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Remarks

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Thank you Commissioners Williamson and Vannoy for this very special invitation, and to Rachel Goldwasser and Dennis Bergeron for your insights and help.

In the interests of time, I'm going to speak from my notes, and NECPUC will make them available on-line.

Criticality Sciences has the mission of reducing the impact of low probability high consequence events on our infrastructure. Our science and software is developed by Ted G. Lewis.

Why should we start spending money on preventing unlikely future events now, when we haven't in the past? Terrorist attacks, cyber disruptions, pandemics, EMP attacks – these have been conceivable for some time. Why step up investment now? This common sense question has at least two profound answers.

One is scientific. We are used to thinking about events in terms of the bell-shaped curve. Actions usually occur near the average, occasionally deviating by large amounts. But as society depends increasingly on connected systems, independent random events are being replaced by highly dependent, conditional events. Our new normal is long-tailed probability distribution, with extreme outlier events.

Constitutional transformation is also driving interest in catastrophe -- constitutional in the legal sense of the social compact by which we live. Safety in daily life is increasingly perceived as a fundamental right. That utilities will stay capable is assumed and demanded.

Almost universally though, we still rely on response -- looking back at what happened and analyzing why and how. The equations and solutions applied are powerful. And yet -- we still have unforeseen catastrophic events. Now scientists including Ted Lewis have begun to chip away at the unforeseeable, providing an opening to shift from response to prevention.

Why was the 2003 NE Blackout so big, given the inconsequential outage in Ohio? Nassim Taleb, who coined the term Black Swan in 2010, would say that unlikely events are still possible and if you toss the dice enough times even the least likely event will occur. We can only understand such events, he said, after they happen.

Charles Perrow, a sociologist who taught at Yale, began examining catastrophic events in the early 1980's. He would have said that the 2003 NE Blackout was the result of a series of events -- a tripped line, an operator error, turning off the warning software. Each one was highly unlikely. A cascade happens when an initial insignificant fault propagates through invisible connections, magnifying consequences as additional faults accumulate, such that whole systems collapse in stages. Perrow concluded that cascades have become normal in our connected society. Their occurrence is probabilistic and highly unlikely. And yet they happen. Complex, engineered systems do fail, with elements of randomness, especially under stress, and are therefore subject to probabilistic, long tailed risk. This is an emerging reality that regulators and utilities need to face.

Since Perrow, more has been learned about how this process unfolds. A trio of physicists in 1987 showed that complex systems evolve into a state of self-organized criticality (SOC), a now established idea from complexity science. In the original demonstration, sand dropped onto a sandpile eventually breaks from the top of the cone and causes the structure to collapse. The cascade collapse marks the emergence of criticality in the sand pile. Even though the sand does not fall in a specified place each time, cascades keep happening; this makes criticality self-organizing rather than deterministic.

Ted Lewis concluded that SOC explains why Perrow's invisible couplings lead to catastrophic collapses. Cascades happen when systems reach a state of SOC.

Can we find out if a system or interdependent systems is at risk of cascade collapse? Networks can be used as a model for infrastructure systems in order to learn more about their propensity to cascade. Nodes can represent assets -- the power transformers and internet servers, and people. Links can represent transmission lines, internet cables, social ties, and so on. This can be done for networks like grids or interconnected systems such as electricity, gas, water, and transportation, or for all critical infrastructure in a given community. This is the approach Criticality is taking to transforming science into practical tools.

The understanding that cascade collapse in a complex system has probabilistic likelihood provides a framework for addressing low probability high consequence events. Three elements seem to me to be essential for business decisionmaking and regulation:

- a way to quantify the financial risk to a system from cascade collapse;
- a means of quantifying the systems' resilience; and
- enough information about the reasons for the level of risk and resilience to permit cost-effective improvements to an acceptable level.

Quantifying risk is important to know what the potential exposure is. Quantifying risk builds cost considerations into decisionmaking. Our framework does this by measuring dynamic risk -- the maximum probable loss due to cascading failure rippling throughout a holistic system. Probable maximum loss or PML risk is analogous to the same term in insurance metrics.

Quantifying resilience is key to enable problem solving. Our framework quantifies a network's resilience in two ways – its ability to withstand disruptions without catastrophic losses, and to recover in reasonable time and at reasonable cost.

A path to improved resilience is also essential. Infrastructure systems can become more reliable under stress by reducing vulnerabilities to stresses such as surges and overloads. Investments – for example storage or undergrounding -- targeted to fragility-spreading locations can reduce the likelihood of long-tailed events. But redundancy does not always mean reduced risk and returns are eventually diminishing.

By moving from a general definition of resilience to specific, quantified measures that point to the level and location of investment we can prevent the worst losses and lower the frequency and scale of ongoing disruptions.

We believe it is a framework that can move us forward. It does have limits. It can't show how to stop cascading, only where to apply resources to optimize return on investment toward lowering risk and raising resilience. Neither the mathematical model for cascade resilience nor the cause and effect it proposes have been validated. But the stress tests we apply make sense in spotlighting sources of fragility and collapse. The emerging reality of long tailed risks, and the potential for continuous improvement, seem to me to make this approach worth pursuing.

How does regulation change in a long-tailed world? Given that it is possible to quantify resilience, we need to consider whether long-tailed events separate response and prevention. We may be entering a new phase where we have to be prepared to respond to high frequency, low impact events, and to seek to prevent low frequency, high impact events.

Thank you for listening; I look forward to our discussion.