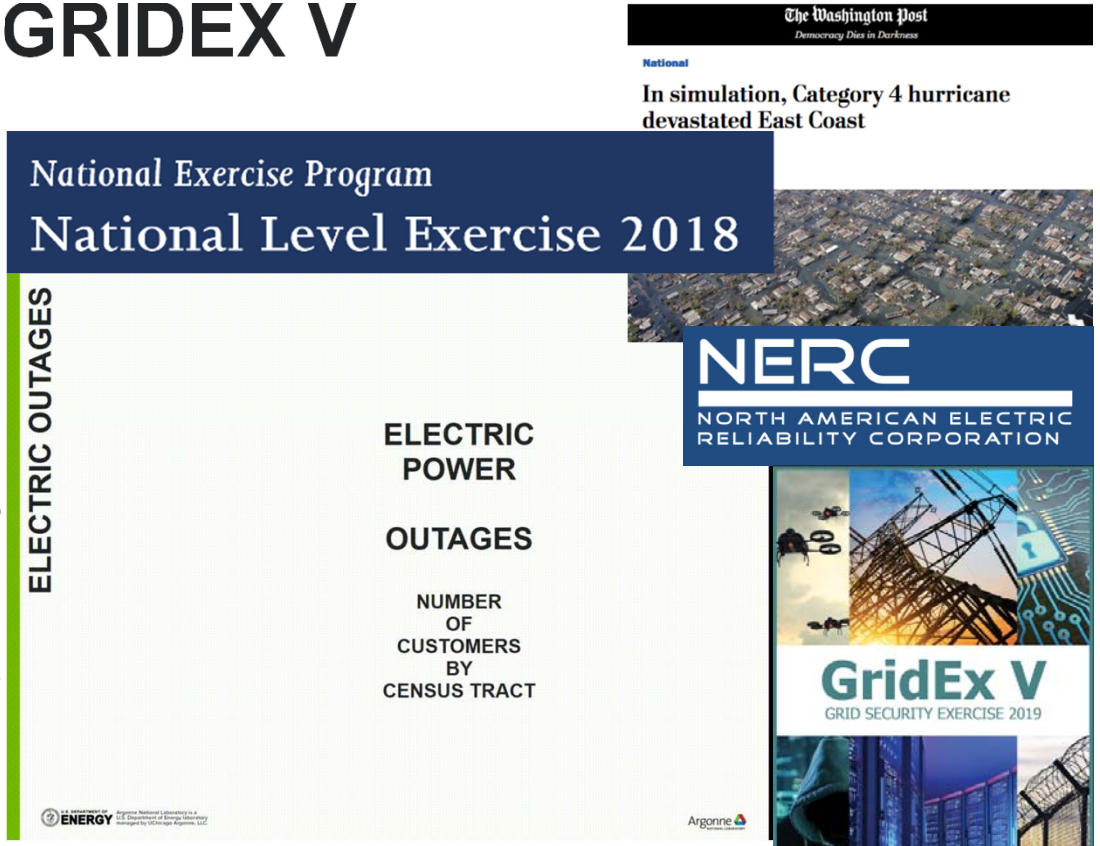
EXAMPLE: PJM FALL 2017 PJM HURRICANE DRILL AND WINTER 2018 GAS-CYBER DRILL



- Developed hurricane scenario for October 2017 PJM Operator Training Cycle and Gas-Electric Cyber scenario for January/February 2018 Operator Training Cycle
- Scenario was implemented in PJM's Dispatcher Training Simulator (DTS) at Alternate Control Room Facility
- Trained 6 full PJM operator shifts in responding to extreme weather event during Sep/Oct-2017 ***("The timing of this training could not have been better given the active hurricane season"*** **Glen Boyle, Manager, Operator Training;** ***"The support and customer service PJM experienced from the planning process all the way through the final debrief session was nothing short of first rate."*** **Mike Lawruk, Lead Trainer** ***)***
- Currently working with PJM on Fall 2019 drill

EXAMPLE: 2018 NATIONAL LEVEL EXERCISE (NLE) AND GRIDEX IV AND GRIDEX V

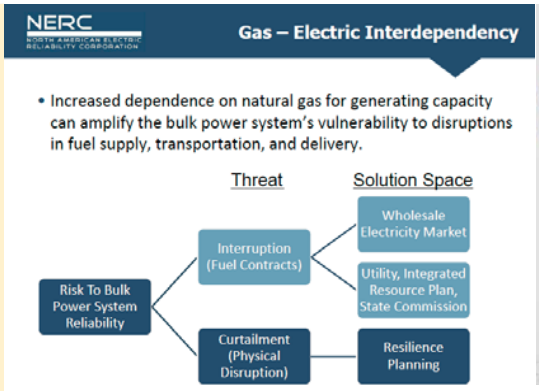
- NLE examined the nation's ability to continue essential government functions in the event of a large hurricane impacting the National Capital Region
  - 12,000 participants, largest Government exercise
  - Provided multi-sector ground-truth on customer outages, bulk-level impacts, fuel supply, and telecom
- Involving gas sector representatives as players through use of GridEx V inject planning with direct collaboration of INGAA and AGA and their member companies

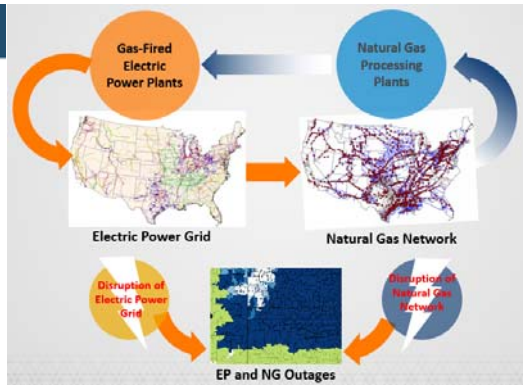


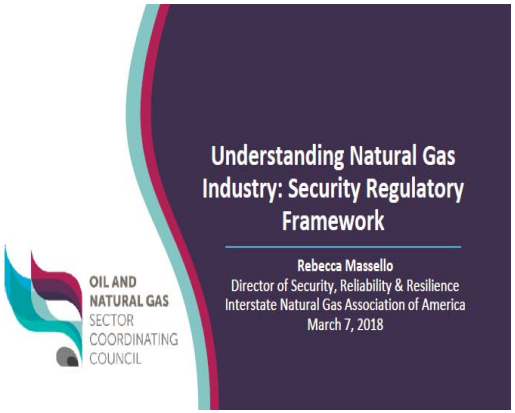
WHAT IS AN IMPORTANT LESSON LEARNED FROM THESE EXERCISES AND ACTIVITIES WITH THE ELECTRIC INDUSTRY?

INCREASED EMPHASIS ON FUEL SUPPLY ADEQUACY AND RESILIENCY — INTERDEPENDENCIES FOCUSED

- 2017 NERC Special Reliability Assessment and WECC studies identify potential resilience concerns related to increased gas-electric interdependencies
- 2017 NERC Reliability Guideline on gas-electric operational coordination considerations aims to minimize reliability/resilience-related risk
- 2018 March CIPC Emerging Technology Roundtable brought together gas and electric stakeholders
- GridEx V emphasizes electric, gas, and other cross-sector participation
- Formation and member of NERC's Electric/Gas Working Group under the PC
- **Focus: Grid impacts attributed to operational fuel adequacy concerns and contingencies**







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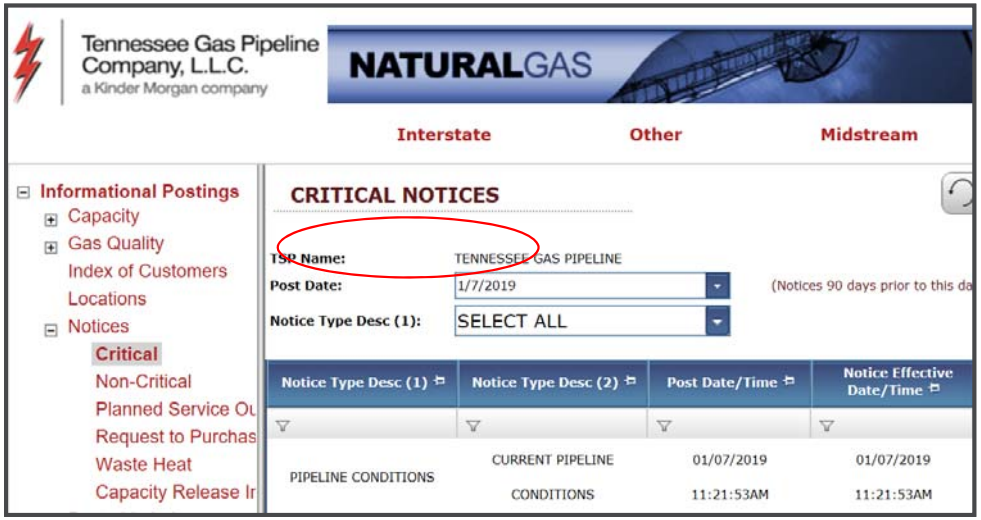
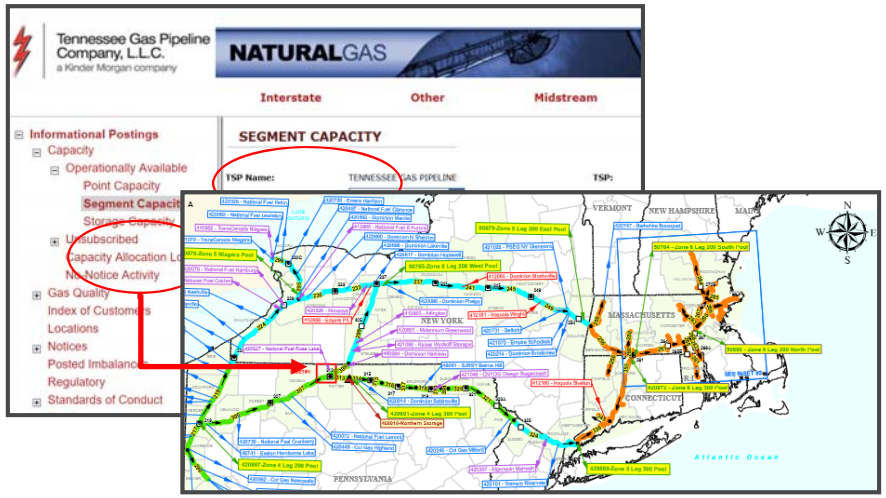
FUEL ADEQUACY AND RESILIENCE BENEFITS

- Makes public gas pipeline information more accessible, reliable, and useable
- Improves data quality compared with Web scraping approach
- Improves responsiveness to gas disruptions and changing market demands
- Supports near-real-time and historical data collection
- Permits customizable parsing of textual content found in notices
- Assists situational awareness for grid operations and planning activities
- Visualization capabilities couple electric and gas fuel adequacy considerations
- Facilitates combined near-real-time natural gas and electric power modeling capabilities
- Available to the electric industry through Argonne's DOE OE funding
- Availability is currently being discussed with RTOs/ISOs

INFORMATIONAL POSTINGS EXIST FOR EACH PIPELINE COMPANY – PUBLIC INFORMATION

- "Informational Posting" generally updated five times per day:
  - "Critical Notices" state severity of operational impacts
  - "Operationally Available Capacity" estimates available pipeline capacity for the current day and cycle.





Example URL for Tennessee Gas Pipeline:
https://pipeline2.kindermorgan.com/Notices/Notices.aspx?type=C&code=TGP

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IMPORTANCE OF CRITICAL NOTICES AND POSTED DATA

- Critical notice declared by Texas Eastern Transmission Company (TETCO) during the Polar Vortex of 2014:
  - Natural gas flows on TETCO were constrained at key points
  - Tolerance band of 0%
  - No curtailment so far
  - Power plant operators required to provide information on hourly scheduling

TSP: 007932908
TSP Name: Texas Eastern Transmission, LP
Critical Desc: Critical notice
Notice Eff Date/Time: 01/06/2014 08:46:12 AM
Notice End Date/Time: 01/31/2014 09:00:00 AM
Notice ID: 42065
Notice Stat Desc: Supersede
Notice Type: Capacity Constraint
Post Date/Time: 01/06/2014 08:46:12 AM
Prior Notice: 41977
Reqrd Rsp Desc: No response required
Rsp Date/Time:
Subject: TE Imbalance and FERC Order 698 Warning Update

Notice Text:
Due to the continued cold weather and high demand throughout the TE system, TE requires all delivery point operators to keep actual daily takes out of the system less than or equal to scheduled quantities regardless of their cumulative imbalance position. All receipt point operators are required to keep actual daily receipts into the system greater than or equal to scheduled quantities regardless of their cumulative imbalance position.

TE may issue action alerts and/or OFOs as permitted in Section 4.3 of its General Term & Conditions of its FERC Gas Tariff against any shipper, point operator or TABS party failing to adhere to this critical notice.

In addition, TE requires all Power Plant Operators to provide information mandated by FERC Order No. 698. Information required includes the hourly consumption profile of directly connected power generation facilities.

Shipper and point operators are reminded of the importance of monitoring TE's postings during this period of heavy demand on the system.

Customers are advised that capacity may become available as the nomination and confirmation process continues throughout the day.

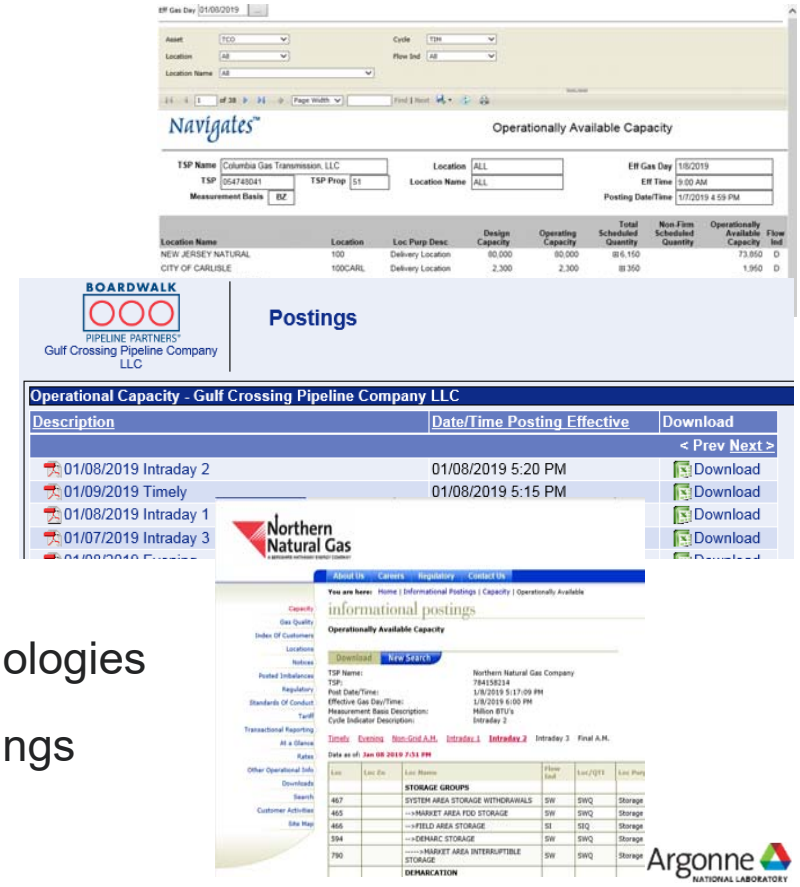
Please contact your Operations Account Manager if you have any questions.

Near-real-time and historic data benefits both operations and planning, respectively.

ELECTRONIC BULLETIN BOARD DATA COLLECTION VIA WEB SCRAPING

- Web-scraping process
  - Research the pipeline webpage posting and the IT used to provide data
  - Develop HTTP request/response process mimicking web browser
  - Collect data files from the postings (format: html/txt/excel/csv)
  - Parse, process, and save data in a structured database

- Major disadvantages and issues
  - Webpage-based EBB server outages
  - Periodic changes in the form or technology of data provided
  - Inconsistency in data postings – different technologies and structures
  - Malfunction of web components with EBB postings
  - Missing data points or meter IDs



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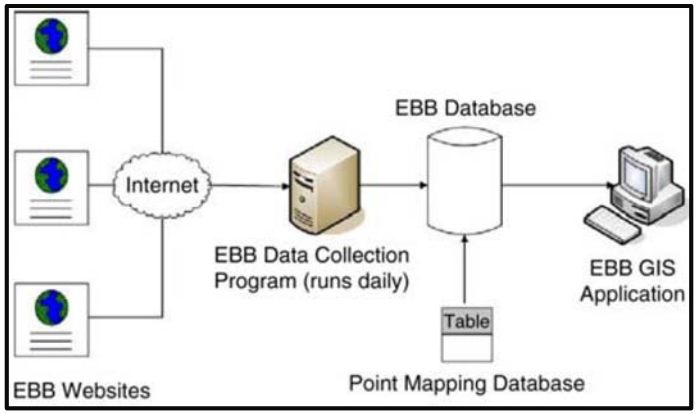
ELECTRONIC BULLETIN BOARD DATA COLLECTION VIA NAESB-EDI

- Argonne is working with NAESB and individual transmission pipelines to collect EBB data:
  - Current approach is to collect EBB data using Electronic Data Interchange (EDI)
  - EDI is computer-to-computer exchange of business documents in a standard electronic format
- Advantages of EDI Data Collection:
  - Expedited transmission of EBB data
  - Data validation is inherent in the process
  - Faster processing compared with Web scraping
  - Increased stability/reliability of collected data
- Uses of EBB/EDI collected data:
  - RTO/ISO dispatch operations
  - Impacts of natural and man-made incidents
  - Better inform flow modeling



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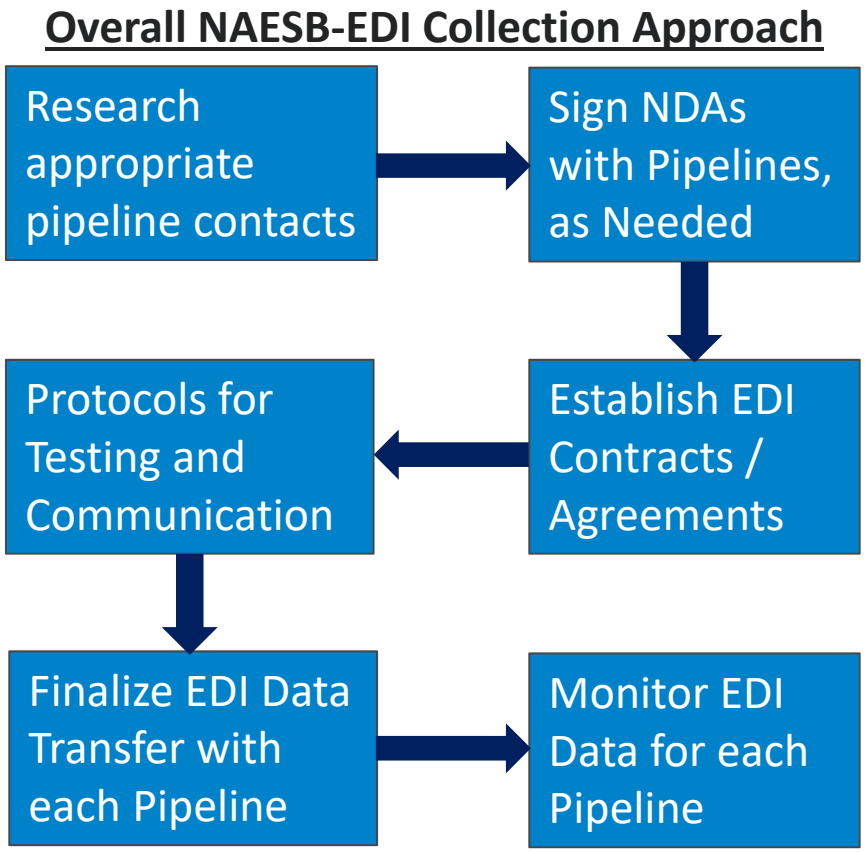
CURRENT DATA COLLECTION EBB/EDI PROCESS

- Currently collecting 4 operating cycles: Evening (EVE), Intraday 1 (ID1), Intraday 2 (ID3), and Intraday 3 (ID3):
  - The Timely cycle is to initialize the nomination process and EVE cycle is the final version
- Currently receiving all data for all points (receiving, delivery, storage, injection, etc.):
  - In the form of raw EDI documents containing data
  - Can be processed and stored in a structured database
- Thanks to all of you who helped during this process!



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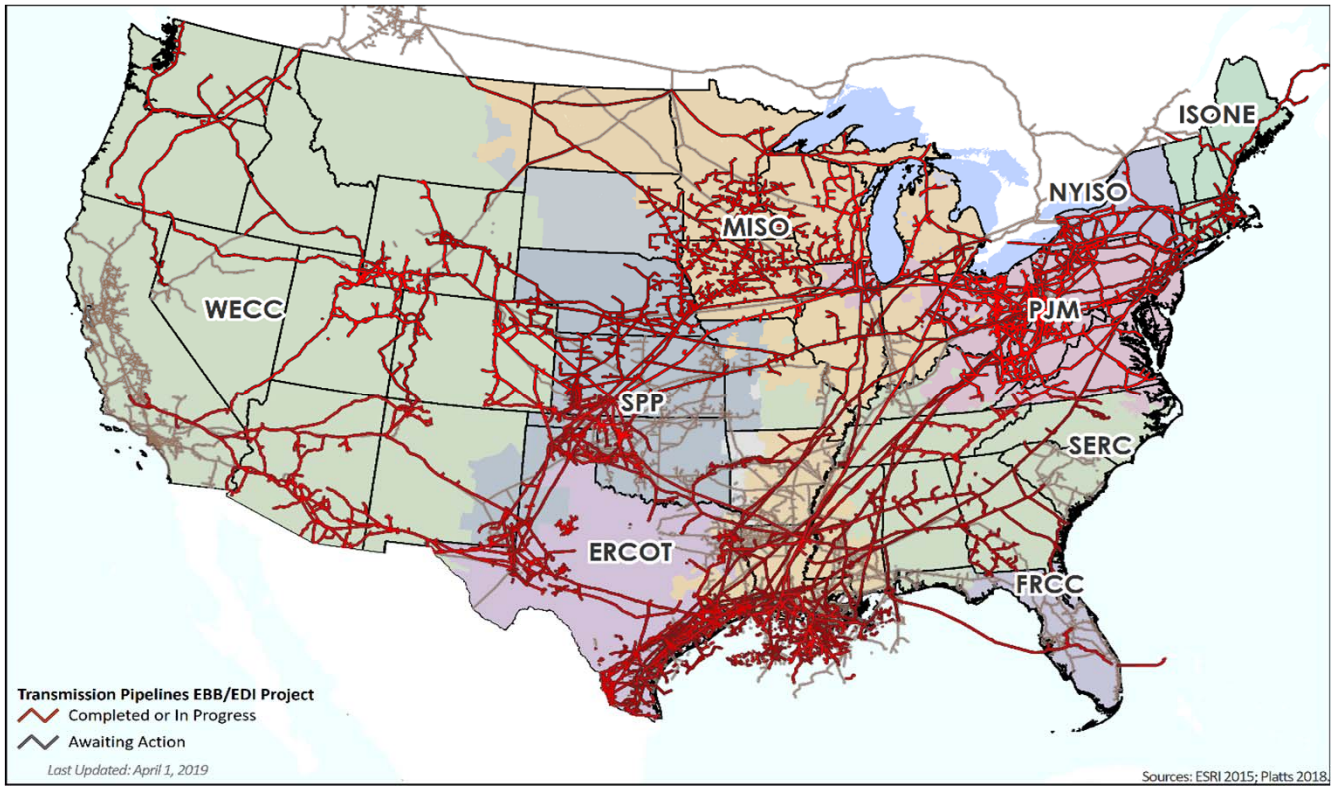
CURRENT DATA COLLECTION FOR U.S. GAS INTERSTATE PIPELINES VIA NAESB-EDI

- Near-real-time and historic EBB data collected using EDI approach:
  - Operational Capacity
  - Unsubscribed Capacity
  - Notices
    - Critical
    - Non-Critical
    - Planned Service Outages



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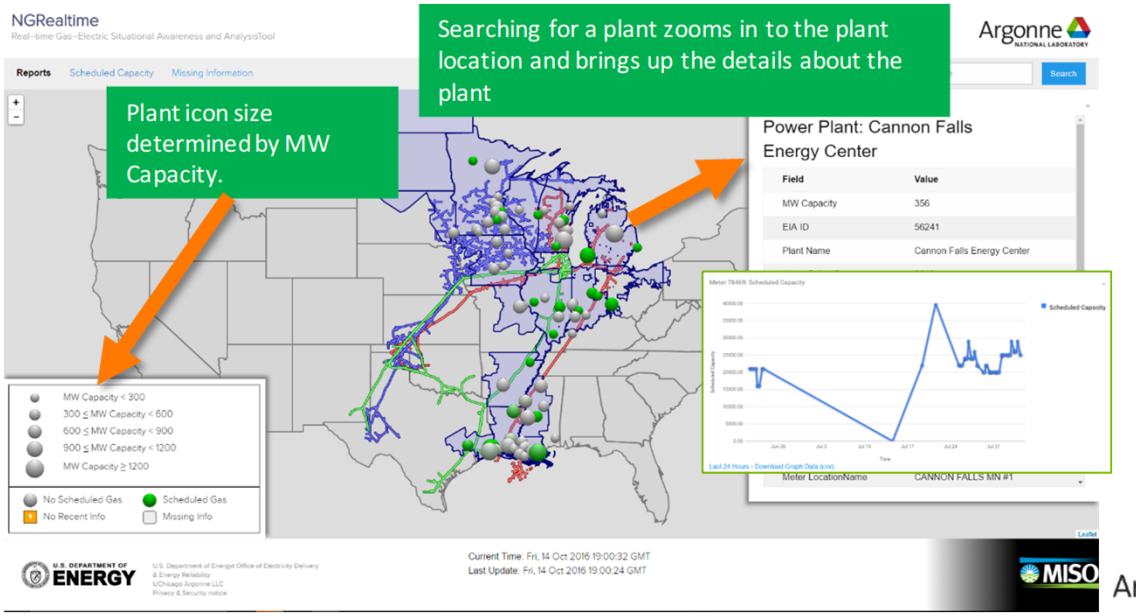
VISUALIZING CAPABILITY FOR NEAR-REAL-TIME GAS-ELECTRIC INFORMATION FOR RTOs/ISOs

- Originally developed for MISO to provide near-real-time gas-electric situational awareness to MISO's gas-electric coordination group
- Initially collected data (five times daily) from EBB websites on nominated gas flows from 21 interstate gas pipelines in MISO service territory
- Website scraping was found to be unreliable
- Pursued more reliable data stream via NAESB and individual pipeline companies
- Modifying tool to accept EBB/EDI data improving tool usefulness



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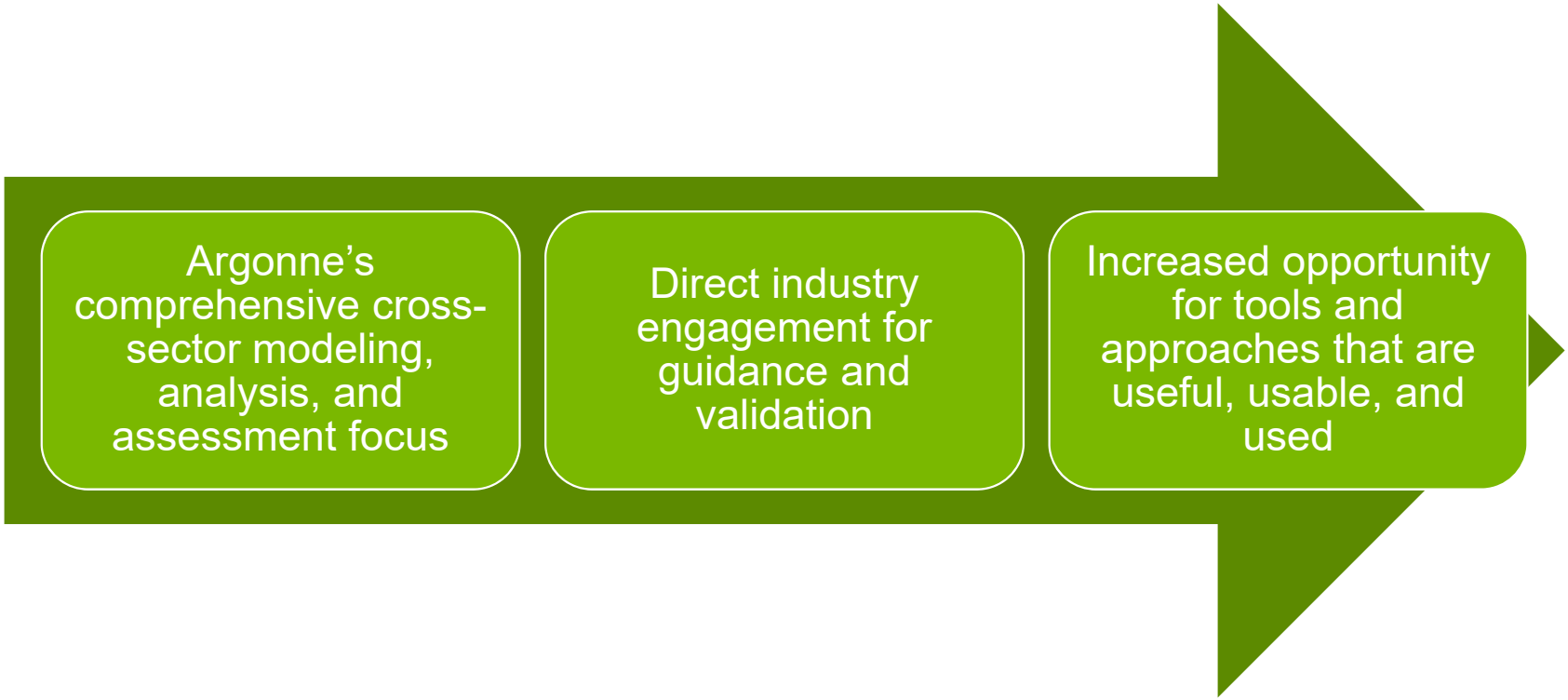
LESSONS LEARNED DURING EDI STARTUP

- First of all, we appreciate the gas industry's patience, time, and willingness to help
- Lessons learned by us:
  - Employed request-respond and direct-data-streaming protocols
  - Discovered limitations of our servers that prompted system upgrades
  - Increased communication with all trading partners in cases of planned or unplanned system outages
- Where we were helpful to others:
  - Operating systems and security protocols
    - Outdated server operating systems
    - Obsolete ciphers for SSL communication
    - Weak encryption protocols
  - Software and bandwidth limitations
    - Limit number of requests per unit of time from the same trading partner

PROJECTS HAVE TANGIBLE RESILIENCE IMPACTS

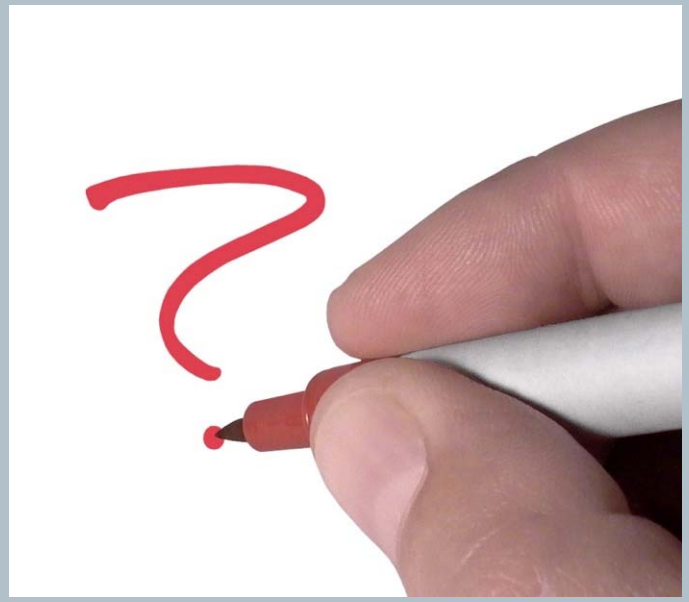
- Large-scale drills and exercises improve preparedness and communication across multiple industry and government stakeholders
- Grid operator training improves resilience by preparing operators for grid operations during extreme weather events
- New real-time natural gas information system provides critical situational awareness and visualization for reliability coordinators
- Transient natural gas tool allows reliability coordinators to explicitly study the reliability impact of natural gas contingencies in real-time to improve grid resilience
- NERC SPOD and WECC studies identify potential resilience concerns related to increased gas-electric interdependencies to initiate cross-sector outreach
- NERC gas-electric coordination guidelines support enhanced coordination of gas-electric utility operations to minimize reliability/resilience-related risk

PROCESS FOR USEFUL, USABLE, AND USED METHODS, PRODUCTS, AND TOOLS




A SPECIAL THANK YOU
FOR MAKING A
DIFFERENCE IN THE INDUSTRY!
WE APPRECIATE YOUR EFFORTS.

QUESTIONS?



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