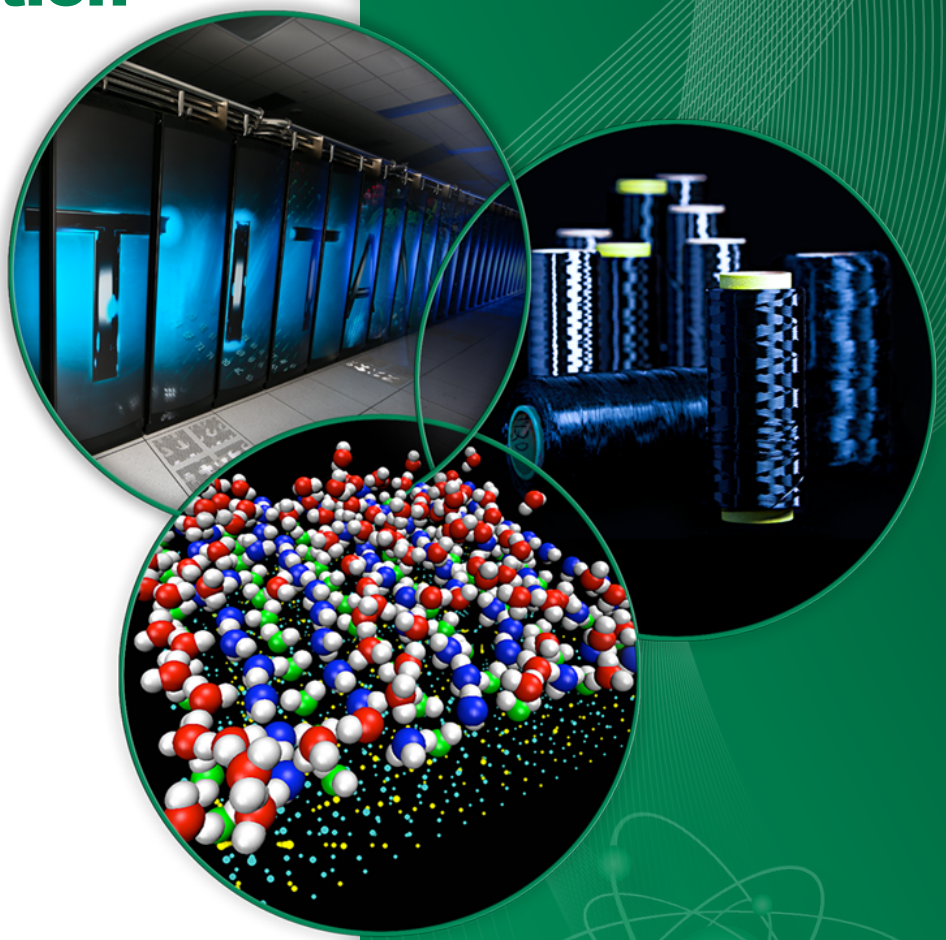
A DOE Research Laboratories' View on Time Synchronization Needs & Challenges



Terry Jones

Oak Ridge National Laboratory

NIST/IEEE Timing Challenges In The Smart Grid Workshop

Talk Outline

- Why do we need Improved Time Synchronization in the Grid?
- Where are we insufficient?
  - Performance Factors
  - Security Concerns
  - Resiliency Aspects
  - Business Considerations
- Conclusions and Discussion

Talk Outline

➢Why do we need Improved Time Synchronization in the Grid?

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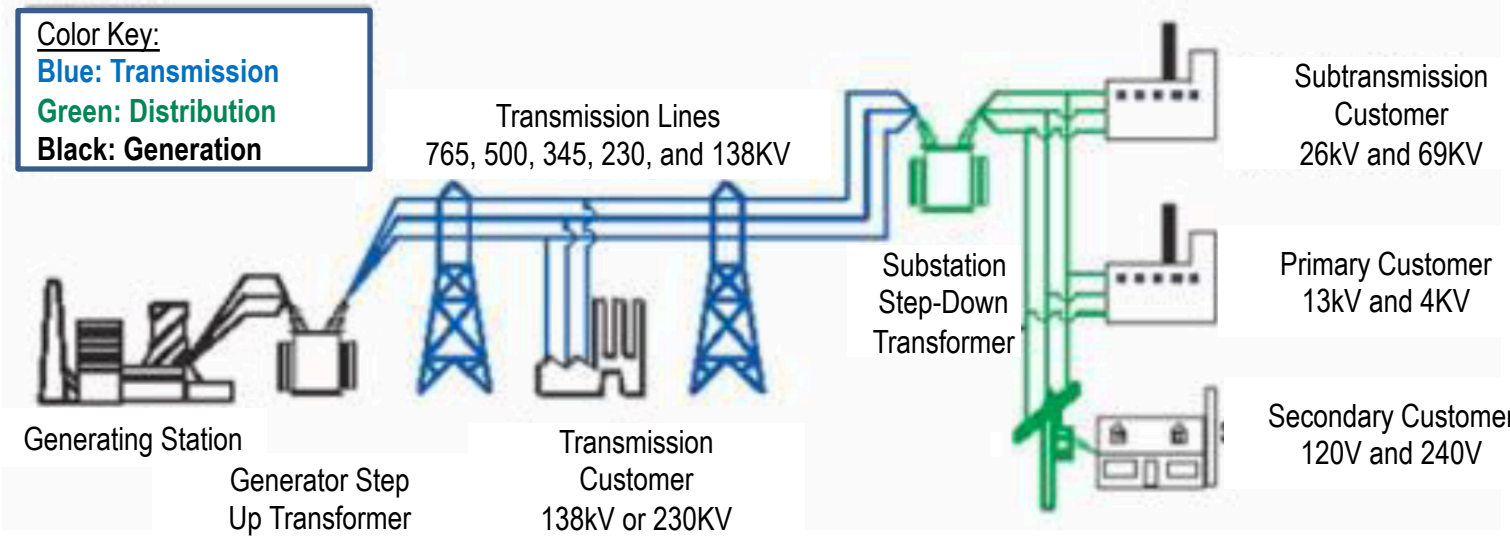
Motivation - Rapid Change

The Past



The Future

Motivation - Rapid Change

The Past

The Future

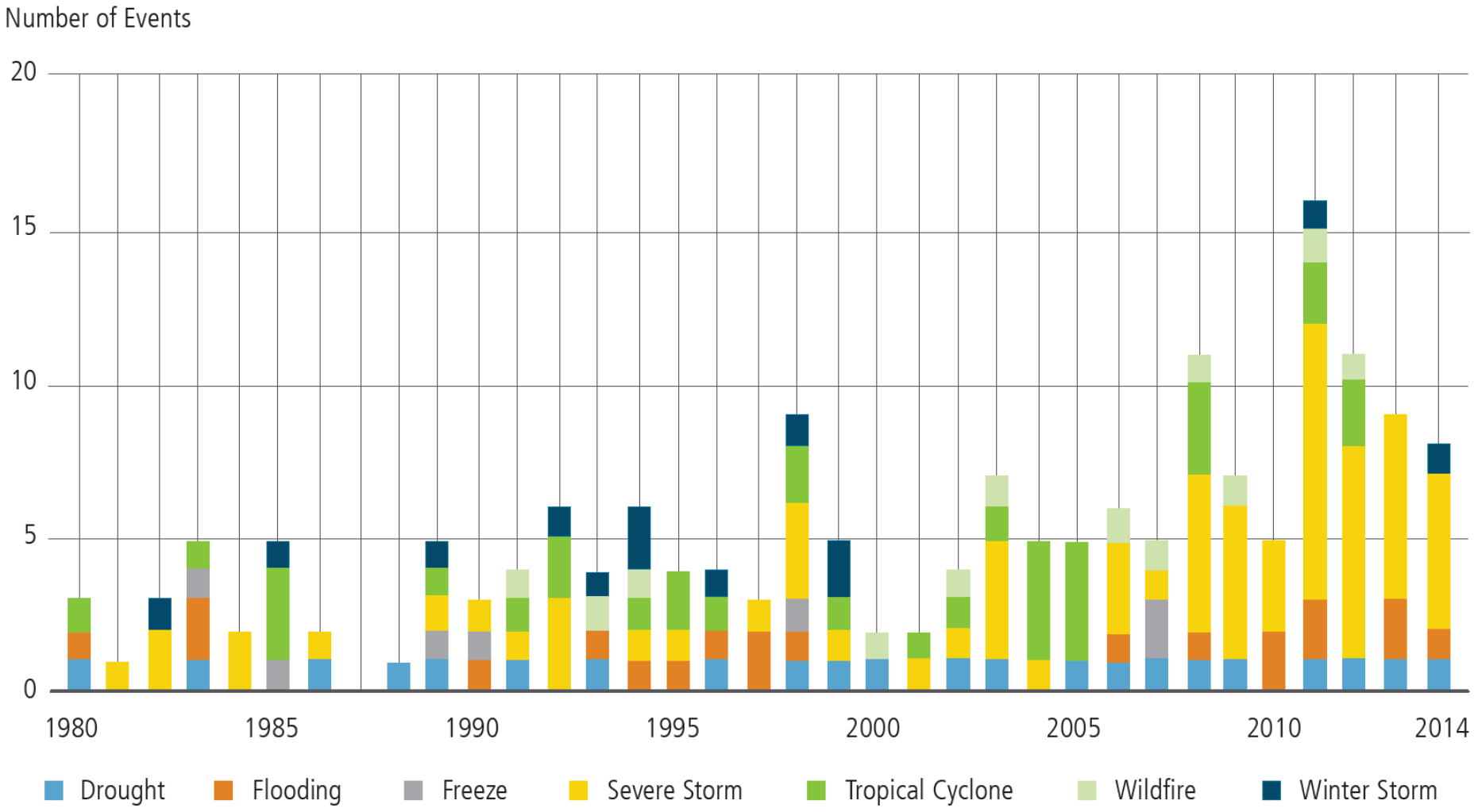
A benchmarking study by the Bonneville Power Administration showed the electric utility industry invests just 0.1 percent of its net sales in R&D.*

Several states, such as California, Hawaii, and New York, have embarked on comprehensive (and different) approaches to changing the entire electricity market ecosystem and its interrelationships.**

*source: National Science Foundation, *Business Research and Development and Innovation: 2011*, Detailed Statistical Tables, NSF 15-307, December 30, 2014

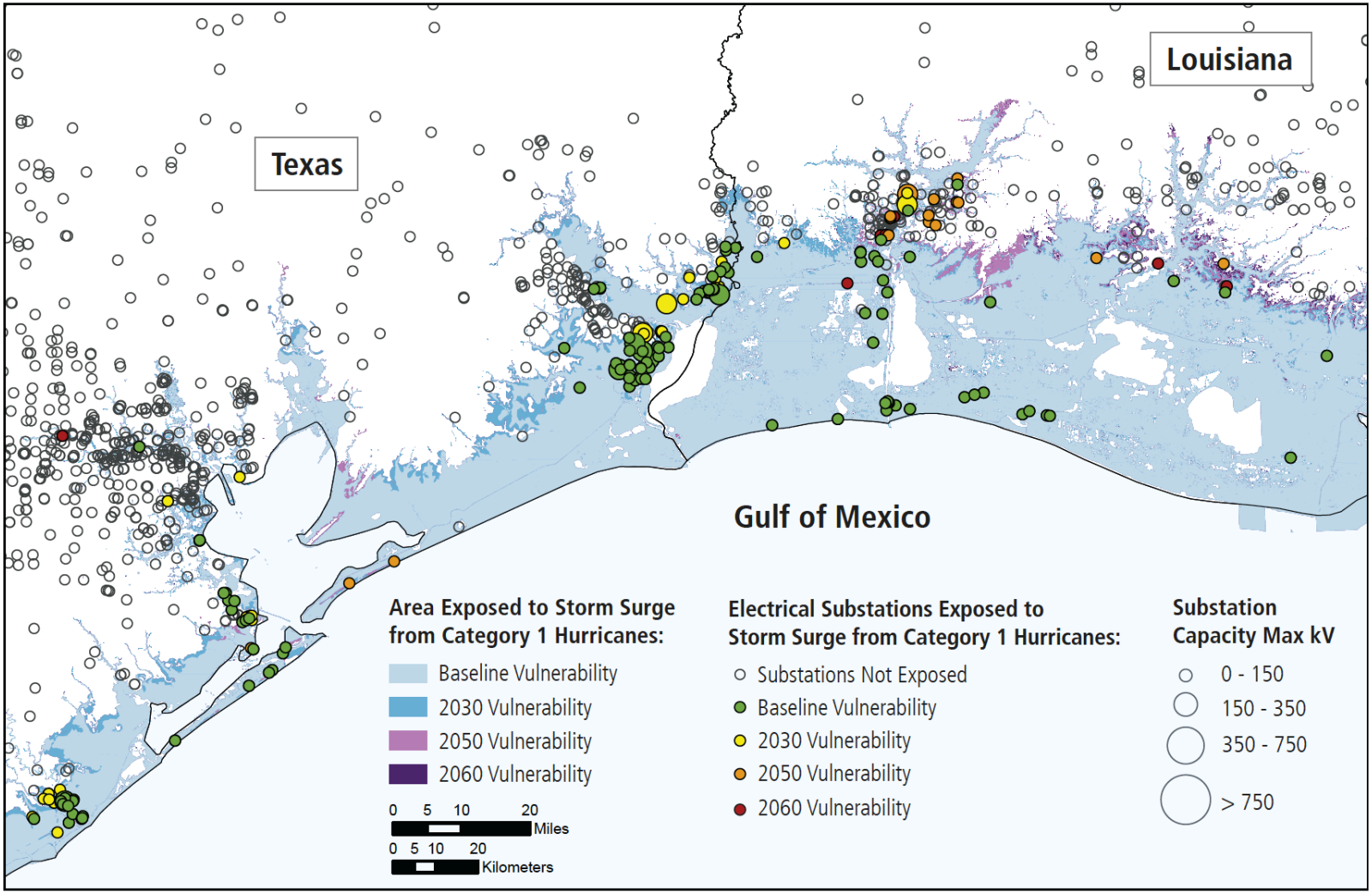
**source: New York Public Service Commission, *REV: Reforming the Energy Vision*; California Public Utilities Commission, *Distribution Resources Plan* and other overlapping activities; and Hawaii State Energy Office, *Energy Policy Directives*.

Motivation 2 – Climate Change



source: The Quadrennial Energy Review: First Installment

Motivation 2 (cont.) – Storm Surge Exposure



source: The Quadrennial Energy Review: First Installment

How Has This Administration Responded?

GMI Goal for 2020: Provide real-time information of solar and wind generation and building loads at high spatial and temporal resolution.

January 09, 2014

For Immediate Release

THE WHITE HOUSE
WASHINGTON

MEMORANDUM FOR THE HEADS OF EXECUTIVE DEPARTMENTS AND AGENCIES

SUBJECT: Establishing a Quadrennial Energy Review

Affordable, clean, and secure energy and energy services are essential for improving U.S. economic productivity, enhancing our quality of life, protecting our environment, and ensuring our Nation's security. Achieving these goals requires a comprehensive and integrated energy strategy resulting from interagency dialogue and active engagement of external stakeholders. To help the Federal Government better meet this responsibility, I am directing the undertaking of a Quadrennial Energy Review.

The initial focus for the Quadrennial Energy Review will be our Nation's infrastructure for transporting, transmitting, and delivering energy. Our current infrastructure is increasingly challenged by transformations in energy supply, markets, and patterns of end use; issues of aging and capacity; impacts of climate change; and cyber and physical threats. Any vulnerability in this infrastructure may be exacerbated by the increasing interdependencies of energy systems with water, telecommunications, transportation, and emergency response systems. The first Quadrennial Energy Review Report will serve as a roadmap to help address these challenges.

What Can The DOE do?

- DOE is able to assess regional and national grid modernization efforts, technology and market developments, and institutional barriers affecting generation, transmission, distribution, and end-use technologies.
- DOE is also the most qualified to conduct foundational work to identify gaps in fundamental knowledge and technology.
- Finally, DOE is able to convene stakeholders to develop consensus roadmaps, deliver new platforms of tools and analytics to catalyze innovation in industry, and accelerate adoption of new technologies.
- In summary, DOE's technical expertise, past accomplishments, and current activities provide the basis for new grid leadership.

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Government Leadership, in the form of Technical Guidance; provide an unbiased appraisal of rapidly changing technologies

Talk Outline

- Motivation for Improved Time Synchronization in the Smart Grid

➢Areas of Concern

  - Performance Factors
  - Security Concerns
  - Resiliency Aspects
  - Business Considerations

- Conclusions and Discussion

Performance Factors (defining the need)

Distributed Situational Awareness Demands Coordination

The Valley Falls, Rhode Island train wreck of the Providence and Worcester Railroad, August 12, 1853

The North American Electric Reliability Council cited a lack of situational awareness as a contributing factor leading to the 2003 blackout.

Among their recommendations was the installation of time-synchronized data recording and reporting devices.

Phasor Measurement Units (PMU)s allow for both a forensic analysis of grid events and real-time grid monitoring.

Accurate measurement of synchrophasors across the grid requires stable and synchronized clock sources.

More than 800 phasor measurement units were deployed under the Recovery Act smart grid projects overseen by DOE for a nationwide total of more than 1,700 as of 2014 (mostly at the transmission level).

Picture from: https://selinc.com/products/2240/

Performance Factors (quantifying success)

…Better Time Agreement ➔ Better Understanding

- According to some work by Zhao et al., angle error as low as ±0.1° can cause a failure, and an angle error of ±0.6° will have an even greater impact.[1]
- From a study of the Northeast Power Coordinating Council model, an angle error as small as ±0.15° is able to change the first responding PMU.
- There is an important standards and testing component to ensuring we employ devices that meet the need. (Not surprising that NIST is hosting this event.) Most PMUs fail the 2011 standards

[1] Jiecheng Zhao, Jin Tan, Ling Wu, Lingwei Zhan, Yilu Liu, Jose R. Gracia, Paul D. Ewing. Impact of Measurement Error on Synchrophasor Applications. ORNL Technical Report

Security Factors (defining the need)

- Requirements for robustness in the presence of directed attacks on the distributed precision time service.
  - Physical or cyber-attack,
  - Exploit storms & earthquakes,
  - Electro-magnetic pulse (EMP),
  - Exploit geo-magnetic disturbances (GMD)

Security Factors (cont.)

- In fiscal year 2012, some 198 cyber incidents were reported across all critical infrastructure sectors. Forty-one percent of these incidents involved the energy sector, particularly the electric power sector.*

- Broader picture, this is seen as part of the overarching "unifying the grid communications network"

*Source: Bipartisan Policy Center, *Cybersecurity and the North American Electric Grid: New Policy Approaches to Address an Evolving Threat*, February, 2014.

Security Factors (cont.)

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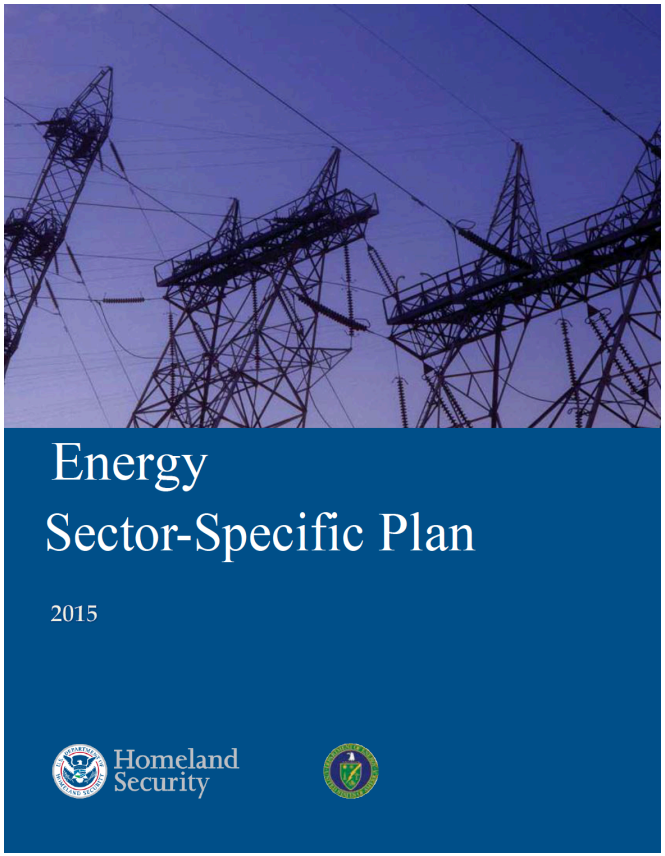
*Source: Bipartisan Policy Center, *Cybersecurity and the North American Electric Grid: New Policy Approaches to Address an Evolving Threat*, February, 2014.

Security Factors (quantifying success)

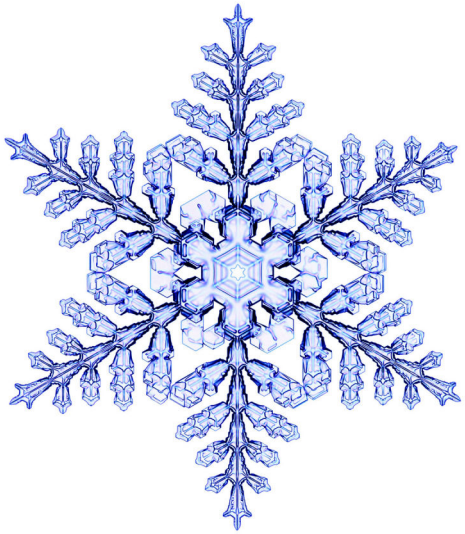
- Strategy based on the NIST cybersecurity framework[1]
- Establishment of three Information Sharing and Analysis Centers (ISACs)
  - Disseminate information on actionable data
- National Level Exercises such as the Cyber Storm series and CyberGuard
- DOE's Cybersecurity Capability Maturity Model (C2M2) Program



[1] National Institute of Standards and Technology, "Framework for Improving Critical Infrastructure Cybersecurity," February 12, 2014, http://www.nist.gov/cyberframework/upload/cybersecurity-framework-021214.pdf .

Resiliency (defining the need)

- Requirements for achieving resilient operation in the face of losing any given timing source. Emphasis on low-cost, lightweight (man portable), and secure devices capable of functioning without external power other than their connection to the grid. Robust (Superstorm Sandy).
- GMI 2020 Goal: Synchrophasor technology that is reliable during transient events:
  - Physical or cyber-attack,
  - Storms & earthquakes,
  - Electro-magnetic pulse (EMP),
  - Geo-magnetic disturbances (GMD)



Resilie

Subject:CGSIC: FW: Official Press Release - GPS Ground System Anomaly
Date: Thu, 28 Jan 2016 01:11:27 +0000
From: Civil Global Positioning System Service Interface Committee (CGSIC) <cgsic@cgls.uscg.mil>
Reply-To:cgsic@cgls.uscg.mil
To:cgsic@cgls.uscg.mil <cgsic@cgls.uscg.mil>

13 Microseconds

Off for a period of over 5 hours!

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All CGSIC:

Air Force Official Press Release - GPS Ground System Anomaly

On 26 January at 12:49 a.m. MST, the 2nd Space Operations Squadron at the 50th Space Wing, Schriever Air Force Base, Colo., verified users were experiencing GPS timing issues. Further investigation revealed an issue in the Global Positioning System ground software which only affected the time on legacy L-band signals. This change occurred when the oldest vehicle, SVN 23, was removed from the constellation. While the core navigation systems were working normally, the coordinated universal time timing signal was off by 13 microseconds which exceeded the design specifications. The issue was resolved at 6:10 a.m. MST, however global users may have experienced GPS timing issues for several hours. U.S. Strategic Command's Commercial Integration Cell, operating out of the Joint Space Operations Center, effectively served as the portal to determine the scope of commercial user impacts. Additionally, the Joint Space Operations Center at Vandenberg AFB has not received any reports of issues with GPS-aided munitions, and has determined that the timing error is not attributable to any type of outside interference such as jamming or spoofing. Operator procedures were modified to preclude a repeat of this issue until the ground system software is corrected, and the 50th Space Wing will conduct an Operational Review Board to review procedures and impacts on users. Commercial and Civil users who experienced impacts can contact the U.S. Coast Guard Navigation Center at (703) 313-5900.
V/R
Rick Hamilton
CGSIC Executive Secretariat
GPS Information Analysis Team Lead
U.S. Coast Guard Navigation Center
703-313-5930

~

V/r,
ROLAND RAINEY, JR., Major, USAF
Director of Operations
2d Space Operations Squadron (GPS)
Schriever AFB, CO
DSN: 560-2523; Comm: 719-567-2523
Cell: 719-209-8740
Work BB: 719-440-6110

Picture from www.garmin.com

Business Challenges (part 1)

- Affordable
  - The average overall cost per phasor measurement unit or PMU (procurement, installation, and commissioning) ranged from $40,000 to $180,000.[A] For industrial applications, the average cost of a sensor is $1,800.[B] These costs are, in part, dependent on the parameter being measured along with complexity of installation.[C] 2020 goals are $10 for end user sensor, $100 for multi-purpose distribution sensor.
- Flexible
  - Coordination: DOE, linking key programs within the Office of Science (SC), Office of Electricity Delivery and Energy Reliability (OE), Office of Energy Efficiency and Renewable Energy (EERE), Office of Fossil Energy (FE), Office of Nuclear Energy (NE), Advanced Research Projects Agency - Energy (ARPA-E), Office of Energy Policy and Systems Analysis (EPSA), and others.
- Sustainable
  - For example, growth in Photovoltaic (PV): there are now more than 600,000 homes and businesses with on-site solar PV. In 2014, PV installations reached 6,200 MW, up 30 percent over 2013 and more than 12 times the amount installed five years earlier.[D]

sources:

[A] Synchrophasor Technologies & their Deployment in the Recovery Act Smart Grid Programs, August 2013;

[B] "Agile Prognostics and Diagnostics for Power Transmission Reliability and Asset Management" White paper, Peter Fuhr, Alex Melin

[C] D. Lineweber , S. McNulty, "Cost of Power Disturbances to Industrial & Digital Economy Companies," *EPRI Report: 3002000476, CEIDS,* 2001.

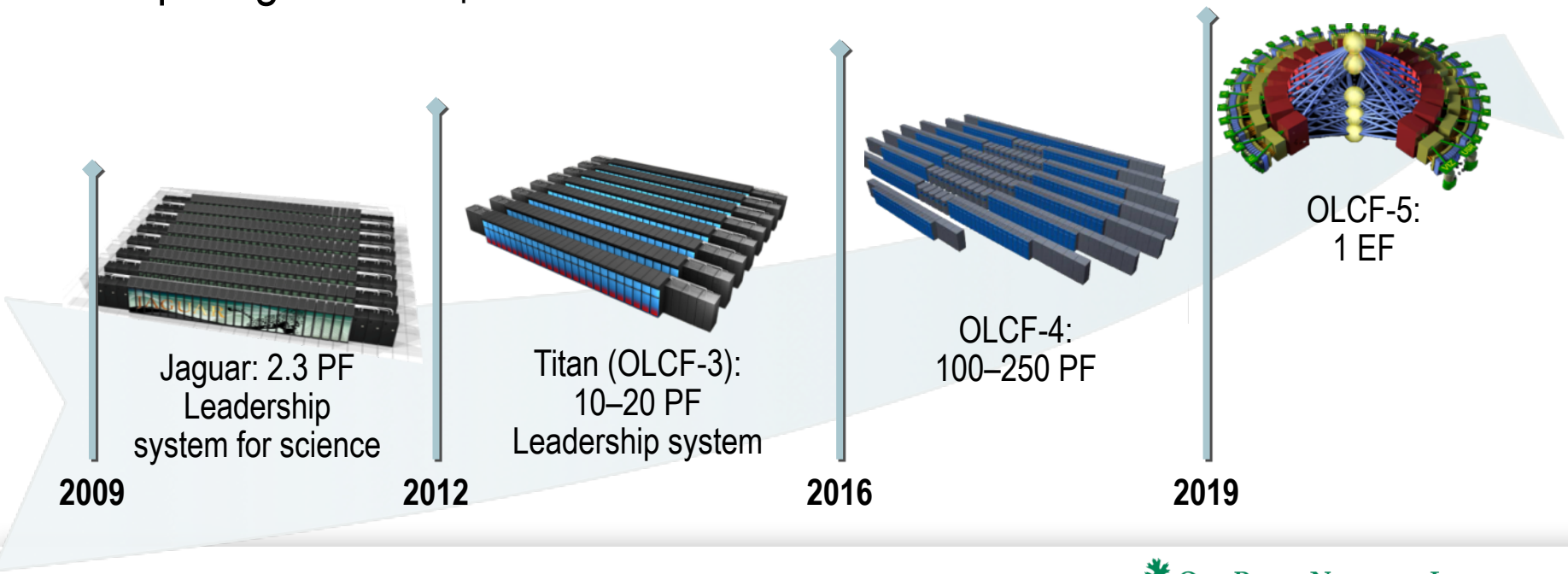
[D] GTM Research and Solar Energy Industries Association, *U.S. Solar Market Insight Report: 2014 Year in Review*, 2015.

Business Challenges (part 2)

- Life with Experimental and Observational Data...
  - What about the long-term QA aspects of maintaining data?
  - What about the logistics of very large data?
  - Staging / Retrieving huge files (can't be on disk)
- Department of Redundancy Department

Business Challenges (part 3)

- Room for Simulation & Data Analytics?
  - Most sciences have moved to incorporating simulation as a first-class citizen in the process of scientific discovery
  - What best-practices can the rapidly evolving power grid take?
- Next-generation power grid applications should seek to develop new methods that maximally leverage the power of parallel computing and cloud computing -- GMIC report



Business Challenges (part 4) ...The Data Deluge

- Key Challenge: Make Sense of So Much Data

2013	4PB disk	& 34PB tape	[Titan]
2017	64PB disk	& 600PB tape	[Summit]
2021	1EB disk	& 10EB tape	(?)

- If “many hands make light work,” how can we enable more people to make sense of the data?
- We’ll Need Better Tools

FIND THE NEEDLE IN THE HAYSTACK

Talk Outline

- Why do we need Improved Time Synchronization in the Grid?
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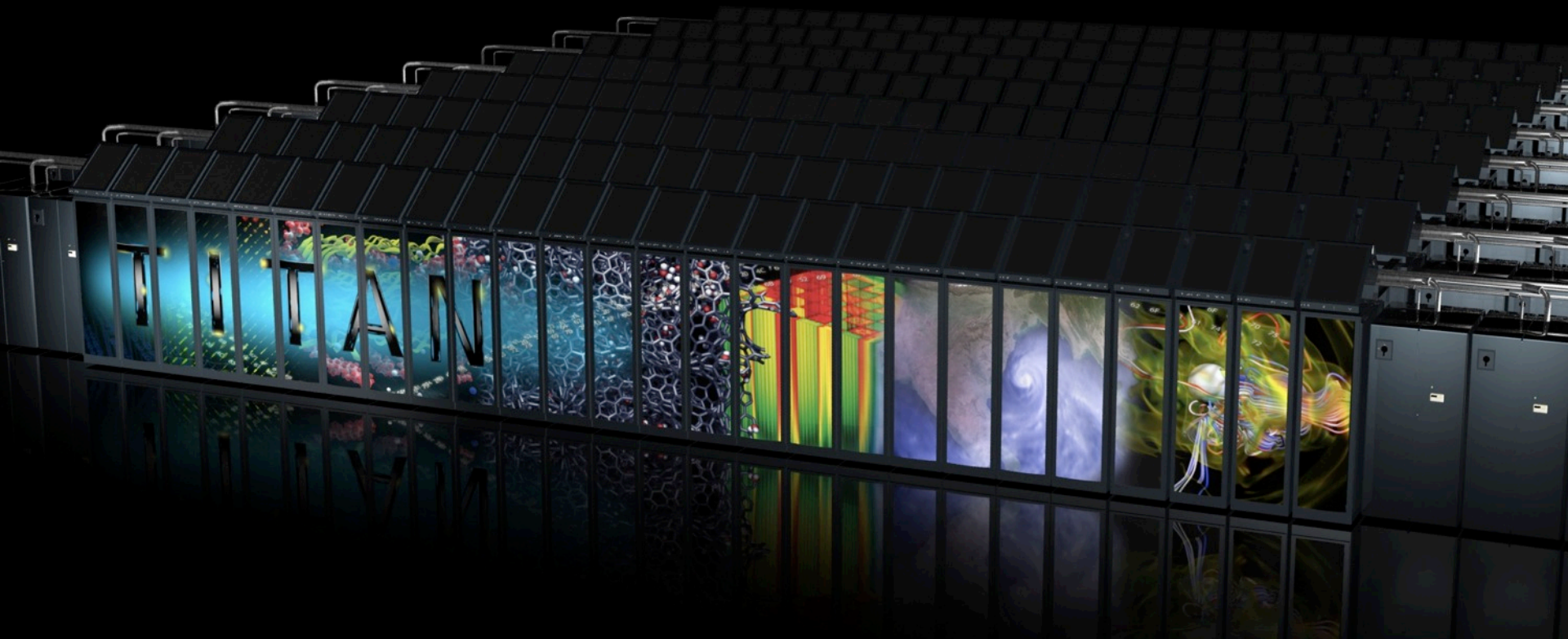
➢Conclusion and Discussion

Summary

- DOE is actively addressing grid modernization and climate change
- We see potential in helping to understand barriers & gaps, and in working with stakeholders to derive a path forward
- Among today's shortcomings:
  - Insufficient precision
  - Insufficient security
  - Insufficient RAS
  - Too Many Business Challenges To Needed Technology
- Multiple Initiatives are intended to address these concerns.

Acknowledgements

This presentation gratefully used information and figures from the Electricity Advisory Committee; DOE's Grid Tech Team; the Office of Electricity Delivery and Energy Reliability (OE); the Office of Energy Efficiency and Renewable Energy (EERE); and the Office of Energy Policy and Systems Analysis (EPSA).



This research used resources of the Oak Ridge Leadership Computing Facility at the Oak Ridge National Laboratory, which is supported by the Office of Science of the U.S. Department of Energy under Contract No. DE-AC05-00OR22725.

Questions?

trj@ornl.gov