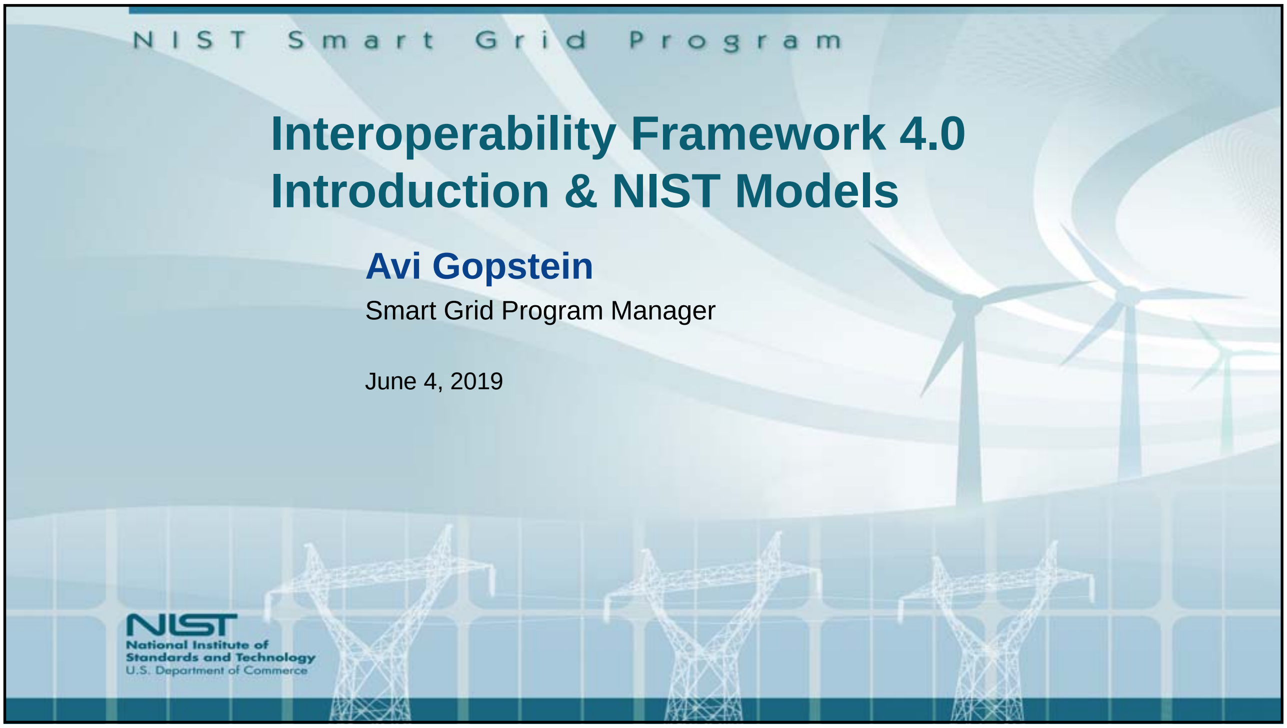


Interoperability Framework 4.0 Introduction & NIST Models

Avi Gopstein
Smart Grid Program Manager

June 4, 2019

National Institute of Standards and Technology
U.S. Department of Commerce

Activities since last SGFAC In-Person Meeting (April 2018)

Stakeholder engagement and feedback at the heart of our process:

Public Events:

June 6:	Launch Webinar
July 9:	Testing & Certification Workshop
September 12:	Georgia Public Service Commission Workshop
September 27:	Indiana Utility Regulatory Commission Workshop
October 16:	California Public Utilities Commission Workshop
November 13-14:	Smart Grid Interoperability Framework & Cybersecurity Workshop
November 29:	Rhode Island Public Utilities Commission Workshop

Significant and **Diverse Participation:**

- 275 unique participants (261 non-NIST; 233 in-person)
- Regulators & state government, standards organizations, equipment manufacturers, technology providers, utilities, ISO/RTO, service providers, T&C laboratories, FFRDCs, National Laboratories, NGOs, consultants, foreign governments, citizens/energy users.

Many evolving pre-publication **documents**

https://www.nist.gov/engineering-laboratory/smart-grid/smart-grid-framework

Energy Independence and Security Act

"It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system."

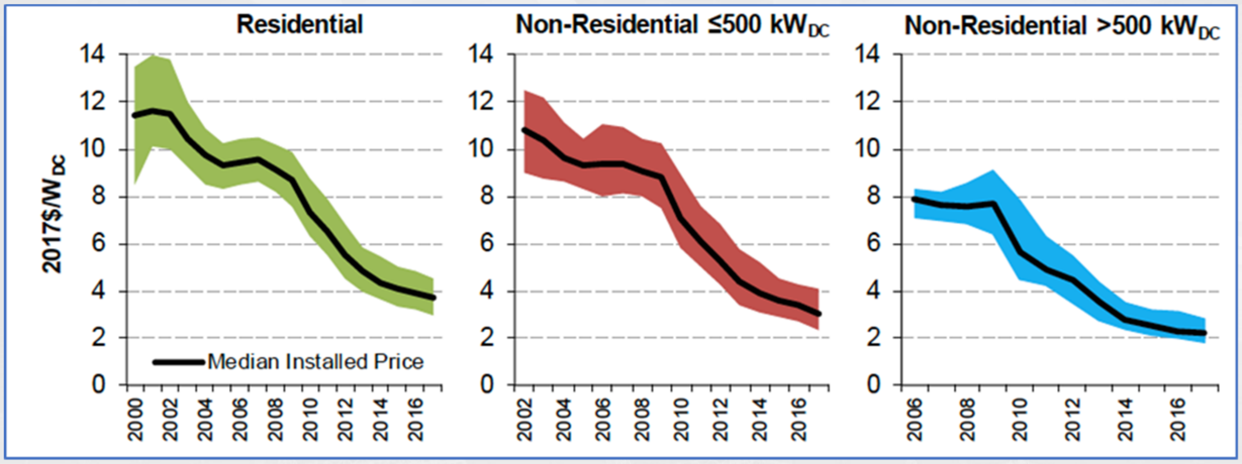
NIST has *"primary responsibility to **coordinate** development of a **framework** that includes protocols and model standards for information management to achieve **interoperability** of smart grid devices and systems…"*

Structure of the NIST Interoperability Framework

Chapter 1: Introduction / Purpose and Scope
Chapter 2: NIST Models for the Smart Grid
Chapter 3: Grid Operations
Chapter 4: Grid Cybersecurity
Chapter 5: Grid Economics
Chapter 6: Standards Testing & Certification

Appendix A, B, C, D, E, F, G, H, I…

The Physical Context for our Grid is Changing



Source: Tracking the Sun: Installed Price Trends for Distributed Photovoltaic Systems in the United States-2018 edition

The Informational Context for our grid is changing

Figure 4.4 Unit costs of key emerging electricity technologies

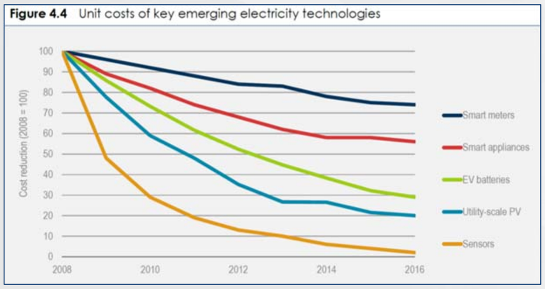


Figure 2.5 Household electricity consumption of appliances and other small plug loads

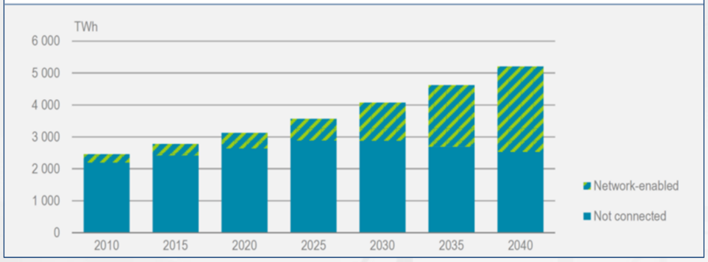


Figure 1.1 Global internet traffic

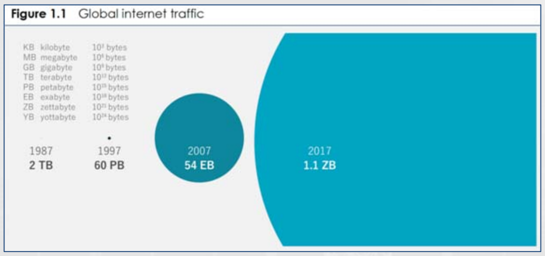
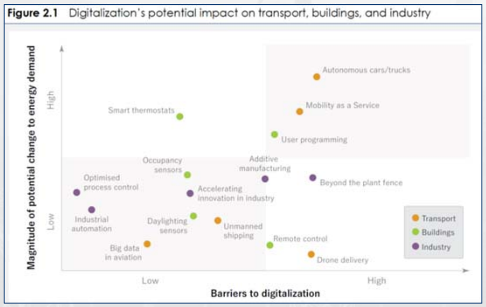


Figure 2.1 Digitalization's potential impact on transport, buildings, and industry



Source (all): IEA 2017, Digitalization & Energy

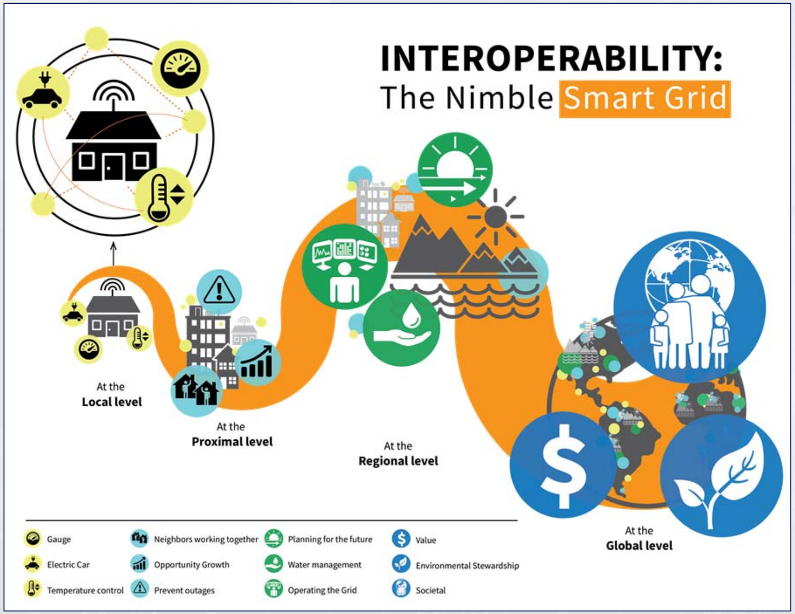
Interoperability requirements are changing

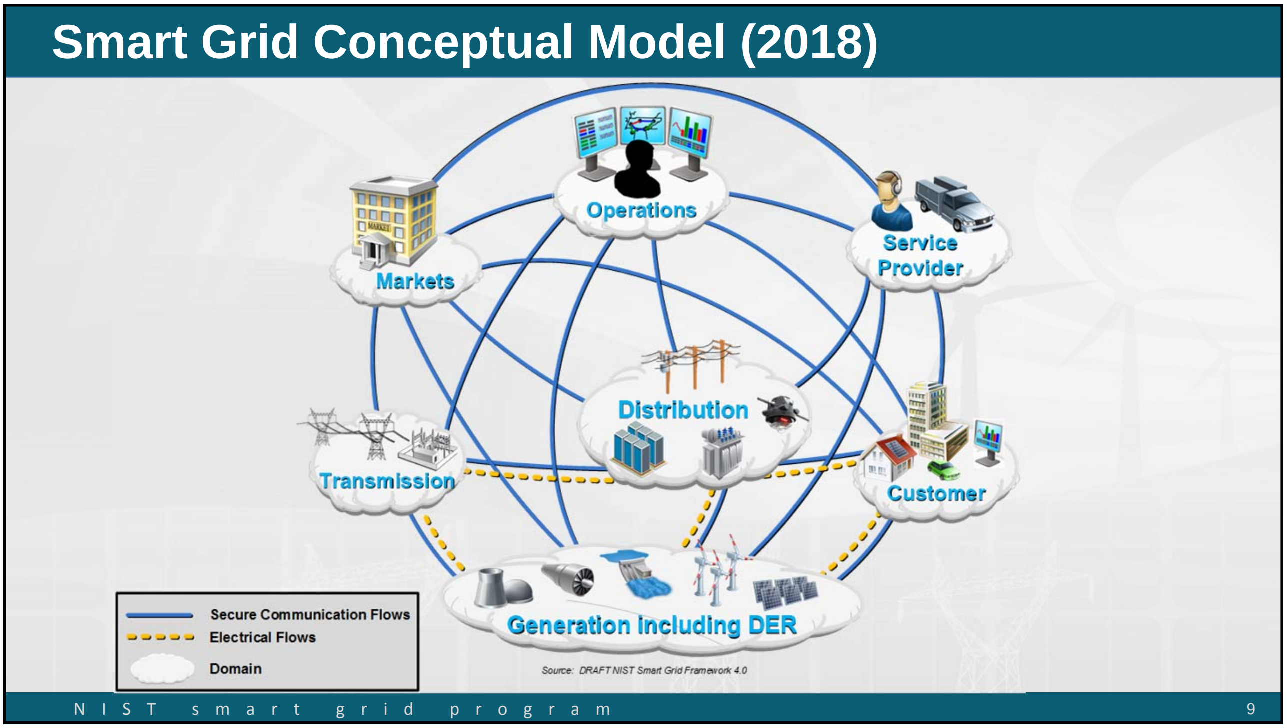
We need to understand the relationships between:

- Physical interoperability and conventional interoperability
- Interoperability and cybersecurity
- Interoperability and emerging economic opportunities
- Standards and interoperability
- Device heterogeneity and interoperability

NIST Conceptual Models for Interoperability and the smart grid must evolve

The Interoperability Value Proposition

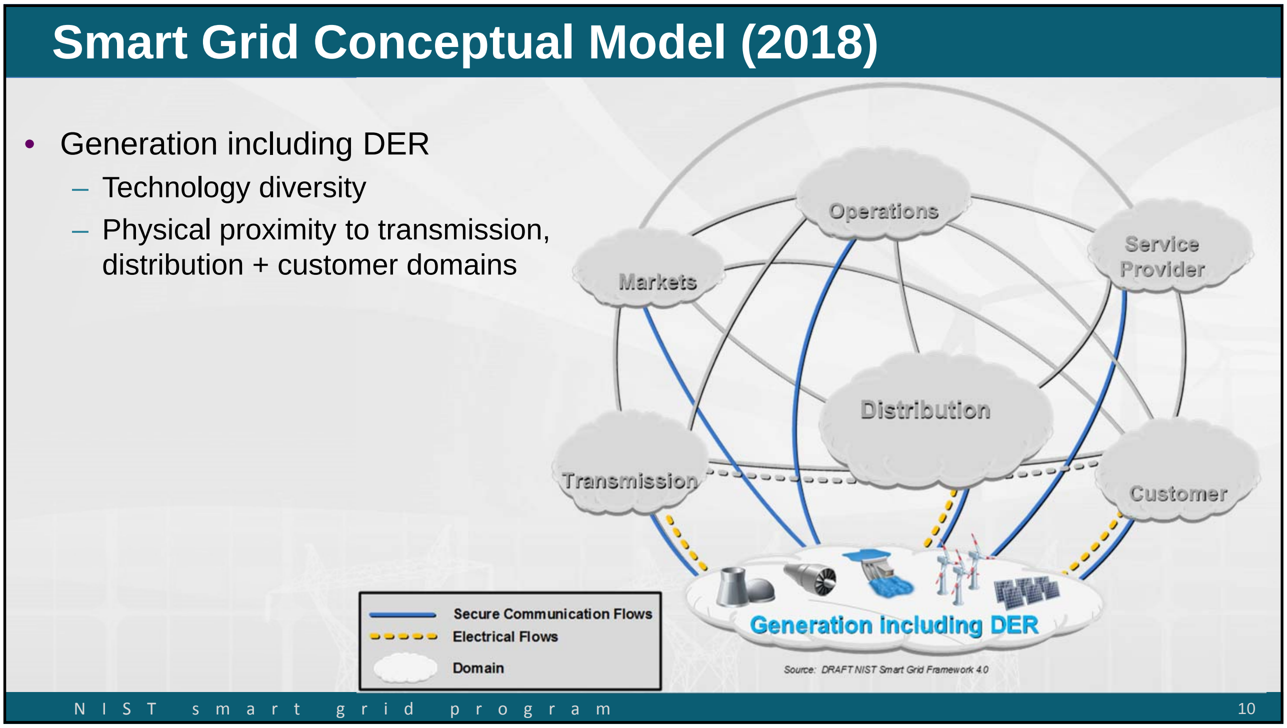




Smart Grid Conceptual Model (2018)

Source: DRAFT NIST Smart Grid Framework 4.0

NIST smart grid program 9

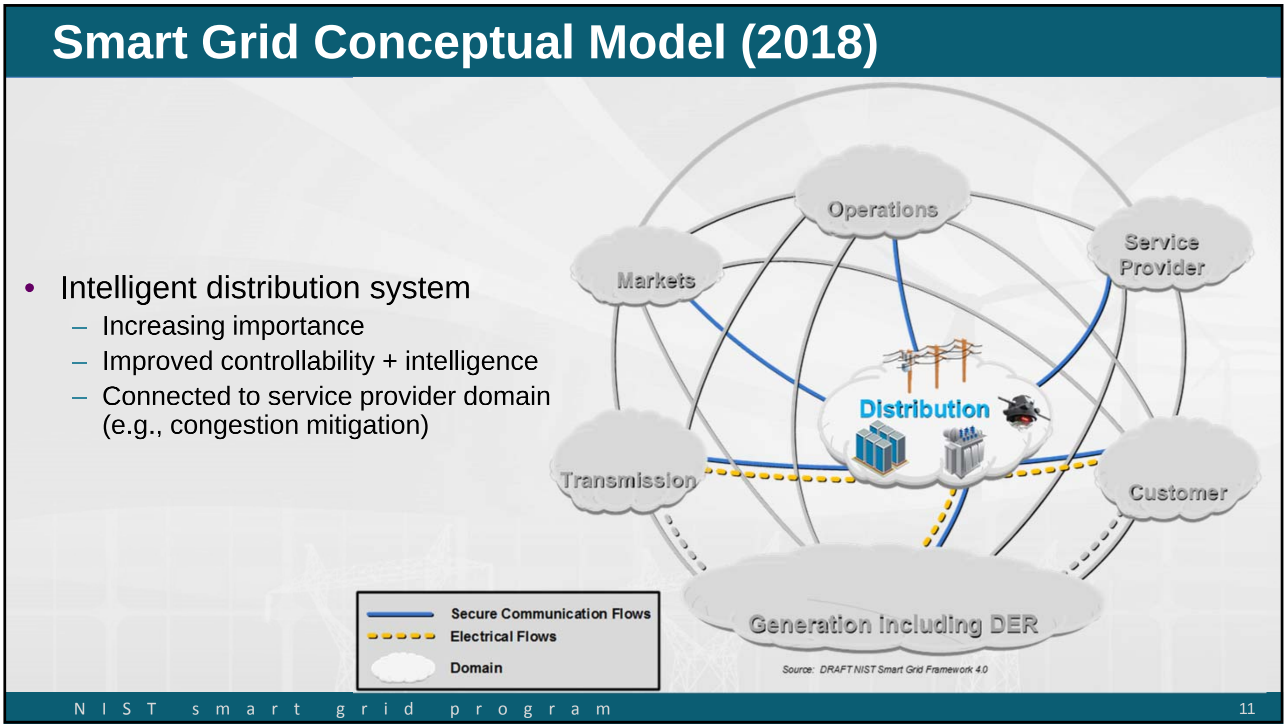


Smart Grid Conceptual Model (2018)

- Generation including DER
  - Technology diversity
  - Physical proximity to transmission, distribution + customer domains

Source: DRAFT NIST Smart Grid Framework 4.0

NIST smart grid program 10

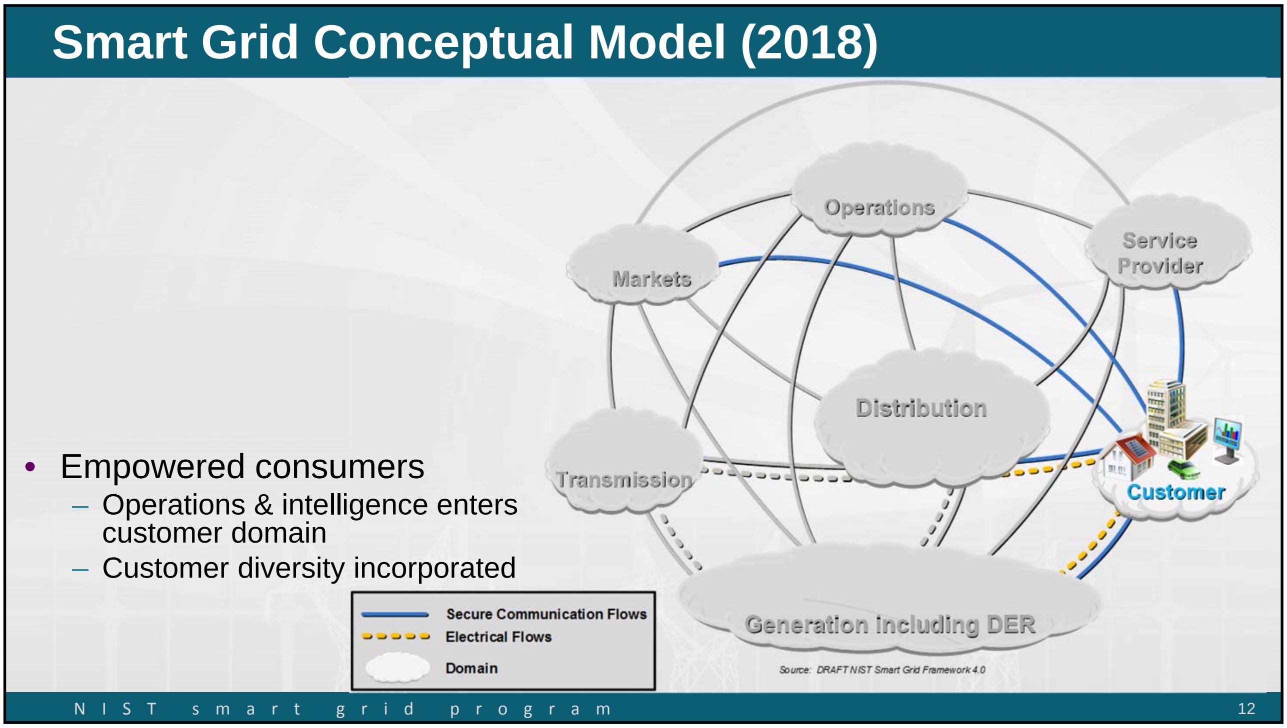


Smart Grid Conceptual Model (2018)

- Intelligent distribution system
  - Increasing importance
  - Improved controllability + intelligence
  - Connected to service provider domain (e.g., congestion mitigation)

Source: DRAFT NIST Smart Grid Framework 4.0

NIST smart grid program 11



Smart Grid Conceptual Model (2018)

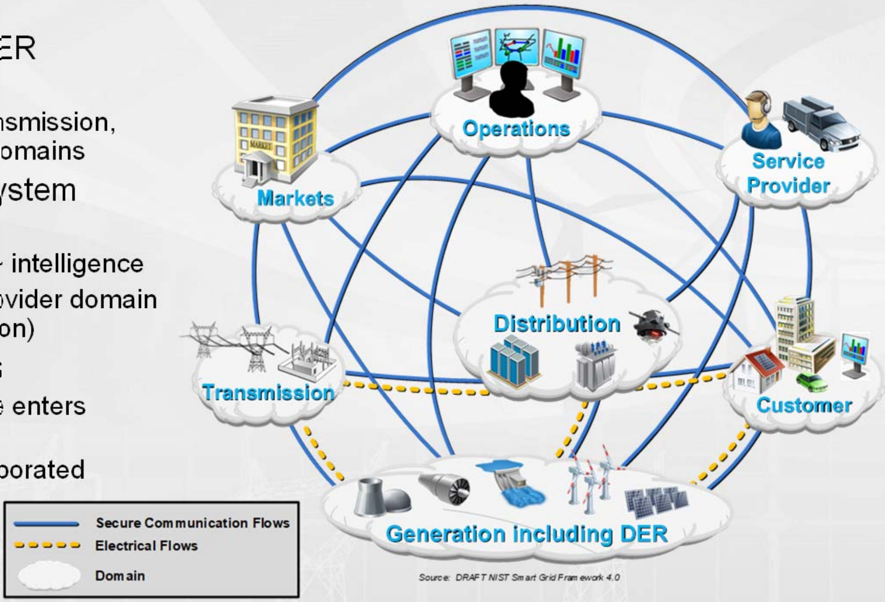
- Empowered consumers
  - Operations & intelligence enters customer domain
  - Customer diversity incorporated

Source: DRAFT NIST Smart Grid Framework 4.0

NIST smart grid program 12

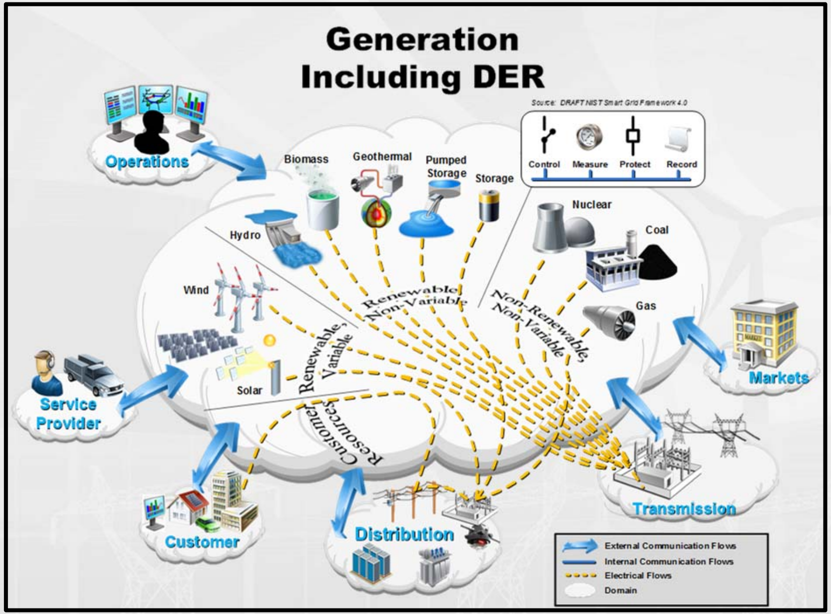
Smart Grid Conceptual Model (2018, Draft)

- Generation including DER
  - Technology diversity
  - Physical proximity to transmission, distribution + customer domains
- Intelligent distribution system
  - Increasing importance
  - Improved controllability + intelligence
  - Connected to service provider domain (e.g., congestion mitigation)
- Empowered consumers
  - Operations & intelligence enters customer domain
  - Customer diversity incorporated
- Emerging Markets
  - Platforms



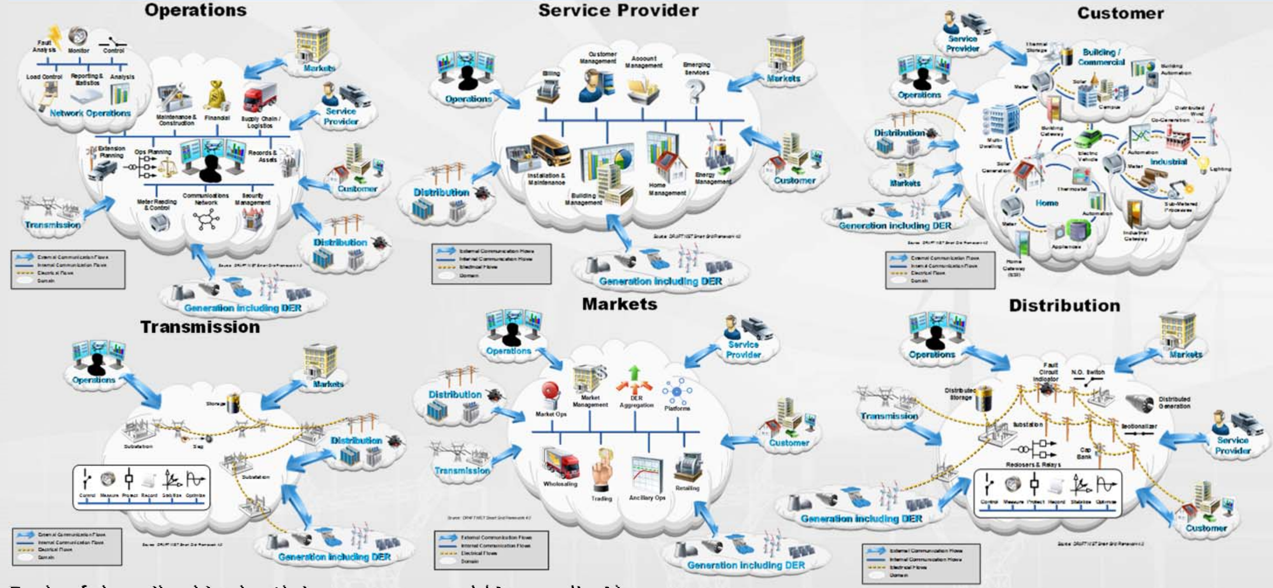
Source: DRAFT NIST Smart Grid Framework 4.0

The Conceptual Model: Generation Including DER



Source: DRAFT NIST Smart Grid Framework 4.0

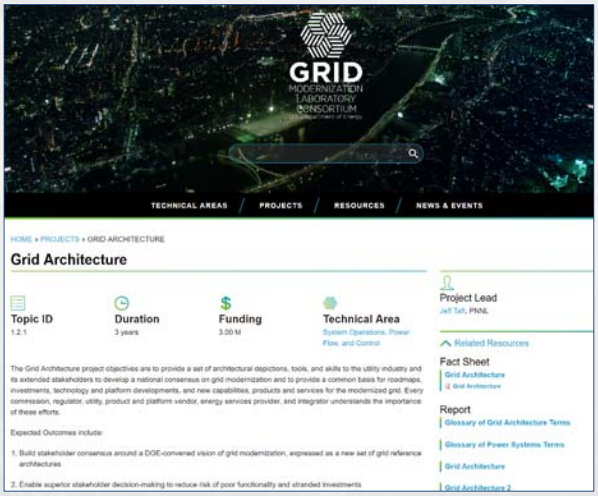
Conceptual Model Domains (2018)



Each of described in depth in your pre-read (Appendix A)

NIST perspective

- Grid architectures are changing
  - Driven by technology and policy
- Changes will impact
  - Operations
  - Economics
  - Cybersecurity
  - Testing & Certification
- No single architecture is “correct”
- NIST are not architects



HOME » PROJECTS » GRID ARCHITECTURE

Grid Architecture

Topic ID
1.2.1

Duration
3 years

Funding
3.00 M

Technical Area
System Operations, Power Flow, and Control

Project Lead
Jeff Taft, PNNL

Related Resources

Fact Sheet
Grid Architecture
Grid Architecture

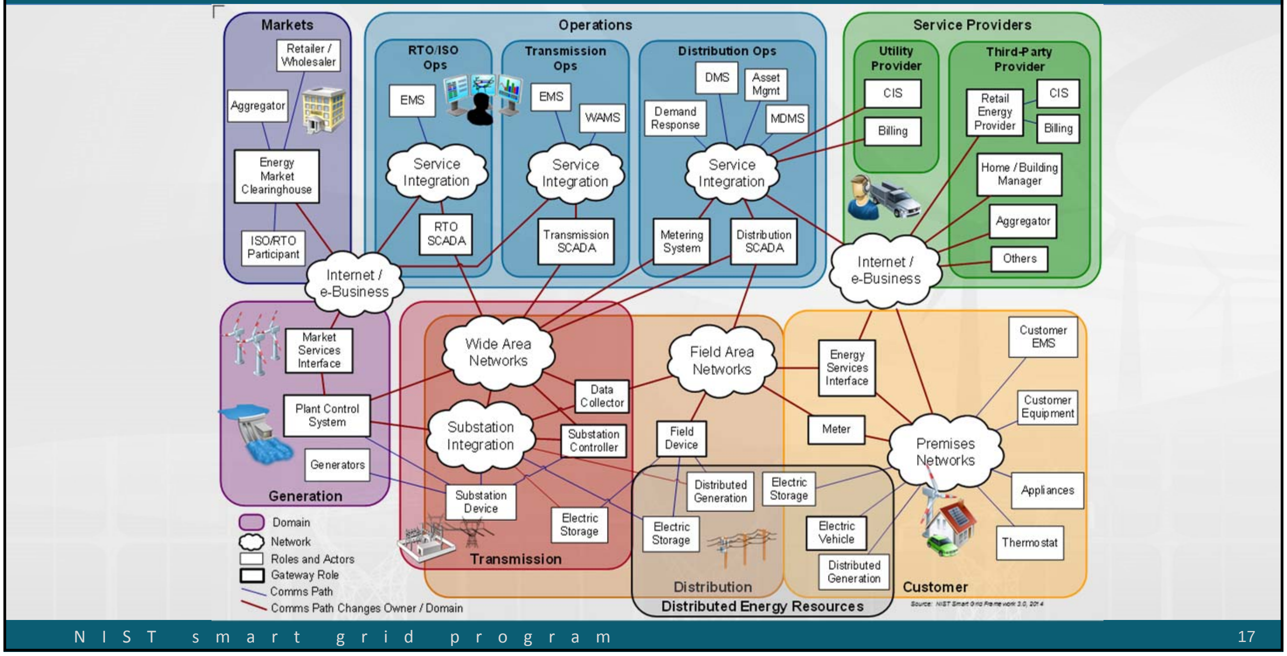
Report
Glossary of Grid Architecture Terms
Glossary of Power Systems Terms
Grid Architecture
Grid Architecture 2

The Grid Architecture project objectives are to provide a set of architectural depictions, tools, and skills to the utility industry and its extended stakeholders to develop a national consensus on grid modernization and to provide a common basis for roadmaps, investments, technology and platform developments, and new capabilities, products and services for the modernized grid. Every commission, regulator, utility, product and platform vendor, energy services provider, and integrator understands the importance of these efforts.

Expected Outcomes include:

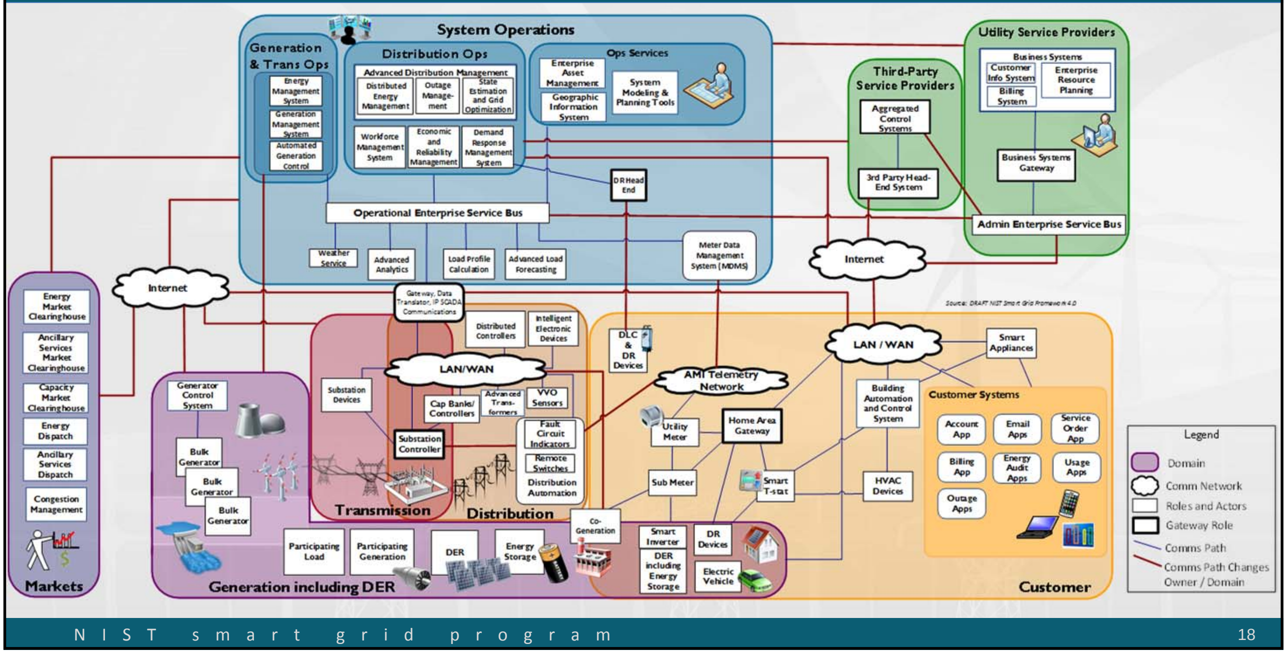
1. Build stakeholder consensus around a DOE-convened vision of grid modernization, expressed as a new set of grid reference architectures
2. Enable superior stakeholder decision-making to reduce risk of poor functionality and stranded investments

Legacy Communication Pathways Scenario

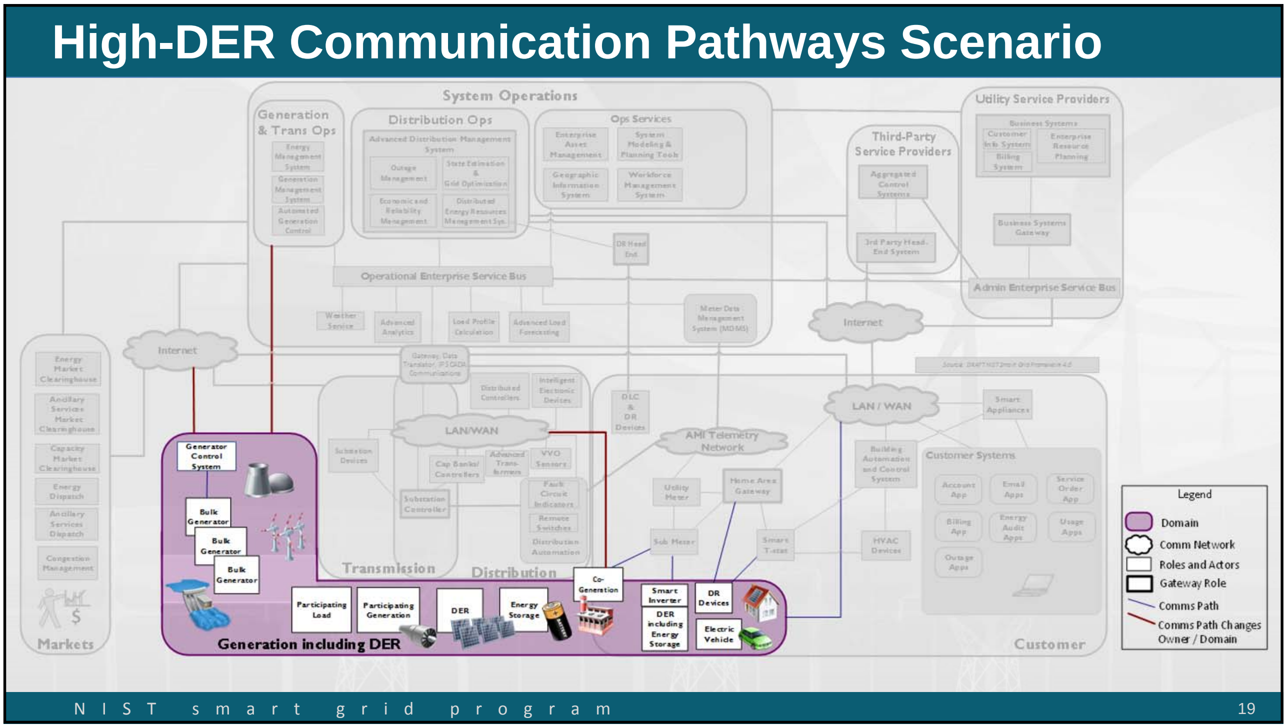


Source: NIST Smart Grid Framework 3.0, 2014

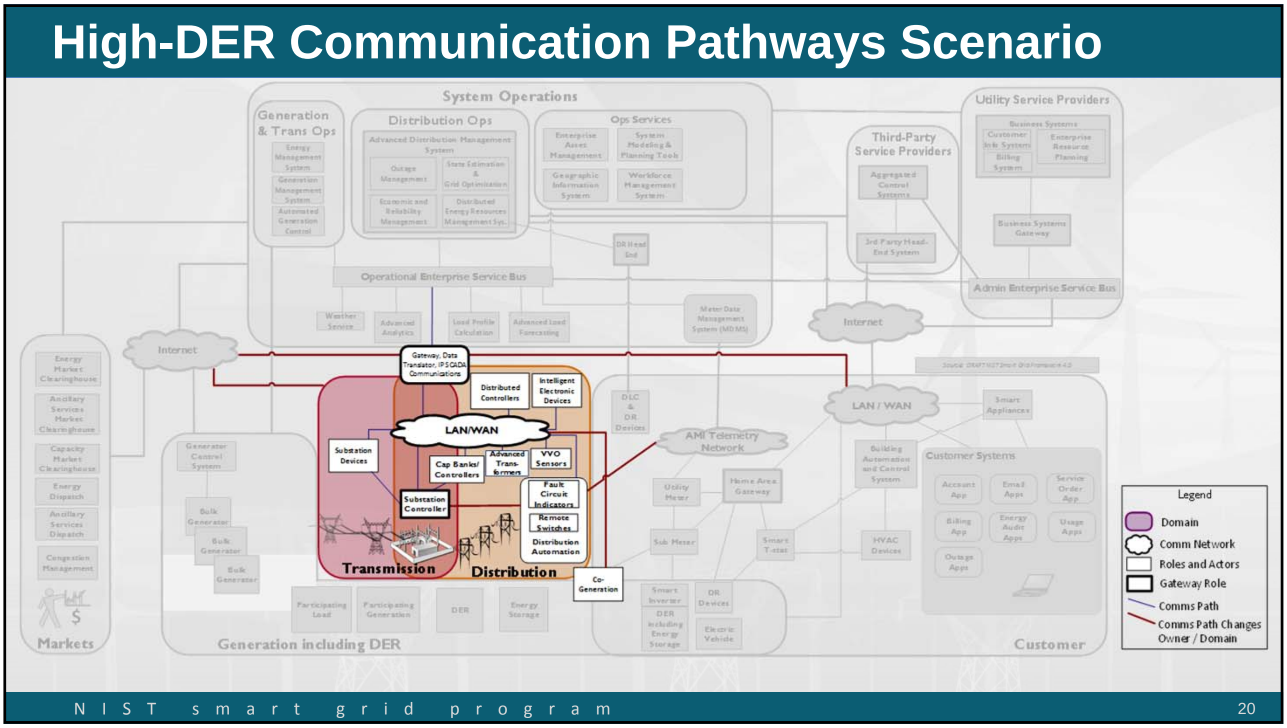
High-DER Communication Pathways Scenario



Source: DRAFT NIST Smart Grid Framework 4.0

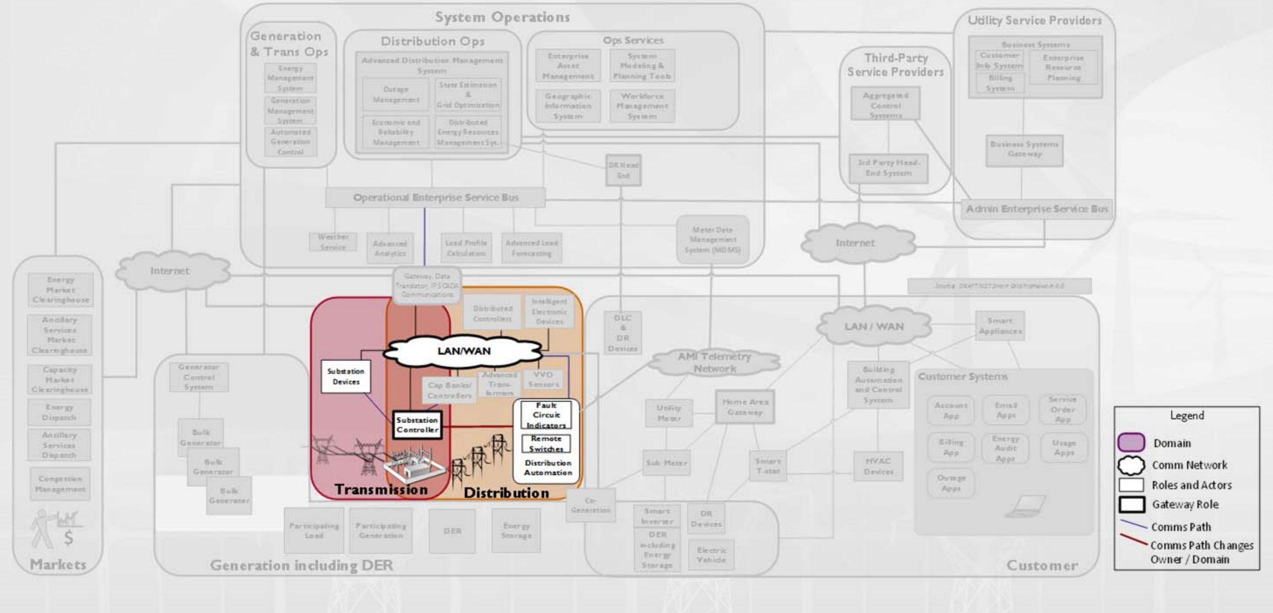


High-DER Communication Pathways Scenario



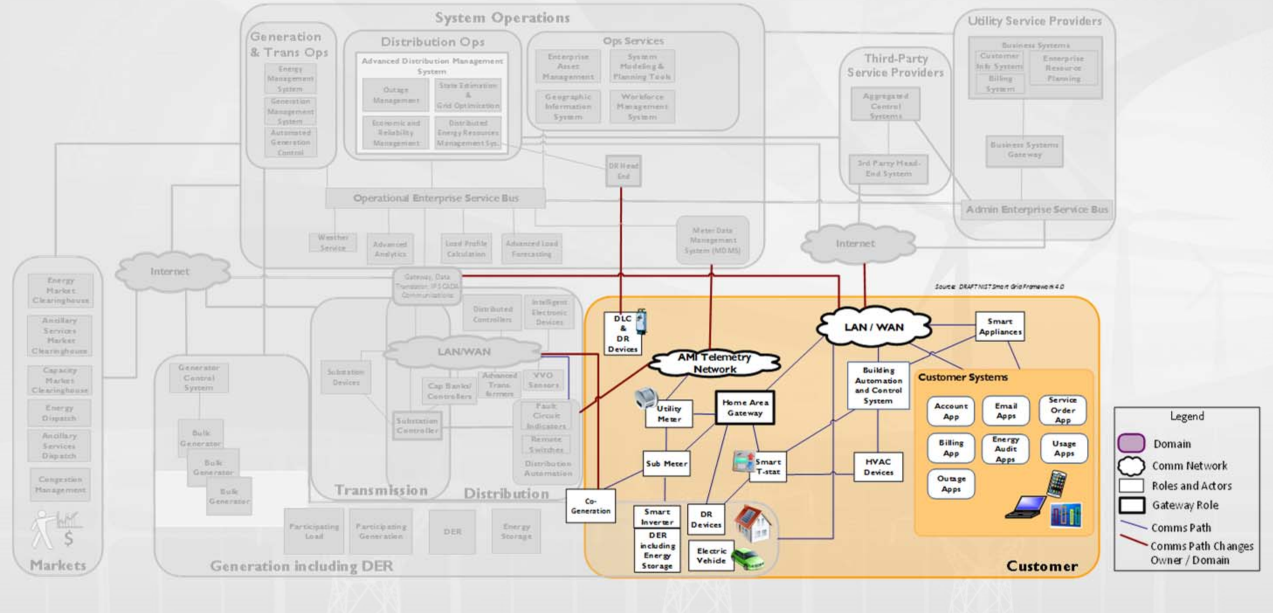
High-DER Communication Pathways Scenario

High-DER Communication Pathways Scenario



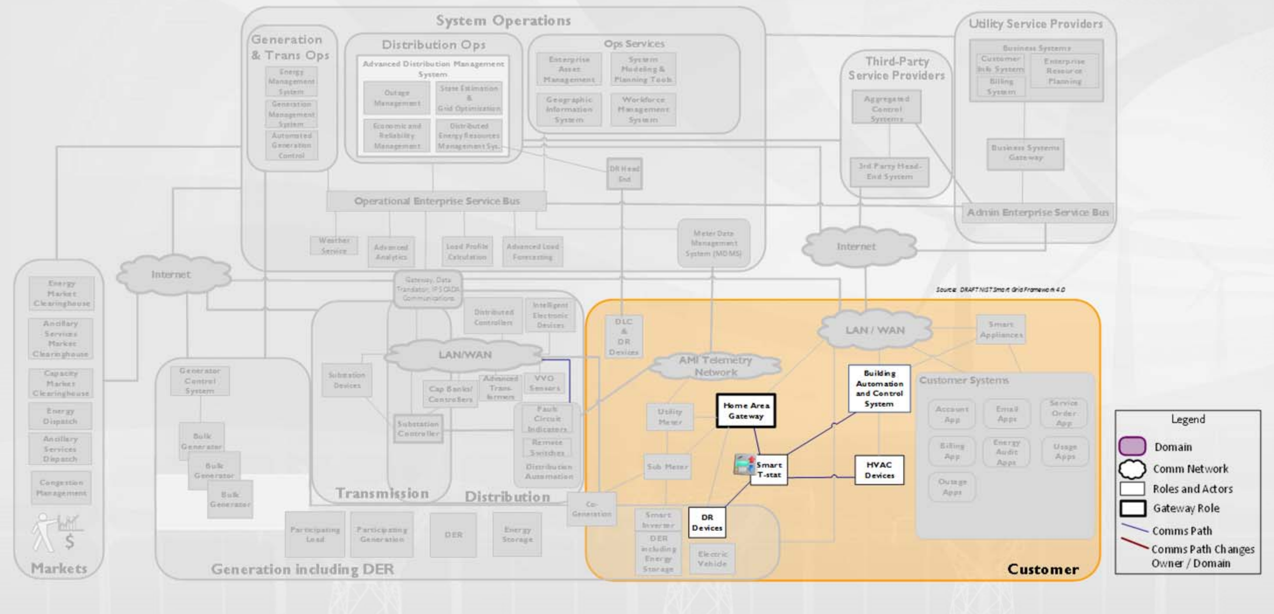
Source: DRAFT NIST Smart Grid Framework 4.0

High-DER Communication Pathways Scenario



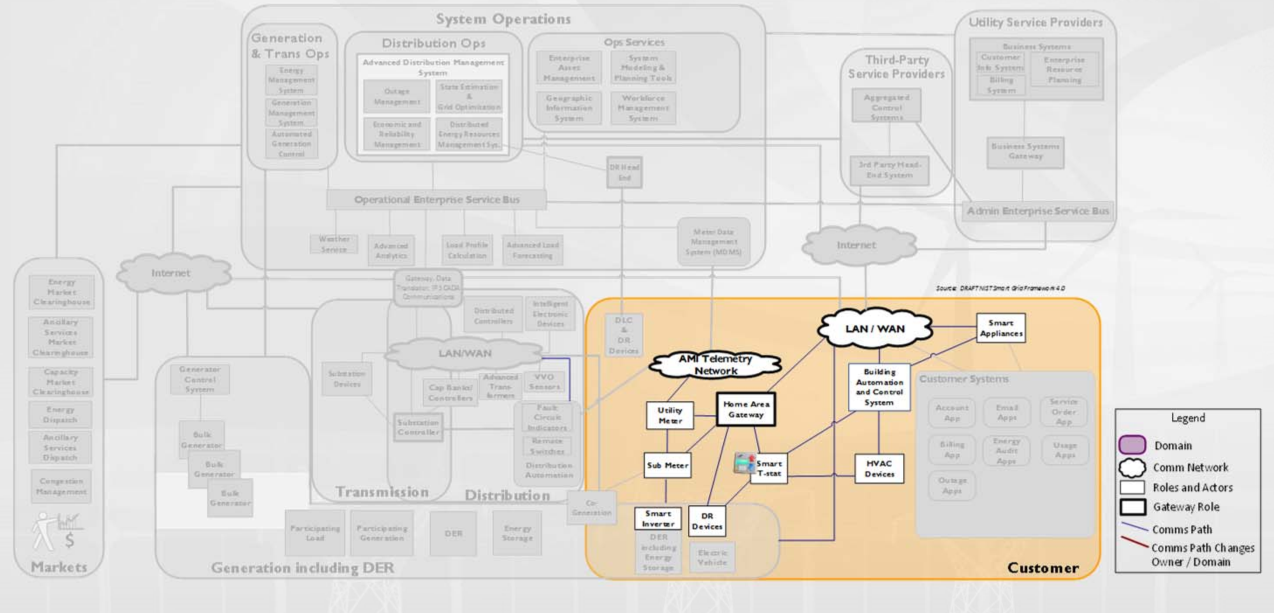
Source: DRAFT NIST Smart Grid Framework 4.0

High-DER Communication Pathways Scenario



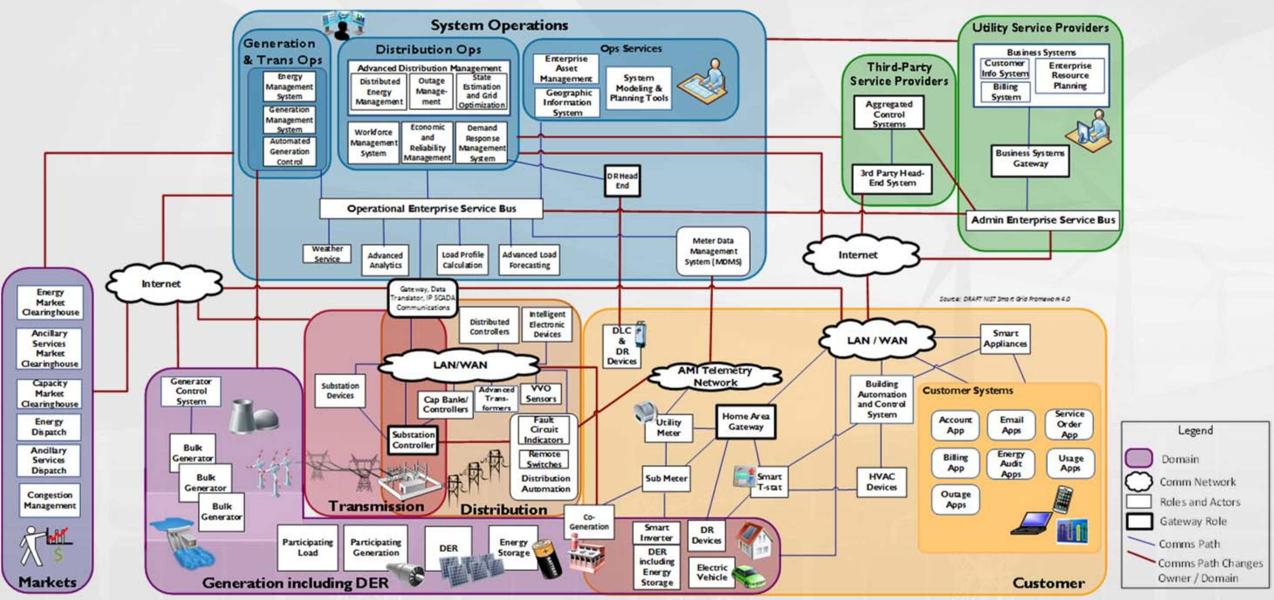
Source: DRAFT NIST Smart Grid Framework 4.0

High-DER Communication Pathways Scenario



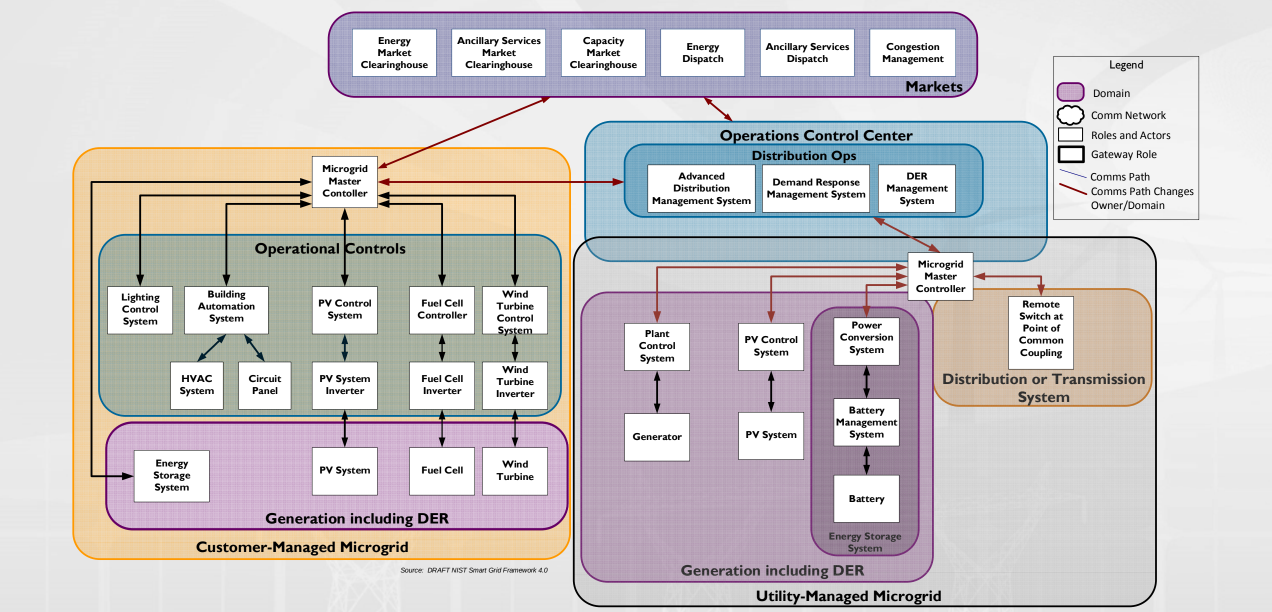
Source: DRAFT NIST Smart Grid Framework 4.0

High-DER Communication Pathways Scenario



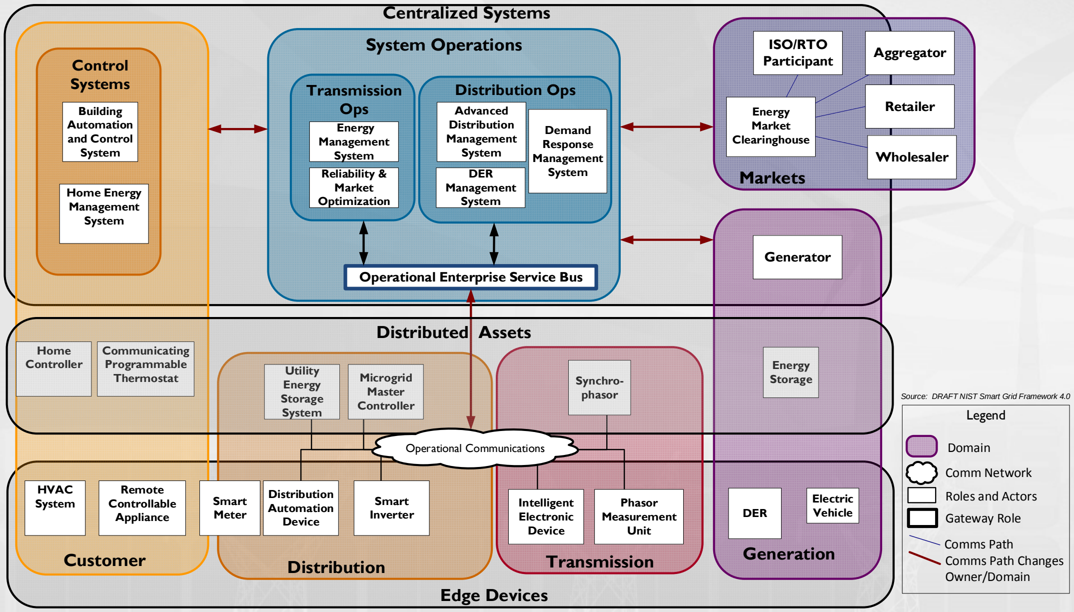
Source: DRAFT NIST Smart Grid Framework 4.0

Microgrid Communication Pathways Scenario



Source: DRAFT NIST Smart Grid Framework 4.0

Hybrid Communication Pathways Scenario



Centralized Systems

Control Systems

- Building Automation and Control System
- Home Energy Management System

System Operations

Transmission Ops

- Energy Management System
- Reliability & Market Optimization

Distribution Ops

- Advanced Distribution Management System
- DER Management System
- Demand Response Management System

Operational Enterprise Service Bus

Markets

- ISO/RTO Participant
- Aggregator
- Energy Market Clearinghouse
- Retailer
- Wholesaler

Generator

Distributed Assets

- Home Controller
- Communicating Programmable Thermostat
- Utility Energy Storage System
- Microgrid Master Controller
- Synchro-phasor
- Energy Storage

Operational Communications

Edge Devices

Customer

- HVAC System
- Remote Controllable Appliance

Distribution

- Smart Meter
- Distribution Automation Device
- Smart Inverter

Transmission

- Intelligent Electronic Device
- Phasor Measurement Unit

Generation

- DER
- Electric Vehicle

Source: *DRAFT NIST Smart Grid Framework 4.0*

Legend

- Domain
- Comm Network
- Roles and Actors
- Gateway Role
- Comms Path
- Comms Path Changes Owner/Domain

NIST Perspective

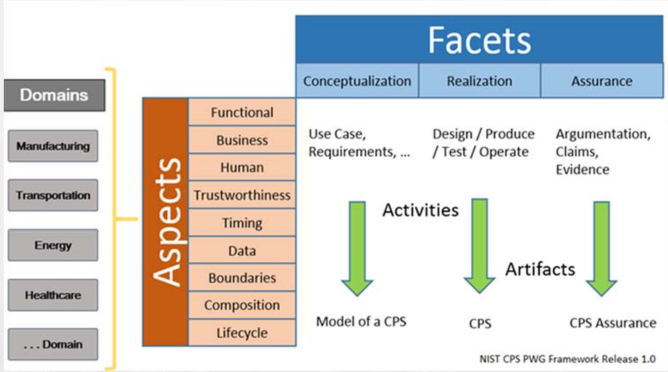
As the electrical grid becomes more complex, the language used to describe the electrical grid must become commensurately more precise.

This requires a model ontology for the grid

The CPS Framework—A Tool to Understand the Smart Grid

Jargon surrounds the electrical grid:

- *Intelligence moving to the edge*
- *Data tsunami*
- *Grid architecture*
- *Cloud / fog computing*
- *Smart grid*
- *Microgrid vs backup power*



NIST CPS PWG Framework Release 1.0

The cyber-physical systems (CPS) framework provides a vocabulary of energy sector semantics, or ontology, through evaluation of CPS framework aspects and concerns

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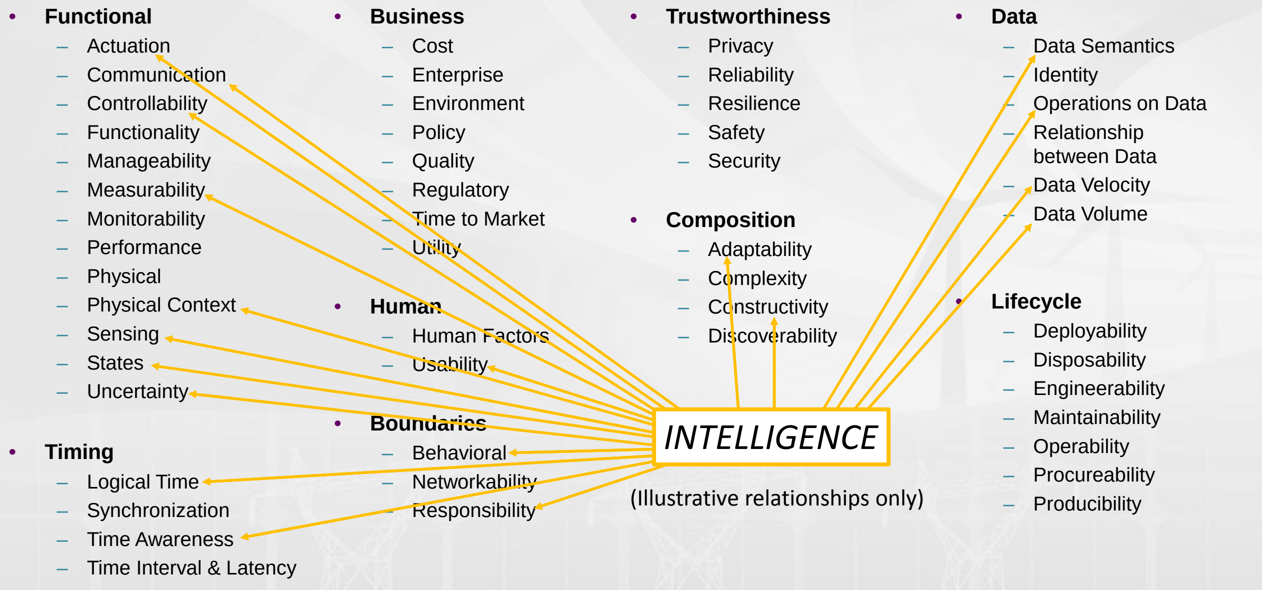
CPS Aspects and Concerns

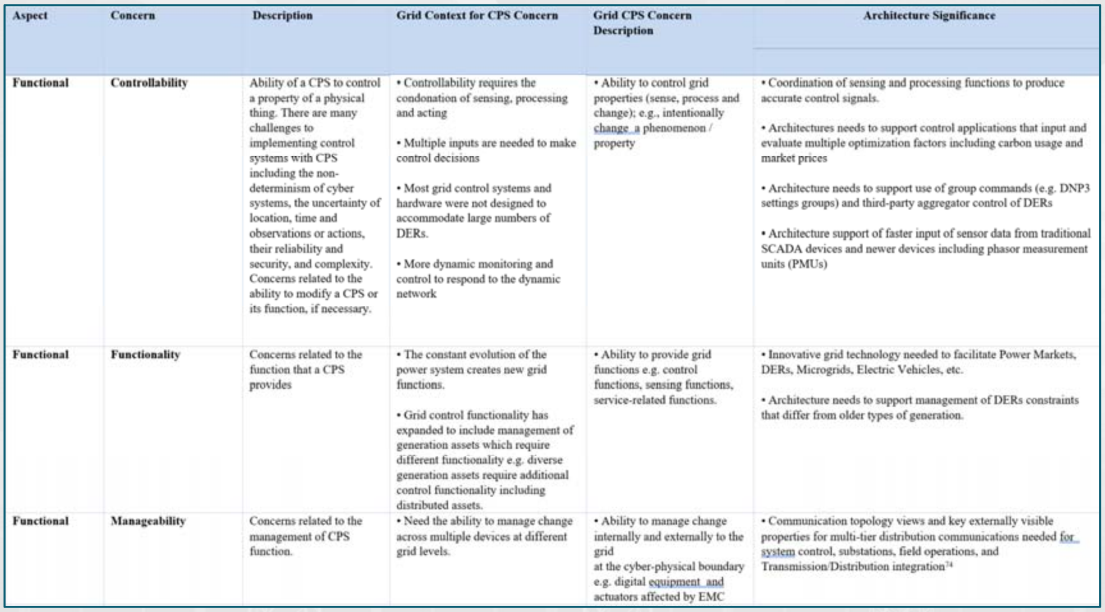


- **Functional**
  - Actuation
  - Communication
  - Controllability
  - Functionality
  - Manageability
  - Measurability
  - Monitorability
  - Performance
  - Physical
  - Physical Context
  - Sensing
  - States
  - Uncertainty
- **Timing**
  - Logical Time
  - Synchronization
  - Time Awareness
  - Time Interval & Latency
- **Business**
  - Cost
  - Enterprise
  - Environment
  - Policy
  - Quality
  - Regulatory
  - Time to Market
  - Utility
- **Human**
  - Human Factors
  - Usability
- **Boundaries**
  - Behavioral
  - Networkability
  - Responsibility
- **Trustworthiness**
  - Privacy
  - Reliability
  - Resilience
  - Safety
  - Security
- **Composition**
  - Adaptability
  - Complexity
  - Constructivity
  - Discoverability
- **Data**
  - Data Semantics
  - Identity
  - Operations on Data
  - Relationship between Data
  - Data Velocity
  - Data Volume
- **Lifecycle**
  - Deployability
  - Disposability
  - Engineerability
  - Maintainability
  - Operability
  - Procureability
  - Producibility

INTELLIGENCE

(Illustrative relationships only)

Description of CPS Concerns for the Smart Grid



Aspect	Concern	Description	Grid Context for CPS Concern	Grid CPS Concern Description	Architecture Significance
Functional	**Controllability**	Ability of a CPS to control a property of a physical thing. There are many challenges to implementing control systems with CPS including the non-determinism of cyber systems, the uncertainty of location, time and observations or actions, their reliability and security, and complexity. Concerns related to the ability to modify a CPS or its function, if necessary.	• Controllability requires the condonation of sensing, processing and acting • Multiple inputs are needed to make control decisions • Most grid control systems and hardware were not designed to accommodate large numbers of DERs. • More dynamic monitoring and control to respond to the dynamic network	• Ability to control grid properties (sense, process and change); e.g., intentionally change a phenomenon / property	• Coordination of sensing and processing functions to produce accurate control signals. • Architectures needs to support control applications that input and evaluate multiple optimization factors including carbon usage and market prices • Architecture needs to support use of group commands (e.g. DNP3 settings groups) and third-party aggregator control of DERs • Architecture support of faster input of sensor data from traditional SCADA devices and newer devices including phasor measurement units (PMUs)
Functional	**Functionality**	Concerns related to the function that a CPS provides	• The constant evolution of the power system creates new grid functions. • Grid control functionality has expanded to include management of generation assets which require different functionality e.g. diverse generation assets require additional control functionality including distributed assets.	• Ability to provide grid functions e.g. control functions, sensing functions, service-related functions.	• Innovative grid technology needed to facilitate Power Markets, DERs, Microgrids, Electric Vehicles, etc. • Architecture needs to support management of DERs constraints that differ from older types of generation.
Functional	**Manageability**	Concerns related to the management of CPS function.	• Need the ability to manage change across multiple devices at different grid levels.	• Ability to manage change internally and externally to the grid at the cyber-physical boundary e.g. digital equipment and actuators affected by EMC	• Communication topology views and key externally visible properties for multi-tier distribution communications needed for system control, substations, field operations, and Transmission/Distribution integration[74]

NIST Smart Grid Program

Interoperability Framework 4.0
Grid Operations and Interoperability

Avi Gopstein

Smart Grid Program Manager

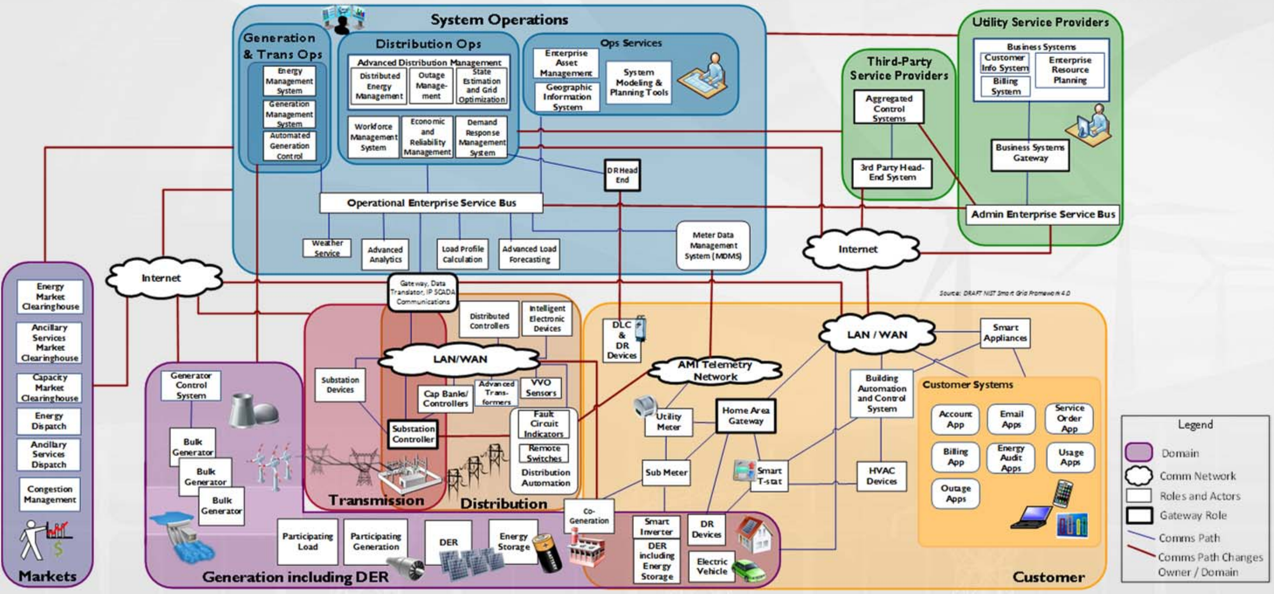
June 4, 2019

National Institute of Standards and Technology
U.S. Department of Commerce

Key issues

- Physical and Conventional Interoperability
  - Observability requirements
  - Controllability requirements
- Deriving Interoperability Requirements
- Priority Interoperability interfaces

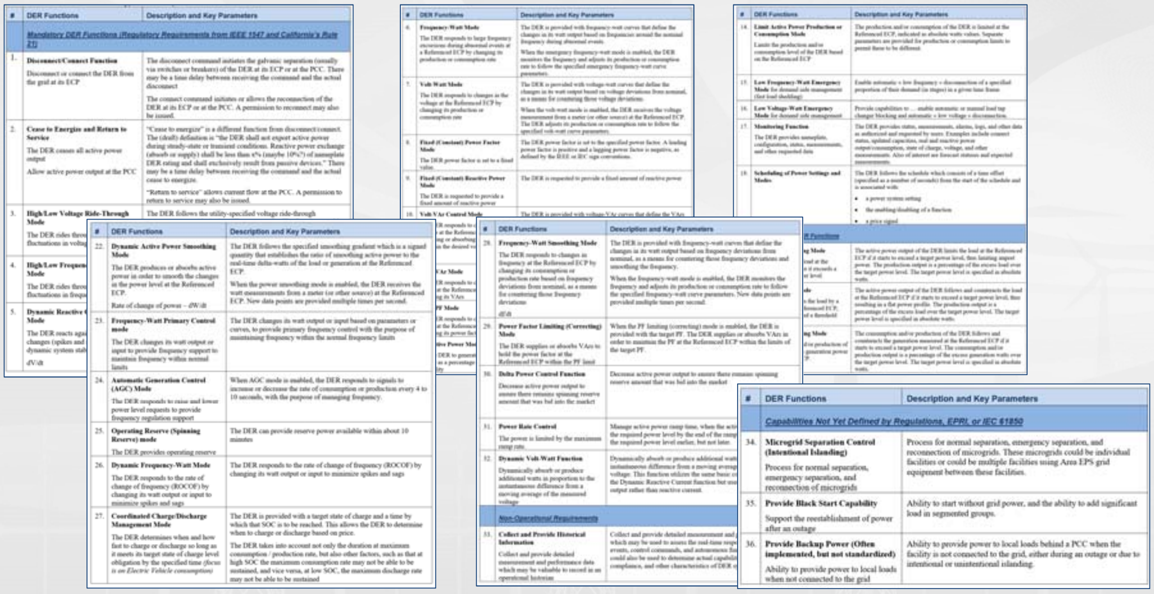
Operational dynamics – what's going on?



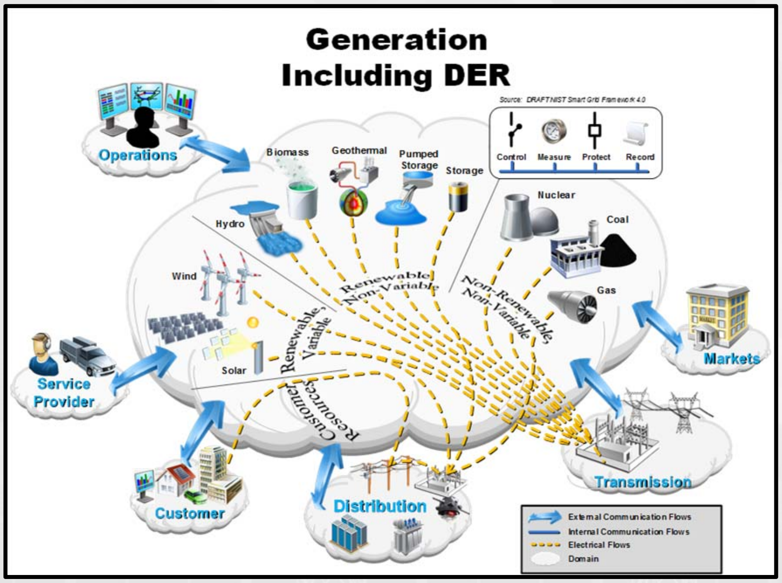
Source: DRAFT NIST Smart Grid Framework 4.0

What role do new(er) resources have in this?

Mandatory DER Functions
(Regulatory Requirements from IEEE 1547 and Rule 21)



The Conceptual Model: Generation Including DER



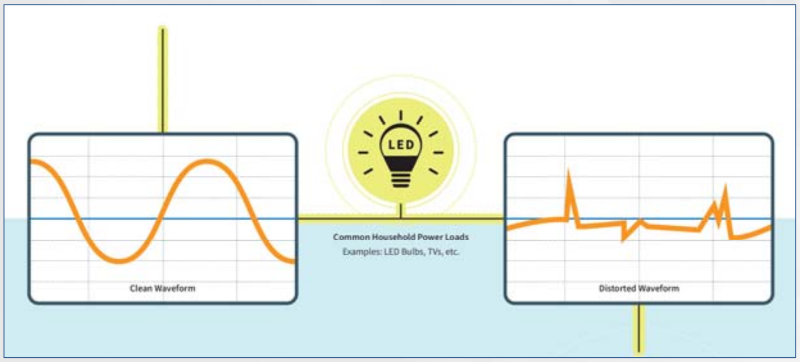
Source: DRAFT NIST Smart Grid Framework 4.0

In 2018:

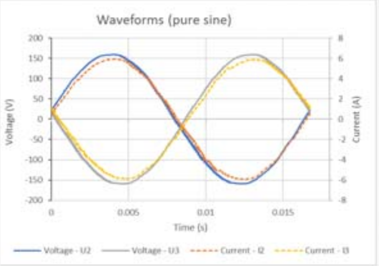
- Utility-scale solar =1.6% net generation
- Distributed solar = 0.7% net generation

Source: EIA Monthly Energy Review tables 7.2b and 10.6

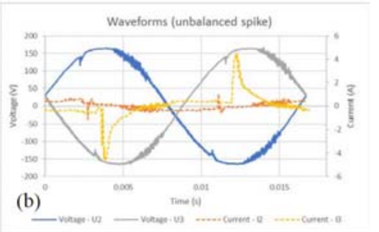
What are the other drivers?



Incandescent Bulbs

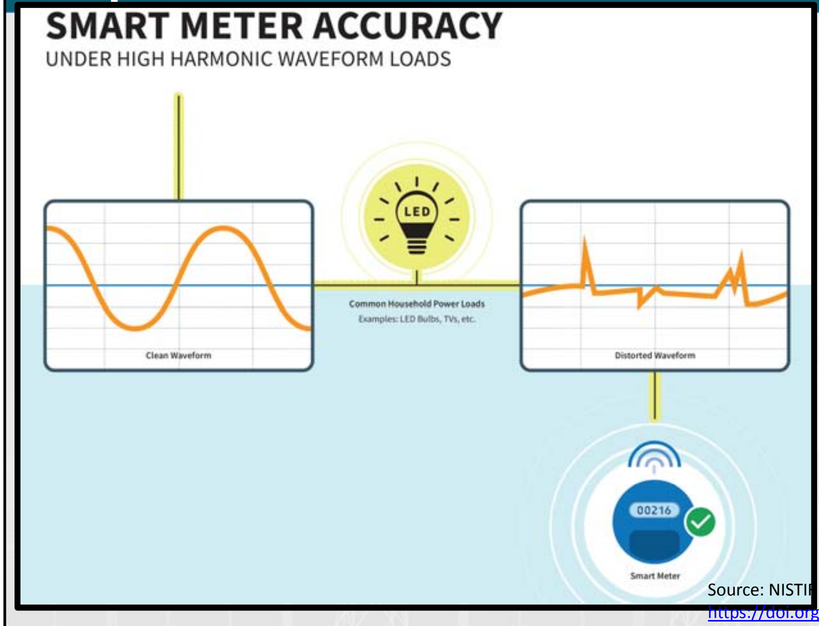


LED Bulbs

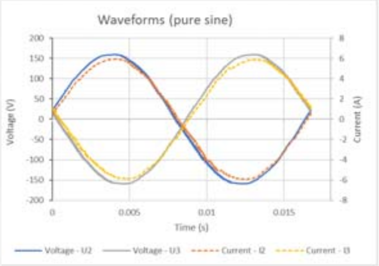


Source: NISTIR 8428
https://doi.org/10.6028/NIST.IR.8248

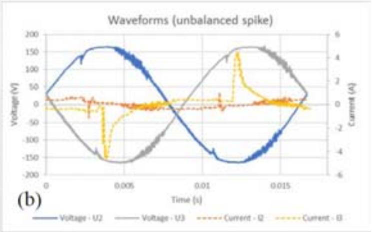
Impacts are minimal when controlled for



Incandescent Bulbs



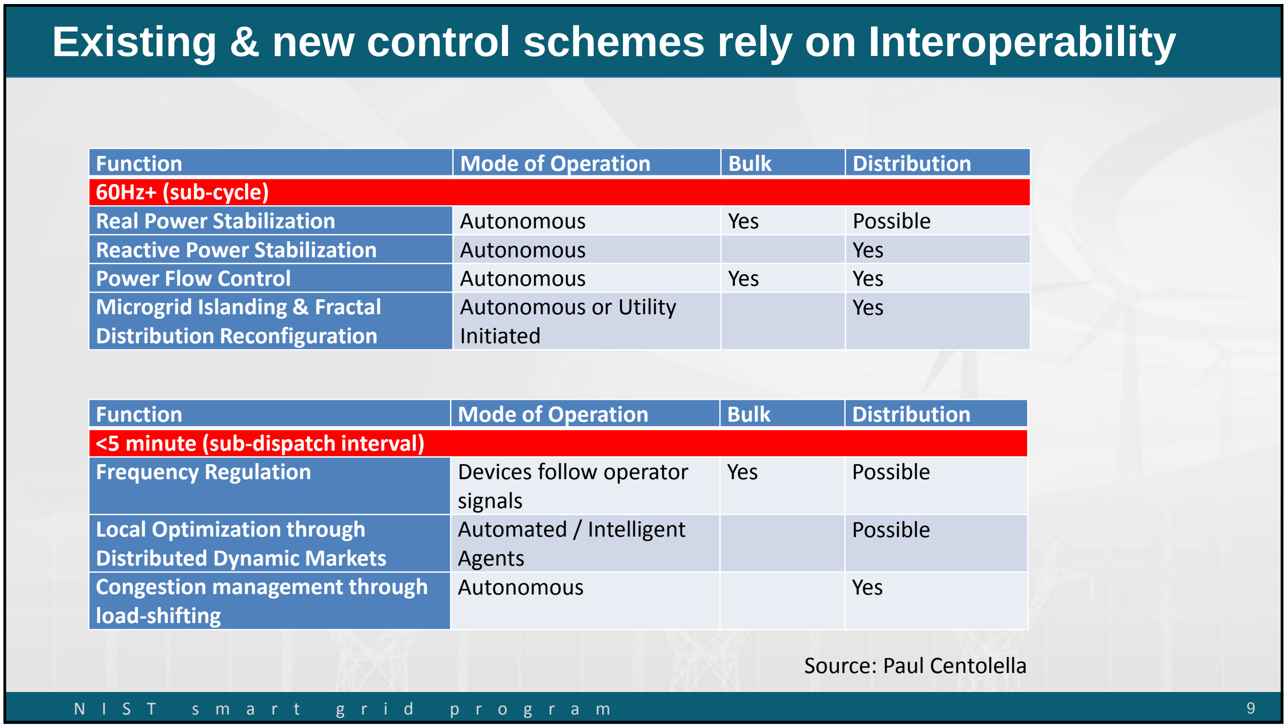
LED Bulbs



Source: NISTIR 8428
https://doi.org/10.6028/NIST.IR.8248

Key Message

- The physics of the grid is changing
  - More than just DERs
  - Nonlinearities in solid-state electronics creates significant uncertainty
  - Only beginning to understand observational requirements
  - Systemic impact & mitigation approaches unclear

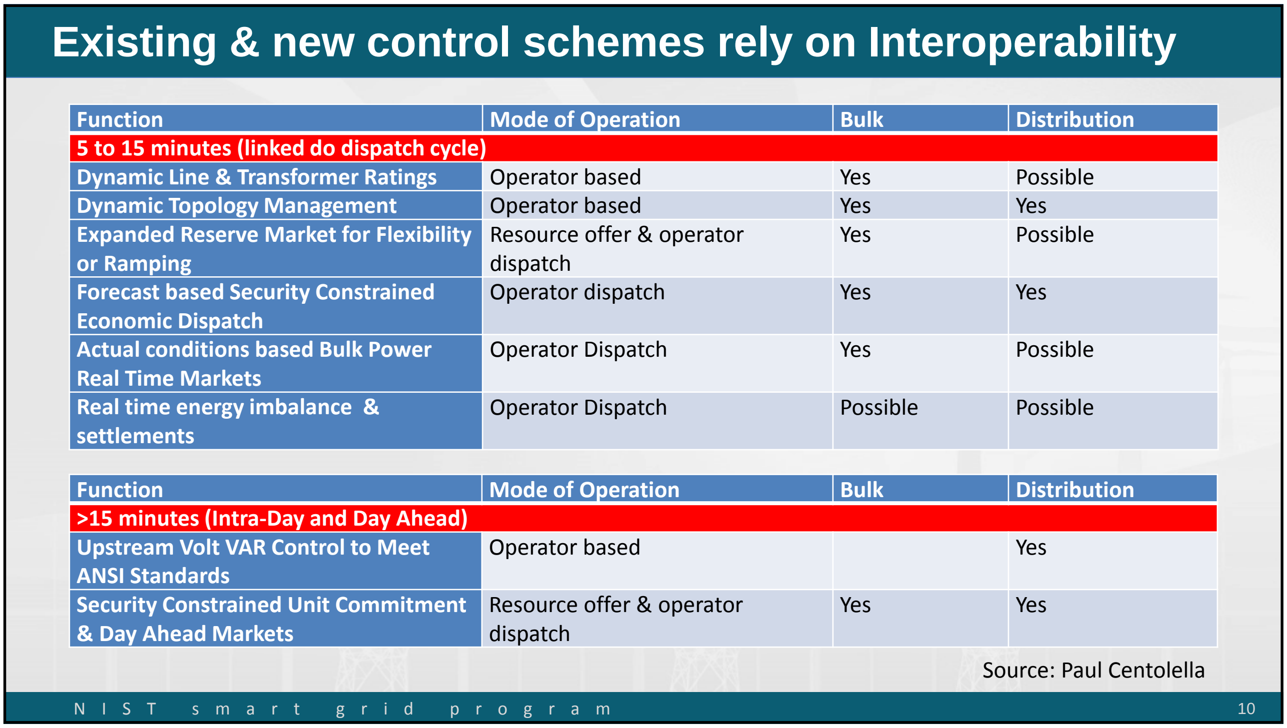


Existing & new control schemes rely on Interoperability

Function	Mode of Operation	Bulk	Distribution
60Hz+ (sub-cycle)			
Real Power Stabilization	Autonomous	Yes	Possible
Reactive Power Stabilization	Autonomous		Yes
Power Flow Control	Autonomous	Yes	Yes
Microgrid Islanding & Fractal Distribution Reconfiguration	Autonomous or Utility Initiated		Yes

Function	Mode of Operation	Bulk	Distribution
<5 minute (sub-dispatch interval)			
Frequency Regulation	Devices follow operator signals	Yes	Possible
Local Optimization through Distributed Dynamic Markets	Automated / Intelligent Agents		Possible
Congestion management through load-shifting	Autonomous		Yes

Source: Paul Centolella



Existing & new control schemes rely on Interoperability

Function	Mode of Operation	Bulk	Distribution
5 to 15 minutes (linked do dispatch cycle)			
Dynamic Line & Transformer Ratings	Operator based	Yes	Possible
Dynamic Topology Management	Operator based	Yes	Yes
Expanded Reserve Market for Flexibility or Ramping	Resource offer & operator dispatch	Yes	Possible
Forecast based Security Constrained Economic Dispatch	Operator dispatch	Yes	Yes
Actual conditions based Bulk Power Real Time Markets	Operator Dispatch	Yes	Possible
Real time energy imbalance & settlements	Operator Dispatch	Possible	Possible

Function	Mode of Operation	Bulk	Distribution
>15 minutes (Intra-Day and Day Ahead)			
Upstream Volt VAR Control to Meet ANSI Standards	Operator based		Yes
Security Constrained Unit Commitment & Day Ahead Markets	Resource offer & operator dispatch	Yes	Yes

Source: Paul Centolella

Opportunity-space for Interoperability-driven controls

Function	Mode	Bulk	Distribution
60Hz+ (sub-cycle)			
Real Power	Autonomous	Yes	Possible
Reactive Power	Autonomous		Yes
Power Flow Control	Autonomous	Yes	Yes
Microgrid / Fractal	Automated +		Yes
<5 minute (sub-dispatch interval)			
Frequency Reg.	Operator signals	Yes	Possible
Local Dyn. Markets	Automated +		Possible
Cong. management	Autonomous		Yes

Function	Mode	Bulk	Distribution
5 to 15 minutes (linked do dispatch cycle)			
Dynamic Ratings	Operator based	Yes	Possible
Dynamic Topology	Operator based	Yes	Yes
Flexibility Markets	Offer + Dispatch	Yes	Possible
Forecast SCED	Operator Dispatch	Yes	Yes
Real Time Energy & Reserves	Operator Dispatch	Yes	Possible
Real time Imbalance	Operator Dispatch	Possible	Possible
>15 minutes (Intra-Day and Day Ahead)			
Upstream VVAR	Operator based		Yes
SCUC	Offer + Dispatch	Yes	Yes

Key Message

- The physics of the grid is changing
  - More than just DERs
  - Nonlinearities in solid-state electronics creates significant uncertainty
  - Only beginning to understand observational requirements
  - Systemic impact & mitigation approaches unclear
- Control schemes for the grid are changing
  - Relationship to emerging physics warrants exploration
  - Interoperability requirements appear application focused (see T&C chapter)
  - Emergent behavior issues need study

Deriving Interoperability Requirements (e.g., Time)

- Time is crucial to:
  - Wide Area Monitoring and Control
  - Communications
  - State estimation
  - Cybersecurity
  - Markets
  - Fault detection / protection
  - (+ more)
- Time requirements tend to derive from time awareness
- Timeliness requirements are not as well characterized
- Similar to other interoperability requirements

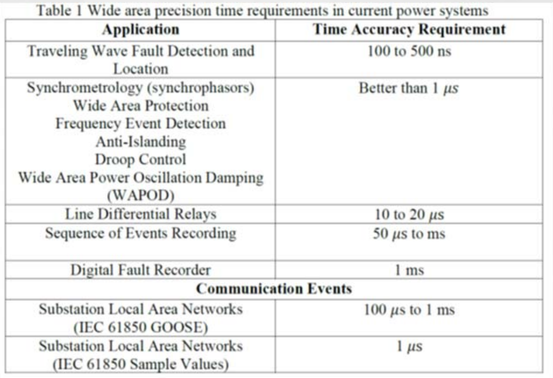
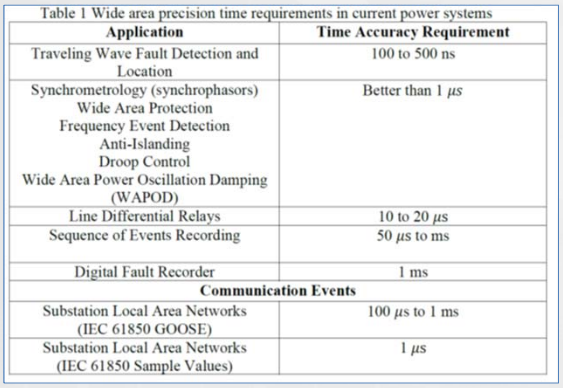


Table 1 Wide area precision time requirements in current power systems

Application	Time Accuracy Requirement
Traveling Wave Fault Detection and Location	100 to 500 ns
Synchrometrology (synchrophasors) Wide Area Protection Frequency Event Detection Anti-Islanding Droop Control Wide Area Power Oscillation Damping (WAPOD)	Better than 1 μs
Line Differential Relays	10 to 20 μs
Sequence of Events Recording	50 μs to ms
Digital Fault Recorder	1 ms
Communication Events	
Substation Local Area Networks (IEC 61850 GOOSE)	100 μs to 1 ms
Substation Local Area Networks (IEC 61850 Sample Values)	1 μs

Source: NIST SP 1500-008

Timing accuracy vs. timeliness



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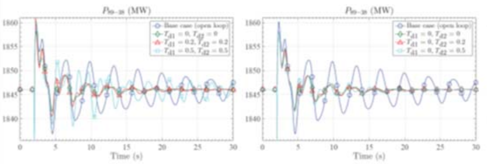
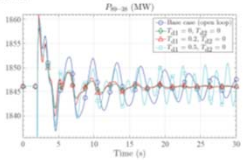
Source: NIST SP 1500-008 (2017)
https://doi.org/10.6028/NIST.SP.1500-08

1 millisecond minimum accuracy requirement



(a) Identical latency in northern and southern measurements **(b)** Latency only in southern measurement



(c) Latency only in northern measurement

Fig. 6: Power transfer in the COI for different scenarios of latency when the event considered is a fault in line 87.

Source: Wilches-Bernal, Schoenwald, et al. (2018) *Analysis of the Effect of Communication Latencies on HVDC-Based Damping Control.*
10.1109/TDC.2018.8440146

~500 millisecond minimum accuracy requirement

Key Message

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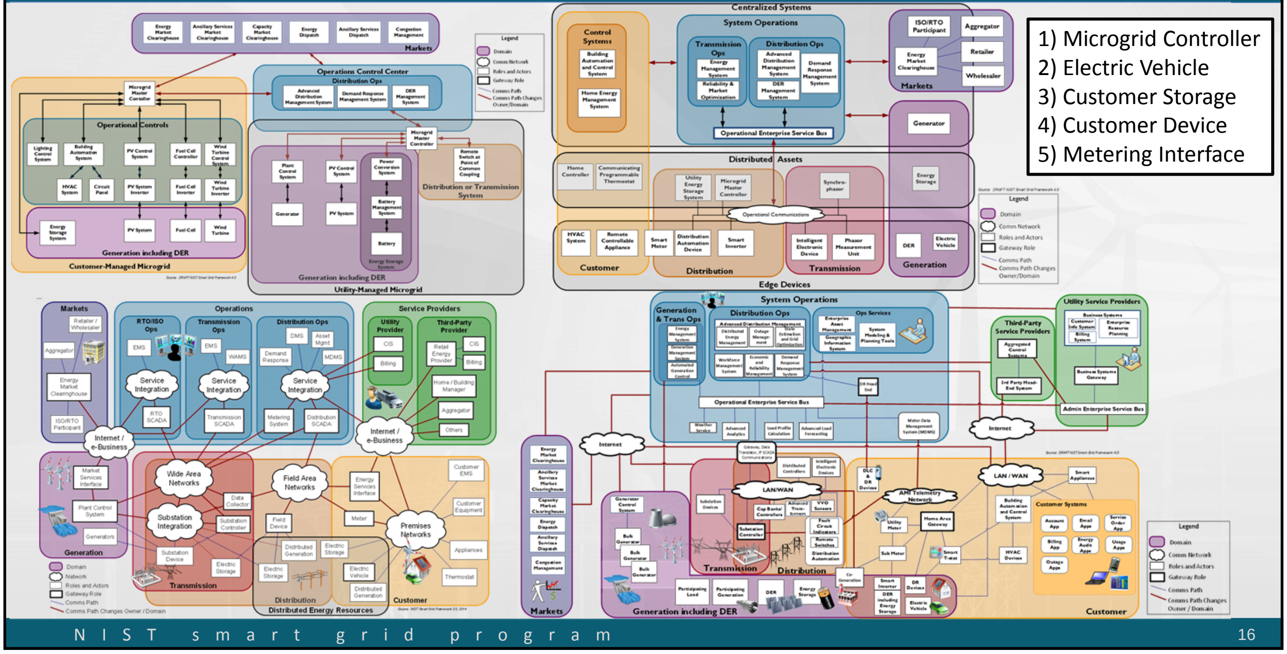
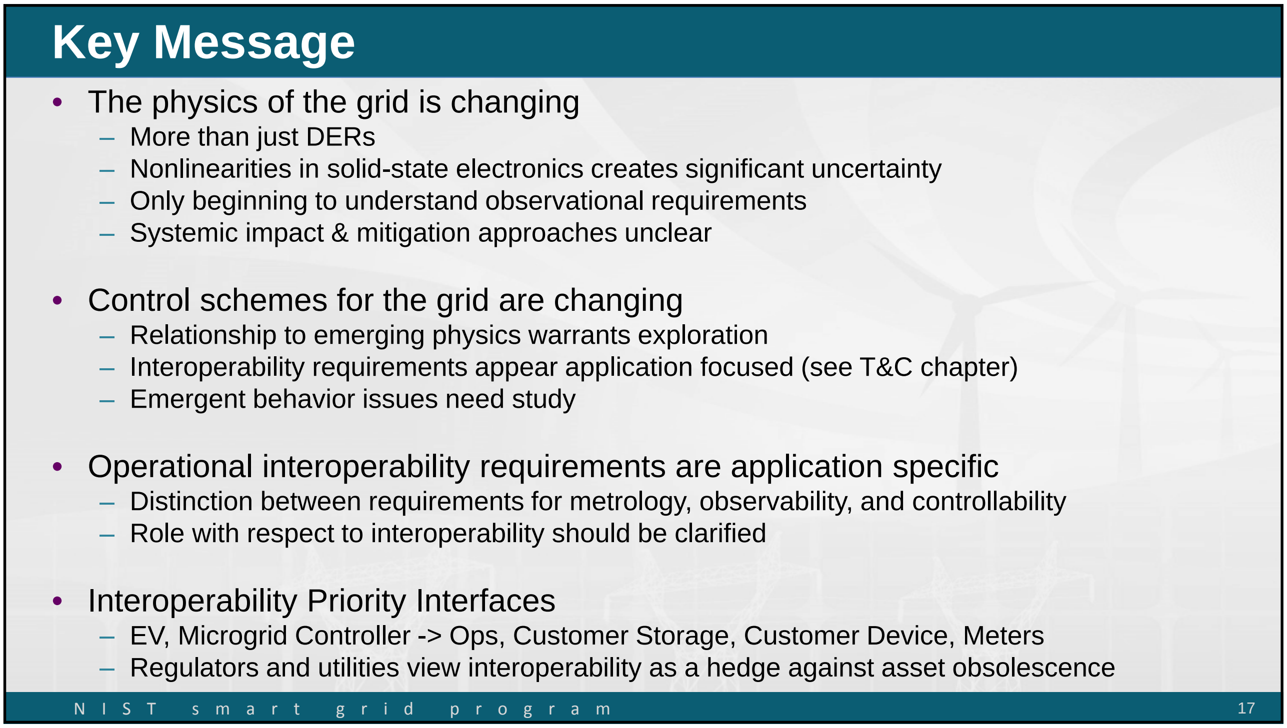
- Operational interoperability requirements are application specific
  - Distinction between requirements for metrology, observability, and controllability
  - Role with respect to interoperability should be clarified

Priority Interoperability interfaces



1) Microgrid Controller
2) Electric Vehicle
3) Customer Storage
4) Customer Device
5) Metering Interface



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  - Role with respect to interoperability should be clarified

- Interoperability Priority Interfaces
  - EV, Microgrid Controller -> Ops, Customer Storage, Customer Device, Meters
  - Regulators and utilities view interoperability as a hedge against asset obsolescence

NIST Smart Grid Program

NIST Smart Grid Framework Cybersecurity Chapter

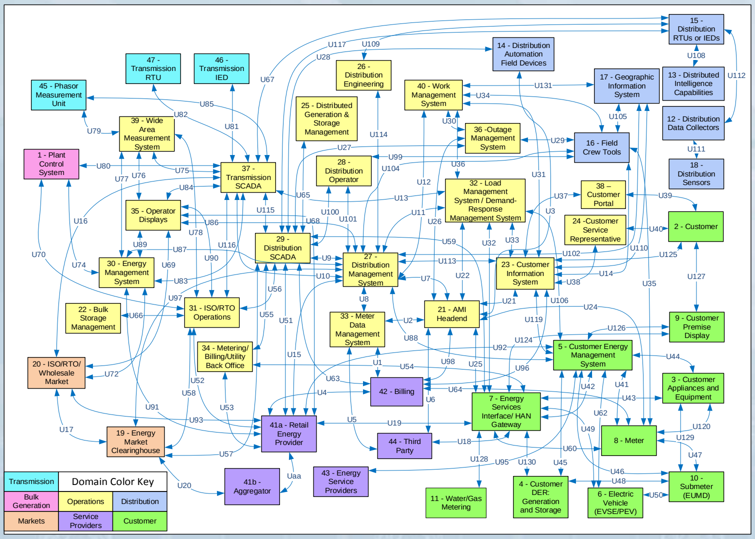
Nelson Hastings
Electronics Engineer
Applied Cybersecurity Division
Information Technology Laboratory

National Institute of Standards and Technology
U.S. Department of Commerce

Scope

- Summarize cybersecurity research and stakeholder feedback that informed the NIST Smart Grid Framework Cybersecurity Chapter
- Smart Grid Interoperability Framework and Cybersecurity Workshop
  - Held at NIST's National Cybersecurity Center of Excellence (NCCoE) in November 13 and 14, 2018
- Impact of High Distributed Energy Resource (DER) Architecture on Logical Interface Categories
- Smart Grid Cybersecurity Profile

NISTIR 7628 Logical Interface Reference Model - “Spaghetti Diagram”



NISTIR 7628 Logical Interface Categories - Sample

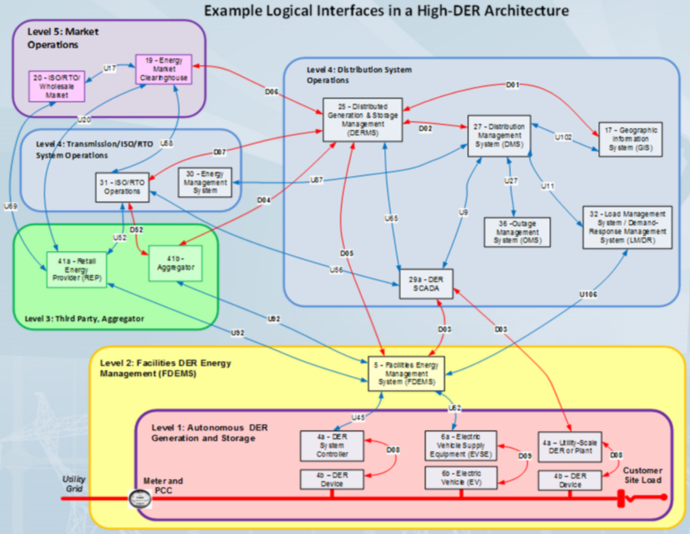
- Control System and Equipment
  - High Availability, Compute/bandwidth constraints
  - No High Availability, Compute/bandwidth constraints
  - High Availability, No compute/bandwidth constraints
  - No High Availability, No compute/bandwidth constraints
- Control systems
  - Intra-organizational
  - Inter-organizational (6)
- Back office systems
  - Under common management authority
  - Without common management authority
- B2B connections
  - Financial/Market transactions

High-DER Architecture Introduces New Logical Interfaces - Example

- Distributed Generation and Storage Management → Distributed Energy Resource Management System (DERMS)
  - New interfaces between the DER devices and DER system controllers
  - New external interface to Distribution System Operations
- Customer Energy Management System → Facilities DER Energy Management System (FDEMS)
  - Three new external interfaces with the Distribution System Operations
- Distribution System Operations
  - New external interfaces to Market Operations, Transmission/ISO/RTO System Operations, and Third Party Aggregator
  - Two new internal interfaces from the DERMS to the Geographic Information System (GIS) and Distribution Management System (DMS)

High DER Architecture – New Logical Interfaces Example

Example Logical Interfaces in a High-DER Architecture

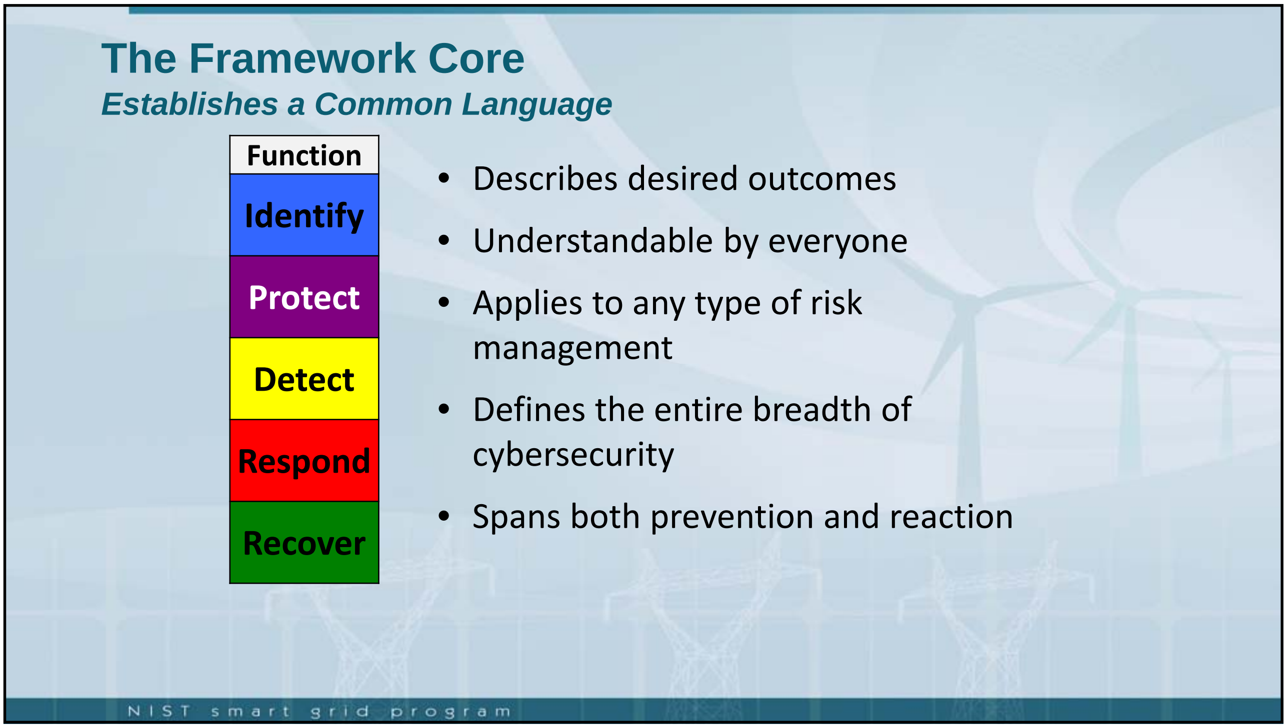


Potential Security Requirements for New Logical Interfaces - Example

- New interfaces D3, D4, D5, D7, and D52 map to NISTIR 7628 LIC 6
- Security requirements for NISTIR 7628 LIC 6:
  - SG.AC-14: Permitted Actions without Identification or Authentication
  - SG.IA-04: User Identification and Authentication
  - SG.SC-05: Denial-of-service protection
  - SG.SC-06: Resource Priority
  - SG.SC-07: Boundry Protection
  - SG.SC-08: Communication Integrity
  - SG.SI-07: Software and Information Integrity

Smart Grid Cybersecurity Profile

- Profiling the NIST Cybersecurity Framework for Smart Grid
- NIST Cybersecurity Framework (CSF) was
  - Created by industry, academia and government participants in response to U.S. Executive Order, *Improving Critical Infrastructure Cybersecurity*
  - Based on workshops, led by NIST, and other outreach to gather input and best practices for improving cybersecurity
- NIST Cybersecurity Framework (CSF) design:
  - Flexible
  - Leverages existing approaches, standards, practices
  - Internationally applicable
  - Focused on risk management vs checklist
- Three Primary Components
  - Core
  - Profiles
  - Implementation Tiers



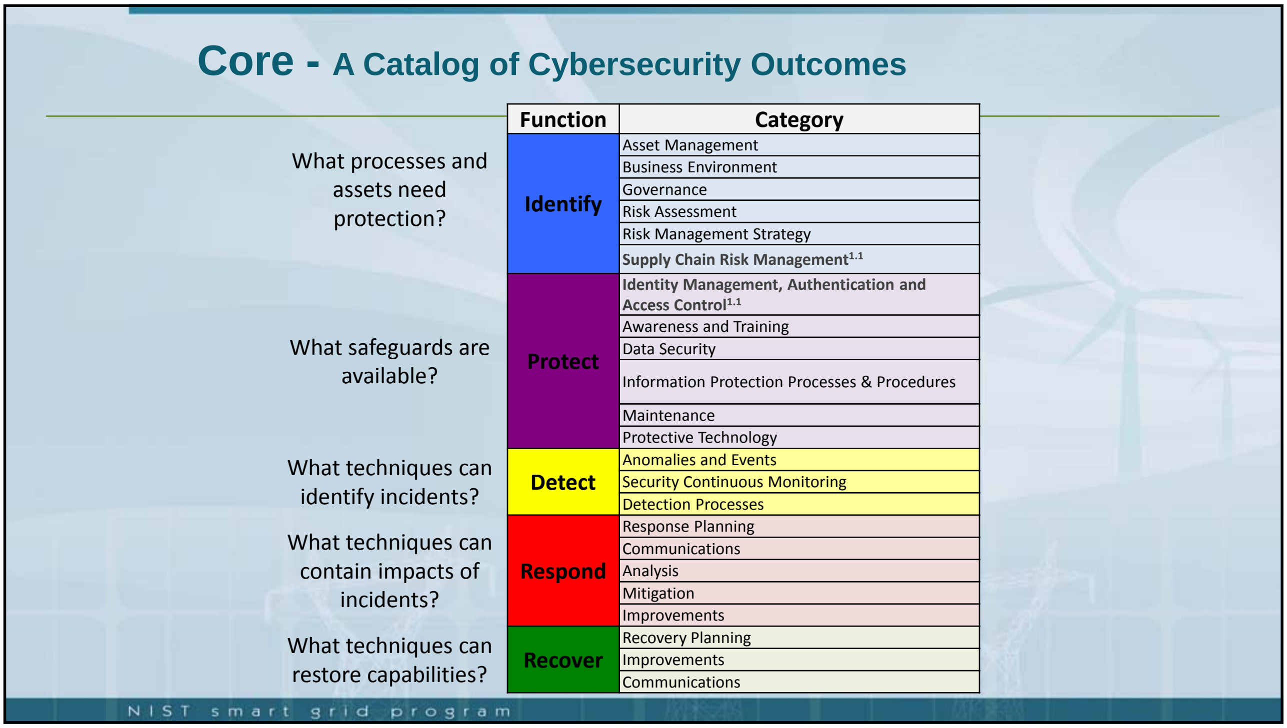
The Framework Core

Establishes a Common Language

Function
Identify
Protect
Detect
Respond
Recover

- Describes desired outcomes
- Understandable by everyone
- Applies to any type of risk management
- Defines the entire breadth of cybersecurity
- Spans both prevention and reaction

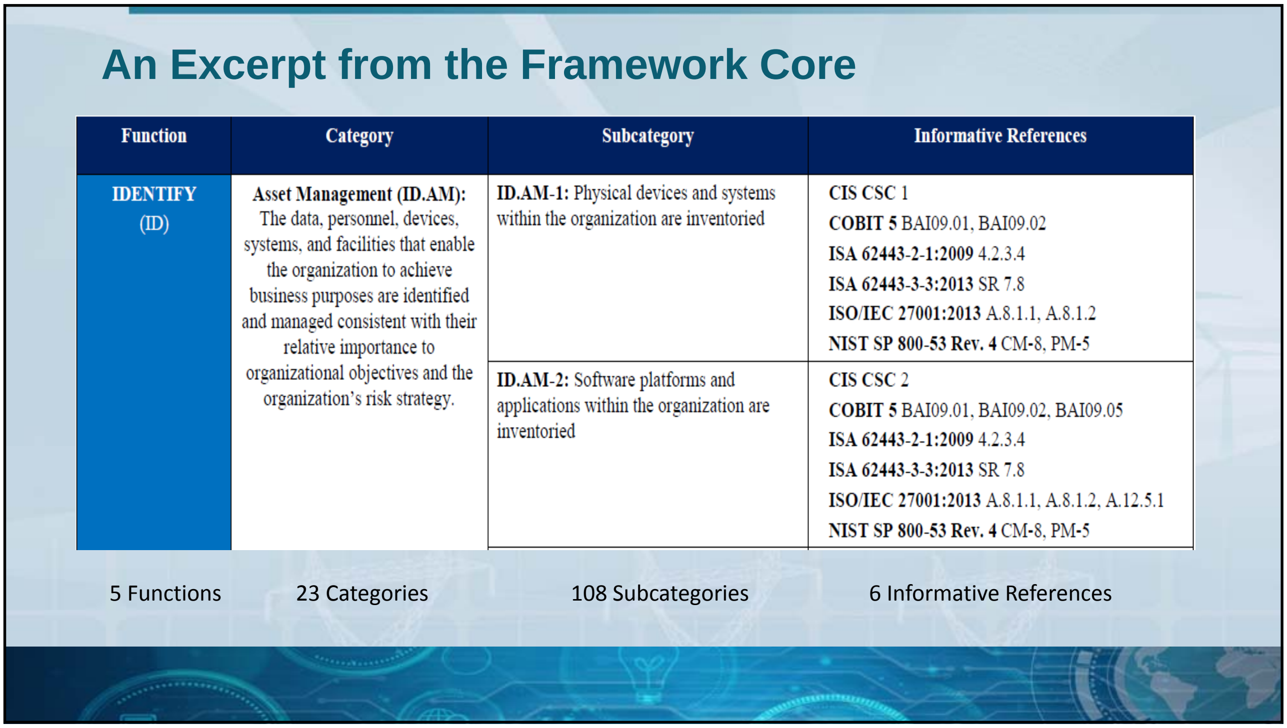
NIST smart grid program



Core - A Catalog of Cybersecurity Outcomes

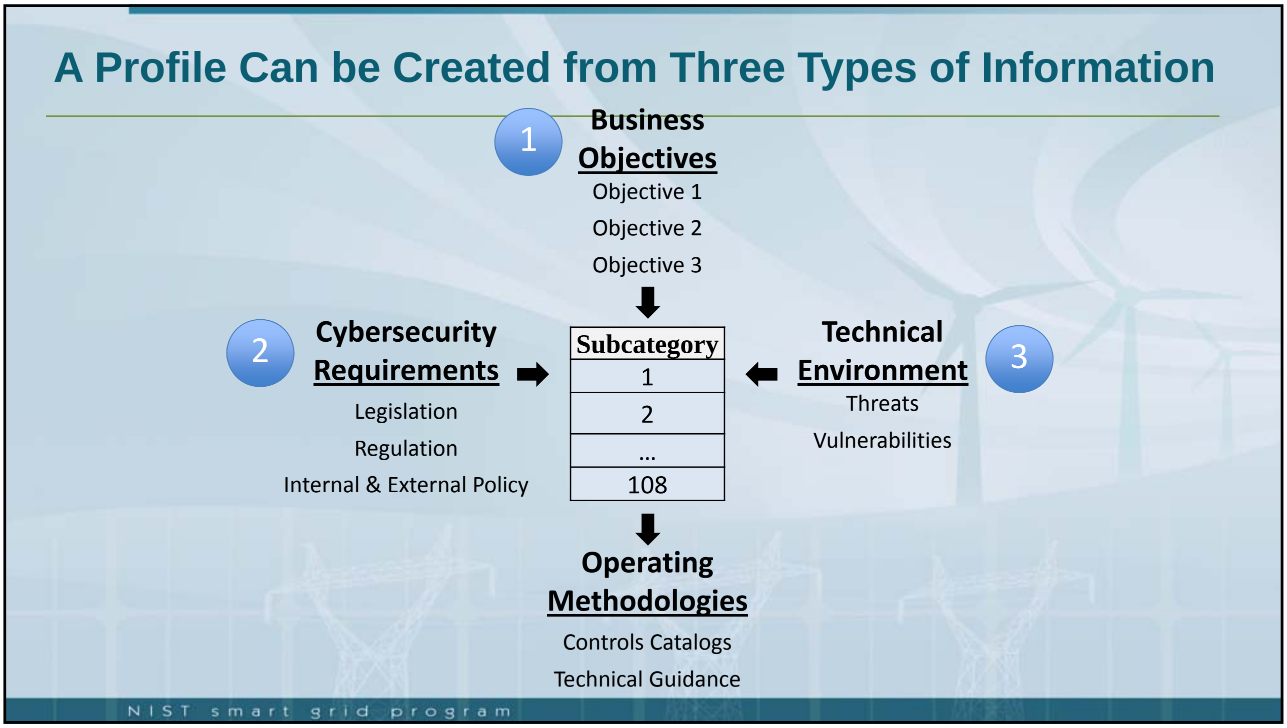
	Function	Category
What processes and assets need protection?	**Identify**	Asset Management
		Business Environment
		Governance
		Risk Assessment
		Risk Management Strategy
		Supply Chain Risk Management$^{1.1}$
What safeguards are available?	**Protect**	**Identity Management, Authentication and Access Control**$^{1.1}$
		Awareness and Training
		Data Security
		Information Protection Processes & Procedures
		Maintenance
		Protective Technology
What techniques can identify incidents?	**Detect**	Anomalies and Events
		Security Continuous Monitoring
		Detection Processes
What techniques can contain impacts of incidents?	**Respond**	Response Planning
		Communications
		Analysis
		Mitigation
		Improvements
What techniques can restore capabilities?	**Recover**	Recovery Planning
		Improvements
		Communications

NIST smart grid program



An Excerpt from the Framework Core

Function	Category	Subcategory	Informative References
IDENTIFY (ID)	**Asset Management (ID.AM):** The data, personnel, devices, systems, and facilities that enable the organization to achieve business purposes are identified and managed consistent with their relative importance to organizational objectives and the organization's risk strategy.	**ID.AM-1:** Physical devices and systems within the organization are inventoried	**CIS CSC** 1 **COBIT 5** BAI09.01, BAI09.02 **ISA 62443-2-1:2009** 4.2.3.4 **ISA 62443-3-3:2013** SR 7.8 **ISO/IEC 27001:2013** A.8.1.1, A.8.1.2 **NIST SP 800-53 Rev. 4** CM-8, PM-5
		ID.AM-2: Software platforms and applications within the organization are inventoried	**CIS CSC** 2 **COBIT 5** BAI09.01, BAI09.02, BAI09.05 **ISA 62443-2-1:2009** 4.2.3.4 **ISA 62443-3-3:2013** SR 7.8 **ISO/IEC 27001:2013** A.8.1.1, A.8.1.2, A.12.5.1 **NIST SP 800-53 Rev. 4** CM-8, PM-5
5 Functions	23 Categories	108 Subcategories	6 Informative References



A Profile Can be Created from Three Types of Information

NIST smart grid program

Smart Grid Cybersecurity Profile

- **Identified high-level business objectives** for a high-DER environment
  - *Business requirements include regulatory requirements and cybersecurity requirements*
  - *Reviewed relevant literature (PNNL smart grid architecture documentation, NIST publications, etc.)*
  - *Interviewed industry experts (i.e., power system owners operators, electric power industry think tanks)*
- **High-level business objectives**:
  - **Maintain safety**
  - **Maintain power system reliability**
  - **Maintain power system resilience**
  - **Support grid modernization**

Smart Grid Cybersecurity Profile

- **Prioritized** Subcategory outcomes:
  - *Analyzed Cybersecurity Framework Core Subcategories in relation to identified business objectives*
  - *Does each Subcategory* ***directly*** *assist power system owners/operators in achieving the business objectives*
  - *Highlighted relevant Subcategories*
- Provided further **considerations** for implementation:
  - Described the rationale for the selection of each Subcategory
  - Provided implementation considerations for power system owners/operators (e.g., challenges that they may encounter as they seek to achieve cybersecurity outcomes)

Smart Cybersecurity Grid Profile Excerpt

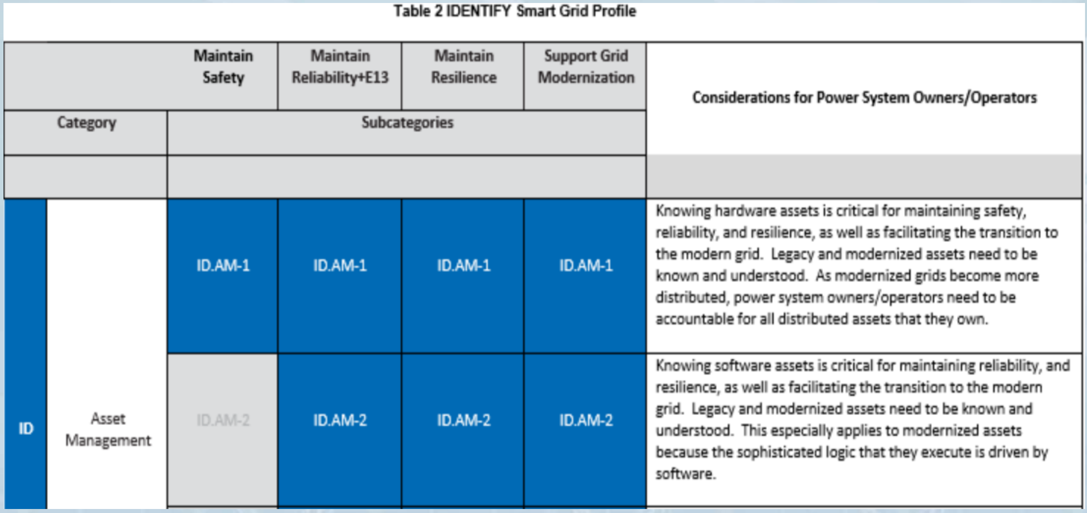
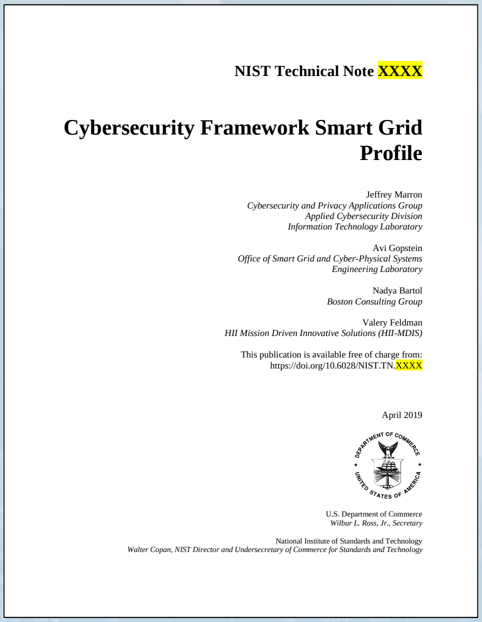


Table 2 IDENTIFY Smart Grid Profile

		Maintain Safety	Maintain Reliability+E13	Maintain Resilience	Support Grid Modernization	Considerations for Power System Owners/Operators
Category		Subcategories				
ID	Asset Management	ID.AM-1	ID.AM-1	ID.AM-1	ID.AM-1	Knowing hardware assets is critical for maintaining safety, reliability, and resilience, as well as facilitating the transition to the modern grid. Legacy and modernized assets need to be known and understood. As modernized grids become more distributed, power system owners/operators need to be accountable for all distributed assets that they own.
		ID.AM-2	ID.AM-2	ID.AM-2	ID.AM-2	Knowing software assets is critical for maintaining reliability, and resilience, as well as facilitating the transition to the modern grid. Legacy and modernized assets need to be known and understood. This especially applies to modernized assets because the sophisticated logic that they execute is driven by software.



NIST Technical Note XXXX

Cybersecurity Framework Smart Grid Profile

Jeffrey Marron
Cybersecurity and Privacy Applications Group
Applied Cybersecurity Division
Information Technology Laboratory

Avi Gopstein
Office of Smart Grid and Cyber-Physical Systems
Engineering Laboratory

Nadya Bartol
Boston Consulting Group

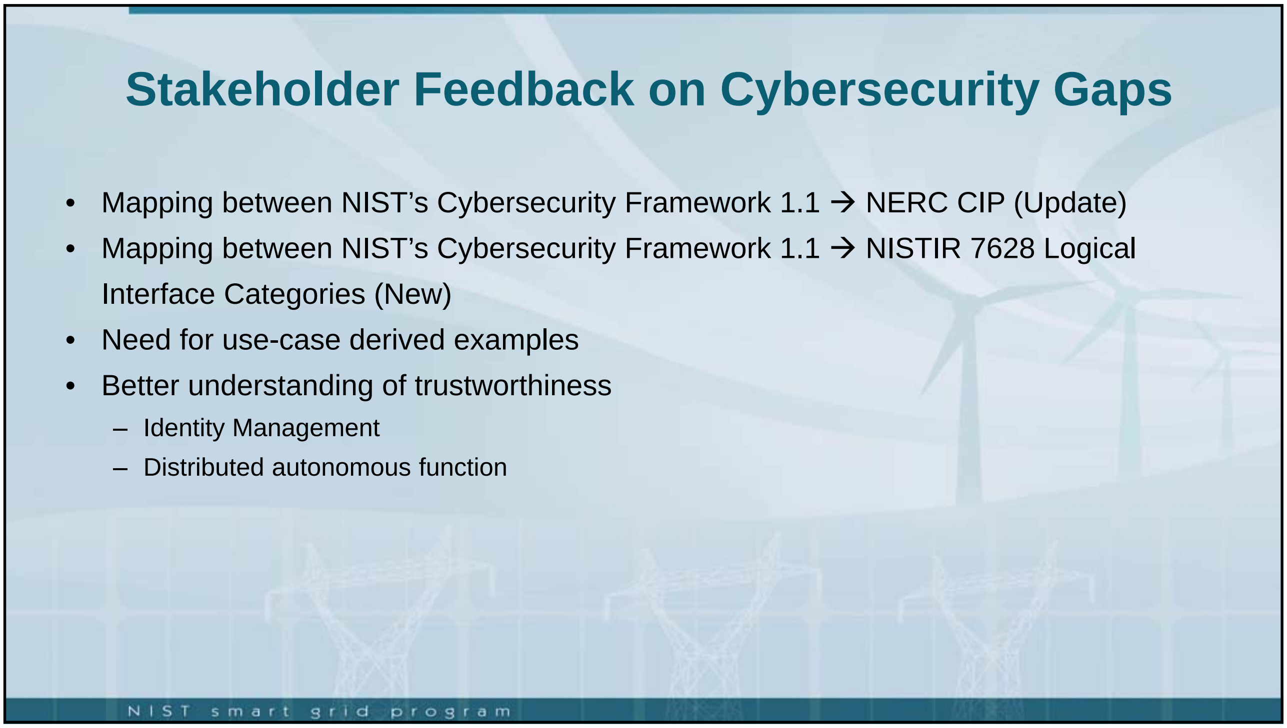
Valery Feldman
HII Mission Driven Innovative Solutions (HII-MDIS)

This publication is available free of charge from:
https://doi.org/10.6028/NIST.TN.XXXX

April 2019

U.S. Department of Commerce
Wilbur L. Ross, Jr., Secretary

National Institute of Standards and Technology
Walter Copan, NIST Director and Undersecretary of Commerce for Standards and Technology



Stakeholder Feedback on Cybersecurity Gaps

- Mapping between NIST’s Cybersecurity Framework 1.1 → NERC CIP (Update)
- Mapping between NIST’s Cybersecurity Framework 1.1 → NISTIR 7628 Logical Interface Categories (New)
- Need for use-case derived examples
- Better understanding of trustworthiness
  - Identity Management
  - Distributed autonomous function

NIST smart grid program

Discussion

NIST smart grid program

NIST Smart Grid Program

NIST Smart Grid Framework Economics Chapter

Cheyney O'Fallon, Ph.D.
Applied Economics Office
Engineering Laboratory

Federal Advisory Committee Meeting
June 4th, 2019

NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Introduction

- **Expectations** of and within the electric power sector are changing rapidly.
- Increasing technical and organizational **modularity** within the sector have opened opportunities for innovation by incumbents and new entrants.
- **Combinatorial Innovation**
- Recent developments are consistent with past historical experiences in which a
  - **"*set of technologies, comes along that offers a rich set of components that can be combined and recombined to create new products*"**
  - (Economics of Information Technology, Varian 2001).
- Modular and distributed energy resources (DER)
- Entrepreneurial capabilities and culture
- Encouragement of a savvy customer base

} evolving structure of electricity markets

Introduction

- The innovative value propositions that are developed in response to the changing business environment must be consistent with:
  - customer preferences
  - technical resources and capabilities
  - the regulatory construct that while under stress remains crucial to:
    - financial stability and maintenance of trust between stakeholder groups

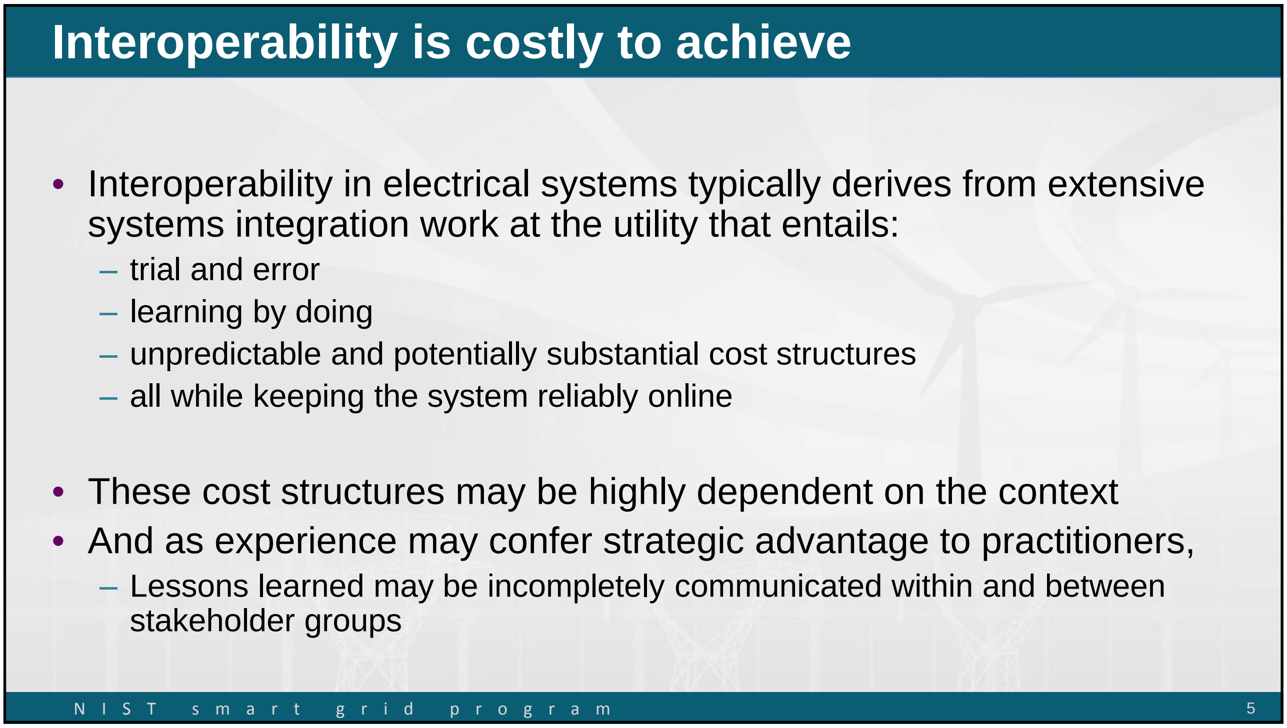
- Evolving expectations and a highly modular value network has:
  - enabled a more transactional approach to commerce in other major sectors of the economy.

Introduction

Interoperability Value Proposition

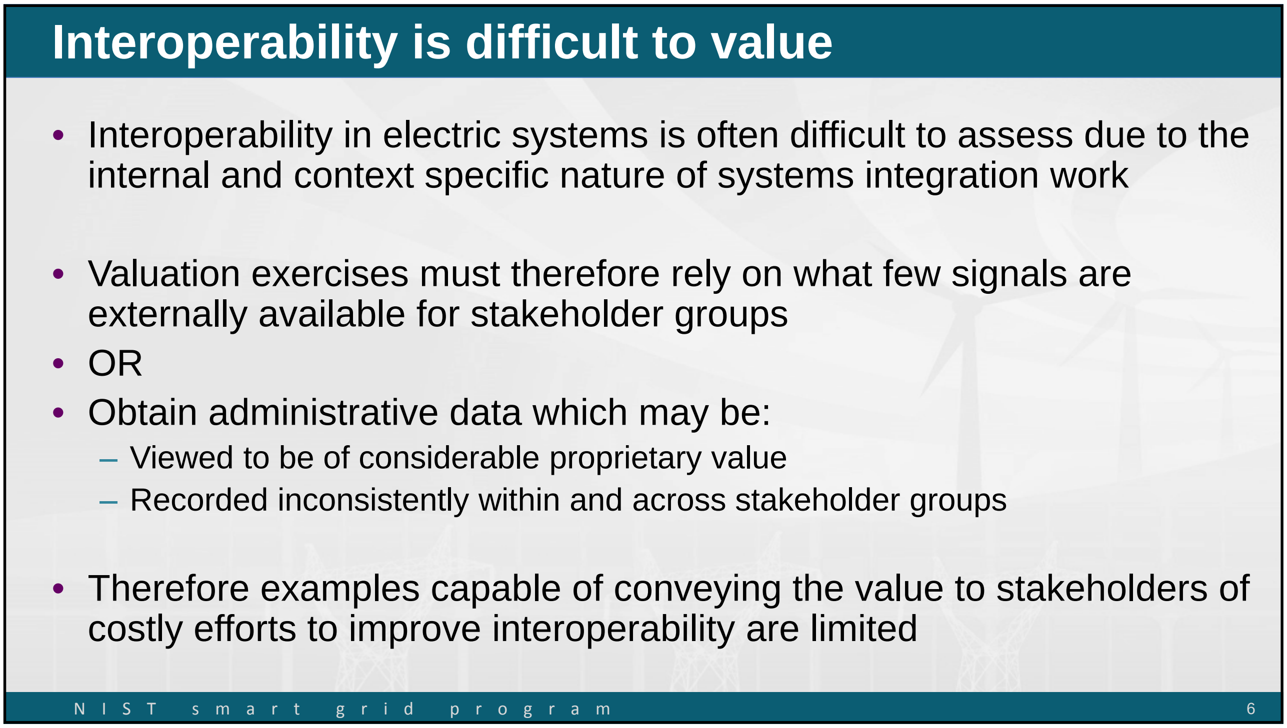
- Interoperability improvements expand the electric power sector’s value network.

- However, while seamless interoperability
  - is often presumed by end use customers…
  - it must be ensured by practitioners.



Interoperability is costly to achieve

- Interoperability in electrical systems typically derives from extensive systems integration work at the utility that entails:
  - trial and error
  - learning by doing
  - unpredictable and potentially substantial cost structures
  - all while keeping the system reliably online
- These cost structures may be highly dependent on the context
- And as experience may confer strategic advantage to practitioners,
  - Lessons learned may be incompletely communicated within and between stakeholder groups



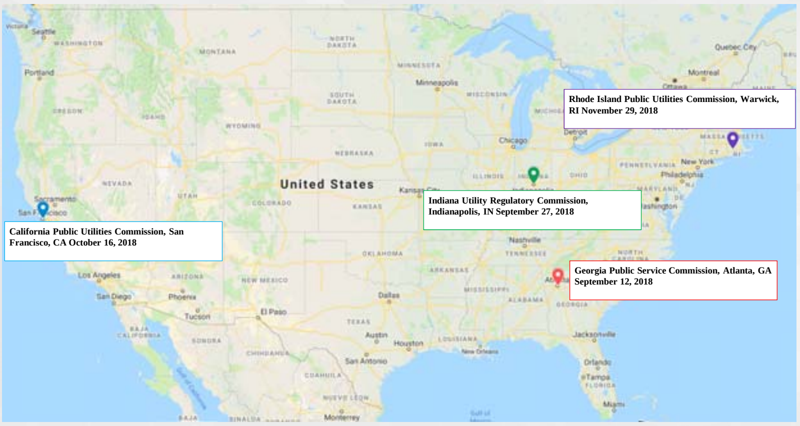
Interoperability is difficult to value

- Interoperability in electric systems is often difficult to assess due to the internal and context specific nature of systems integration work
- Valuation exercises must therefore rely on what few signals are externally available for stakeholder groups
- OR
- Obtain administrative data which may be:
  - Viewed to be of considerable proprietary value
  - Recorded inconsistently within and across stakeholder groups
- Therefore examples capable of conveying the value to stakeholders of costly efforts to improve interoperability are limited

Intertemporal Importance of Interoperability

- Electric utilities face significant uncertainty with respect to their future operating environment.
- Managers are therefore concerned with the pursuit of no-regrets moves that will pay off regardless of how the uncertainty is ultimately resolved.
- Cost-cutting initiatives are prototypical examples of such regret-free strategies (Courtney 1997).
- The cost of integrating new technology with the legacy grid while ensuring interoperability could be a consistent source of uncertainty if unaddressed.
- Developing and disseminating best practices for system integration and ensuring interoperability constitute regret free strategies across the sector.

Spatial Importance of Interoperability



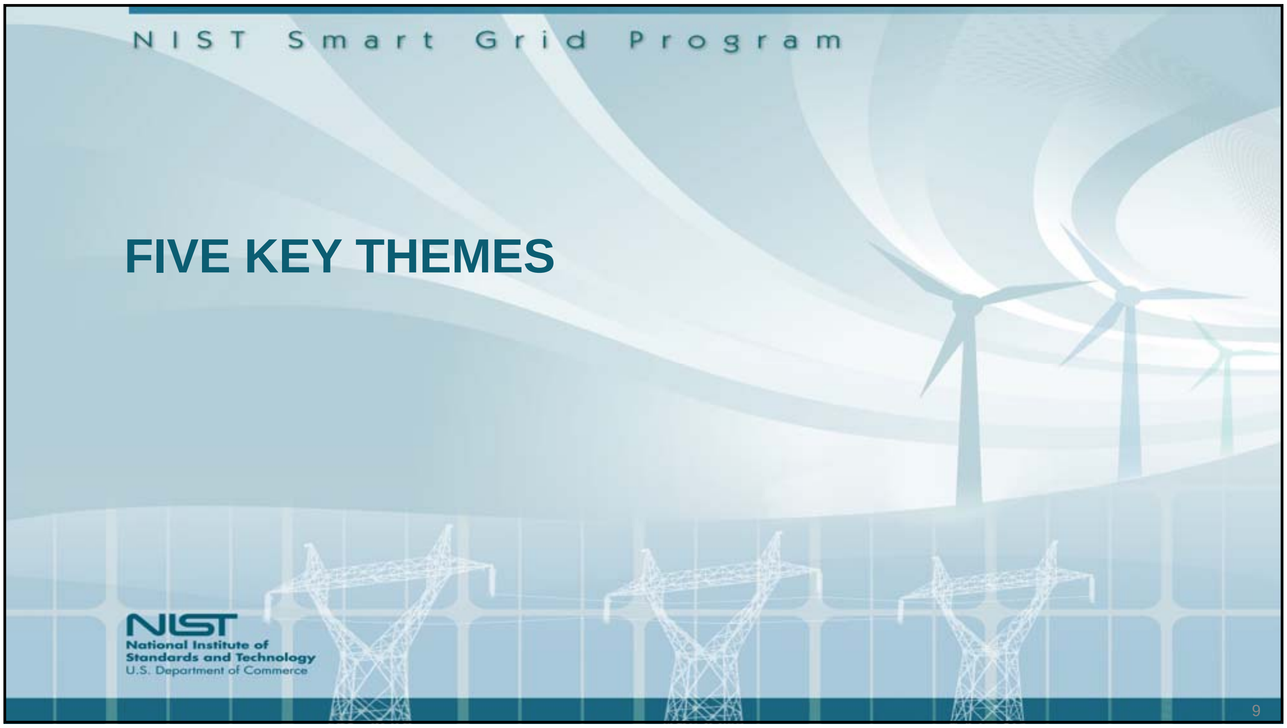
Rhode Island Public Utilities Commission, Warwick, RI November 29, 2018

Indiana Utility Regulatory Commission, Indianapolis, IN September 27, 2018

California Public Utilities Commission, San Francisco, CA October 16, 2018

Georgia Public Service Commission, Atlanta, GA September 12, 2018

Stakeholders described encountering interoperability challenges across the country



FIVE KEY THEMES

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1) Interoperability and Specificity

Interoperability can help to overcome the barriers of device specificity and support the marketing efforts and revenue outlook of new and existing grid services.

Organizational Strategy

1. Organizations invest in resources and capabilities that strengthen their core competencies.
2. Investments may commit an organization to certain competitive strategies and business models.
3. Firms may discover subsequent, synergistic opportunities.

Smart Grid Context

1. Asset specificity often results from efforts to meet technical requirements and contribute to a value chain.
2. Specificity may then act as a barrier to broader or further utilization of devices and systems.
3. Interoperability offers a strategy set through which to reduce “specificity barriers”.

Value chains and value networks

The value of DER and conventional assets to the electric grid will improve as interoperability enables these resources and capabilities to make additional contributions across the sector’s value network

2) Interoperability and Customer Empowerment

Interoperability is crucial to customer empowerment.

1. Enabling customers to be better informed regarding their own electricity-use decisions.
   a. Improved utilization of current assets
   b. Better decision making with respect to technological adoption
   c. Accurate signals are critical to economic efficiency
2. Enabling a plug-and-play environment.
   a. Expectation that devices purchased will work with rest of the system
   b. Devices can be selected for customer optimality
   c. Reduced transaction costs of integrating customer equipment
3. Informational improvements may contribute to greater customer agency
   – The cost of “political organization” may fall for some stakeholders connected through interoperable systems.

3) Complexity and Cost Structures

Interoperability can counter rising transaction and production costs associated with the increasing complexity of interaction among diverse organizations of varying regulatory status.

1. Value chain complexity is rising with asset specificity
2. The regulatory status of firms varies across the value chain
3. Coordinating value-adding activities is costly

} **Impact on Cost Structures**

Transaction costs are rising in salience

“Current writing has helped bring out the point that market failure is not absolute; it is better to consider a broader category, that of transaction costs, which in general impede and in particular cases completely block the formation of markets. It is usually though not always emphasized that **transaction costs are costs of running the economic system**”.
(Arrow 1969)

Interoperability strategies can directly address cost escalation due to complexity

4) Trust and Assurance

Testing and certification regimes can provide the level of trust or assurance needed to accelerate adoption rates for emerging technologies and engender the growth of new revenue streams and business models in the electric power sector.

1. Uncertainty impacts investment decisions
2. Assurances provided by testing and certification can mitigate certain types of uncertainty that could slow technology adoption
3. Testing and certification can mitigate the transaction costs that may "impede" or "completely block" the formation of markets for new services.
   - Informational Costs
   - Costs of troubleshooting and integrating new technology
   - Coordination Costs
   - Labor Costs

5) Testing and Certification

Effective and efficient testing and certification regimes are needed to ensure that devices, systems, and components perform as expected and are fit for purpose.

1. Achieving interoperability will require initial and ongoing testing of devices, systems, and systems of systems.
2. Interoperability investments constitute cooperative strategies for improving the efficiency of the electric grid.
3. Some interoperability benefits are likely to be split between stakeholder groups.
4. Testing and Certification regimes can help to identify and discipline problem areas/actors as well as inform subsequent strategy formation and product development.

Testing and Certification Options

Command and control approaches to T&C

- may be viable in some applications or as a fallback strategy
- could create additional barriers which slow grid evolution
- with mixed societal benefits

Open Third Party T&C programs

- flexible, market-based institutions
- may offer alternative, more-predictable cost structures
- accelerate grid evolution to deliver value today

The Evolution of a Complex Electric Grid

Accelerating grid evolution can create economic growth within and beyond the sector

Stakeholders are challenged to rapidly and reliably evolve the grid while serving the critical needs of all sectors of the economy.

We will not move from a the current grid to a smart grid in a single leap

Testing and certification programs can help ensure the existence of **stable intermediate forms** in the smart grid value network by demonstrating **systems integrations that deliver value through interoperability**.

System evolution and stable intermediate forms

Why care about stable intermediate forms?

“The time required for the evolution of a complex form from simple elements depends critically on the numbers and distribution of potential intermediate stable forms”(p.471).

“the existence of stable intermediate forms exercises a powerful effect on the evolution of complex forms that may be likened to the dramatic effect of catalysts upon reaction rates”(p472).

The Architecture of Complexity, Herbert A. Simon (1962)

Testing and Certification as Problem Solving

“Problem solving requires selective trial and error… In problem solving, a partial result that represents recognizable progress toward the goal plays the role of a stable subassembly”(p.472).

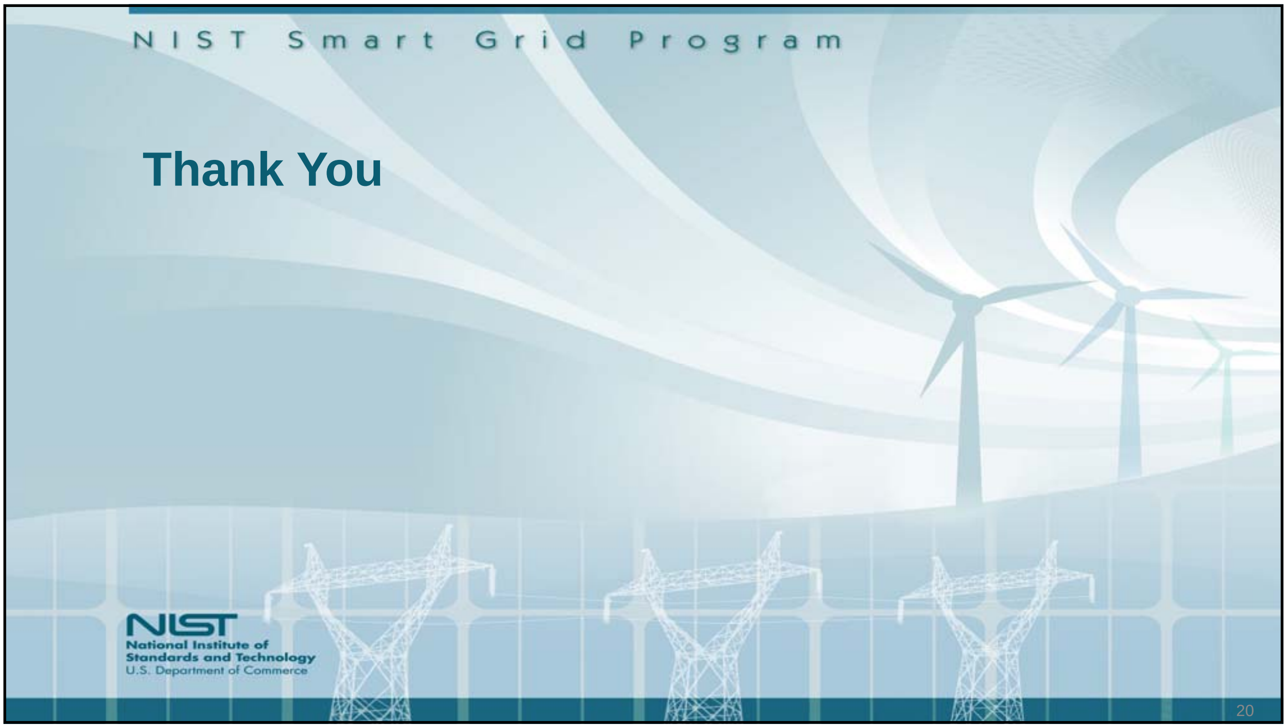
The Architecture of Complexity, Herbert A. Simon (1962)

Testing and certification programs can increase the number of stable (interoperable) subassemblies from which stakeholders may choose.

An Economic Perspective

Visible and measurable success in achieving interoperability, through the creation stable subassemblies for selection by stakeholders can help:

- Demonstrate prudence of investments to regulators by showing worthy innovations to be used and useful
- Entice new investment and combinatorial innovation
- Develop new platforms for service provision
- Enable market formation
- Facilitate transactive energy strategies and institutions



NIST Smart Grid Program

Thank You

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NIST Smart Grid Framework Testing and Certification Chapter

Cuong Nguyen

NIST Smart Grid Program

NIST Smart Grid Advisory Committee Meeting
June 4, 2019

National Institute of Standards and Technology
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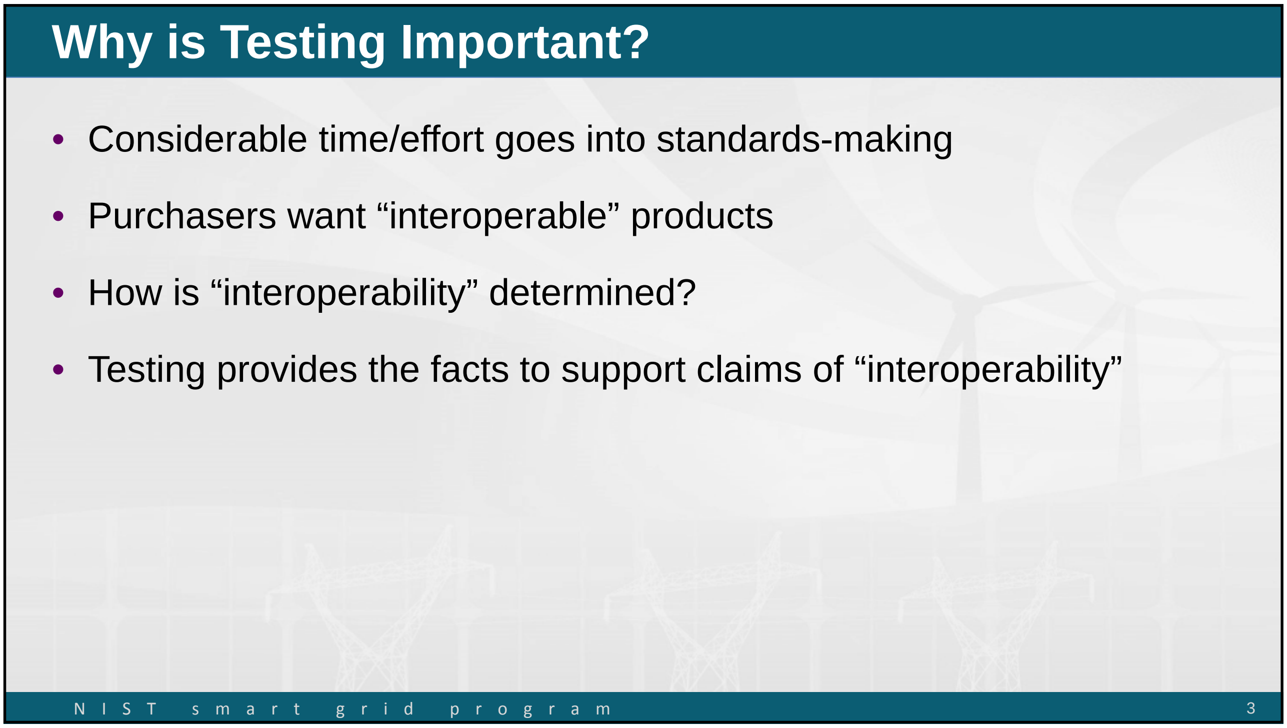
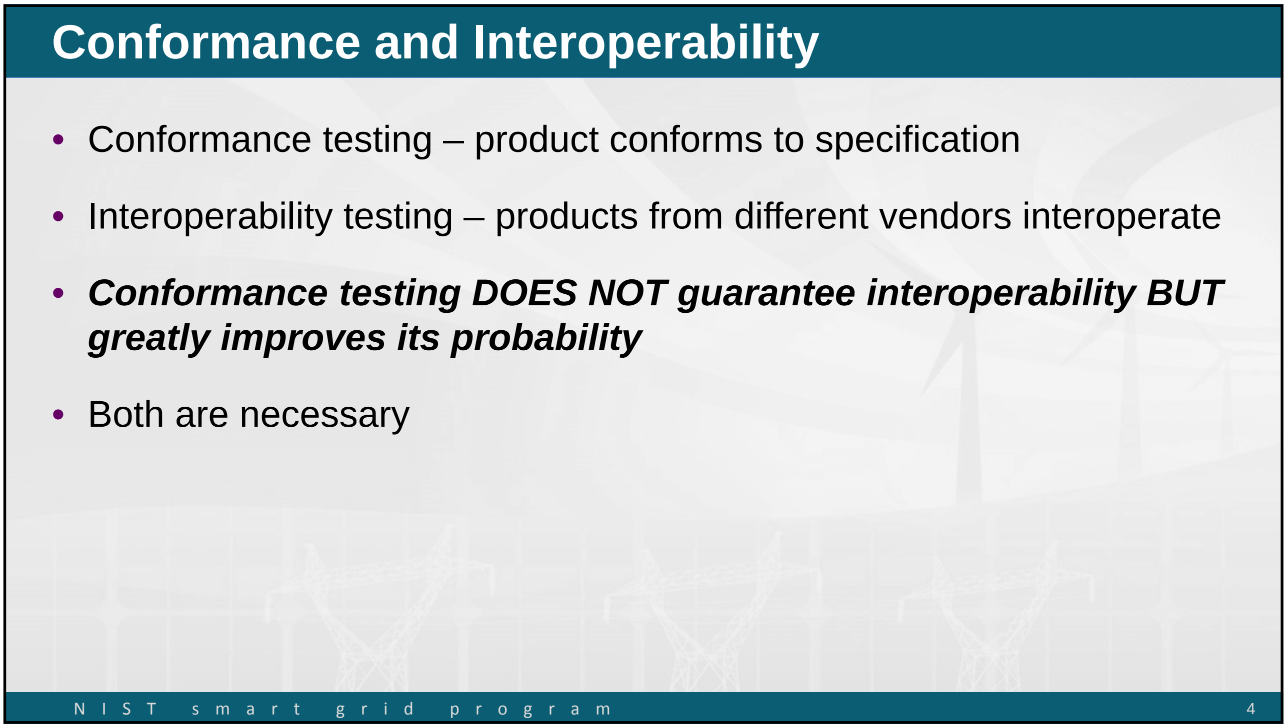
Outline

- Overview of Testing and Certification
- Smart Grid Testing and Certification Landscape
- Current Initiatives
- Stakeholder Engagement
- Future Directions



Why is Testing Important?

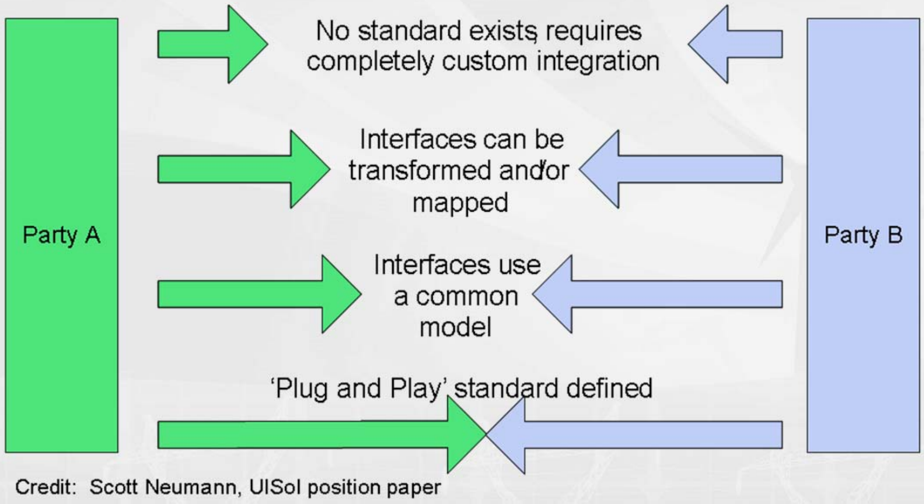
- Considerable time/effort goes into standards-making
- Purchasers want “interoperable” products
- How is “interoperability” determined?
- Testing provides the facts to support claims of “interoperability”



Conformance and Interoperability

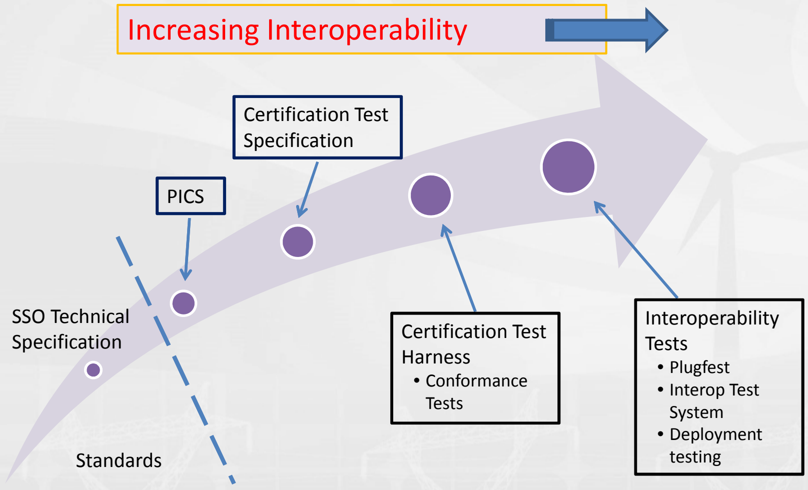
- Conformance testing – product conforms to specification
- Interoperability testing – products from different vendors interoperate
- ***Conformance testing DOES NOT guarantee interoperability BUT greatly improves its probability***
- Both are necessary

Different Levels of Interoperability



Credit: Scott Neumann, UISol position paper

Testing and Certification Process



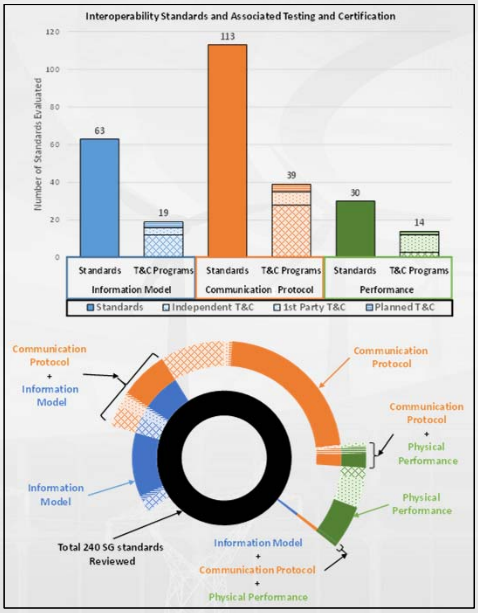
Certification Regimes

- **First-party certification:** A manufacturer attests that the product meets the standard’s requirements (self-certification).
- **Second-party certification:** A user tests and certifies the product to verify that it meets the standard’s requirements.
- **Third-party certification:** A complete process through an independent authority that includes a certification body and associated test lab.

	Speed	**Transparency**	**Independence**
First Party	High	Low	Low
Second Party	Medium	Medium	Medium
Third Party	Low	High	High

Interoperability standards landscape assessment

- Of the 240 standards reviewed, only a small percentage were found to have T&C programs either existing or planned.
- The results show limited availability of device certification for the substantial majority of interoperability relevant smart grid standards.
- The lack of availability for certification-based assurance programs with each functional grouping confirms the need to stimulate the development of T&C programs for smart grid interoperability standards.



Catalog of Test Programs

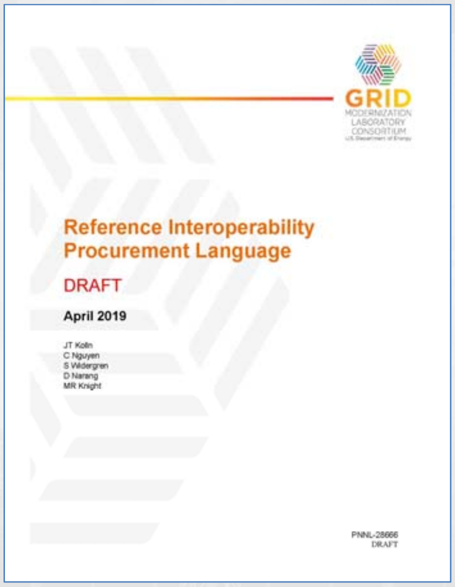
- It is challenging to find available test programs even for those with industry knowledge and awareness.
- The catalog will provide guidance to purchasers to reference test programs if they are available when they procure products.
- It will also provide visibility for test program operators to increase their usage.

CoTP Entry Information

- Program Information
  - Summary of the Certification Program
- Technical Specification
  - List of technical specifications to which the product will be certified
- Testing Information
  - Testing Categories
    - Conformance
    - Interoperability
  - Certification
    - Intent to Issue a Certificate
    - Intent to Issue a Mark or Logo
- Program Qualifications
  - ISO 17025 Testing Laboratories
  - ISO 17025 Certification Bodies
- Product and Technical Information
  - How to obtain technical specifications and other program documents

Reference Interoperability Procurement Language

- It is crucial to use procurement language to specify interoperability requirements for products so that integration issues can be addressed and mitigated before deployment.
- Initial document includes a list of interoperability criteria along with metrics to evaluate if the criteria is being met.
- Future activity includes the development and curation of model procurement languages that apply to actual examples.



GRID
MODERNIZATION
LABORATORY
CONSORTIUM
U.S. Department of Energy

Reference Interoperability
Procurement Language

DRAFT

April 2019

JT Kolln
C Nguyen
S Widergren
D Narang
MR Knight

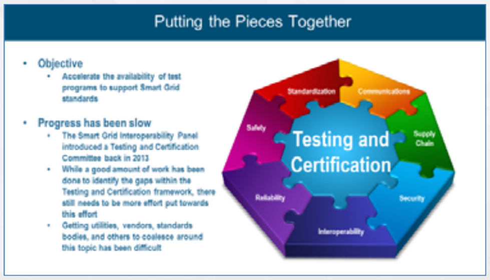
PNNL-28666
DRAFT

Stakeholder Engagement

- A proactive stakeholder engagement strategy for smart grid testing and certification is needed to:
  - Engage key stakeholders and product decision makers in advocating the value of smart grid test programs
  - Align end-user technology priorities with the areas where focus is needed to accelerate the creation of new test programs
  - Build broader awareness of testing programs, processes, and resources across the smart grid community
- Testing and certification programs require demand drivers for their success.
- Demand drivers lead to widespread adoption of testing programs.

Testing and Certification Workshop

- Industry participants confirmed that there is a lack of continued momentum in developing testing programs to support the smart grid.
- Technical challenges for smart grid T&C
  - Variation in certified functionalities
    - Lack of conformity leads to additional integration
  - Data quality, availability, and transparency
    - Lack of ability to use data where it is most valuable
  - Harmonization of standards and protocols
  - Technology and infrastructure
    - Exploding complexities with end device proliferations
  - Current standards landscape
- Non-technical challenges for smart grid T&C
  - Value proposition and business case
    - A major expense for individual entity
  - Market and technology uptake
  - Institutional awareness and commitment
- Interoperability profile that includes an open source test harness could stimulate the development of T&C programs.

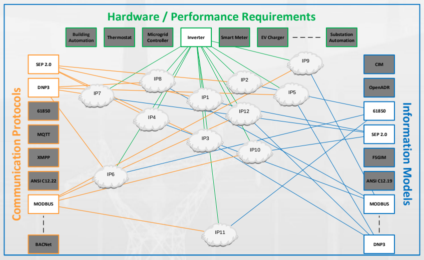


Putting the Pieces Together

- Objective
  - Accelerate the availability of test programs to support Smart Grid standards
- Progress has been slow
  - The Smart Grid Interoperability Panel introduced a Testing and Certification Committee back in 2013
  - While a good amount of work has been done to identify the gaps within the Testing and Certification framework, there still needs to be more effort put towards this effort
  - Getting utilities, vendors, standards bodies, and others to coalesce around this topic has been difficult

Interoperability Profile

- A profile is a description of a well-defined subset of the standard that has been agreed upon by a user community, testing authority or standards body.
- The specification and use of profiles allows the interoperability gap to be narrowed by reducing the degrees of freedom of implementation flexibility in the context of interest by the device supplier, implementer and system owner.
- Basic set of elements for a profile include:
  - Physical performance specifications
  - Communication protocol
  - Information model



Interoperability Profile Development Scope

- Interoperability profile includes standard elements utilized in specific application or use case
- Need to identify and prioritize candidates for profile development
  - Partner with SEPA through the Testing and Certification Working Group
- Develop technical requirements for selected profile
  - Physical asset performance, communication, information model
- An example profile could include
  - IEEE 1547 (physical asset performance)
  - IEEE P2030.5 (communication)
  - IEC 61850-7-420 (information model)

Interoperability Profile Development – Phase I

- White paper describing the purpose and value of interoperability profile and a list of potential candidates
- Convening and facilitation of industry group meetings including but not limited to
  - Electric Utilities
  - Solution Providers and Non-Utility Actors
  - Testing Providers
- Report of the findings from the convened meetings including a refined list of the standards and elements identified, and the interoperability profile selected for development

Interoperability Profile Development – Phase II

- Document requirements of the interoperability profiles including:
  - Key features and functionality
  - Performance requirements and operational limits
  - Communication requirements
  - Information model requirements
  - Interoperability requirements
  - Relevant elements of applicable standards
- Publish interoperability profile requirements as a white paper

Interoperability Profile Development – Phase III

- Use the interoperability profile requirements document to create a test plan
  - Develop protocol implementation conformance statement (PICS) from the requirements
  - Use the PICS to create a test suite specification (TSS)
- Develop an open source test harness based on the test plan
  - Automate the test cases
  - Create an open source tool for testing conformance to the interoperability profile

NIST Smart Grid Program

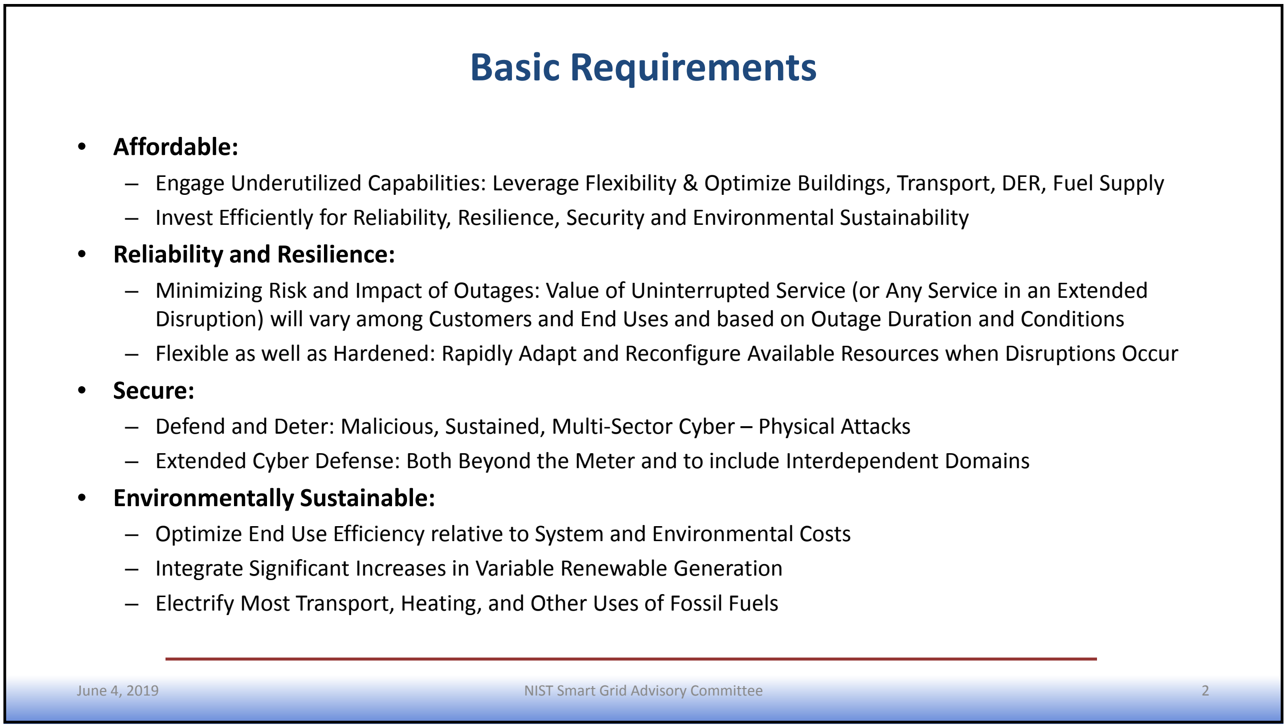
Thank you!

NIST National Institute of Standards and Technology U.S. Department of Commerce

Coordination of Standards Development for an Distributed Intelligent Energy Future

Paul Centolella
President, Paul Centolella & Associates, LLC
Senior Consultant, Tabors Caramanis Rudkevich

National Institute of Standards and Technology
Smart Grid Advisory Committee
June 4, 2019

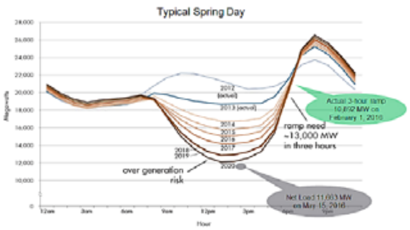


Basic Requirements

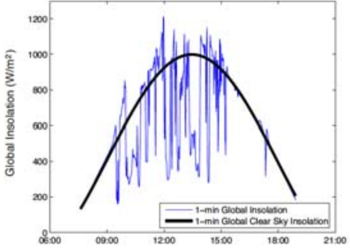
- **Affordable:**
  - Engage Underutilized Capabilities: Leverage Flexibility & Optimize Buildings, Transport, DER, Fuel Supply
  - Invest Efficiently for Reliability, Resilience, Security and Environmental Sustainability
- **Reliability and Resilience:**
  - Minimizing Risk and Impact of Outages: Value of Uninterrupted Service (or Any Service in an Extended Disruption) will vary among Customers and End Uses and based on Outage Duration and Conditions
  - Flexible as well as Hardened: Rapidly Adapt and Reconfigure Available Resources when Disruptions Occur
- **Secure:**
  - Defend and Deter: Malicious, Sustained, Multi-Sector Cyber – Physical Attacks
  - Extended Cyber Defense: Both Beyond the Meter and to include Interdependent Domains
- **Environmentally Sustainable:**
  - Optimize End Use Efficiency relative to System and Environmental Costs
  - Integrate Significant Increases in Variable Renewable Generation
  - Electrify Most Transport, Heating, and Other Uses of Fossil Fuels

Examples of Increasing Variability

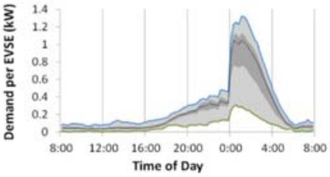
CA ISO Solar Duck Curve [1]



Solar on Partly Cloudy Day [2]

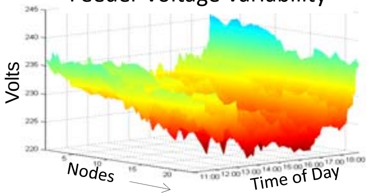


EV Demand with TOU Rate



450kW Bus Fast Charger

Feeder Voltage Variability [3]



Feeder Voltage with PV [4]

Rapid Growth of Distributed Intelligence

- Inexpensive processors and sensors, ubiquitous connectivity, data analytics and machine learning are enabling distributed intelligent devices and smart control systems
- Rapid growth in Customer sited Intelligent Devices
  - Smart Thermostats: In estimated 13% U.S. households in 2017, 30% by 2020; capable of reducing peak Air Conditioning Demand by as much as 50%
  - Commercial Building Management Systems are increasingly integrating smart sensors and controls; capable of reducing sector peak demand by 16% & energy use in some buildings by up to 50%
  - Behind-the-Meter Storage Capacity additions doubled in 2018 to more than 160MW and could increase to more than 10X that level by 2024 [5]
  - EVs: U.S. sales up 80% from 2017 to 2018, forecasted to be 20% to 40% of new car sales in 2030 [6]
  - Behind-the-Meter Storage, Smart Thermostats, & EVs could add 60 GW of flexible demand by 2023 [7]
- Technical Potential: Over 50% Demand with Thermal Inertia or Timing Flexibility
- Intelligent technologies are being introduced into the Electric Grid
  - Advanced Solid State Power Electronics
  - Dynamic Control Systems

Impact of Distributed Intelligence on Power Systems

- Assumptions of Uncorrelated Variability in Individual Customer Demands and Gradual Interval-to-Interval Changes in Aggregate Demand may be No Longer Valid
- Smart Technology will respond to Time-Varying Rates with Large, Instantaneous, Discrete Shifts in Net Demand
- Smart Technology will Anticipate Demand Response Events, Increasing Baseline Usage to Maximize Incentive Payments
- Computational Complexity Significantly Increases:
  - Today Regional Operators Dispatch large generators and Control a limited number of flowgates, often fewer than 10,000 total control points
  - Single Distribution Utility could soon include Millions of Smart End Use Devices, Hundreds of Thousands of EVs, and Thousands of MW of Distributed Resources
- Dynamic, Complex Optimization Architecture is required:
  - Increased supply and demand variability in a dynamic energy system (topology & flow control) across multiple: layers (home to circuit to distribution utility to regional operations), time scales (sub-cycle to multi-hour receding time horizons), and domains (buildings, transport, DER, and fuel supply)
  - Complicates an already Hard Non-Convex Power Flow Optimization Problem with model and data limitations

Threads in Development of Future Energy Systems

Grid Modernization Topics

- Grid Architecture
- Distributed Locational Marginal Pricing Valuation and Markets
- Pricing of flexibility
- Transactive Energy Markets
- Platform markets and business models
- Future Utility Regulatory and Business Models
- Jurisdictional and Legal Issues
- Advanced solid-state power electronics
- Fractal and Microgrid Topologies
- Grid topology optimization
- Power Flow Control
- Flexible Demand and Building Optimization

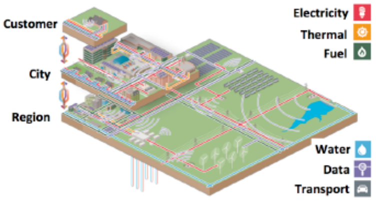
Autonomous Energy Grid Topics

- Data Analytics and Machine Learning
- Real Time Distributed Optimization
- Control Theory for System Stability
- Controller Architecture
- Complex Systems Theory & Modeling
- Dynamic Resilience
- Cyber-Physical Security for Autonomous Systems
- Autonomous Energy System integration

Distributed and Autonomous Energy Systems

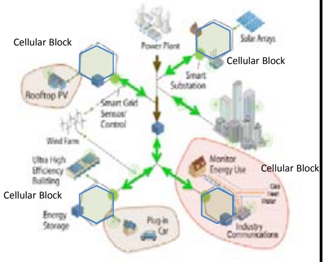
- Nested Distributed Systems will operate simultaneously at different geographic scales
- Arranged and coordinated in a laminate structure, i.e. Operator at Level A cannot call on Device at Level C without the coordination of levels: A,B, & C
- In each layer, demand and resources are in interconnected, fractal cells each capable of islanding and optimizing with others
- Fractal cell has capabilities of other layers
- Real time optimization updates DER set points on a second or sub-second basis
- Communications between cell control platform & customers to optimize customer objectives within cell's electrical limits
- Message passing among cells to enable Optimum Power Flow with agreed upon real & reactive power exchanges

Laminate

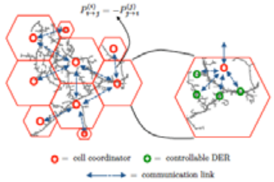


NREL
Autonomous Energy Grids

Cellular and Fractal



Real Time Communications



New & Emerging Use Cases

- Sub-Cycle to Sub-Interval:
  - Buffering Real Power Variability: Offsetting Rapid Changes in sub-Frequency Response timeframes
  - Grid Edge Conservation Voltage Optimization (CVO): Compressing Voltage Volatility
  - Automated Topology Response: FLISR & Variability
  - Microgrid Control: Separation, Reconnection, & Managing Island Operations
  - Fractal Grid Control: Rapid local optimization of DER & demand & intercell message passing
  - DC - AC Conversions: including DC as a Service
  - Real-time Grid Awareness, including T&D PMUs
  - Power Flow Control: Controlling Line Reactance
- Interval-to-Interval:
  - Granular Pricing and DLMP Markets: Value and Manage Distribution Constraints, Marginal Losses, and Equipment Overloads and Degradation
  - Integrating DLMP & Existing LMP Power Markets
  - Ramping: Valuing & Managing Flexible Reserves
- Multiple Intervals to Hours:
  - Integration of Smart Demand, Storage, DER: that Respond to Forward Price Vectors & Conditions
  - Granular & Layered Forecasts of DER & Demand
  - Demand and DER Capacity Contracts to Avoid or Defer Capacity Additions and Upgrades
  - Integrated Voltage Control: Coordinating LTCs & Cap Banks with Grid Edge Controls & Inverters
  - Resilient Service during Outages: From Backup Power to Dynamic System Reconfiguration
  - Dynamic Line / Equipment Ratings and Forecasts
  - Transmission & Distribution Topology Optimization
  - Intelligent Asset Management: Equipment Monitoring and Maintenance
  - Co-optimization of Power Markets & Gas Pipelines
- Longer Time Frames:
  - Develop Platform Market for Customer Services
  - Extending Cyber / Physical Security from Grid to Connected Devices, and Interdependent Systems

Discussion Questions

- In what time frame should we expect distributed, intelligent, and autonomous devices and systems to play a significant role in energy systems?
- How do we anticipate such devices and systems to alter the power grid?
- What roles should the Federal Government play in facilitating the development of future energy systems that integrate many more distributed, intelligent, and autonomous devices and systems?
- What advice can we provide NIST regarding its role both within the Federal Government and in coordinating with the private sector in the development of power grids that integrate such distributed, intelligent, and autonomous devices and systems?

Paul Centolella
President, Paul Centolella & Associates, L.L.C.
Senior Consultant, Tabors Caramanis Rudkevich
(614) 530-3017
centolella@gmail.com

Additional References

Not Included in previously distributed: Connecting Threads to Create a Roadmap to an Intelligent Energy Future

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