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Panel II – Advancing Reliability and Resilience of the Grid

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Thank you for the opportunity to join you today to talk about electric system reliability and resilience. I am an independent consultant with experience working at FERC, the Texas Public Utility Commission and a major electric utility, and I was the organizer, lead researcher and primary drafter of the Department of Energy's 2017 "Staff Report on Electric Markets and Reliability."

The views I offer here are my own. However, these views are discussed in detail in the paper I submitted in this docket, "A Customer-Centric View of Electric Resilience," coauthored with Rob Gramlich and Michael Goggin of Grid Strategies, Inc.,[1] and funded by NRDC and the Environmental Defense Fund.

This panel is charged with addressing how reliability and resilience are related. My comments below address the specific questions asked. But first I would like to explain how my view of resilience differs from FERC's framing and that of the Department of Energy and some other commenters.

<u>How to look at resilience</u>

FERC is properly concerned with the resilience and reliability of the bulk power system, including electric generation and transmission but excluding distribution) because that system is your statutory responsibility. But let us be clear that the customers and public whom we serve do not care whether an outage arises from a generation problem, a transmission problem, or a distribution problem – they care about being out of service, and they really care about extended power outages. Customers and the public whom you serve think that you can best deliver resilience by making power outages as infrequent, short and contained as possible.[2]

So let's look, from the customer's perspective, at what causes power outages:

[1] "A Customer-focused Framework for Electric System Resilience," May 2018, at https://elibrary.ferc.gov/idmws/file_list.asp?accession_num=20180508-5100 .
[2] I am comfortable with the Commission's "understanding" of the meaning of resilience, as stated in "the ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such an event." FERC Order 162 FERC ¶ 61,012, Docket RM18-1-000, January 8, 2018.

- The Department of Energy reports that over 90% of all outages occur due to distribution-level problems.[3]
- Typically no more than 10% of all power outages are due to major events.[4]
- The Executive Office of the President reported that, "[s]evere weather is the leading cause of power outages in the United States."[5]
- Out of all the bulk power system (BPS)-level outages that occurred over the 2012-2016 period, less than 0.0001% of customer outage-hours were due to generation shortfalls or fuel supply.[6]
- NERC's State of Reliability report finds that energy emergency alert events resulting from an electricity supply shortfall continue to decline, and account for fewer outage MWs than transmission-related events.[7]
- As Appendix A shows, out of the 27 major blackouts occurring in the U.S. since 2002, only four were due to non-weather problems. Three started on the transmission system (the 2003 Northeast Blackout, the 2008 Turkey Point blackout, the 2011 Southwest Blackout) and one arose from a power plant fire (Puerto Rico 2016). Only the ERCOT 2011 rolling blackouts were related to a generation shortfall (most due to inadequate equipment weatherization for extremely cold weather).

Some insist that, "[t]hose who continue to focus on transmission and distribution solutions to address the resilience crisis do not fully understand what the crisis is really about," and that, "the threats to the electric grid's resilience stem first and foremost from problems with the Nation's fuel supply mix."[8] [9] But those arguments ignore the fundamental reason that we all work to

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[3] DOE Quadrennial Energy Report, (2017), pp. 4-5.
[4] LaCommare, Larsen & Eto, "Severe Weather and Other Factors that Impact Power System Reliability," November 24, 2015, at http://www.brinknews.com/severe-weather-and-other-factors-that-impact-power-system-reliability/.
[5] Executive Office of the President, "Economic Benefits of Increasing Electric Grid Resilience to Weather Outages," (August 2013), at https://www.energy.gov/downloads/economic-benefits-increasing-electric-grid-resilience-weather-outages, p. 3.
[6] Marsters et al., Rhodium Group, (October 23, 2017), at https://rhg.com/research/electric-system-reliability-no-clear-link-to-coal-and-nuclear/.
[7] NERC, "2018 State of Reliability Report," (June 2018), pp. 17, 170.
[8] First Energy comments, AD18-7-000, (May 9, 2018), p. 13.
[9] There is a difference between fuel security, fuel assurance, and on-site fuel and what each of those terms mean for resilience:

- On-site fuel -- As the Department of Energy and others use the term, on-site fuel means that there is a store of usable coal or nuclear fuel on-site to enable extended plant operations, which will assure that those plants can continue to generate under challenging circumstances. It is helpful to have fuel on-site – unless the plant with the on-site fuel is forced to shut down due to:
  - flooded coal piles (Hurricane Harvey),
  - frozen fuel piles or broken conveyor lines (Texas 2011 freeze),
  - NRC rules (week-long Turkey Point shutdown and slow ramp back after Hurricane Irma),
  - loss of cooling water (Georgia and Texas during extended droughts),
  - transformer failure at the plant busbar as from flooding or equipment failure,
  - loss of deliverability to customers due to catastrophic transmission and distribution losses (oil-fired plants in Puerto Rico after Hurricane Irma),
  - if the plant is older with a high forced outage rate, and fails as did 13,700 MW of PJM coal plants during the Polar Vortex event. (PJM, "Analysis of Operational Events and Market Impacts During the January 2014 Cold Weather Events," (September 14, 2014)).

improve power system reliability and resilience – to improve the performance of the grid overall, to reduce the frequency, magnitude and duration of customer outages. As the above statistics show, since customer outage events and minutes are overwhelmingly caused by transmission and distribution failures rather than generation or fuel supply failures, it follows that we can improve grid resilience and reduce customer outages more effectively by investing in transmission and distribution rather than generation and fuel supply.

Most outage events and threats have common consequences – they damage transmission and/or distribution assets, causing customers to lose electric service. A proactive approach to reliability and resilience would take an all-hazards approach and focus on how to address and soften these common consequences, managing risk by taking measures that mitigate against as many threats as possible.

The best ways to enhance system resilience entail threat-agnostic measures that address problems common to many hazards and consequences:

- Harden, upgrade and maintain the system to reduce its vulnerability to frequent threats such as flooding, extreme heat and extreme winds, as well as cyber-security protections;
- Continue improving system protection and operation to reduce the frequency of mis-operations and human-caused failures and to identify, prevent and contain small incidents and problems before they cascade into larger disruptions;
- Continue improving outage response measures, including emergency response drills, outage management systems, extensive critical spare and other key equipment inventories, and mutual assistance programs, to expedite outage recovery;
- And because it is impossible to prevent all outages, and because the severity and frequency of extreme weather events are increasing, help customers and society better survive extended outages.

This is not to say that generation and fuel supply are not important or not worth working on. Fuel diversity has demonstrably improved over the past decade,[10] and plant reliability and forced outage rates have improved with the retirement of many old, inefficient fossil-fired power plants. NERC's State of Reliability Report confirms that, "the trend over the five years shows improving reliability for the generator fleet," as forced outage rates have declined.[11] But most power plant forced outages do not cause either localized or widespread blackouts, because there

- Fuel security – As several RTOs and others use the term, fuel security appears to mean ensuring that power plants have or can get the fuel they need to run, particularly in winter. But fuel security does not protect a plant against cyber-attack (whether against the plant's controls, the grid operator's dispatch instructions, or the transmission system) or physical attack.
- Fuel assurance – The term fuel assurance appears to mean both physical and contractual ways to obtain needed fuels for power generation. Fuel assurance concerns have been particularly focused on natural gas pipeline capacity, reliability, and contractual assurances that needed fuel will be delivered when needed. However, fuel assurance should also consider issues such as the 93% of the nation's nuclear fuel that is imported from nations including Canada, Australia, Kazakhstan, Russia and several other eastern European and African nations.

[10] DOE, "Staff Report on Electric Markets and Reliability," (August 24, 2017), and Energy Information Administration data.

[11] NERC, "2018 State of Reliability Report," (June 2018), p. 5.

is so much fuel diversity and supply associated with reserve margin requirements, generation import capability and demand and price response, that grid operators can usually keep the system operating without obvious disruption. It is clear that the composition of generation resources is changing rapidly, and economics-driven retirements mean that past grid operational patterns may no longer be good predictors of future performance.[12] But it seems highly unlikely that (at the generic level, outside New England) generation and fuel supply problems will cause more grid problems and outages than bad weather and transmission and distribution events.

Despite some claims to the contrary, the fundamental resilience reality is that most of the factors that cause grid disruptions and outages arise not from generation shortfalls or fuel supply problems, but from bad and severe weather and problems (either weather- or equipment-related) at the transmission and distribution systems that prevent power plants from delivering to loads. America's resources are not unlimited. We could spend a fortune to retain coal and nuclear power plants but, because generation and fuel cause so few grid disruptions, doing so would have little meaningful impact on grid reliability or resilience.

If we spent the dollars requested for coal and nuclear bailouts on spare transformers, energy storage, tree trimming, cyber-security and more energy efficient apartment buildings and community centers, we would materially improve power system resilience while improving society's ability to survive upcoming hurricanes and winter storms.

FERC has jurisdiction over the bulk power system and power markets. But just because you have the ability to act does not mean you must do so. It is possible that the future grid could be marginally more reliable and resilient with some minimum level of coal and nuclear plants -- but to date our nation's experts have not found that the plants now retiring are needed for generic grid reliability or security.[13] Until we see detailed, credible, public analyses that show how specific coal or nuclear plants possess particular operational and locational capabilities that are needed to maintain the reliability and resilience for a particular region, to protect it against multiple credible threats, you have no obligation to act based on vague assertions of unsupported, hypothetical, dark consequences.

Our society's resources and budgets are not unlimited. If you commit our money to subsidizing a small corner of the generation fleet, you will take away funds that the electric sector and electric customers could spend on measures that could deliver much greater resilience and survivability benefits, such as community micro-grids and replacement transformers. In fact, spending money to subsidize inefficient, inflexible, less dependable coal plants for additional years may well make the power system less resilient and reliable, because it would increase electricity costs while diverting funds from supply, demand, and operational measures that strengthen resilience and reliability.

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[12] It is worth noting that in the PJM and ISO-NE fuel security studies done to date, resource portfolios with high levels of renewable generation consistently turn out to be highly reliable relative to other resource mixes.

[13] As documented in the DOE "Staff Report on Electric Markets and Reliability" and by subsequent RTO reports, most of the coal, gas and nuclear plants that have retired to date were older, less fuel-efficient, and had higher forced outage rates and lower dispatch rates due to their lack of operational flexibility. Their retirement has made the grid today more flexible, economic, reliable and resilient.

What level of resilience do the NERC Reliability Standards planning and operating requirements mandate? What attributes of the bulk power system … could the Reliability Standards address that would also enhance the resilience of the grid? What other actions could the industry or ERO take to enhance resilience?

I cannot speak to the specific level of resilience that current NERC Reliability Standards mandate, particularly since we don't have a well-established definition of resilience nor a set of metrics with which to measure it. However, many current NERC initiatives and industry practices are already supporting resilience, including efforts such as the GridEx emergency drills and black-start capability requirements and drills.[14] NERC and FERC standards that require generators to ride through disturbances and regulate frequency and voltage address key aspects of resilience.

In addition to the list of general, threat-agnostic preparation measures noted above, here are a few more things that FERC, NERC and the industry could do better to enhance resilience.

- Rather than continuing to use old assumptions about how grid services should be provided, hasten the exploration and identification of essential reliability services more appropriate to modern portfolios of diverse high-speed, highly flexible supply- and demand-side resources and customers. These grid services need to be technology-neutral, performance-based, uniformly required for grid participation, and appropriately compensated. They should recognize the capabilities of new inverter-based supply-side resources and automated demand-side resources.[15] The essential services definitions need to look forward to a fast, energy-dominated, two-way grid rather than back to a slower, supply-dominated, inertia- and capacity-oriented system.
- Develop more extensive, deeper spare equipment inventories and requirements, including more interchangeability of key parts.
- Continue work on gas-electric market coordination and harmonization.
- Rethink grid design with respect to decentralization, distributed assets, and how to balance between hardened assets and fast triage and replacement of assets in high-risk locations.
- Develop and implement forward-looking asset design that modifies transmission and generation to deal with new extreme weather challenges, including more extreme precipitation and flooding, heavier winds, longer and hotter heat spells, longer droughts, higher sea levels and flooding. These severe weather threats will compromise substations, power plant operations and integrity, current line sagging and thermal limits, transmission tower integrity, and more.

What data and metrics are available to measure and track the resilience of the grid? For example, is it possible to expand the definition of an adequate level of reliability, used as the

[14] NERC, "Resilience Framework," (March 2018), at https://www.nerc.com/comm/PC/Agenda%20Highlights%20and%20Minutes%202013/Draft_PC_Meeting_Presentations_March_6-7_2018_Jacksonville_FL.pdf, pp. 57-67.

[15] These capabilities have been extensively demonstrated and are summarized in Appendix B of our Customer-focused Resilience paper filed in this docket.

basis for the NERC Reliability Standards, to include resilience? Are there gaps in the data and metrics that, if filled, could shed additional light on the resilience of the grid?

We do not have good data today to describe or measure the resilience of the grid. Resilience itself is an effort to avoid and avert disaster and recover from those disruptions that occur; but we do not often recognize and track the near-miss events that didn't turn into outages. Even the data on actual power system outages are poorly and inconsistently reported and explained. National laboratory studies and the Energy Information Administration have discussed the paucity and poor quality of outage and other resilience-related data. While NERC reliability reports provide extensive, sophisticated analysis of grid issues, they do not offer simple, clearly comparable statistics about the numbers of grid events caused by transmission versus generation events and how to associate those with outages. In particular, most NERC analyses deliberately drop out severe weather events, even though those are the events that most often compromise power system performance.

Mr. Lauby's testimony describes some specific grid performance measures that are short-term electrical responses to individual electrical events. These do not describe the power system's overall grid capabilities and its ability to withstand and survive a wide range of events and conditions. In contrast, a metric such as reserve margin describes a longer-term characteristic that affects both reliability and resilience.

More work is needed on the meaning and measurement of resilience before you can expand the definition of an adequate level of reliability to include resilience. Resilience should be viewed as part of and complementary to reliability, and it is much broader than either the BPS or fuel supply and diversity measures.

What opportunities exist for NERC and the Regional Entities to work with states and other jurisdictions collaboratively to improve resilience of the grid?

As discussed above, electric resilience is bigger than the power system, so customer welfare needs to be considered more explicitly. State regulators and state and local officials have the responsibility, knowledge and opportunity to do much more to protect their citizens against the same threats that challenge the electric and gas systems. A few collaborative opportunities include:

- State regulators have jurisdiction over distribution utilities, but share the consequences of outages and severe weather outside the BPS scope. FERC, NERC and EIA should consult with state regulators and outside experts to develop meaningful definitions and metrics for resilience (and its failures) across the entire generator-to-customer spectrum. Those definitions and metrics should be built into better data collection tools that elicit accurate and consistent reporting from all utilities and BPS participants, across all states and communities.
- FERC, NERC, DOE, DHS and the Regional Entities should be communicating honestly with state officials about the breadth and magnitude of the threat environment and helping to develop joint plans for emergency response and customer and community survivability when the grid fails.

- FERC, NERC and the REs should be sharing useful data about power system reliability and resilience performance and holding meaningful conversations on these topics in state and regional forums.
- NERC and the REs should be conducting region-specific research into the magnitude and nature of extreme weather threats and sharing that information with state officials to collectively address adaptations and mitigations such as asset hardening, modification, abandonment, and customer protection.
- Since state officials affect resilience factors such as transmission line siting, gas pipeline approvals, housing efficiency standards, energy efficiency programs, automated demand response, and distributed generation and micro-grid interconnection, BPS stakeholders should work with those officials to help them appreciate the impact of their decisions on overall system resilience and regional security.
- FERC should work closely with NARUC and state regulators to ensure that state and federal jurisdictional boundaries do not cause a mis-allocation of resources that harm rather than improve resilience.

Should Reliability Standards require minimum parameters for system resilience?

NERC's standards today address specific measures that address reliability and resilience, including vegetation management, emergency preparedness, black-start operations, and identifying and sharing lessons learned.

If we can't define what resilience is and how to measure it, we can't set minimum standards for it. It may be impossible to determine and count how many outages or major grid disruptions were averted by good system protection, aggressive operator action, or modernized equipment and asset management analytics. We are already doing many of the right things to facilitate disaster response and recovery, but severe weather events and other grid disruptions are highly diverse and regional, so it may be hard to craft appropriate resilience requirements.

Some will recommend resilience metrics such as minimum fuel diversity, days of fuel on-site, or the ability to avoid outages under a few contrived, highly unlikely circumstances – but such parameters are unlikely to improve actual system performance against the broad suite of threats we face today and will not be applicable in many regions of the country.

Should [reliability] standards specifically address high-impact, low-frequency events (e.g., physical and cyberattacks, accidents, extended fuel supply disruptions, or extreme weather events)?

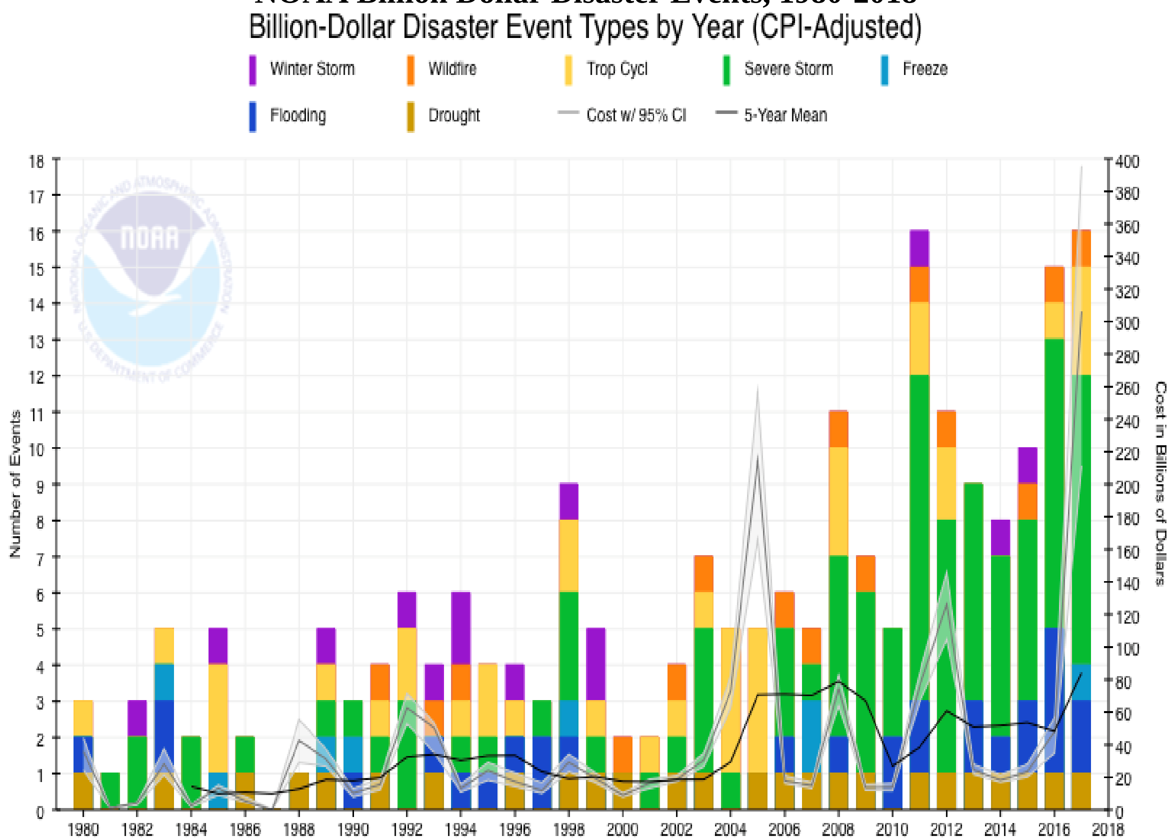
Yes, but reliability standards and resilience efforts should not be restricted to HILF events. We must recognize that in the current threat environment, many of the events that we used to view as HILF are no longer low frequency. For instance, the U.S. Director of National Intelligence says that the "digital infrastructure of the United States is literally under attack, with targets including federal government agencies, the military,"[16] and critical infrastructures and businesses. The

[16] https://www.huffingtonpost.com/entry/dan-coats-warns-of-dangerous-new-cyber-attacks_us_5b4aa5b5e4b0bc69a787c923, July 15, 2018. NERC's 2018 State of Reliability Report says that while

Department of Homeland Security warned in March that Russian government hackers have targeted the energy sector, among others, in a two-year campaign to collect information on industrial control systems.[17] Duke Energy reported that it dealt with more than 650 million intrusion attempts on its networks in 2017.[18] Clearly cyber-attacks are not low-frequency any more.

Extreme weather events are also becoming more frequent, as documented by the National Oceanic & Atmospheric Administration (see figure below) and insurance companies. Major hurricanes, wildfires, floods, and heat waves now occur so often that they are not low-frequency, even as these events are becoming larger and more destructive than ever before.

NOAA Billion Dollar Disaster Events, 1980-2018



At present, the only types of events that still appear to be low-frequency and high-impact are severe geomagnetic disturbances, electromagnetic pulse attacks, massive communications systems failures and pandemics.

there were no "reportable" cyber- or physical security outage incidents reported in 2017, the actual risk of such incidents is higher than the statistics suggest.

[17] US-CERT, "Alert (TA18-074A), Russian Government Cyber Activity Targeting Energy and Other Critical Infrastructure Sectors," (March 15, 2018).

[18] https://www.cyberscoop.com/electric-utilities-use-red-teaming-ai-to-prepare-for-advanced-threats/ (July 13, 2018).

HILF events can cause major grid disruptions. But with the exception of major storms or a widespread cyber-attack, most major grid disruptions begin with one or two isolated events (e.g., an equipment failure at a substation, the loss of a single transmission line, or the failure of equipment at a single generator), and grow into a larger outage (e.g., a 500 kV line fault associated with a wildfire led to tripping of 1,000 MW of distributed photovoltaics in 2016, a field technician error at the Hassayampa substation cascaded into the 2011 Southwest blackout, and inadequate tree-trimming and inadequate situational awareness by First Energy in Ohio led to the loss of several transmission lines that cascaded into the 2003 Northeast Blackout). While it is useful to worry about and protect against true HILF events, recognize that many of those events may lead to the same consequences as the more frequent, garden-variety disasters that we deal with regularly on the grid – and many of the same solutions, such as better community preparedness and customer energy efficiency, will protect against HILF and other disasters alike.

In closing

Thank you for taking the time to think carefully through the meaning and implications of resilience and reliability, which are deeply intertwined. But do not forget that if you view resilience from the customer's perspective and needs – which is why we operate the grid -- then resilience for customers is infinitely larger than resilience of the power system, which is much larger than resilience of the generation fleet. Please design your reliability and resilience policies accordingly.

Appendix A -- Major North American Blackouts Since 2001

(based on DOE OE-417 data and public reports)

Year	Location	Customers affected (million)	Time until most power restored	Cause
2002 – January 30	OK	1.9	1 week	Ice storm
2003 – August 14	Northeast US & Ontario	55	1 week	Transmission in Ohio
2003 – September 19	VA, NC	1.8	12 days	Hurricane Isabel
2004 – August 13	FL	1.2	10 days	Hurricane Charley
2004 – September 4	FL	2.8	10 days	Hurricane Frances
2004 – September 25	FL	3.4	10 days	Hurricane Jeanne
2005 – August 29	FL, LA, MS, AL, TN, AR, KY	2.6	2 weeks	Hurricane Katrina
2005 – October 23	FL	3.2	1 week	Hurricane Wilma
2005 – December 31	CA	1.7	1 week	Severe storms
2006 – July 19	MO, IL	2.5	12 days	Thunderstorms
2008 – January 4	CA	2.6	11 days	Winter storm
2008 – February 26	FL	4	1 day	Transmission at Turkey Point plant
2008 – September 13	TX	2.5	3 weeks	Hurricane Ike
2010 – January 18	CA	1.7	10 days	Severe storms
2011 – February 2	TX	1	1 day rolling outages	Cold weather & generation failures
2011 - April 27	AL	1.2	1 week	Storm, tornado
2011 – August 27-28	NC, VA	1	2 days	Hurricane Irene
2011 – September 8-9	AZ, CA, northern Mexico	2	2 days	Transmission in AZ
2011 - late October	ME, CT, MA, NH, RI	1.4	9 days	Snowstorm
2012 – June 29	IA, IL, IN, OH, WV, PA, MD, NJ, VA, DE, NC, KY, DC	6	4 days	Thunderstorms, wind storms, derecho
2012 – October 29	NY, NJ, CT, MA, MD, DE, WV, OH, PA, NH, RI, VT	8	10 days	Hurricane Sandy
2016 – September 21	Puerto Rico	3.5	3 days	Power plant fire
2016 – October 6	FL	1.2	3 days	Hurricane Matthew
2017 – March 8	MI	1	2 days	Wind storm
2017 – August 26	TX	1.1	2 weeks	Hurricane Harvey
2017 – September 10	FL, GA, SC, Puerto Rico	4.5	1 week	Hurricane Irma
2017 – September 20	Puerto Rico & islands	3.5	many months	Hurricane Maria