Overview of NIST and the Engineering Laboratory

Dr. Howard Harary, Director
Engineering Laboratory

NIST at a Glance

3400+
EMPLOYEES

FOCUS ON
ADVANCED MANUFACTURING

2 CAMPUSES
GAITHERSBURG, MD [HQ], BOULDER, CO

FOCUS ON
QUANTUM SCIENCE

4
NOBEL PRIZES

FOCUS ON
HEALTH & BIOSCIENCE

FOCUS ON
ADVANCED COMMUNICATIONS

400+
BUSINESS USING NIST FACILITIES

FOCUS ON
CYBERSECURITY

3800+
ASSOCIATES & FACILITIES USERS

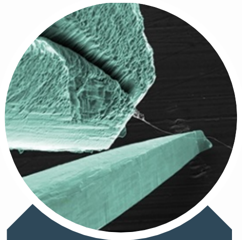
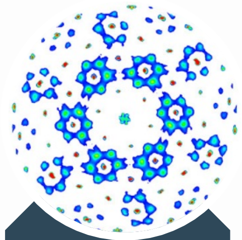
FOCUS ON
DISASTER RESILIENCE

9
COLLABORATIVE INSTITUTES

NIST Laboratory Programs





Material Measurement Laboratory	Physical Measurement Laboratory	Engineering Laboratory	Information Technology Laboratory	Communication Technology Laboratory	Center for Nanoscale Science and Technology	NIST Center for Neutron Research

Metrology Laboratories

Driving innovation through Measurement Science and Standards

Technology Laboratories

Accelerating the adoption and deployment of advanced technology solutions

National User Facilities

Providing world class, unique, and cutting-edge research facilities

NIST Mission

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life

measurement science

Creating the experimental and theoretical tools – methods, metrics, instruments, and data – that enable innovation

standards

Disseminating physical standards and providing technical expertise to documentary standards that enable comparison, ensure interoperability, and support commerce

technology

Driving innovation through knowledge dissemination and public-private partnerships that bridge the gap between discovery and the marketplace

Measurements are critical…

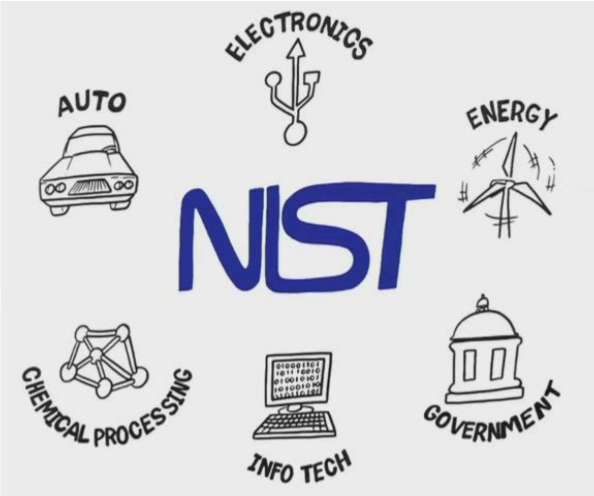
to commerce

"Uniformity in the currency, weights, and measures of the United States is an object of great importance, and will, I am persuaded, be duly attended to."

George Washington, State of the Union Address, 1790

to innovation

If you know how to measure something, you can design it, compare it, understand it, and improve it



NIST Illustrated, https://youtu.be/2j9BGVKbzS4

and to international trade

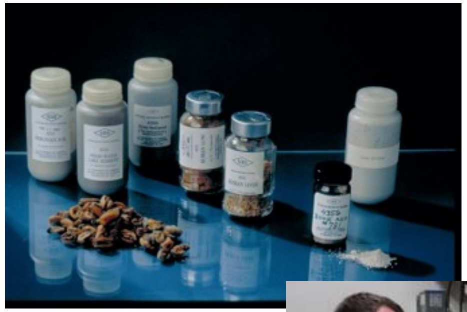
Up to 92% of U.S. exports affected by standards/technical regulations

NIST measurement science provides the foundation for innovation in every industry and economic sector, from manufacturing to health care to defense

NIST Laboratory Products and Services

Serving industry and other stakeholders in the U.S. and globally

- **1200+** Standard Reference Material (SRM) products
- **100+** Standard Reference Data (SRD) products
- **600+** measurement services
- **800+** accreditations of testing and calibration laboratories per year



NIST Documentary Standards

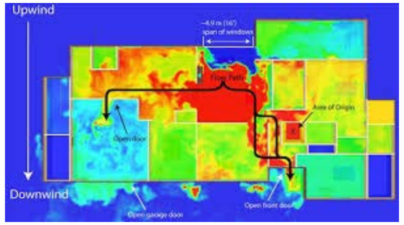
Providing support to industry and government for voluntary standards development

NIST's unique role

- NIST coordinates standards policy among federal agencies (National Technology Transfer and Advancement Act, 1996)
- NIST Director is President's principal advisor on standards (American Innovation and Competitiveness Act, 2016)
- NIST's laboratory expertise provides measurement-based and unbiased data to improve decision-making in standards bodies

Expert participation

- 400+ NIST technical staff in 100+ standard committees
- Leadership in international standards bodies such as ASTM, IEEE, ISO, IEC



NIST studies of fire behavior led to life-saving changes in U.S. building codes

Standards and assessments for public safety communications are transforming emergency response

NIST robotics standards are catalyzing U.S. manufacturing automation transformation

NIST Laboratory Programs

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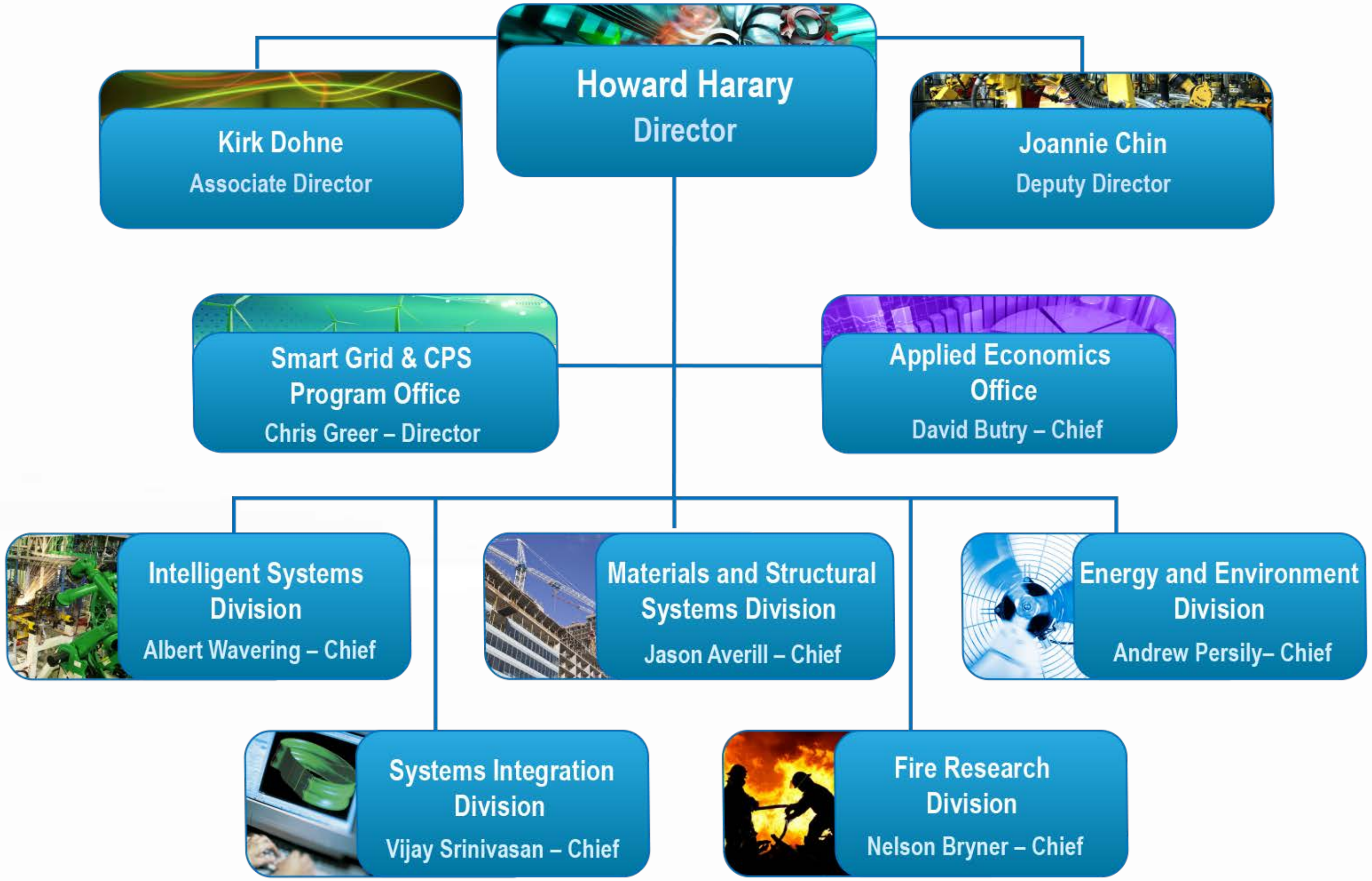
EI Leadership Team



EL Mission

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology for engineered systems in ways that enhance economic security and improve our quality of life

measurement science

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Engineering Laboratory Goals

Resilience

Smart Manufacturing

Cyber Physical Systems

Energy

11

Engineering Laboratory Goals

Resilience

-

Community Resilience
Fire Risk Reduction
Earthquake
Structural Performance
Engineered Materials

Smart Manufacturing

Cyber Physical Systems

Energy

Engineering Laboratory Goals

Resilience

Smart Manufacturing

-

Additive Manufacturing
Robotic Systems
Systems Design/Analysis
Ops Planning/Control

Cyber Physical Systems

Energy

Engineering Laboratory Goals

Resilience

Smart Manufacturing

Cyber Physical Systems

-

Smart Grid
Cyber Physical Systems

Energy

14

Engineering Laboratory Goals

Resilience

Smart Manufacturing

Cyber Physical Systems

Energy

-

Embedded Intelligence in Buildings

Net Zero Energy, High Performance Buildings

Engineered Systems Research

Unique Engineered Systems Research

- Cyber-Physical Systems and Smart Grid testbeds for “smart” everything
- Models and measurements of materials, buildings, and other infrastructure for disaster- resilient communities; Fire models and data for improved, performance-based building codes
- Robotics, control systems, and digital data exchange standards for smart manufacturing infrastructure
- Sensing systems and data to enable net zero energy buildings while maintaining air quality

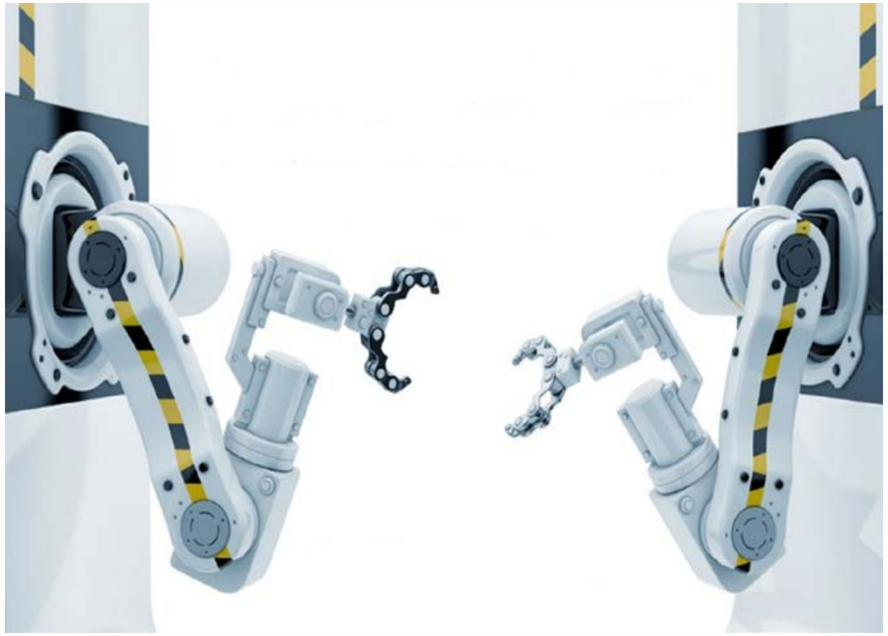
Unique Facilities and Functions

- Smart Grid Interoperability Panel
- National Fire Research Laboratory
- Robotics Test Facility
- Net-Zero Energy Residential Facility
- National Construction Safety Team
- Disaster investigations, studies and interagency research coordination
- Community Resilience Center of Excellence

engineering laboratory

Thank you

Smart Grid and Cyber-Physical Systems Programs



Dr. Chris Greer
Director, Smart Grid and
Cyber-Physical Systems Program Office
Engineering Laboratory, NIST
christopher.greer@nist.gov

Overview

- Review Agenda
- SG & CPS Program Vision
- CPS Program Components

Agenda – Day 1

10:00 AM	**BREAK**
10:20 AM	**Smart Grid Program Update** Avi Gopstein
11:50 PM	**LUNCH**
1:00 PM	**Ethics Briefing** Eric Johnson
1:30 PM	**Smart Grid Interoperability and Building to Grid Integration** Steve Bushby
1:50 PM	**Smart Grid Cybersecurity** Nelson Hastings
2:10 PM	**Grid Architecture and System Dynamics** DJ Anand
2:30 PM	**BREAK**
2:50 PM	**SEPA Update** Sharon Allan
3:10 PM	**Discussion of Plans for NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 4.0** All
4:50 PM	**Wrap Up** Chris Greer
5:00 PM	**Adjourn for the day 6:00 PM**

Optional Dinner

Agenda – Day 2

August 18, 2017

8:30 AM	**Convene in Building 101**
8:45 AM	**Smart Grid Interoperability Testbed Tour** All
10:00 AM	**Discussion on NIST Smart Grid Research Portfolio and Future Priorities** All
11:30 AM	**Public Comments**
11:45 AM	**Planning for Next Meeting and Wrap Up** Chris Greer
12:00 PM	**Adjourn**

engineering laboratory

SG & CPS Program - Statistics

FY17 Budget

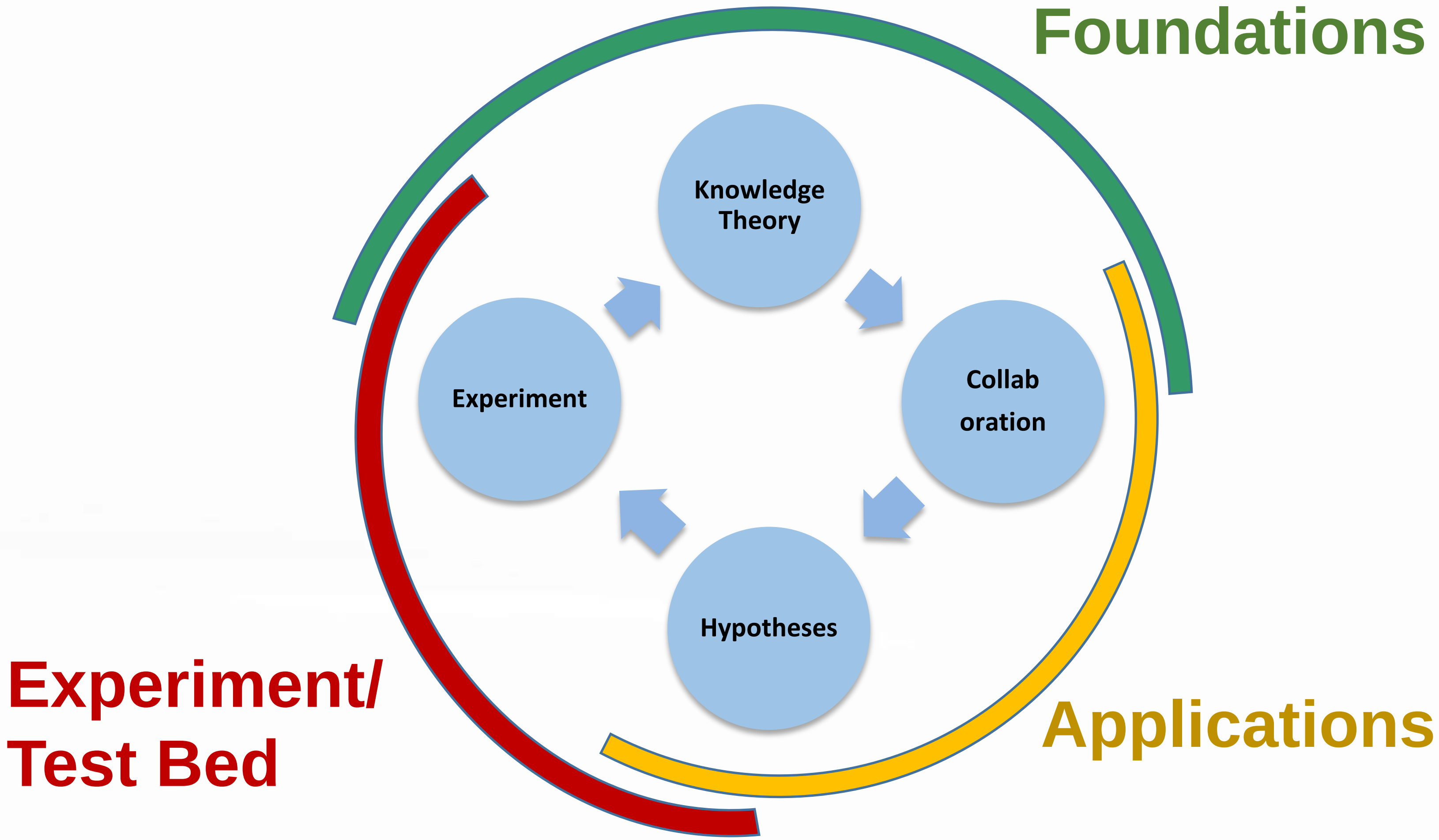
Component	$M
Cyber-Physical Systems	$3.2
Smart Grid	$8.5
Total	$11.7

Core Personnel

Category	FTE*
Research	7
Support	2
Management	2
Total	11

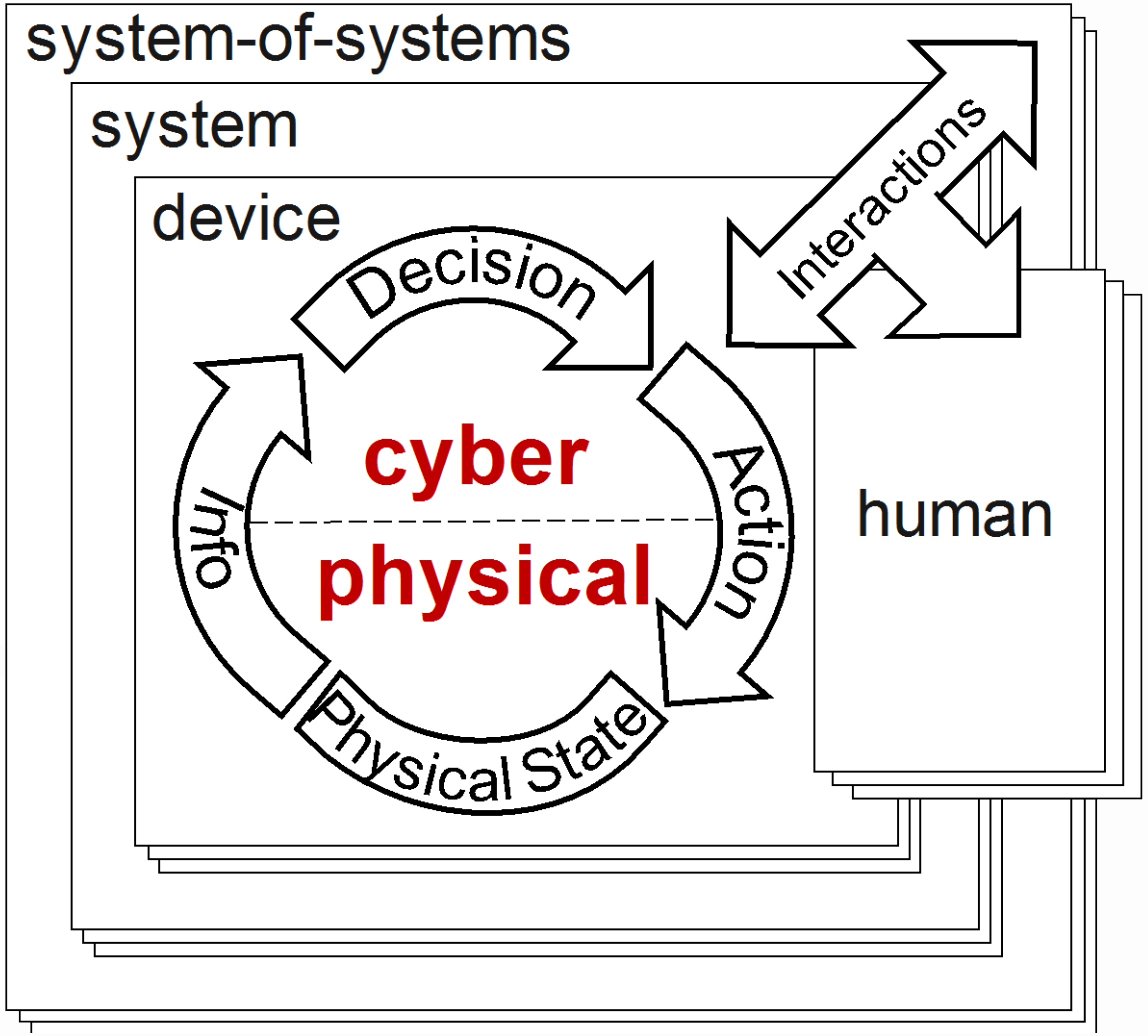
* Not included: Associates, contractors, other NIST, Federal, corporate, university partners

SG & CPS Program Strategy



Cyber-Physical Systems

Cyber-Physical Systems (CPS) comprise interacting digital, analog, physical, and human components engineered for function through integrated physics and logic.

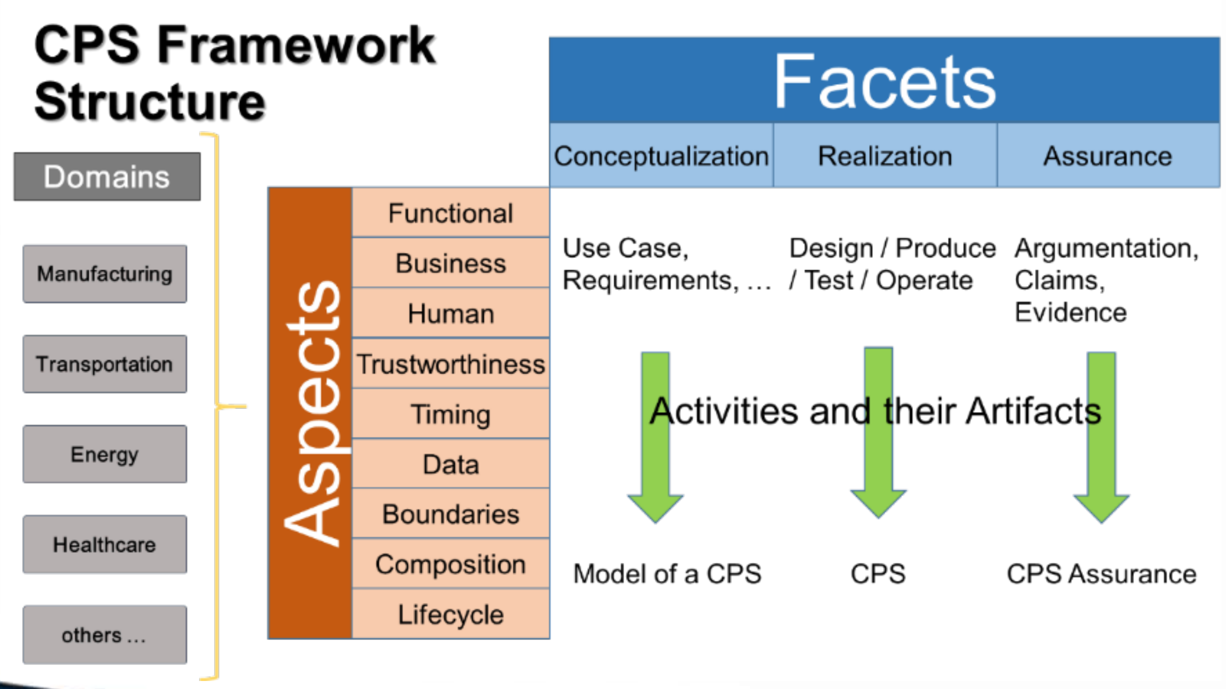


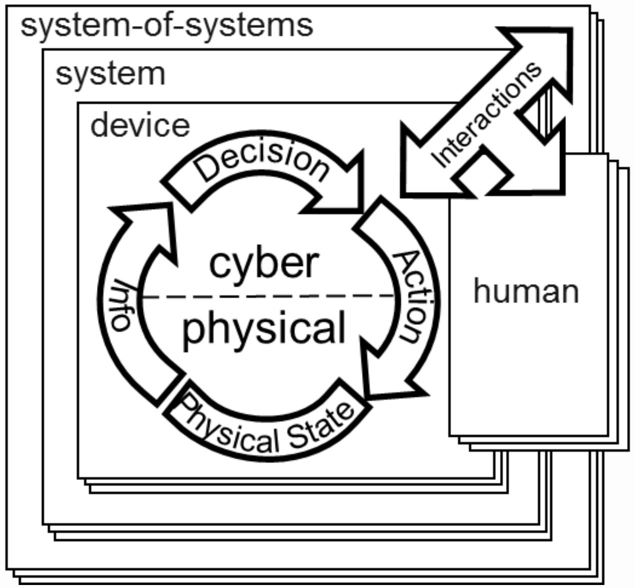
- Examples include a smart grid, a self-driving car, a smart manufacturing plant, an intelligent transportation system, a smart city, and Internet of Things (IoT) instances connecting new devices for new data streams and new applications.
- Common notions of IoT have emphasized networked sensors providing data streams to applications.
- CPS concepts complete these IoT notions, providing the means for conceptualizing, realizing and assuring all aspects of the composed systems of which sensors and data streams are components.

The Framework for Cyber-Physical Systems was released by the NIST CPSPWG on May 26, 2016

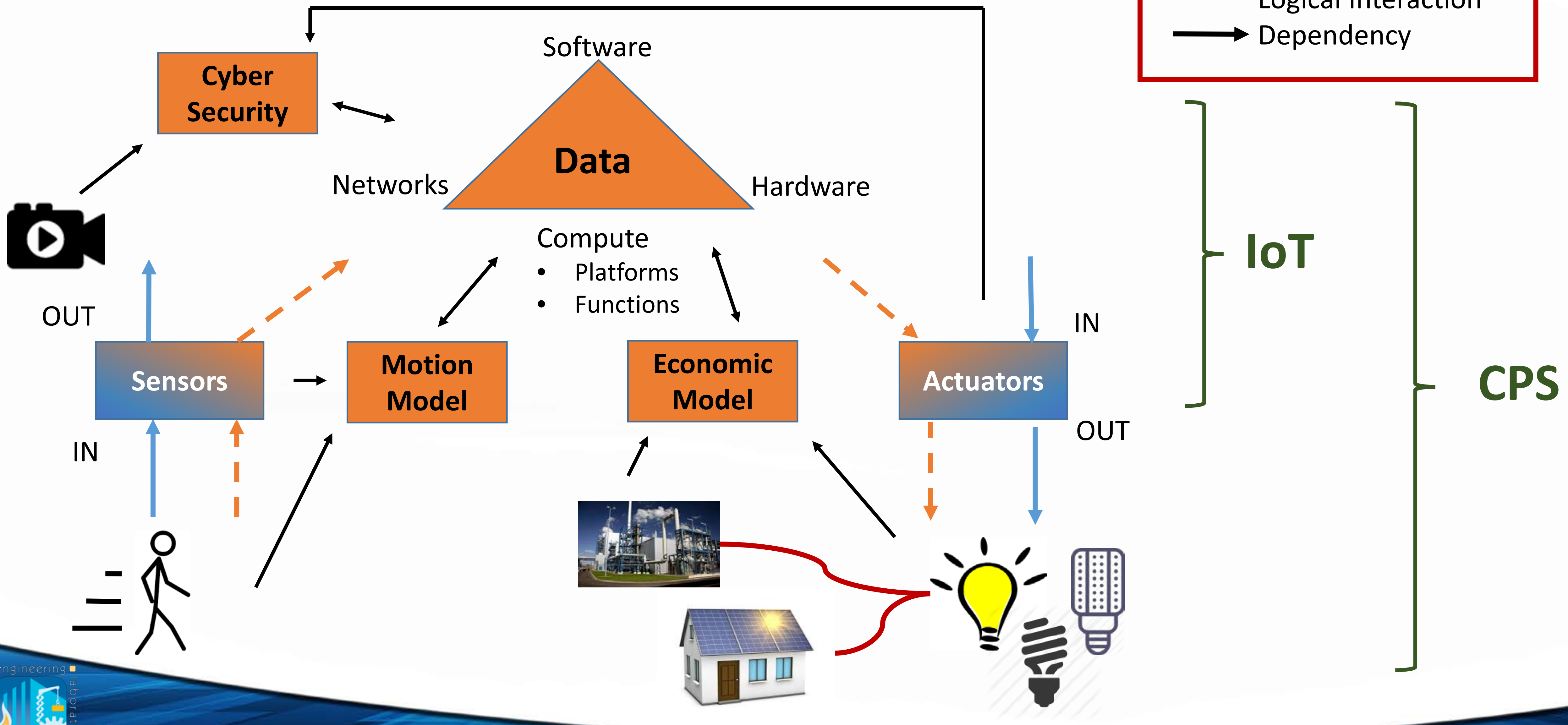
Foundations

- **NIST Cyber-Physical Systems (CPS) Framework**
  NIST CPS Public Working Group (5 working groups, led by industry, academia and NIST co-chairs) produced CPS Framework, published as NIST SP 1500-201 and 1500-202.

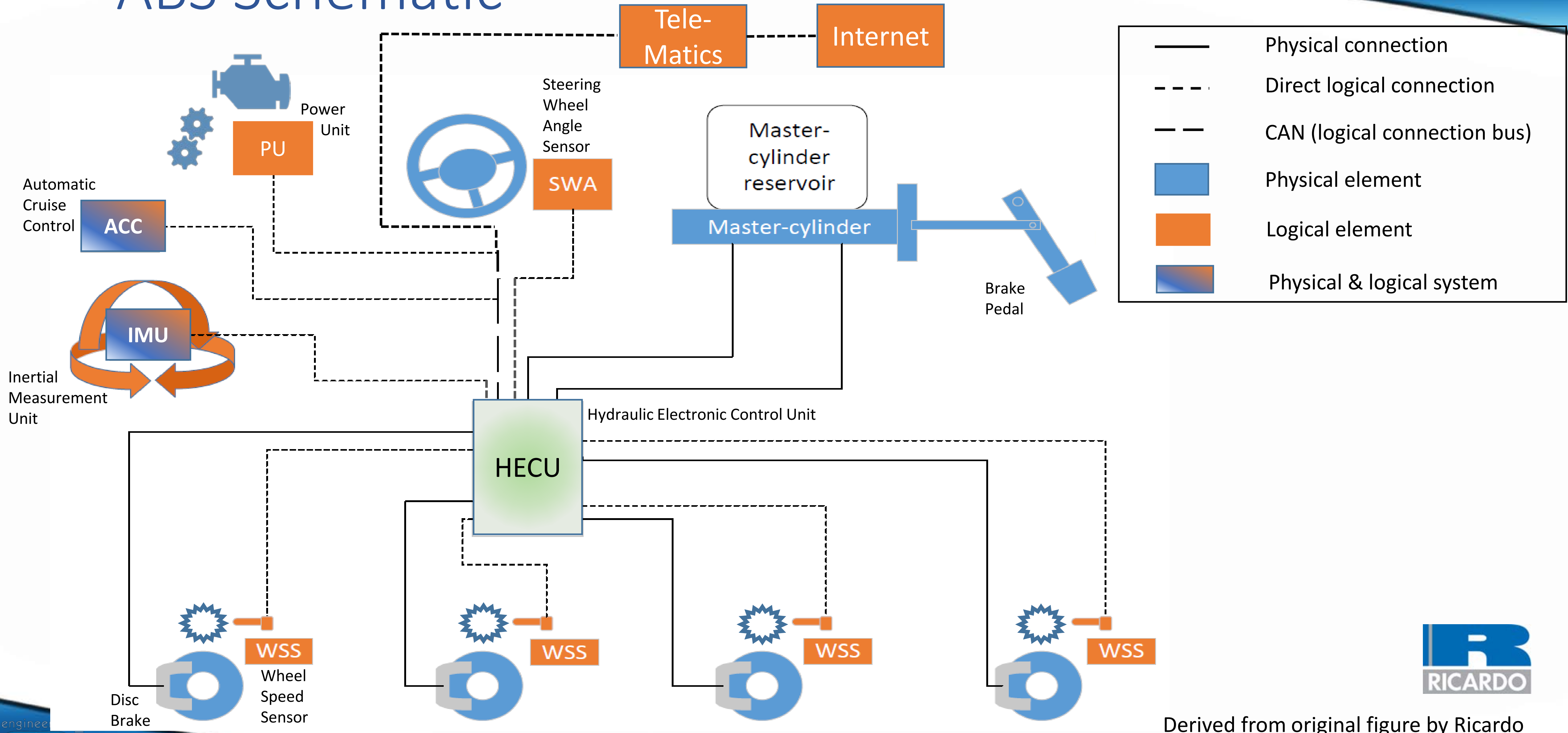




CPS vs IoT by Example:
Home Energy Management System



ABS Schematic



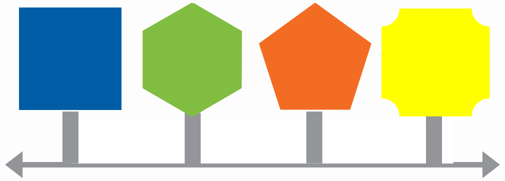
Derived from original figure by Ricardo
www.ricardo.com

Experiment/Testbed

UCEF Federated Testbed Architecture

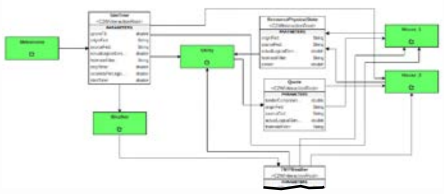
- Integrative
  - Able to combine unlike things
    - sectors such as energy, transportation, …
    - real and virtual components such as simulations, external systems, hardware in the loop
    - technologies including Java, C++, MatLAB, LabVIEW, …

- Reconfigurable and Reproducible
  - Composable experiments with the “federate” interface model
  - Experiment orchestration language, Courses of Action (COA)
  - Communications and other co-simulation



- Scalable
  - Small sets of components up to large collections

- Usable
  - Partition experiment design from experiment component design
  - Allows designer focus on component implementation
  - Proprietary components can be exposed by designed experiment interfaces



Applications

Global City Teams Challenge

GCTC: Over 160 Participating Cities and Communities

Examples:

- Saitama (Japan)
- Shirahama (Japan)
- Portland, OR
- Newport News, VA
- Greenville, SC
- Raleigh, NC
- Montgomery County, MD
- Winooski, VT
- San Mateo County, CA
- New York, NY

- Washington, DC
- Columbus, OH
- Kansas City, MO
- Nashville, TN
- Austin, TX
- Amsterdam (Netherlands)
- Genova, Perugia (Italy)
- Coruna, Valencia (Spain)
- Saint-Quentin (France)
- Abuja City, Obia-Akpor City (Nigeria)
- Busan, Seoul, Daegu (Korea)

And, over 400 companies, universities, non-profits, government agencies

Visit www.globalcitychallenge.org for the full list of participating cities in 2016-2017

GCTC 2016 Partners

NIST

GLOBAL CITY TEAMS CHALLENGE

us ignite

NATIONAL SCIENCE FOUNDATION

INTERNATIONAL TRADE ADMINISTRATION

U.S. DEPARTMENT OF TRANSPORTATION

U.S. DEPARTMENT OF STATE

GSA

NCO National Coordination Office

United States Census Bureau

NAT. TELECOMMUNICATIONS & INFORMATION ADMIN.

U.S. DEPARTMENT OF HOMELAND SECURITY

FIWARE

WeGO World e-Governments Organization of Cities and Local Governments

industrial internet CONSORTIUM

METROLAB NETWORK

R20 REGIONS OF CLIMATE ACTION

ICMA

pti Public Technology Institute

USGBC

current powered by GE

IBM

intel

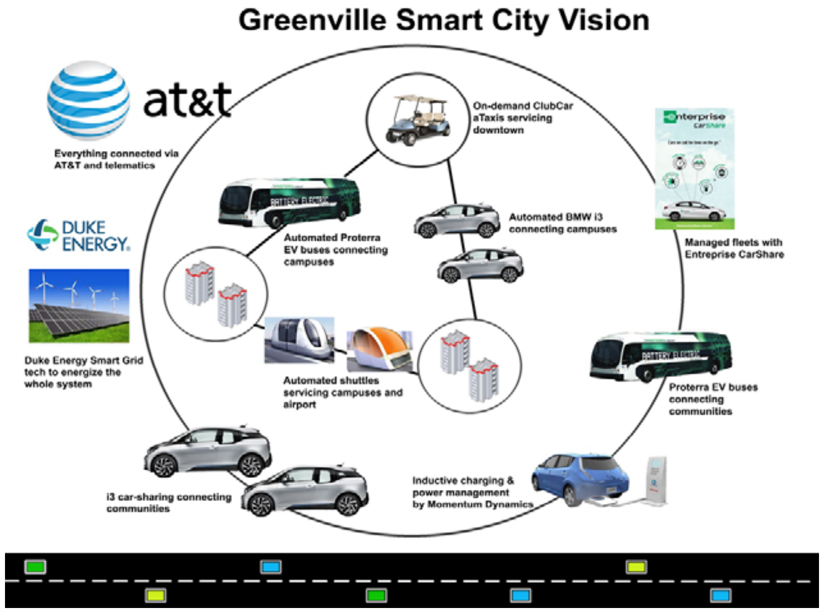
ch2m

QUALCOMM

verizon

URBAN-X BY MINI & HAX FUTURES


LinkNYC by City Bridge
First-of-its-kind communications network that will bring the fastest available municipal Wi-Fi to millions of New Yorkers and visitors
Source:
New York City, Qualcomm Incorporated, Titan360, Control Group, COMARK Corporation, Antenna Design


Greenville Smart City Vision
at&t
Everything connected via AT&T and telematics
DUKE ENERGY.
Duke Energy Smart Grid tech to energize the whole system
On-demand ClubCar aTaxis servicing downtown
Automated Proterra EV buses connecting campuses
Automated BMW i3 connecting campuses
Managed fleets with Entreprise CarShare
Automated shuttles servicing campuses and airport
Proterra EV buses connecting communities
i3 car-sharing connecting communities
Inductive charging & power management by Momentum Dynamics


StormSense Project
Forecasting Flooding from Storm Surge, Rain, and Tide
Partners (as of April 2016):
Newport News
VIMS
HAMPTON VA
PORTSMOUTH
NORFOLK
Virginia Beach
CHESAPEAKE Virginia
York County
WILLIAMSBURG
CHRISTOPHER NEWPORT UNIVERSITY
WETLANDS WATCH
VDH


SMART MOBILE OPERATION: OSU TRANSPORTATION HUB (SMOOTH)
The Ohio State University
Center for Automotive Research
First Mile/Last Mile Solutions
On demand automated vehicles will move passengers the first mile to the bus stop and the last mile from the bus stop (bottom picture).
Scheduled or on demand vehicles will move passengers through a closed loop within OSU campus (through roads and pedestrian areas, top picture).
The vehicles will:
– use automated driving technology;
– use V2V communication for convoy driving;
– be equipped with vulnerable road user protection technology enabling them to function in pedestrian zones.
SMOOTH will keep track of vehicles and guide them.
Smartphone applications will be developed to schedule and track the on-demand automated vehicles.
PARTNERS
Ohio State University - Center for Automotive Research
City of Columbus
Mid-Ohio Regional Planning Commission (MORPC)
Team ARIBO
Location: Columbus, Ohio
Automating the First and Last Miles

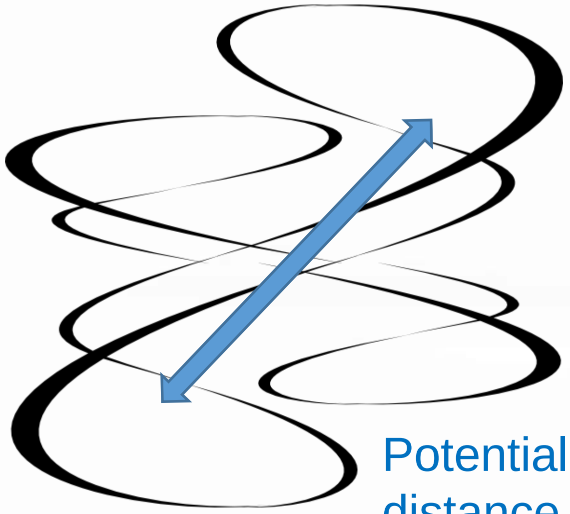
Applications - IoT-Enabled Smart City Framework

- Smart City technologies are being developed and deployed at a rapid pace and most smart city deployments are custom solutions.
- A number of architectural design efforts are underway worldwide but have not yet converged.
- NIST and its partners convened a public working group to distill a common set of architectural features from these architectural efforts and city stakeholders.

Goal: Facilitate the development of incremental and composable Smart Cities

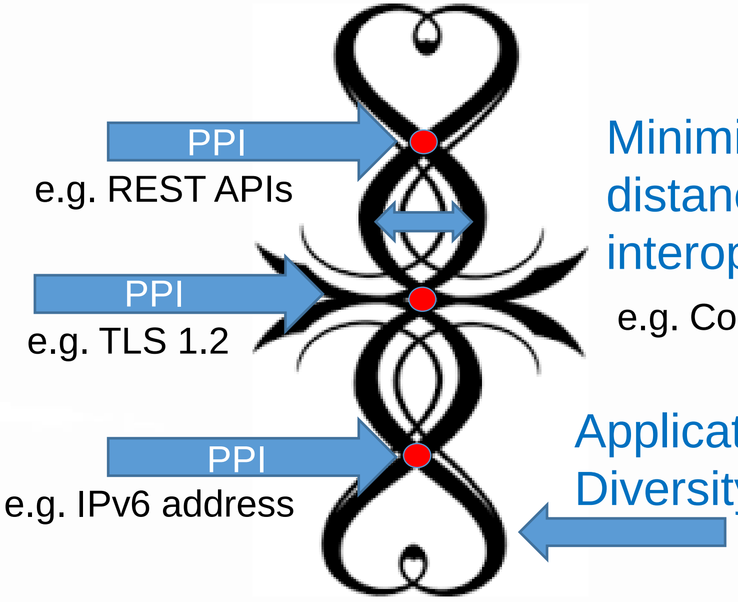
Pivotal Points of Interoperability (PPI)

Independent technology deployments



Potentially large distance to interoperability

With Pivotal Points of Interoperability



Minimize distance to interoperability

e.g. Convert XML to JSON

Application Diversity

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11:50 PM LUNCH

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All

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Chris Greer

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Smart Grid Program Overview
Federal Advisory Committee Presentation

Avi Gopstein

Smart Grid Program Manager

Smart Grid and Cyber-Physical Systems Program Office
National Institute of Standards and Technology

U.S. Department of Commerce

August 17, 2017

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

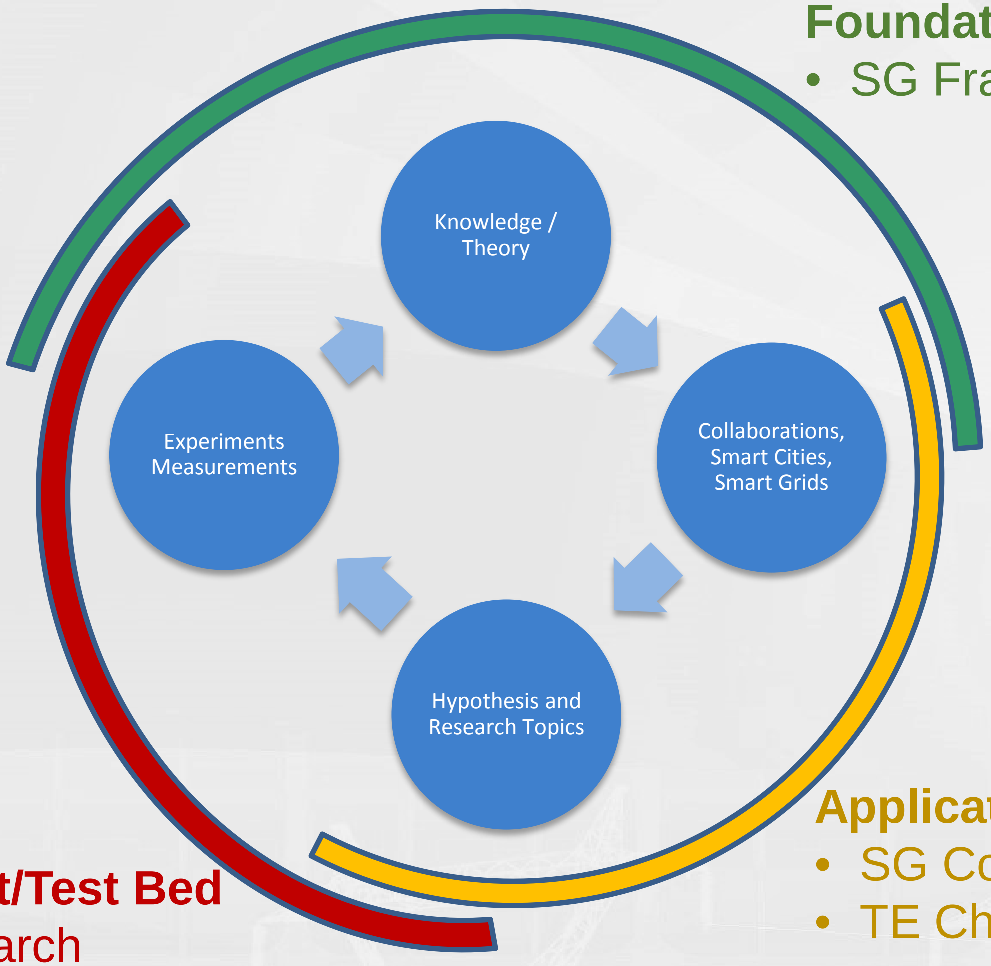
NIST's Mission

To promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life

Energy Independence and Security Act

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…"*

SGCPS Program Strategy

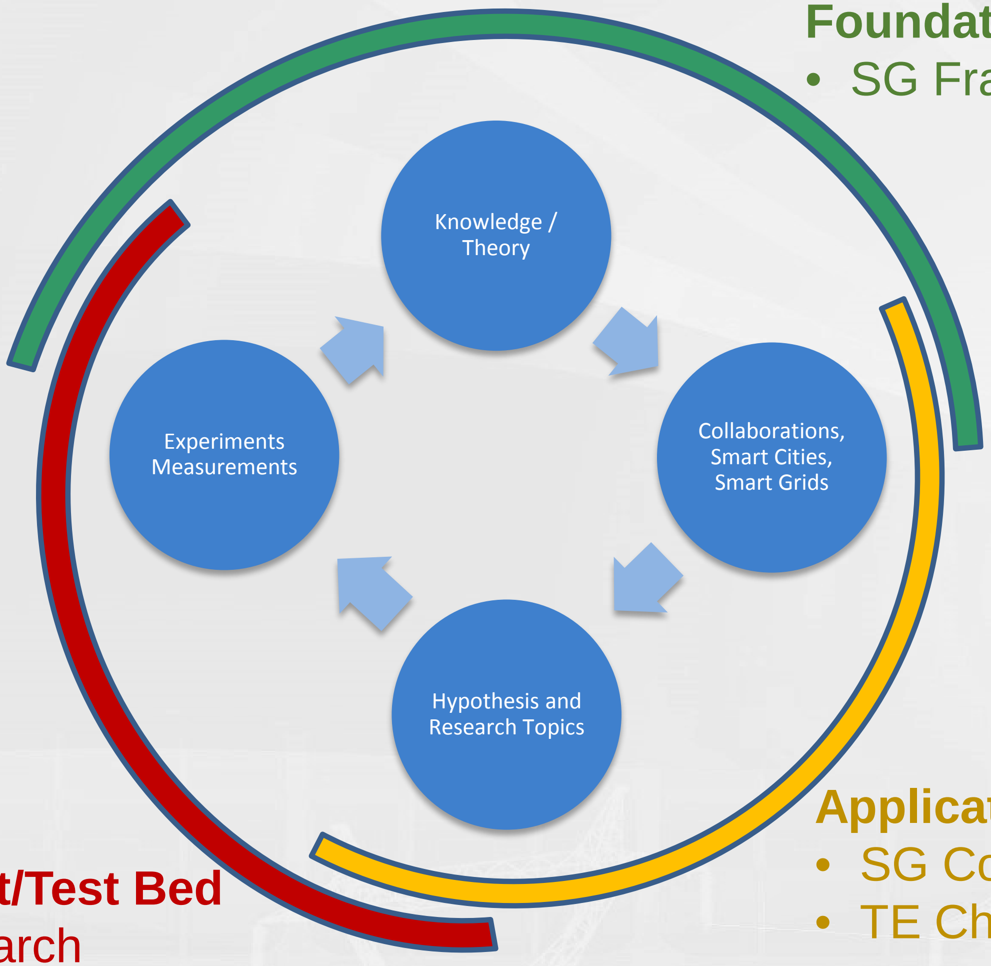


Foundations
- SG Framework

Applications
- SG Coordination
- TE Challenge

Experiment/Test Bed
- SG Research
- SG Test Bed

Smart Grid Program Overview



Foundations
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- TE Challenge

Experiment/Test Bed
- SG Research
- SG Test Bed

Coordination

- Standards development
- SGIP / SEPA
- Interoperability Framework V4

Experimental facilities

- Smart Grid Testbed
- Testbed commissioning & integration
- Expanding capabilities

Research

- Integrated research, common objectives
- Monitoring and Control
- Cybersecurity
- Communications & timing
- Operations and economics

Smart Grid Program

Program Manager: Avi Gopstein

	FY17 Allocation
*Program**:	*$4.28 M*
SGIP/SEPA:	*$1.20 M*
Transfer to other NIST labs:	*$3.06 M*
Total:	**$8.54 M**

Objective: To improve the efficiency, sustainability, economics, and resiliency of the nation's electric grids by developing and demonstrating advances in measurement science to improve grid interoperability and facilitate the use of the distribution grid as an enabling platform for modern energy services.

NIST Smart Grid Program – Budgetary Structure

Smart Grid Program
Smart Grid Test Bed
Smart Grid System Testbed Facility (SL SGP) - Boynton
Power Conditioning Systems for Renewables, Storage, and Microgrids (PML) - Hefner
National Coordination + Strategy
Smart Grid Secretariat (EL SGP) - Gopstein
Smart Electric Power Alliance (EL SGP) - Nguyen
Smart Grid Testing and Certification (EL SGP) - Nguyen
Smart Grid Projects
Cybersecurity for Smart Grid Systems (ITL) - Hastings
Smart Grid Communication Networks (CTL) - Griffith
Smart Grid Communication Networks (ITL) - Gharavi
Precision Timing for Grid Systems (ITL) - Li-Baboud
Wide-area Monitoring and Control of Smart Grid (PML) - FitzPatrick
Electromagnetic Compatibility (CTL) - Ladbury
Building Integration with Smarg Grid (EL) - (*not incl. $300k EIB) - Holmberg/Gopstein
Quantifying Key Economic Issues in the Smart Grid (EL AEO) - O'Fallon

Experimental Facilities

Coordination

Research

COORDINATION

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

External Coordination: Frameworks

NIST Special Publication 1108

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0

Office of the National Coordinator for Smart Grid Interoperability

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

2010

NIST Special Publication 1108R2

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0

Office of the National Coordinator for Smart Grid Interoperability,
Engineering Laboratory
in collaboration with
Physical Measurement Laboratory
and
Information Technology Laboratory

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

2012

This publication is available free of charge from http://dx.doi.org/10.6028/NIST.SP.1108r3

NIST Special Publication 1108r3

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0

Smart Grid and Cyber-Physical Systems Program Office
and Energy and Environment Division,
Engineering Laboratory

in collaboration with
Quantum Measurement Division,
Semiconductor and Dimensional Metrology Division,
and Electromagnetics Division,
Physical Measurement Laboratory
and
Advanced Network Technologies Division
and Computer Security Division,
Information Technology Laboratory

http://dx.doi.org/10.6028/NIST.SP.1108r3

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

2014

Interoperability Framework V1

NIST Special Publication 1108

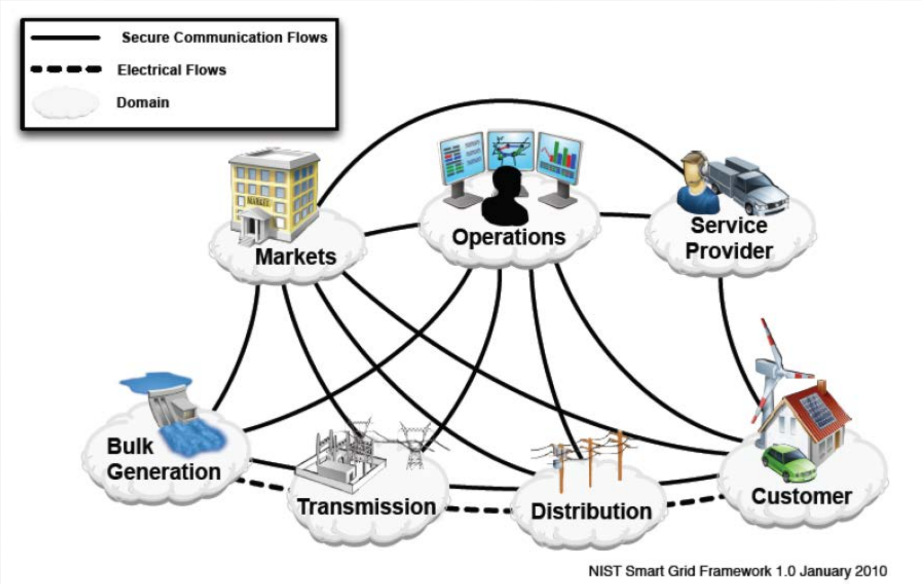
NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0

Office of the National Coordinator for Smart Grid Interoperability

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

2010

Introduced grid domains

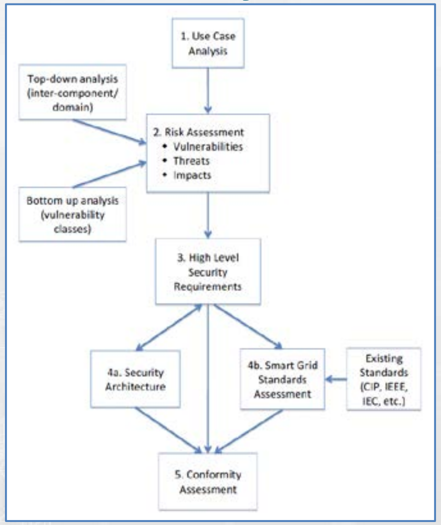


Explored network information exchange

Identified 25 standards

	Standard	Application	Comments
Standards and Specifications			
1	ANSI/ASHRAE 135-2008/ISO 16484-5 BACnet - A Data Communication Protocol for Building Automation and Control Networks http://resourcecenter.ashrae.org/store/ashrae/newstore.cgi?itemid=30853&view=item&page=1&loginid=39839941&priority=none&words=135-2008&method=and&	BACnet defines an information model and messages for building system communications at a customer's site. BACnet incorporates a range of networking technologies to provide scalability from very small systems to multi-building operations that span wide geographic areas using IP protocols.	Open, mature standard with conformance testing developed and maintained by an SDO. BACnet is adopted internationally as EN ISO 16484-5 and used in more than 30 countries. This standard serves as a customer side communication protocol at the facility interface and is relevant to the Price, DR/DER, and Energy Usage PAPs (see Sec. 5.5 - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP03PriceProduct , Sec. 5.4 - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP09DRDER, and Sec. 5.3- http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP10EnergyUsagetoEMS).
2	ANSI C12 Suite : ANSI C12.1 http-p://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+C12.1-2008 ANSI C12.18/IEEE P1701/MC1218 http://webstore.ansi.org/FindStandards.aspx?SearchString=c12.18&SearchOption=0	Performance and safety type tests for revenue meters. Protocol and optical interface for measurement devices.	Open, mostly mature standards. It is recognized that ANSI C12.19 is an extremely flexible revenue metering model that allows such a wide range of options that requests for actionable information from a meter, such as usage in kilowatt hours, requires complex programming to secure this information. ANSI C12.19 2008 has a mechanism by which table choices can be described, termed Exchange Data Language (EDL), that can be used to constrain oft-utilized information into a well-known form. A Priority Action Plan (PAP) has been set up to establish common data tables for meter information that will greatly reduce the time for

… and cyber



Interoperability Framework V1

Smart Grid Interoperability Panel

- Created SGIP as public-private partnership
- Became a major force alongside NIST
  - **Priority Action Plans**
    - Working Groups formed to address gaps
    - Targeted deliverables
      - map to existing standards
      - new standards
  - **Catalog of Standards**
    - 81 standards
    - navigation tool
- Detailed discussion later today

SGIP's Smart Grid Catalog of Standards

Full List of Standards by Entry Number

SGIP Catalog of Standards	Date
1. ANSI C12.1-2008 listed Sept 5 2012	10/15/2014
2. ANSI C12.18-2006 listed Sept 5 2012	10/15/2014
3. ANSI C12.19-2008 listed Sept 5 2012	10/15/2014
4. ANSI C12.19-2012-dated 2014-10-07	08/17/2015
5. ANSI C12.20-2010 listed Sept 5 2012	10/15/2014
6. ANSI C12.21-2006 listed Sept 5 2012	10/15/2014
7. ANSI C12.22-2008 listed Sept 5 2012	10/15/2014
8. ASHRAE 135-2010 BACnet listed Nov 21 2011	10/15/2014
9. CEA-709.1-C-2014-02-14rev1	10/15/2014
10. CEA-709.2-A-2014-02-14rev1	10/15/2014
11. CEA-709.3-2014-02-14rev1	10/15/2014
12. CEA-709.4-2014-02-14rev1	10/15/2014
13. CEA-852.1-2014-02-14rev1	10/15/2014
14. CEA-852-B-2014-02-14rev1	10/15/2014
15. CEA-CEDIA-CEB29- dated 2012-03-01v1	10/15/2014
16. IEC 15067.3-dated 2012-11-05	08/17/2015

SGIP Catalog of Standards	Date
43. IEC 62351-8-dated 2014-03-21	08/17/2015
44. IEC-62541 Parts 1-7 listed Nov 2013	10/15/2014
45. IEEE 1377-dated 2011-02-02	08/17/2015
46. IEEE 1701	10/15/2014
47. IEEE 1815-2010 listed Dec 31 2011	10/16/2014
48. IEEE 1901-2010 listed Jan 31 2013	10/16/2014
49. IEEE C37.238	10/16/2014
50. IEEE C37.239-2010 listed May 4 2012	10/16/2014
51. IEEE1901.2-dated 2011-09-02L	08/17/2015
52. IETF RFC 6272 listed July 7 2011	10/16/2014
53. ITU-T G.9960	10/16/2014
54. ITU-T G.9972	10/16/2014
55. MultiSpeak® Security V1.0-dated 2013-12-05	10/16/2014
56. MultiSpeak® V3.0-dated 2013-12-05v1	10/16/2014
57. NAESB REQ 19	10/16/2014
58. NAESB REQ 21	10/16/2014

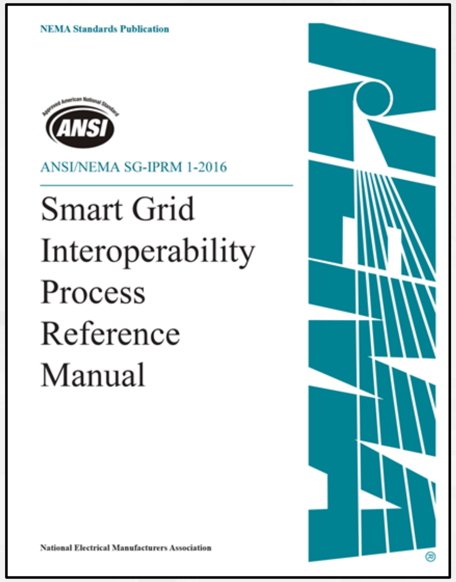
Interoperability Framework – Moving forward

- Subsequent frameworks updated and expanded on issues
- Significant changes across industry since 2014
- To be continued…

External Coordination: Standards

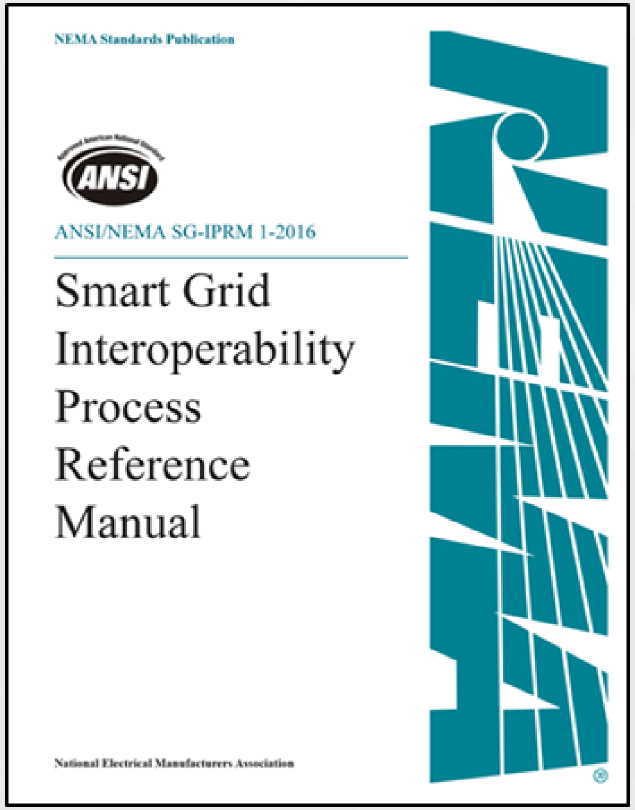
<u>Every</u> Research Project

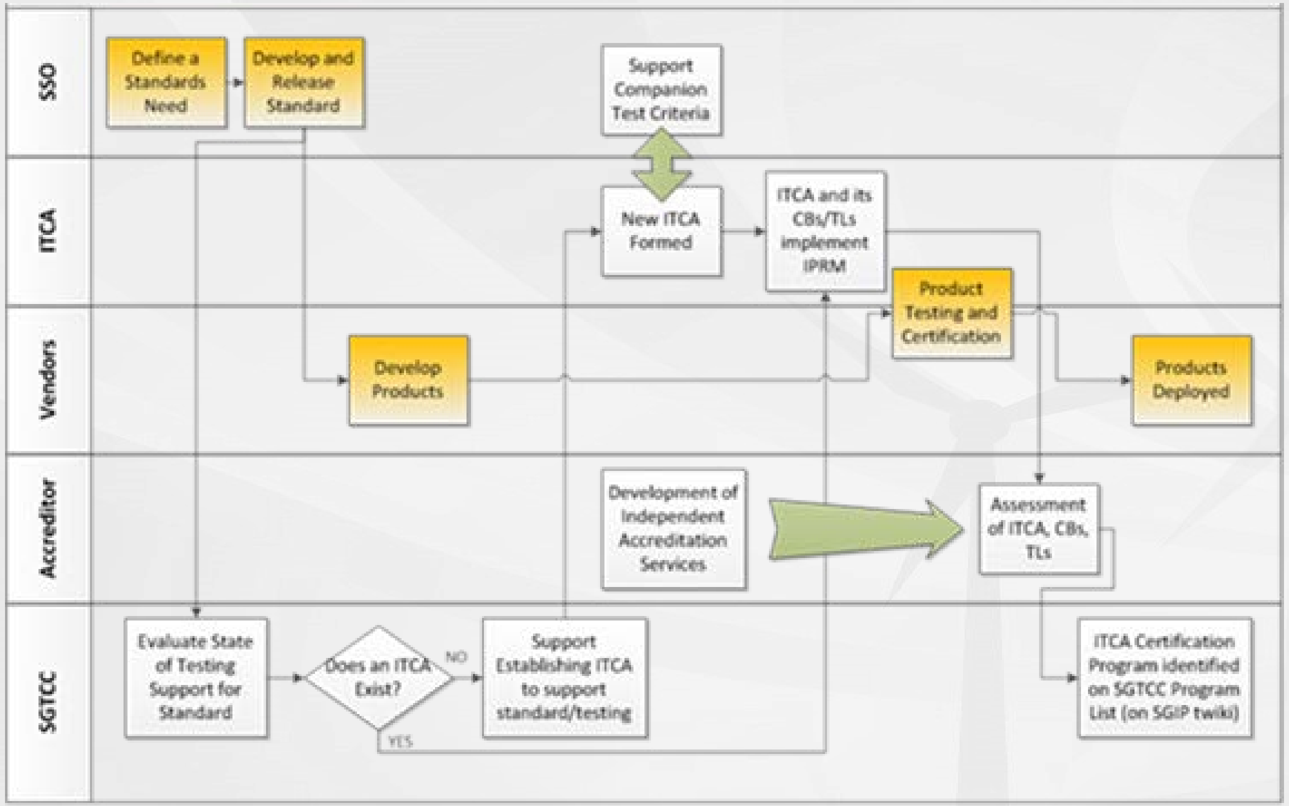
- Successes:
  - NEMA Interoperability Process Reference Manual (IPRM)
  - IEEE Std. 21451-001-2017: Recommended Practice for Signal Treatment Applied to Smart Transducers
  - Published ANSI C12.20 standard on electricity metering requirements, including harmonics (WAMC)
  - International ballots initiated for approval of OpenADR 2.0 (enables demand response) (BISG)
  - ASHRAE/NEMA Facility Smart Grid Information Model (FSGIM) standard adopted by ISO (BISG)
  - Published IEC PC118 Technical Report 62939 TR Ed.1 Smart Grid User Interface (BISG)
  - Contributed Green Button utility tariff model to the CIM (BISG)
  - SGIP PAP 12 / IEEE 1815.1-2016 standard for exchanging information between networks (WAMC)



- Plans:
  - IEEE 1547.1 test specifications for DER including smart inverters (PCS)
  - IEEE / IEC 61850-9-3 Precision Time Protocol Power Profile Conformity Assessment Steering Committee – test plan and methodology development (SGTC)
  - IEEE Microgrid Controller standards 2030.7 & 2030.8 (PCS)
  - Smart inverter functions required by IEEE 1547 are defined in IEEE 61850-7-420 and implemented in IEEE 2030.5 (PCS)
  - Continue promoting the international adoption of US/SGIP standards (SGNC)
  - Joint IEC/IEEE 60255-118-1 PMU standard (WAMC)
  - IEC 60859-13 Standalone Mus (WAMC)

Standards & NIST: NEMA IPRM

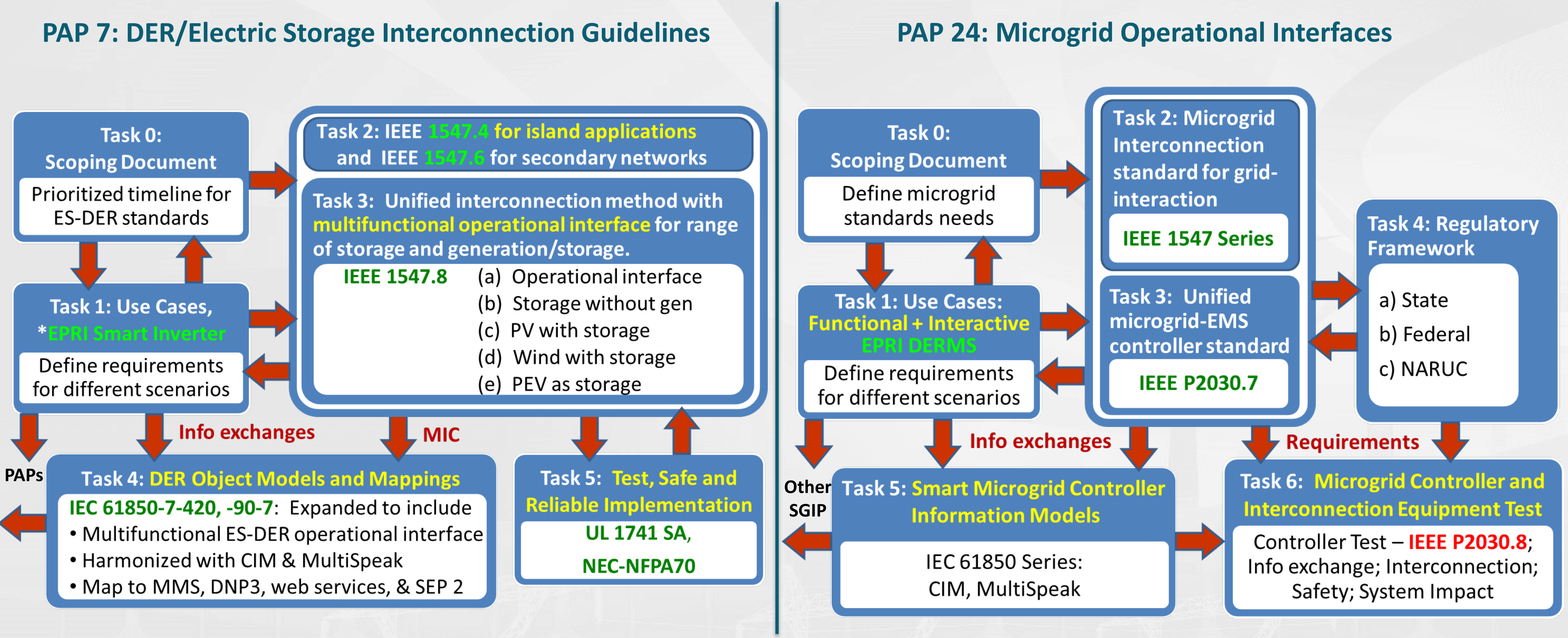




Recommended model for smart grid product testing flow

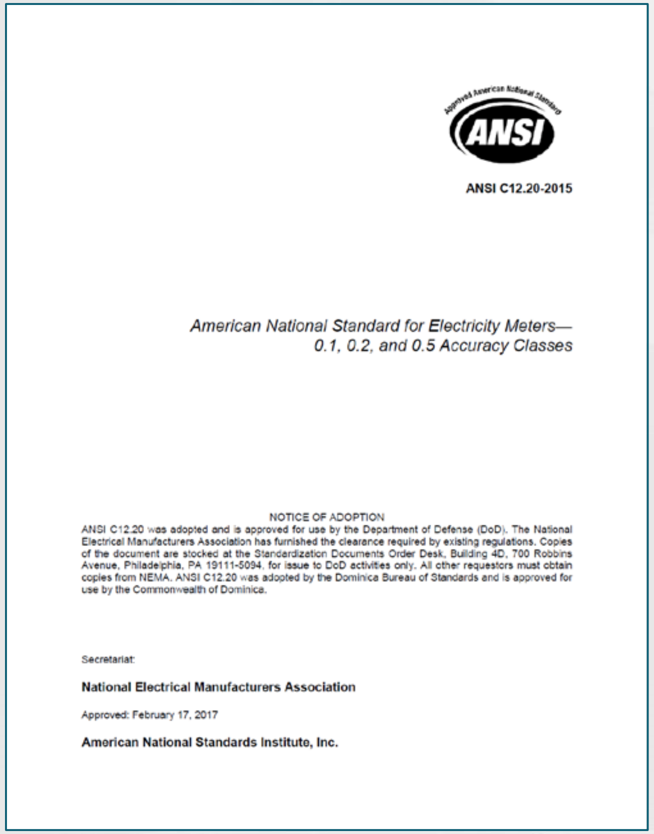
- Establishes a standard approach to understanding and evaluating interoperability for device manufacturers
- Developed under the SGIP SGTCC and NEMA Distribution and Automation section
- Chaired by NIST's Cuong Nguyen and NEMA's Steve Griffith

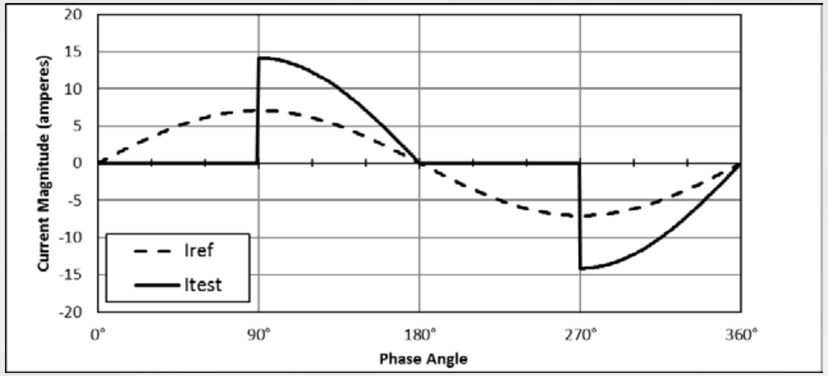
Standards & NIST: IEEE Inverter & Microgrid Controller



Primary Contributions by Al Hefner and NIST Associates

Standards & NIST: ANSI C12.20-2015

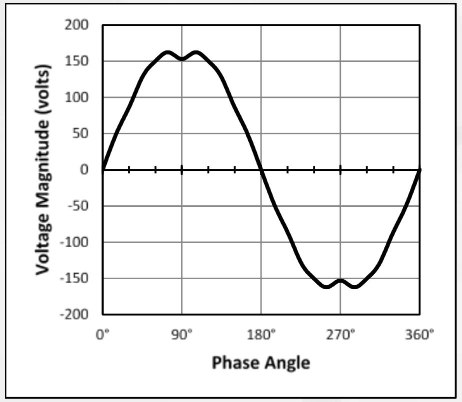




Condition	Voltage Waveform	Current Waveform	Maximum Deviation in Percent from Reference Performance		
			Accuracy Class		
			0.5	0.2	0.1
(1)	V_{ref} Sinusoidal	I_{ref} Sinusoidal	Reference	Reference	Reference
(2)	V_{ref} Sinusoidal	90 Degree Phase Fired Waveform	±0.5%	±0.3%	±0.2%

Test #39: 90 Degree phase fired waveform

Harmonic	Voltage Amplitude % V_{ref}	Phase	Current Amplitude % I_{ref}	Phase	Demand
1	100	0	100	0	100.00
3	3.8	0	30	180	-1.140
5	2.4	180	18	0	-0.432
7	1.7	0	14	180	-0.238
11	1.1	0	9	180	-0.099
13	0.8	180	5	0	-0.040
				Total Demand	98.051



Condition	Voltage Waveform	Current Waveform	Maximum Deviation from Reference Performance		
			Accuracy Class		
			0.5	0.2	0.1
(1)	V_{ref} Sinusoidal	I_{ref} Sinusoidal	Reference	Reference	Reference
(2)	V_{ref} Sinusoidal	Peaked Current Waveform	±0.5%	±0.3%	±0.2%
(3)	Peaked Voltage Waveform	Peaked Current Waveform	±0.8%	±0.5%	±0.3%

Test #41: Peaked waveform

- Creates a 0.1 accuracy class (±0.1%)
- Includes harmonic waveform testing
- ANSI C12/SC16 Committee chaired by NIST's **Shannon Edwards**
- ANSI C12 chaired by NIST's **Tom Nelson**

Standards & NIST: IEC PC 118

PC 118 Smart grid user interface

Scope: Standardization in the field of information exchange for demand response and in connecting demand side equipment and/or systems into the smart grid

- IEC TR 62939-1:2014 Smart grid user interface – Part 1: Interface overview and country perspectives
- IEC 62939-2 Smart grid user interface – Part 2: Architecture and requirements (CD in review)
- IEC 62939-3 Smart grid user interface – Part 3: Energy interoperation services (CD in review)
- IEC 62746-10-1 Systems interface between customer energy management system and the power management system – Part 10-1: Open Automated Demand Response (CDV ballot in progress)
- IEC 62746-10-3 Systems interface between customer energy management system and the power management system – Part 10-1: Adapting smart grid user interfaces to IEC CIM (CDV ballot in progress)

NIST involvement: Steven Bushby, David Holmberg

Standards & NIST Smart Grid Program

Information

BACnet (ISO 16484-5)

FSGIM (ISO 17800)

Green Button (NAESB REQ.21)

IEC PC118 (OpenADR)

IEEE 1815.1-2016

SAE J2836/3

IEEE 21451

Device & Measurement

ANSI C12.20-2015

IEC/IEEE 60255

IEC 60859

IEEE 1613.1

UL 1741

IEEE C37.118

IEEE C37.242

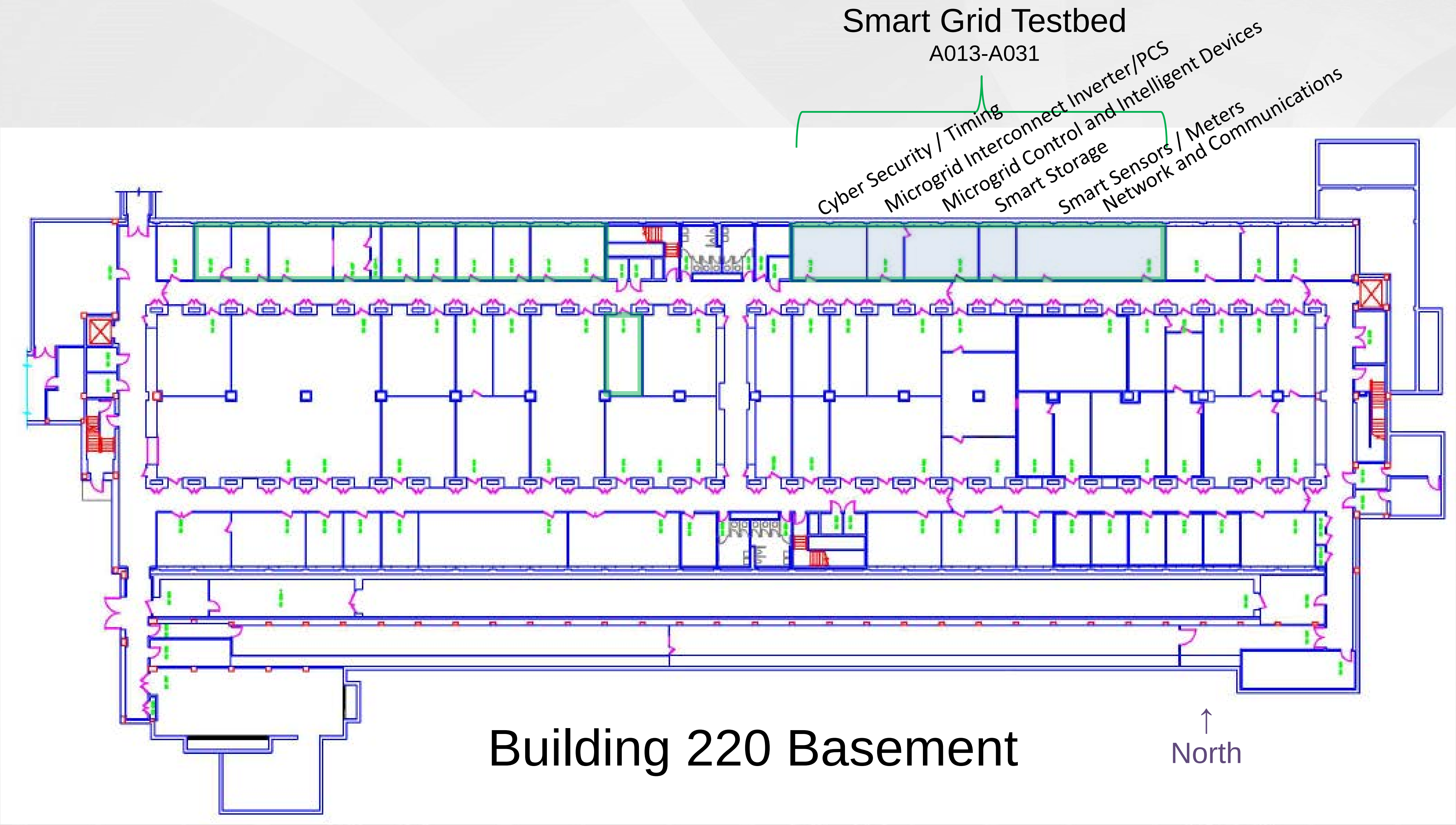
Operations

IEEE 1547.1
IEEE 1547.4
IEEE 1547.8
IEEE 2030.2
IEEE 2030.5
IEEE 2030.7
IEEE 2030.8
NEMA IPRM
IEC 61850-7
IEC 61850-9
IEEE C37.238

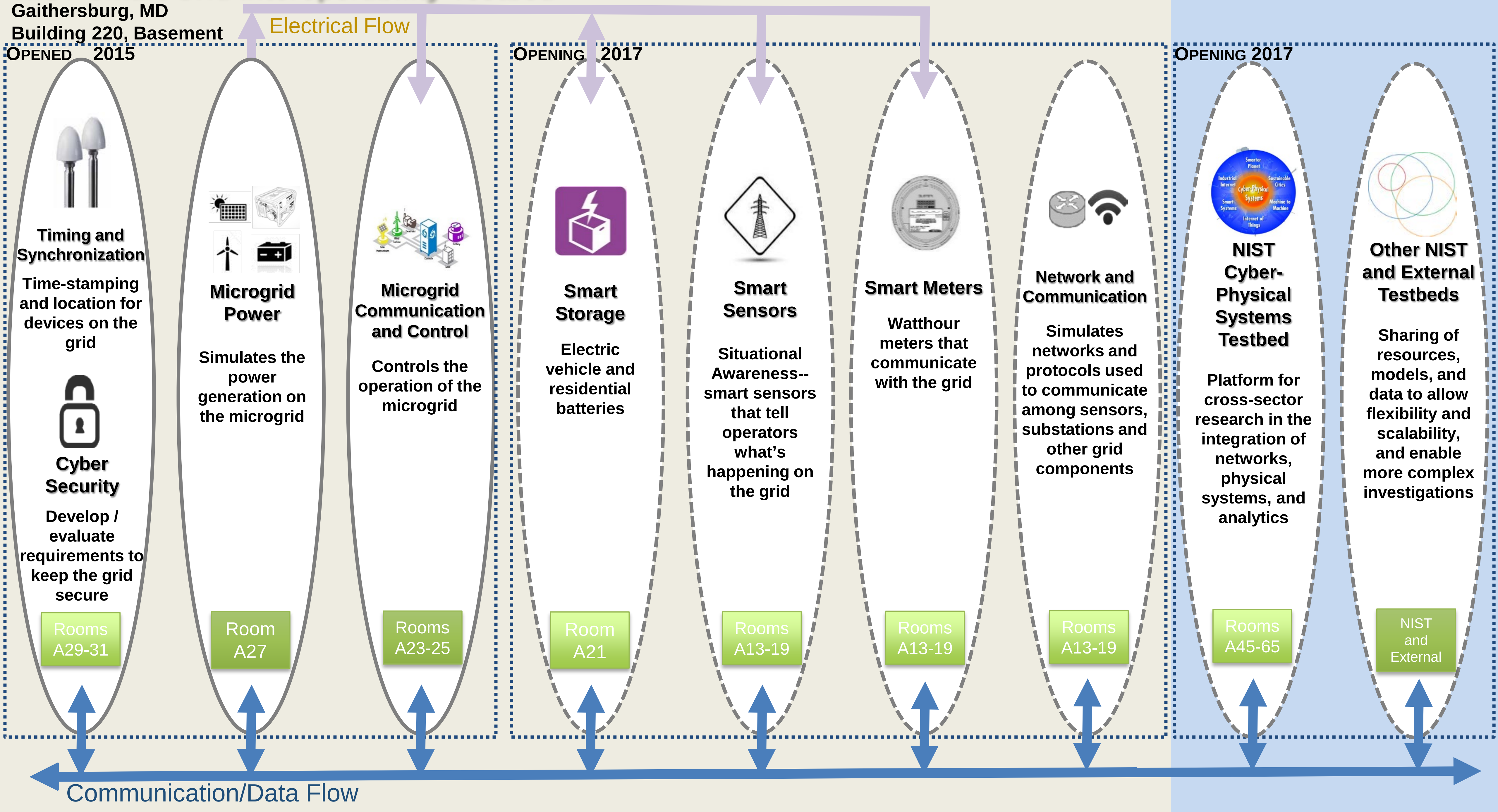
EXPERIMENTAL FACILITIES

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

Experimental Facilities: Smart Grid Testbed

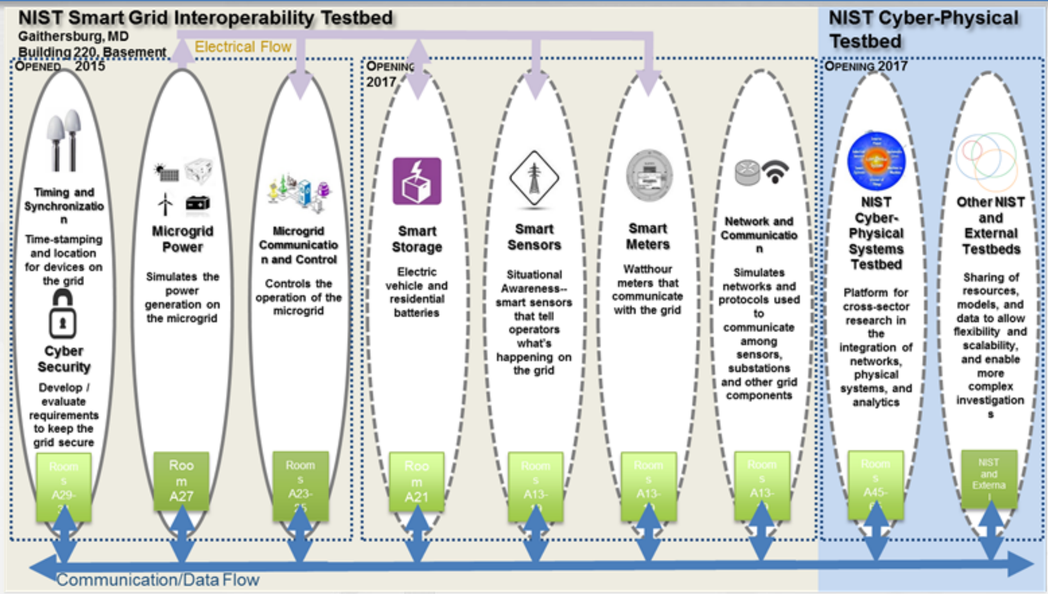


NIST Smart Grid Interoperability Testbed

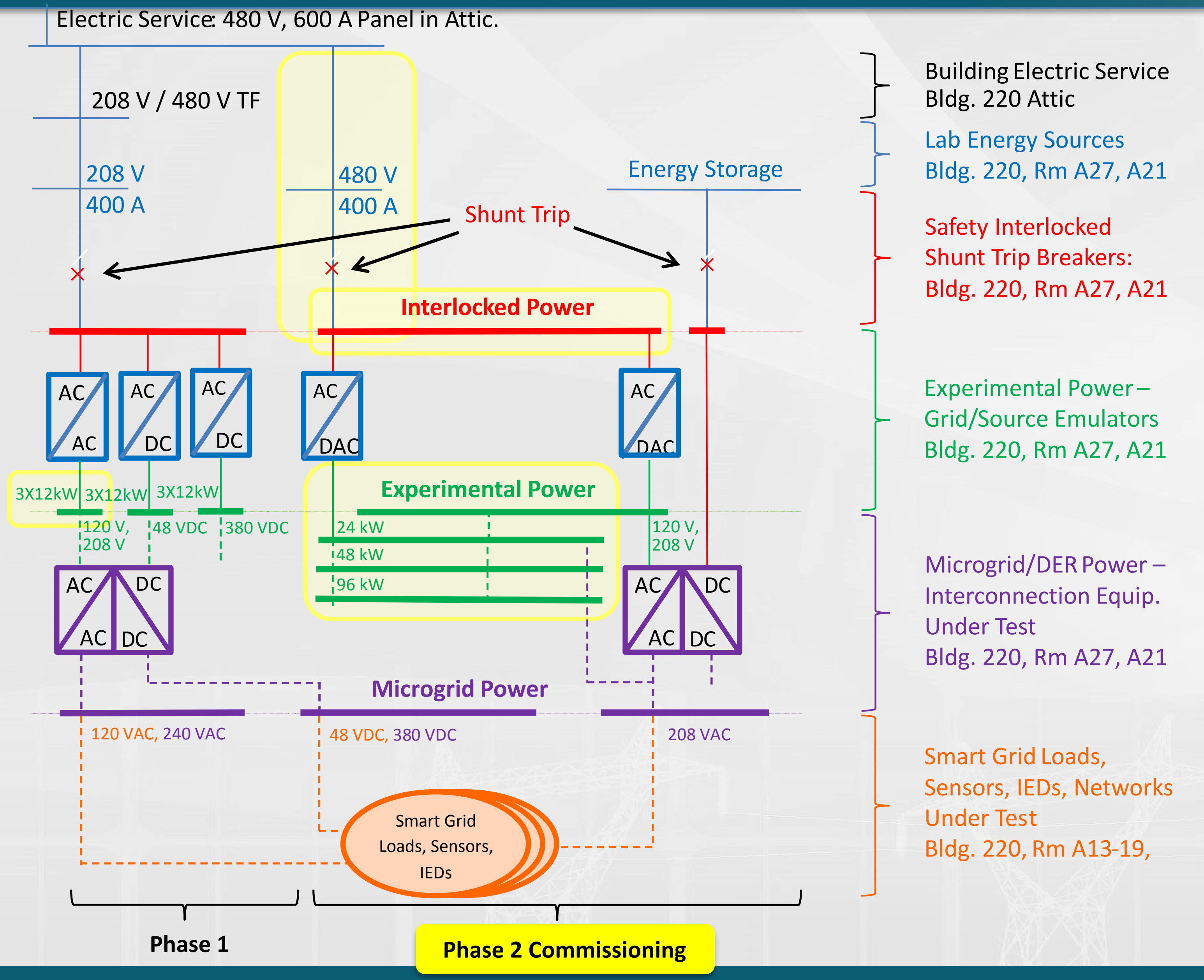


Experimental Facilities: Smart Grid Testbed

- Smart Grid Testbed Expansion expected to be completed this month (August 2017)
  - Followed by testing of the electrical power equipment and safety interlock system prior to commissioning.
  - Multi-OU safety coordination group reviewing all hazard reviews, safety incidents and concerns
  - Guidance document, operational processes, and safety manual are complete or near final draft form.
  - Hazard Reviews will begin after handoff from Plant
- FY18:
  - Microgrid Power to be extended into the Great Room
  - Hazard Reviews completed for A21 Smart Storage
  - Testbed Network operational across all testbed rooms
  - Develop testbed user management tool
  - Engage stakeholders / internal users to revise testbed vision



Experimental Facilities: Testbed commissioning



Key FY18 Plans

- Demonstrate conformance testing for smart inverter functions for 10 kW and 30 kW systems
- Acquire microgrid and DERMS controllers
- Demonstrate conformance test of advanced interactive microgrid controller functions
- Demonstrate interoperability testing and performance characterization of multiple DERs and loads

RESEARCH

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

Research: A bit of context

- 30 Researchers
- 9 Divisions
- 4 Laboratories

Smart Grid Projects
Cybersecurity for Smart Grid Systems (ITL) - Hastings
Smart Grid Communication Networks (CTL) - Griffith
Smart Grid Communication Networks (ITL) - Gharavi
Precision Timing for Grid Systems (ITL) - Li-Baboud
Wide-area Monitoring and Control of Smart Grid (PML) - FitzPatrick
Electromagnetic Compatibility (CTL) - Ladbury
Building Integration with Smarg Grid (EL) - (*not incl. $300k EIB) - Holmberg/Gopstein
Quantifying Key Economic Issues in the Smart Grid (EL AEO) - O'Fallon

This is just the research linkages

Does not include coordination, testbed, or external collaborations

Research: Common Themes

- Monitoring and Co[illegible]ol
- Cybersecu[illegible]
- Co[illegible] and Timing
- O[illegible]ns and Economics

NOT YET

RESEARCH: CYBERSECURITY

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

How to think about cybersecurity

This publication is available free of charge from http://dx.doi.org/10.6028/NIST.IR.7628r1

NISTIR 7628 Revision 1

Guidelines for
Smart Grid Cybersecurity

Volume 1 - Smart Grid Cybersecurity Strategy, Architecture, and High-Level Requirements

The Smart Grid Interoperability Panel – Smart Grid Cybersecurity Committee

http://dx.doi.org/10.6028/NIST.IR.7628r1

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

Framework for Improving
Critical Infrastructure Cybersecurity

Draft Version 1.1

National Institute of Standards and Technology

January 10, 2017

Draft NISTIR 8138

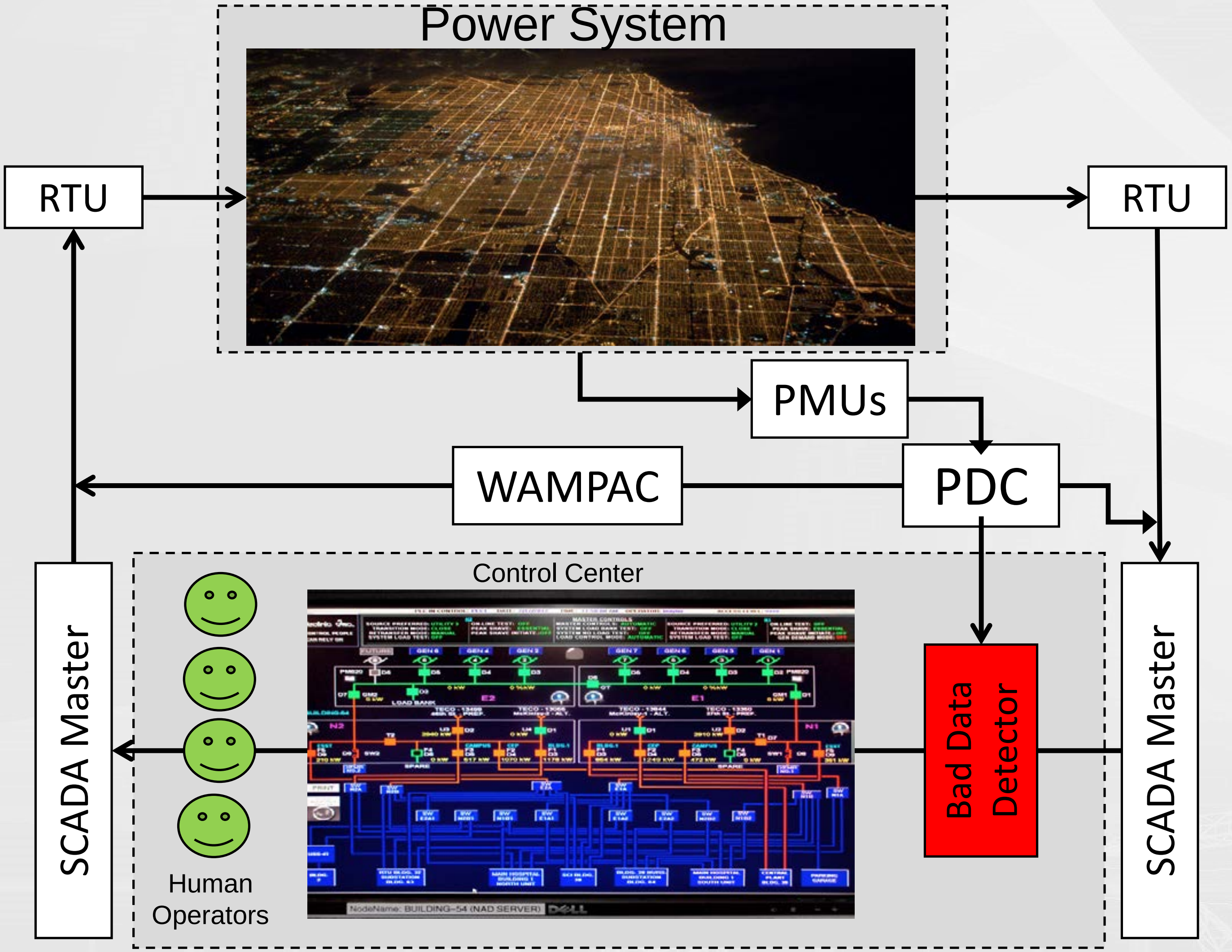
Vulnerability Description Ontology (VDO)

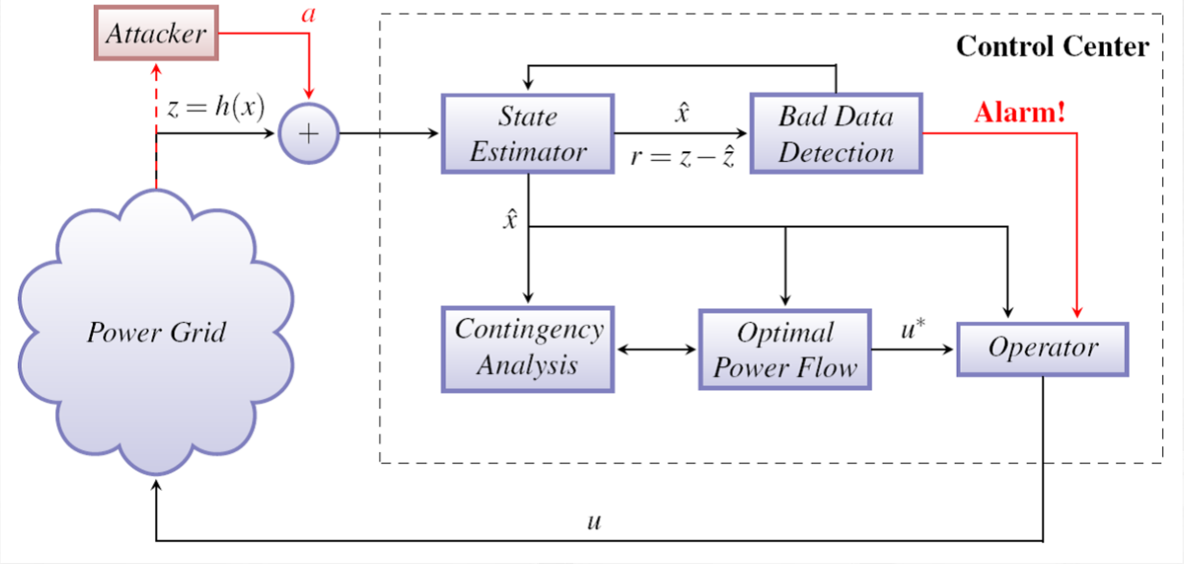
A Framework for Characterizing Vulnerabilities

Harold Booth
Christopher Turner

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

Characterizing cyber vulnerabilities by their physical impact





When sensors or sensor aggregators are attacked, the primary impact of the attack is on the state estimator. Inaccurate state estimates in turn may result in bad control decisions.

RESEARCH: COMMUNICATIONS

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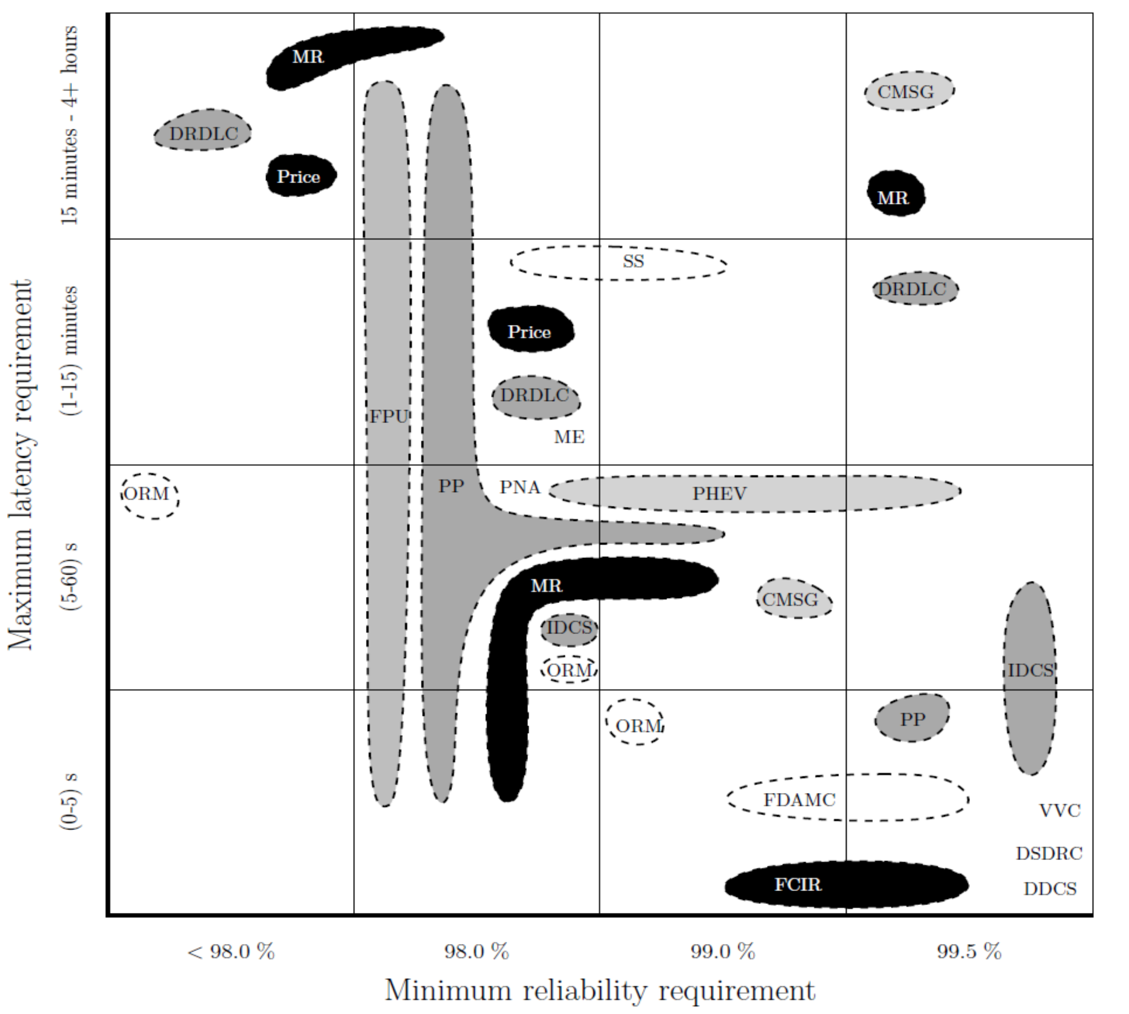
Varying QoS Requirements for Smart Grid Applications

- Right figure shows QoS requirements for a set of applications identified in the OpenSG Smart Grid Requirements matrix, as an outcome of Smart Grid Interoperability Panel (SGIP) Priority Action Plan 2 (PAP02)
- This calls for the study of future network technologies and architectures (5G, etc.) to support smart grid and other CPS



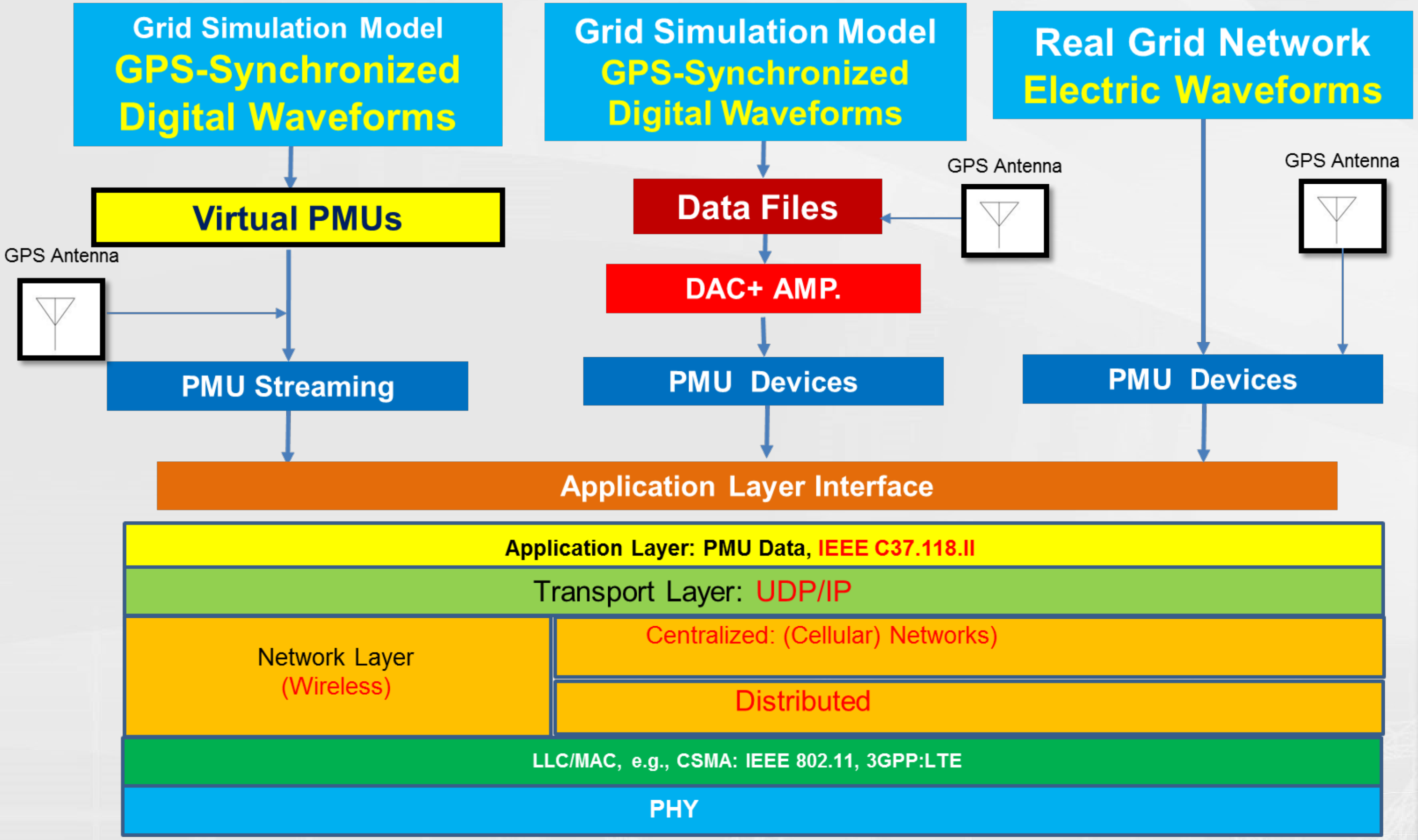
Use Cases

CMSG: Customer Information / Messaging
DDCS: Dispatch Distributed Customer Storage
DRDLC: Demand Response-Direct Load Control
DSDRC: Demand Response-Centralized Control
FCIR: Fault Clear, Isolation, and Reconfigure
FDAMC: Field Distribution Automation Maintenance-Centralized Control
FPU: Firmware/Program Update
IDCS: Islanded Distributed Customer Storage
ME: Meter Events
MR: Meter Reading
ORM: Outage Restoration Management
PHEV: Plug-in Hybrid Electric Vehicle
PNA: Premise Network Administration
PP: Prepay Price
SS: Service Switch
VVC: Volt/VAR-Centralized Control

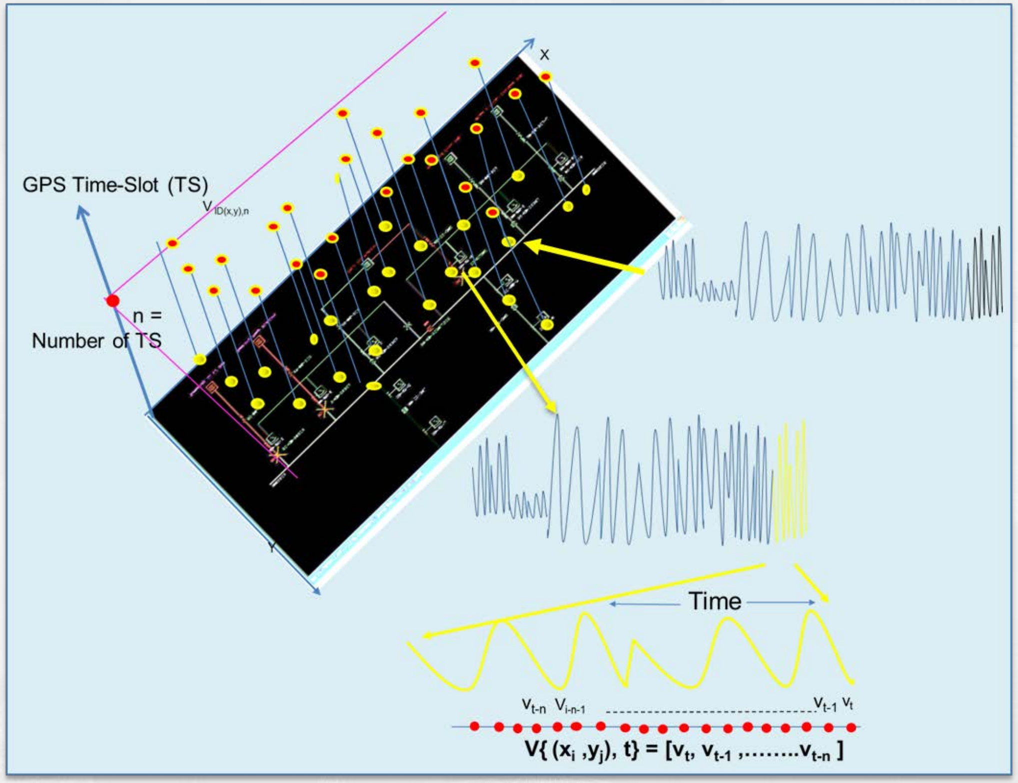
Figure: Major Smart Grid Use Cases, Categorized by Latency and Reliability Requirements
David Griffith, Michael Souryal, and Nada Golmie (NIST), "Wireless Networks for Smart Grid Applications," a Chapter in Book, Titled "Smart Grid Communications and Networking," Cambridge University Press, UK, 2012, ISBN: 9781107014138

Combined Grid/Communication with Multiple Test Configurations

Hardware-in-the-loop experiments



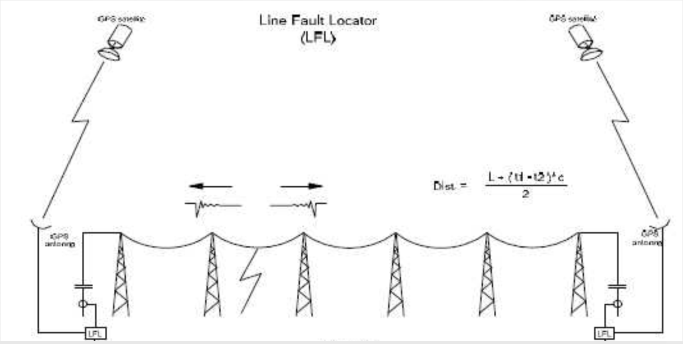
New approaches to observability



RESEARCH: TIME

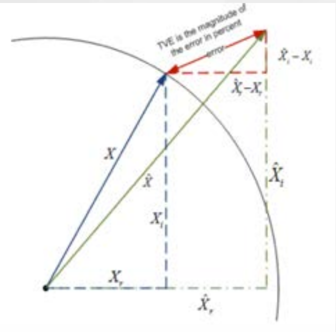
System physics drives timing requirements

Time of arrival accuracy determines location precision and accuracy



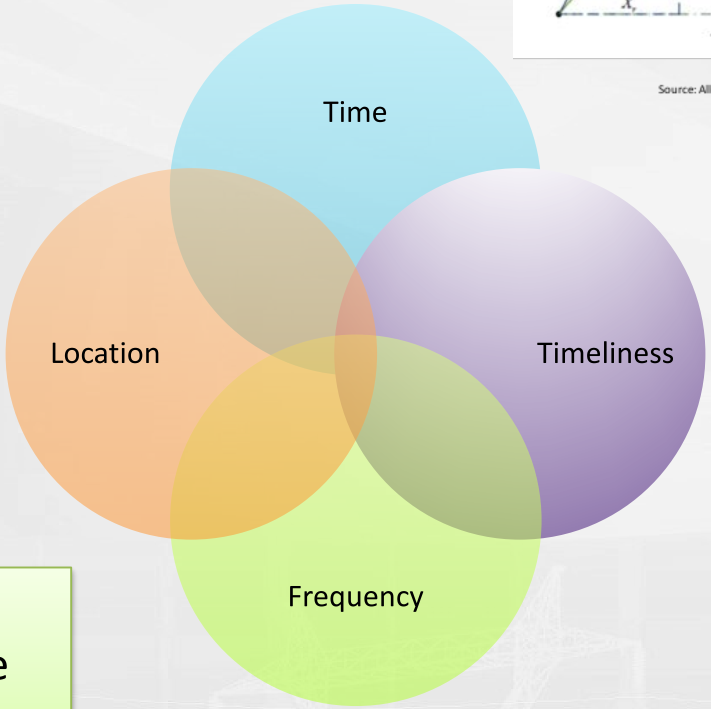
http://www.powerguru.org/keeping-the-electricity-flowing-in-southern-africa/

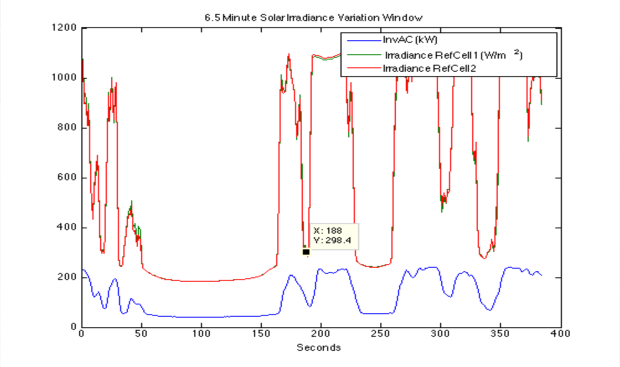
Requirement of < 1 µs synchronization



Source: Allen Goldstein

Time error manifests as measurement error



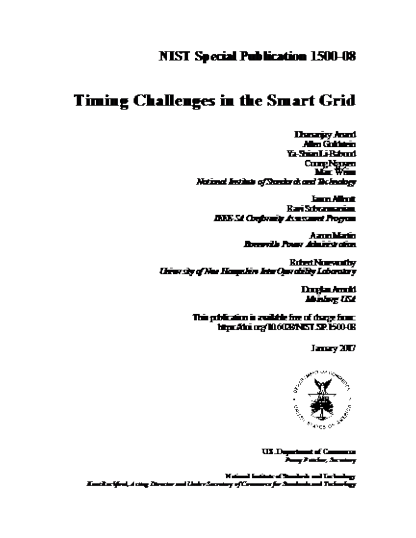


Data source: Matthew Boyd, NIST

High frequency transients require fast sampling

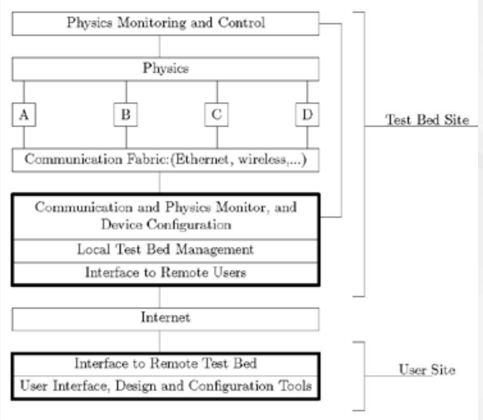
Changing dynamics require lower latencies

Timing Priorities (at NIST)



Improving integrity assurance in timing for power systems

Source: Julien Amelot, PTP Dashboard Software.



Andrade, H. A., Derler, P., Eidson, J. C., Shrivastava, A., Li-Baboud, Y. S., Stanton, K., & Weiss, M. (2015, December). Towards a reconfigurable distributed testbed to enable advanced research and development of timing and synchronization in cyber-physical systems.

Testing and certification

- Device conformity
- End-to-end system interoperability
- Quantifiable test methods
- Interoperability events

Monitoring and anomaly detection

- Real-time monitoring against traceable reference source
- Stochastic characterization of normal behavior

Applications driven requirements

- Research system dynamics
- Parameterize performance metrics and requirements
- Explicit time specification

Alternative sources

- Terrestrial radio (eLORAN, WWVB)
- Network (PTP, NTP)
- Ensembling multiple sources

RESEARCH: WIDE AREA MONITORING AND CONTROL

National Institute of Standards and Technology
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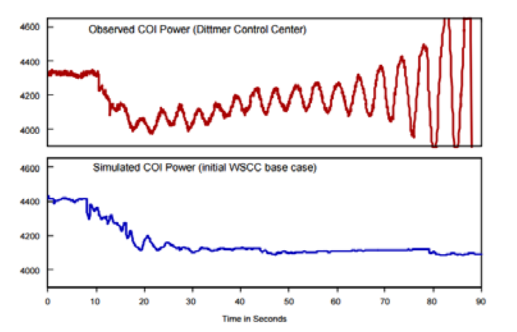
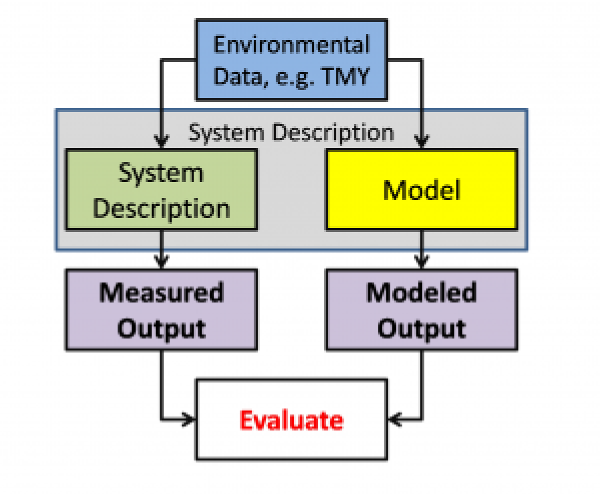
Model Validation



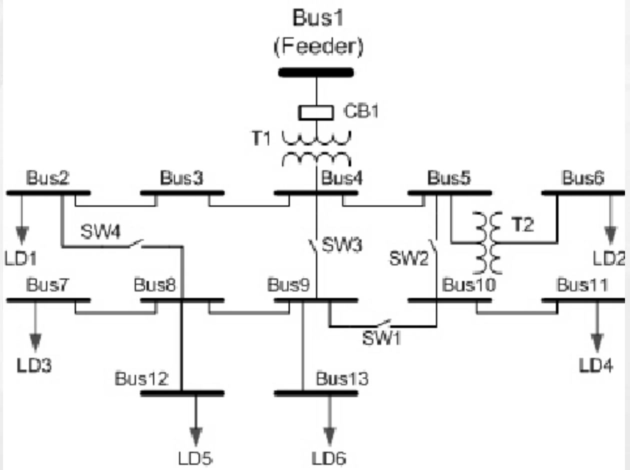
Credit: NERC Model Validation Task Force

- Models are relied upon throughout the power system.
- We compare measurements of “actual values” against model predictions to help validate the model
  - But how *actual* are the “actual values?”
    - *And how bad can they be before there is a problem?*



Credit: Sandia National Laboratory

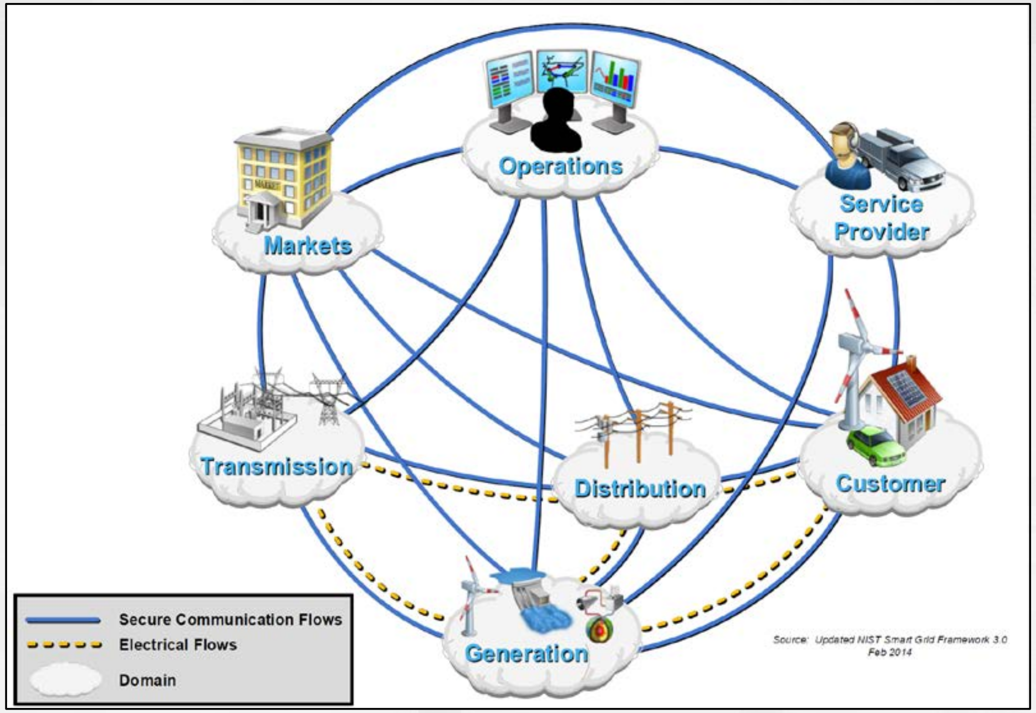
- NERC requires models to be validated
  - Many policies, reports and papers have been published on the topic.
- What is the impact of synchronized measurement error on model validation?

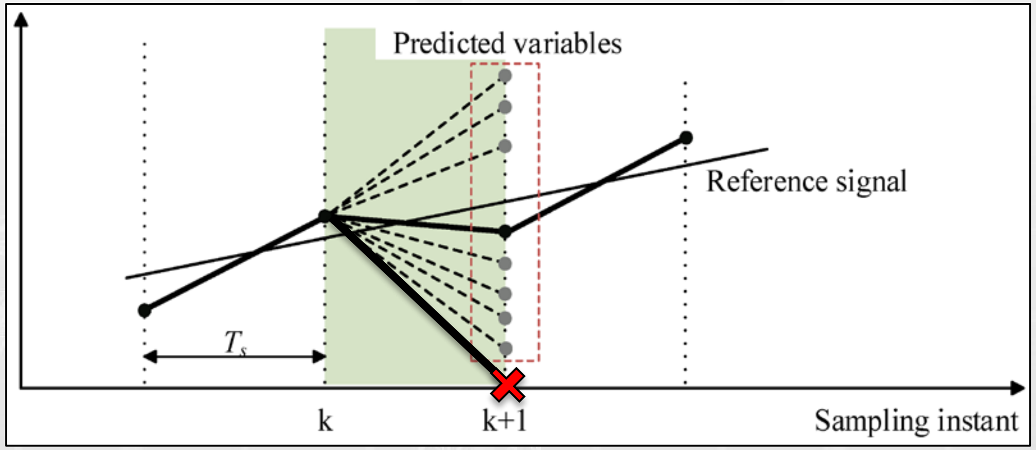


IEEE 13 Bus model

Uncertainty is a dominant challenge

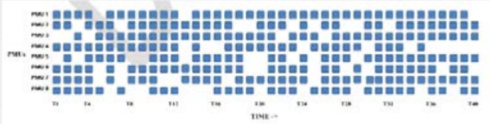
- **Grid is highly distributed and complex**
  - Increasing diversity of device, resource, and control
- **Uncertainty is growing**
  - Growing numbers and increasing dynamics of variables lessen the likelihood of well-behaved, predictable system
  - Legacy models and tools incapable of addressing the growing uncertainty
- **Progress needed across multiple dimensions**
  - New grid physics
  - Networked measurements
  - Diversified applications
  - Expanding customer-base



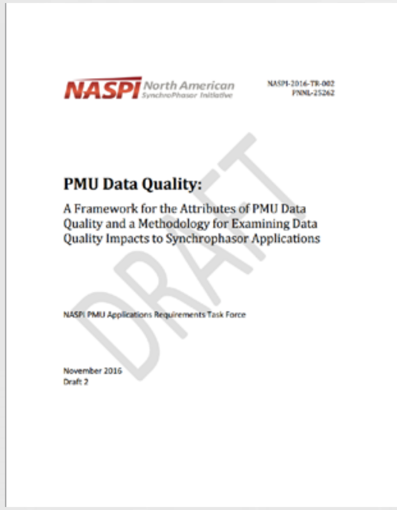


PMU Application Requirements

- Two years ago, NASPI formed the PMU Applications Requirements Task Force
  - NASPI-wide, about 40 members



Data drop outs


NASPI North American SynchroPhasor Initiative

NASPI-2016-TR-002
PNNL-25262

PMU Data Quality:

A Framework for the Attributes of PMU Data Quality and a Methodology for Examining Data Quality Impacts to Synchrophasor Applications

NASPI PMU Applications Requirements Task Force

November 2016
Draft 2

DRAFT

- NASPI, NIST, and PNNL collaborated on a white paper which is published by NASPI today. Provides guidelines and terminology for assessing application needs

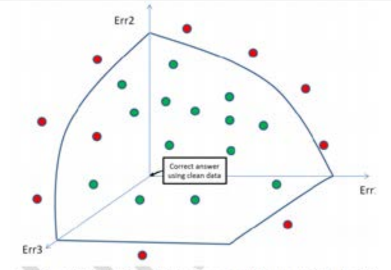
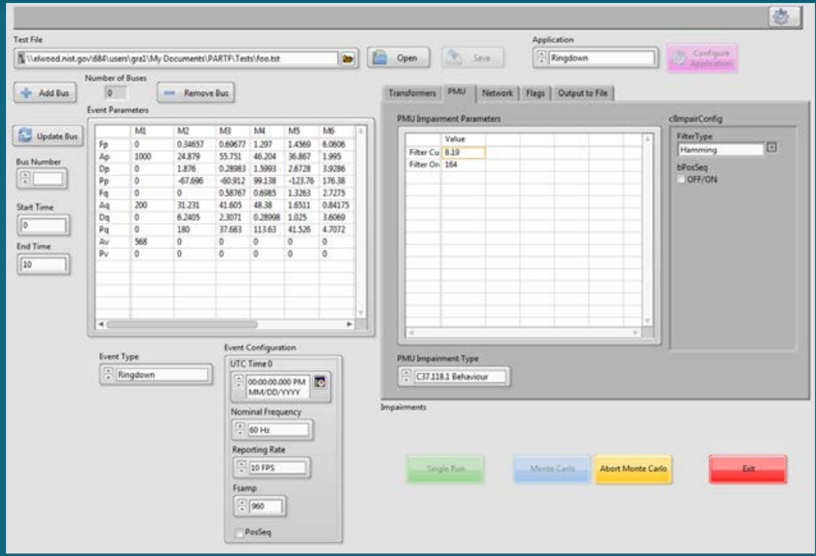


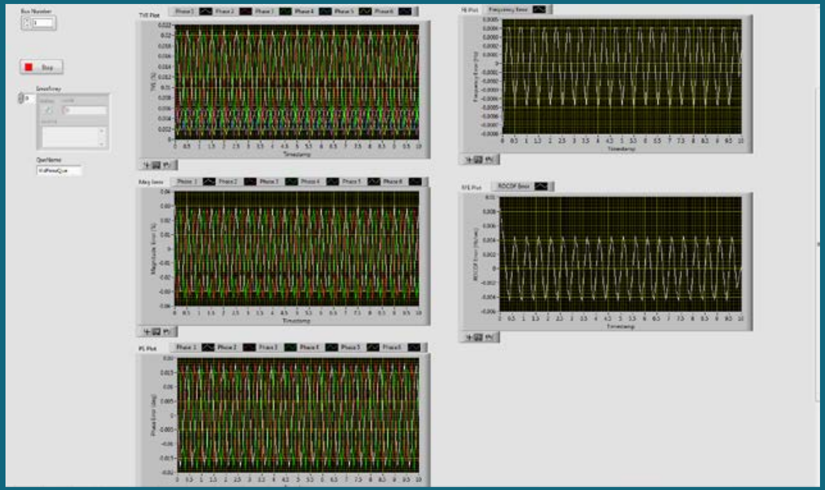
Figure 4-2: Application Performance Envelope for varying data errors relative to clean data

Application Performance Envelope

- Work is in progress at NIST, collaborating with PNNL, WSU, GE, BPA and other vendors, academics, and utilities to create an open source composable application testing framework.

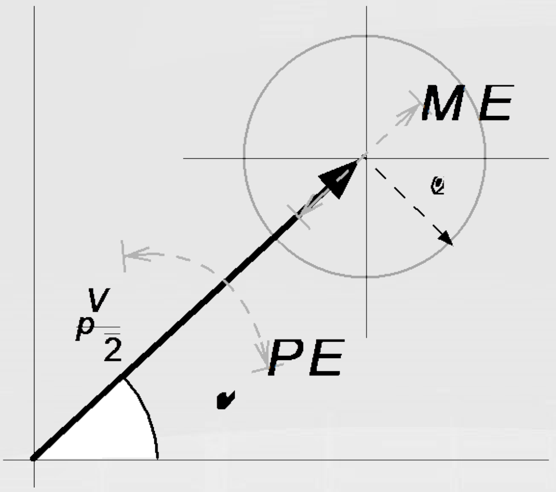


Framework front panel and Visualization App



Uncertainty representation in sensor standards

PMU standards currently specify the error budget for the sensor but there is no explicit measure of uncertainty.



There are several applications being considered for PMUs in the distribution circuit. Each of these applications use a different representation of uncertainty.

Dynamic State Estimation	Additive White Gaussian models
Monitoring and Protection	Confidence intervals
Fault Localization	Bayesian inference
Harmonic Estimation	Mixed Gaussian models
Load modeling	Markov models
Parameter estimation	Set theoretic models
Closed loop control of feeders	Stochastic optimization

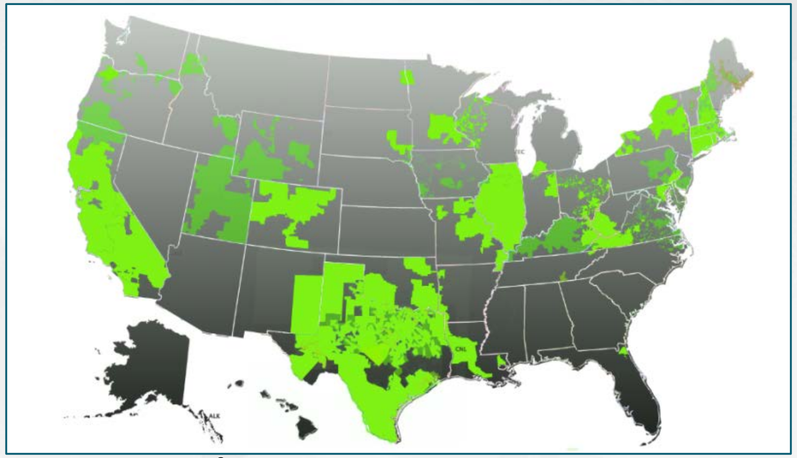
Differentiating error vs. uncertainty and formally specifying uncertainty of sensor measurements and corresponding models will greatly aid in the ability of designers and operators to propagate uncertainty through multiple interacting components and to develop confidence in system level performance.

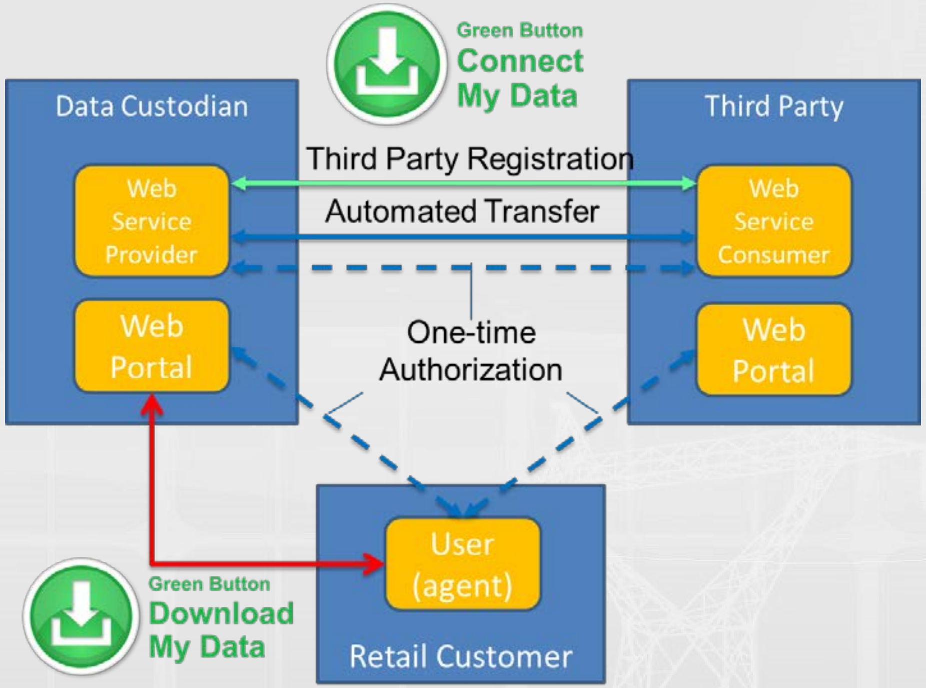
RESEARCH:
BUILDING INTEGRATION WITH SMART GRID

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

Green Button Initiative

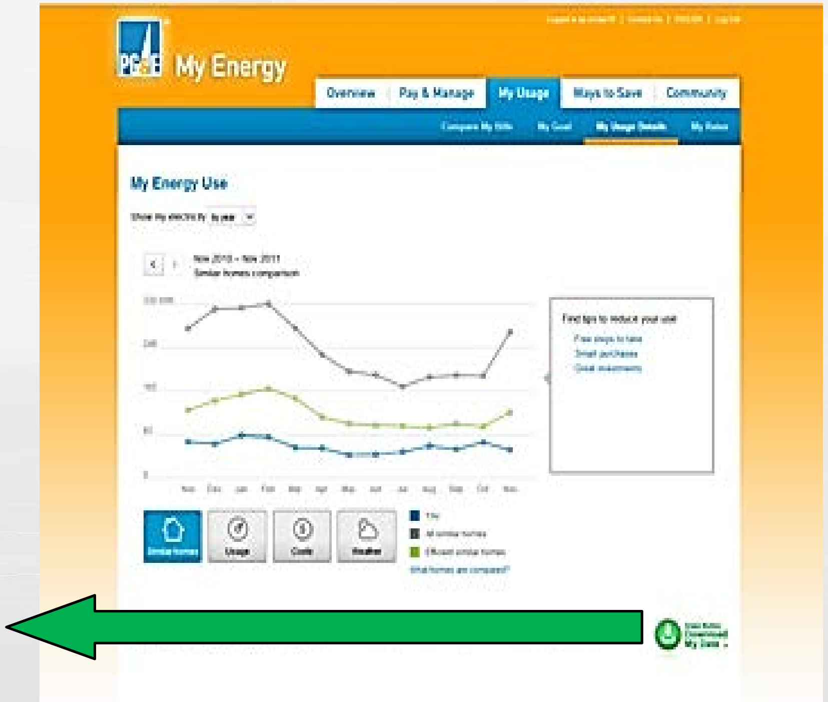
- Enables electronic consumer access to energy data and supports development of ecosystem (apps)
- Available to 100+ million consumers in the US and and additional CANADA: 8 million+ consumers
- Result of collaboration among White House, NIST, DOE, state regulators, utilities, vendors, SGIP, and North American Energy Standards Board
- Trade Org: Green Button Alliance


Map of US Green Button Commitments



Green Button
Connect
My Data

Green Button
Download
My Data



Transactive Energy Challenge: Phase 1

Building up the TE community and TE model simulation foundations

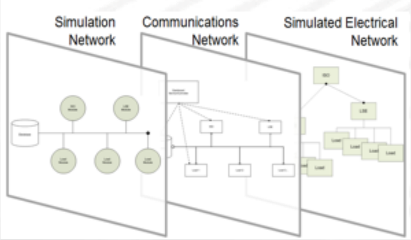
Seven teams/workflows

Common Transactive Services

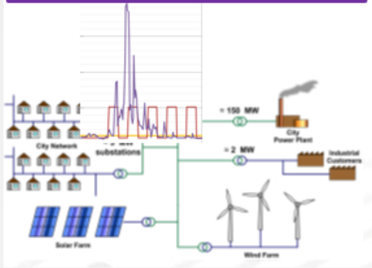
PowerMatcher IoT

PowerMatcherSuite
Transactive Smart Energy

Co-simulation Platform



Reference Grid and Scenarios



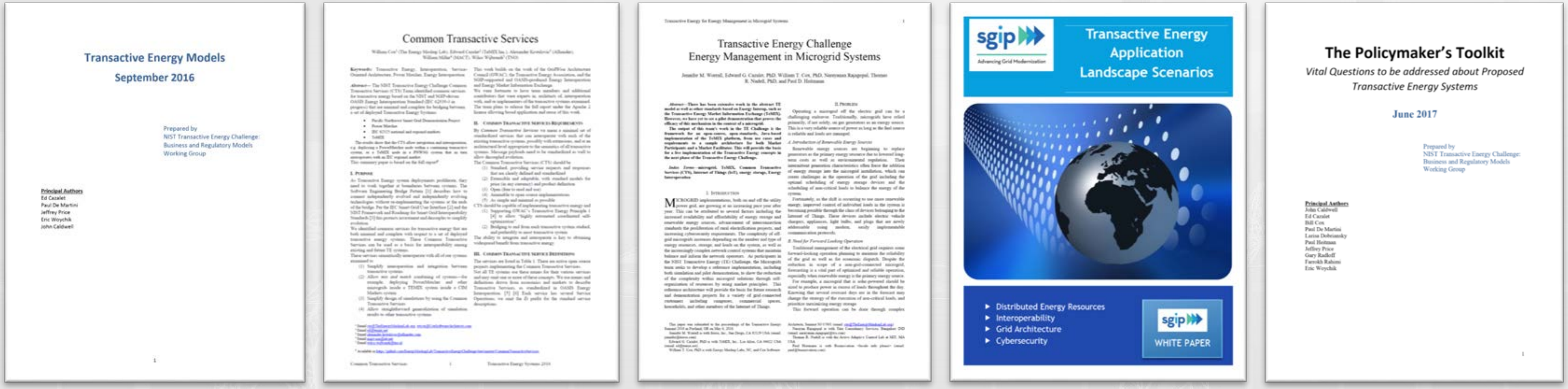
Transactive ADR

openADR Transactive

TE Regulatory and Business Models

TE Microgrids Demonstration

Knowledge gained



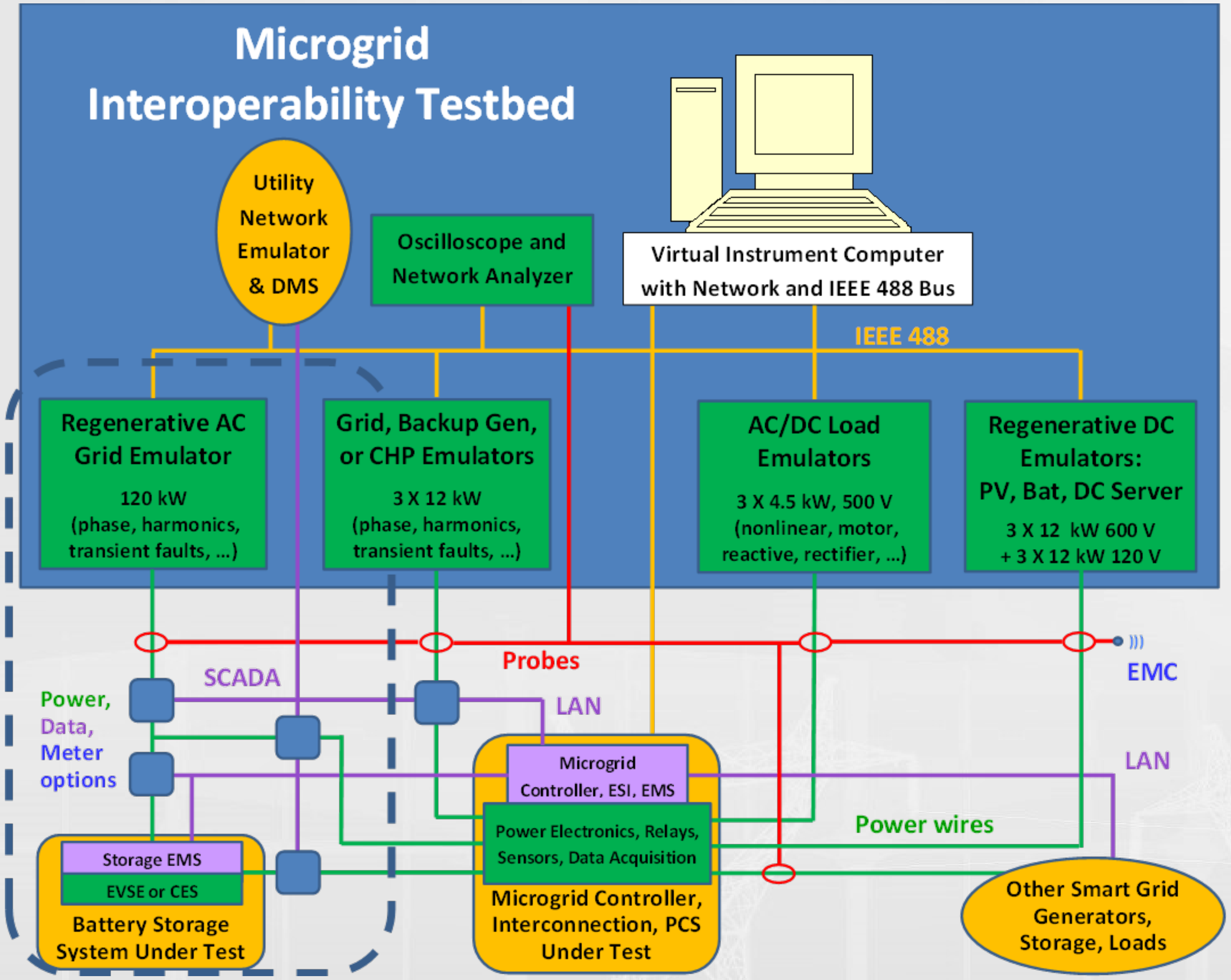
Research: Common Themes

GOAL: Maximize the ability of grid systems to accommodate DER

- **Monitoring and Control:** Improve our understanding of distribution system dynamics, and enhance our ability to control and optimize the system
- **Cybersecurity:** Enable ever-diversifying devices to securely interact, and facilitate reliable and resilient grid operations
- **Communications and Timing:** Maximize system controllability while minimizing infrastructure and computational overhead
- **Operations and Economics:** Quantify how changing economic context impacts technology applications and potential

Research: Monitoring and Control

Enhance our ability to control distribution sysesms



- Commission equipment in testbed, to include:
  - Grid/load emulators
  - Smart inverter functions at 10kW (=> 30kW)
  - Configure and program example microgrid scenario using microgrid controller, rotating machine generator emulator, and loads

- Demonstrate conformance testing of microgrid controller using IEEE 2030.8
- Demonstrate interoperability testing of multiple DER's and Loads
- Coordinate development of microgrid controller information model

Output: Microgrid Interoperability Testbed that provides capability to test conformity of power conditioning systems devices to standards, and to test interoperability of multiple devices in microgrid scenarios

Research: Monitoring and Control

Improve our understanding of distribution system dynamics

Can we evaluate the limits of distributed sensing with installed base?

In 2018 NIST will test smart meters with highly distorted waveforms to assess metering errors.

The results will help us understand the extent to which smart meters can be used as distributed voltage and current sensors

Is data exchange between sensors possible as intended?

In 2017 NIST constructed an interoperability test station, evaluated against IEC 61850-9-2 based Merging Units

In 2018 NIST will quantify measurement uncertainties and develop a software tool to analyze microgrid interoperability across sensors

Research: Cybersecurity

Enable secure device interactions: Create architecture driven cybersecurity risk profiles

NEWS

New Cybersecurity Framework "Profile" to Help Ensure Safe Transfer of Hazardous Liquids at Ports

November 10, 2016

NIST worked with the U.S. Coast Guard and industry to create a new cybersecurity document to improve the safety of transferring hazardous liquids at U.S. ports, including this port in Bayonne, New Jersey.

Credit: ©Roman Babakin/Shutterstock

MEDIA CONTACT

Evelyn A Brown
evelyn.brown@nist.gov
(301) 975-5661

ORGANIZATIONS

Information Technology Laboratory
Applied Cybersecurity Division
National Cybersecurity Center of Excellence

Function	Category	Category Unique ID
Identify	Asset Management	ID.AM
	Business Environment	ID.BE
	Governance	ID.GV
	Risk Assessment	ID.RA
	Risk Management Strategy	ID.RM
Protect	Access Control	PR.AC
	Awareness and Training	PR.AT
	Data Security	PR.DS
	Information Protection Processes & Procedures	PR.IP
	Maintenance	PR.MA
	Protective Technology	PR.PT
Detect	Anomalies and Events	DE.AE
	Security Continuous Monitoring	DE.CM
	Detection Processes	DE.DP
Respond	Response Planning	RS.RP
	Communications	RS.CO
	Analysis	RS.AN
	Mitigation	RS.MI
	Improvements	RS.IM
Recover	Recovery Planning	RC.RP
	Improvements	RC.IM
	Communications	RC.CO

Subcategory	Informative References
ID.BE-1: The organization's role in the supply chain is identified and communicated	COBIT 5 APO01.02, DSS06.03 ISA 62443-2-1:2009 4.3.2.3.3 ISO/IEC 27001:2013 A.6.1.1 NIST SP 800-53 Rev. 4 CP-2, PS-7, PM-11
ID.BE-2: The organization's place in critical infrastructure and its industry sector is identified and communicated	COBIT 5 APO08.04, APO08.05, APO10.03, APO10.04, APO10.05 ISO/IEC 27001:2013 A.15.1.3, A.15.2.1, A.15.2.2 NIST SP 800-53 Rev. 4 CP-2, SA-12
ID.BE-3: Priorities for organizational mission, objectives, and activities are established and communicated	COBIT 5 APO02.06, APO03.01 NIST SP 800-53 Rev. 4 PM-8
ID.BE-4: Dependencies and critical functions for delivery of critical services are established	COBIT 5 APO02.01, APO02.06, APO03.01 ISA 62443-2-1:2009 4.2.2.1, 4.2.3.6 NIST SP 800-53 Rev. 4 PM-11, SA-14
ID.BE-5: Resilience requirements to support delivery of critical services are established	ISO/IEC 27001:2013 A.11.2.2, A.11.2.3, A.12.1.3 NIST SP 800-53 Rev. 4 CP-8, PE-9, PE-11, PM-8, SA-14

Functions, **Categories**, and **Subcategories** of the Cybersecurity Framework

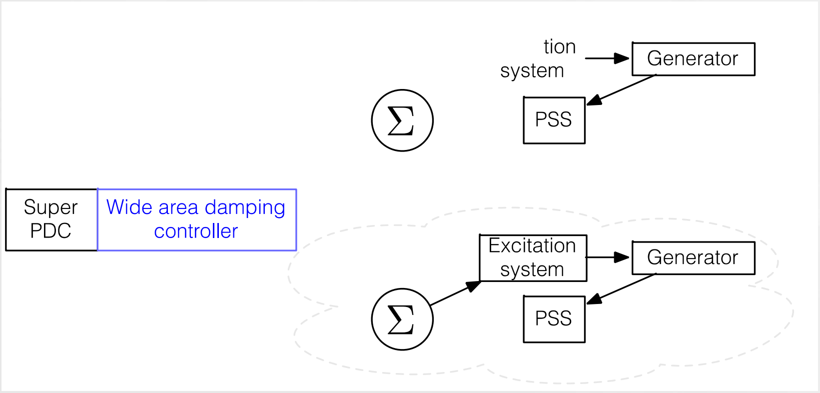
Function	Category	Subcategory	Mission Objectives ●●● = High Priority, ●● = Moderate Priority, ● = Other Implemented Subcategories							
			1	2	3	4	5	6	7	8
IDENTIFY (ID)	**Asset Management (ID.AM):** The data, personnel, devices, systems, and facilities that enable the organization to achieve business purposes are identified and managed consistent with their relative importance to business objectives	**ID.AM-1:** Physical devices and systems within the organization are inventoried	●	●●●	●	●	●●	●	●	●
		ID.AM-2: Software platforms and applications within the organization are inventoried	●	●●	●	●	●	●	●	●
		ID.AM-3: Organizational communication and data flows are mapped	●	●	●	●	●●	●	●	●

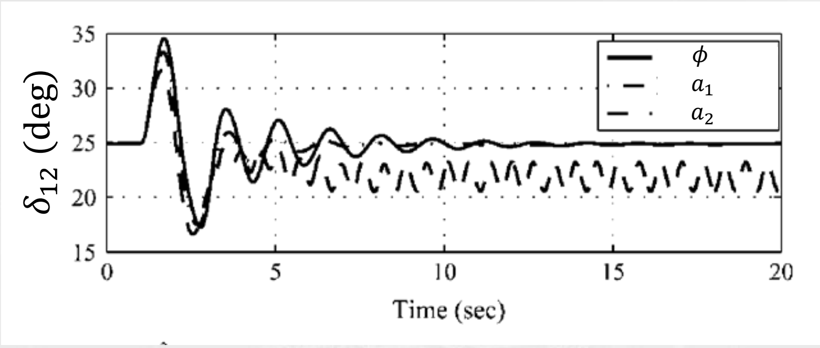
Summary of Subcategory **Priorities** by **Mission Objective**

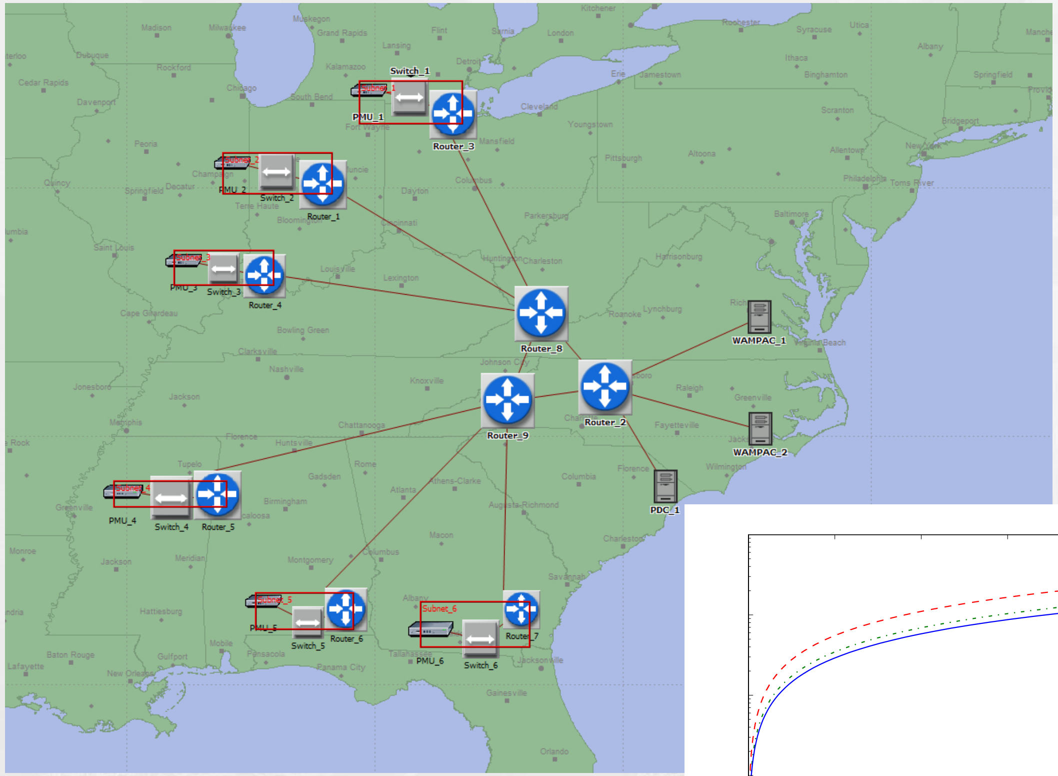
Characterize authentication and encryption performance for publish-and-subscribe networks (e.g., OpenFMB)

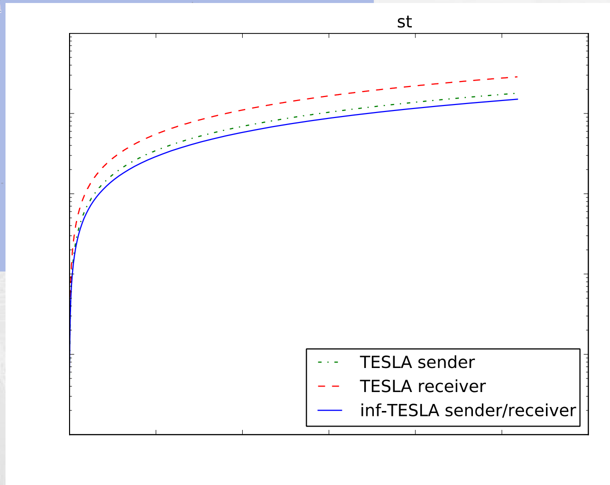
Research: Cybersecurity

Facilitate reliable grid operations by using Physical dynamics as a metric for security tools (inf-TESLA)





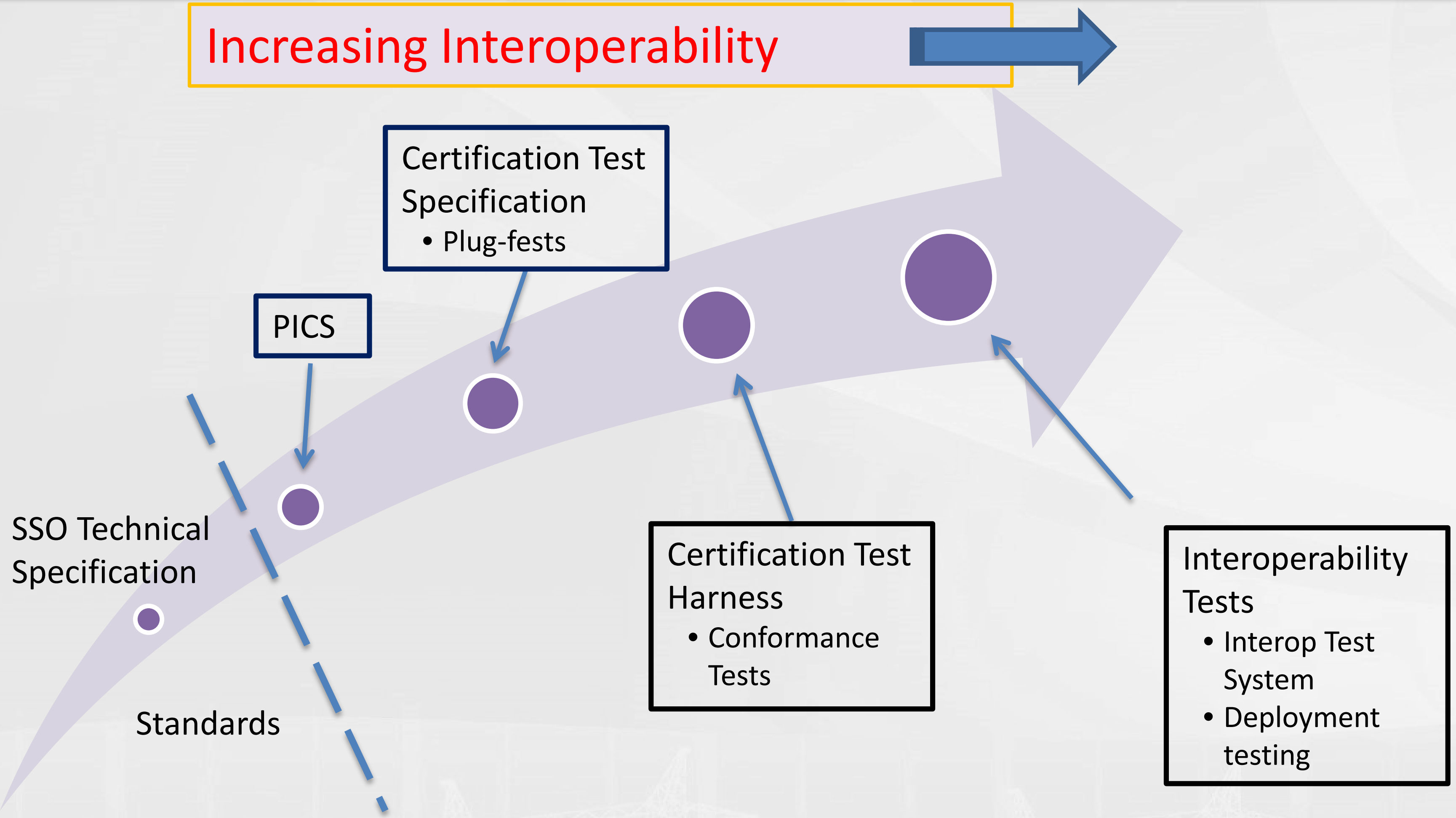


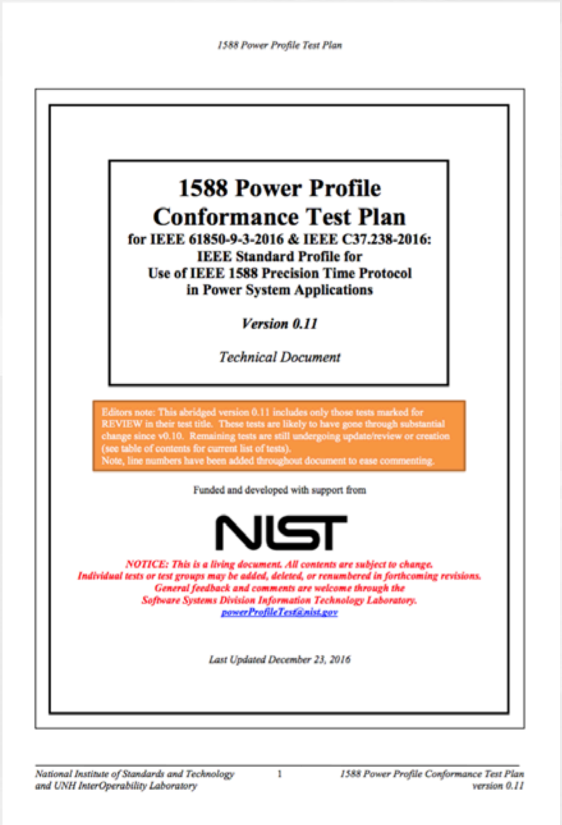


The delayed system is asymptotically stable if there exists real symmetric positive-definite matrices $P = P^T > 0$, $Q = Q^T > 0$ satisfying the LMI:

$$\begin{bmatrix} PA_s + A_s^T P + Q & PA_v \\ A_v^T P & -Q \end{bmatrix} < 0$$

Research: Communications & Timing




1588 Power Profile Test Plan

1588 Power Profile Conformance Test Plan
for IEEE 61850-9-3-2016 & IEEE C37.238-2016: IEEE Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications

Version 0.11

Technical Document

Editors note: This abridged version 0.11 includes only those tests marked for REVIEW in their test title. These tests are likely to have gone through substantial change since v0.10. Remaining tests are still undergoing update/review or creation (see table of contents for current list of tests).
Note, line numbers have been added throughout document to ease commenting.

Funded and developed with support from

NIST

NOTICE: This is a living document. All contents are subject to change. Individual tests or test groups may be added, deleted, or renumbered in forthcoming revisions. General feedback and comments are welcome through the Software Systems Division Information Technology Laboratory.
powerProfileTest@nist.gov

Last Updated December 23, 2016

National Institute of Standards and Technology and UNH InterOperability Laboratory 1 *1588 Power Profile Conformance Test Plan version 0.11*

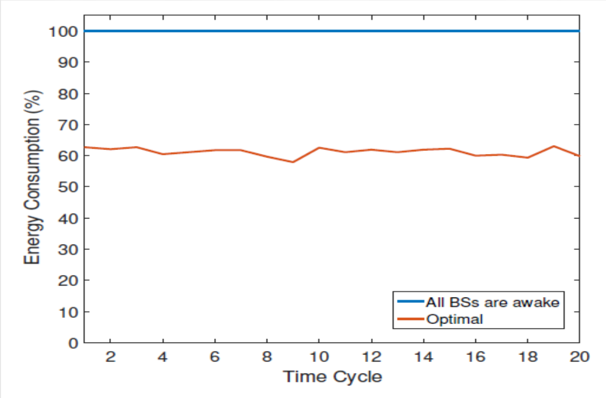
Source: Bob Noseworthy, et. al Draft 1588 Power Profile Conformance Test Suite Specification. University of New Hampshire Interoperability Lab.

- Collaborate with industry to accelerate the development of test programs for smart grid standards
- Support industry test programs through test methods development
- Participate in plug-fest and interoperability test events
- Build awareness and encourage adoption of test programs to enhance interoperability

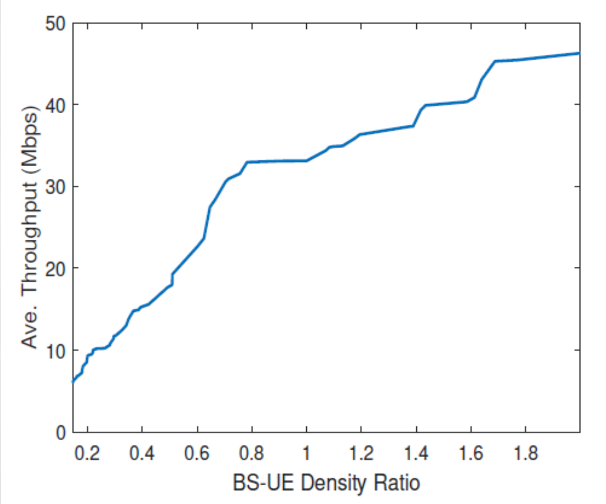
Research: Communications & Timing

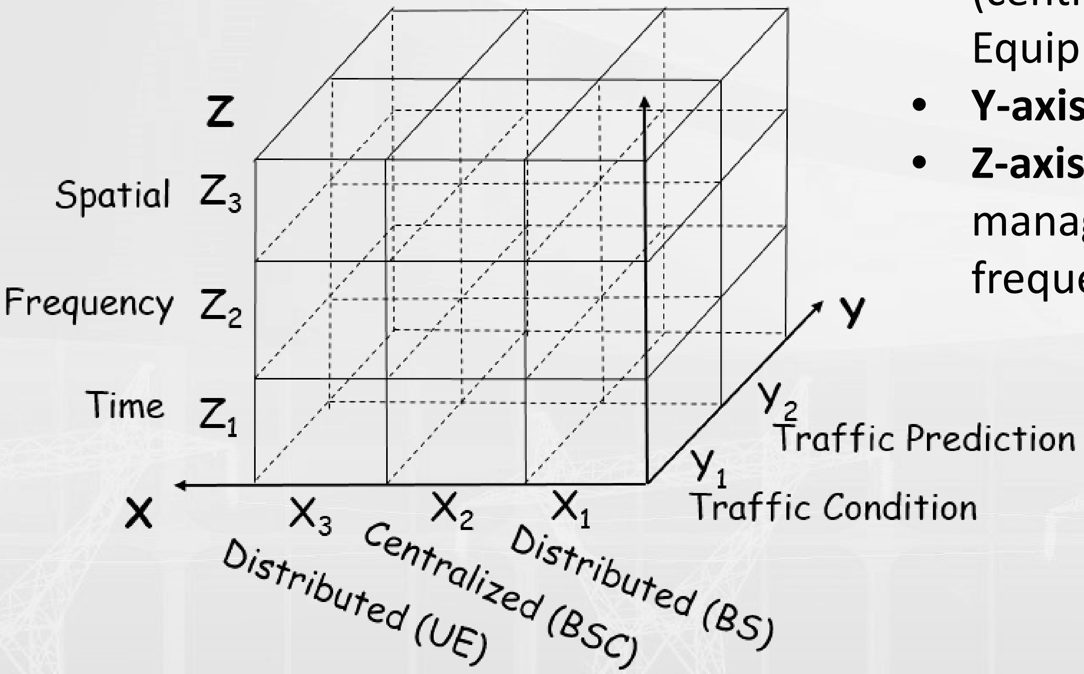
Minimize infrastructure for smart implementation of distributed applications by characterizing technologies and architectures for efficient future wireless networks

Base Station Impact on Energy Demand



Architecture Impact on Throughput





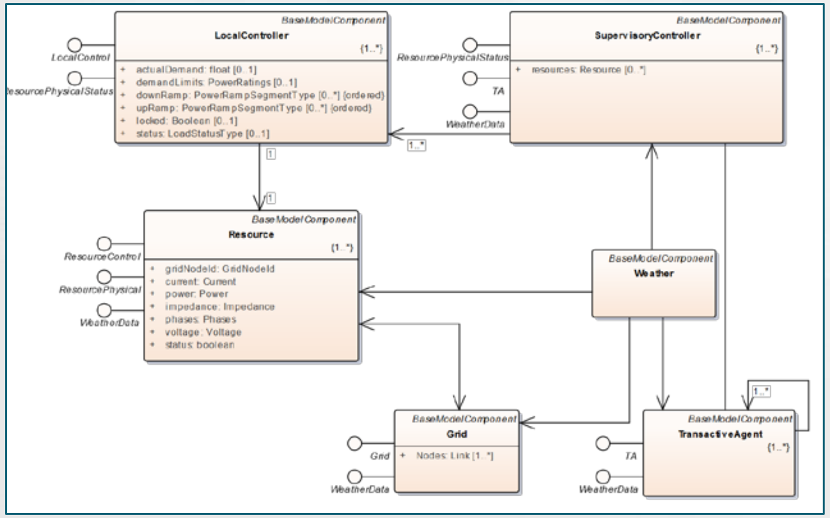
Systematically investigate different techniques for energy resource management in 5G

- **X-axis**: Mechanisms for control (centralized vs. distributed, User Equipment vs. base station control)
- **Y-axis**: Adaption based on network status
- **Z-axis**: Mechanisms for resource management with respect to time, frequency and spatial domains

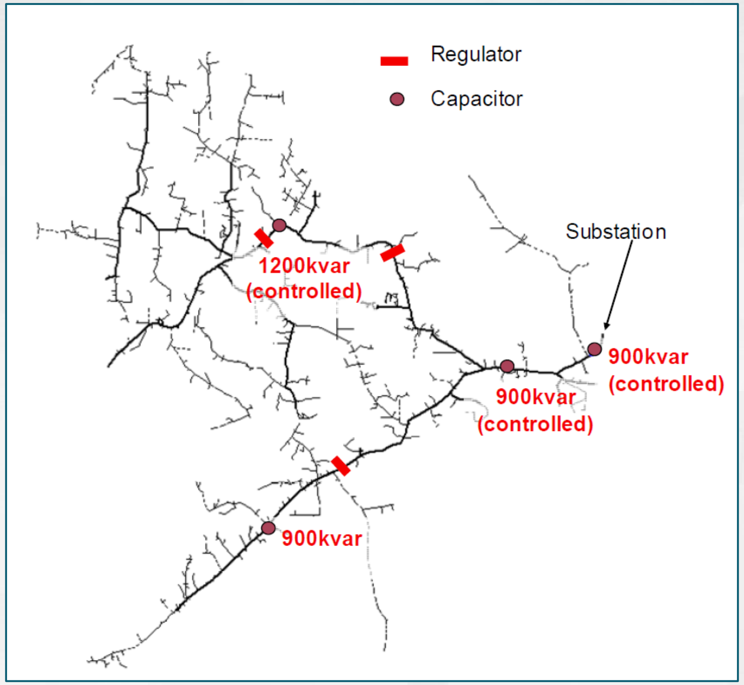
Research: Operations and Economics

TE Challenge Phase 2:

- Model the same electric grid with the same scenario



NIST Common Model



Source: IEEE 8500-Node Test Feeder

- Implement different TE models

Pacific Northwest NATIONAL LABORATORY
pnnl / tesp
ORACLE
NREL NATIONAL RENEWABLE ENERGY LABORATORY
THAYER SCHOOL OF ENGINEERING AT DARTMOUTH
Massachusetts Institute of Technology
TATA TATA CONSULTANCY SERVICES
NAVIGANT
VANDERBILT UNIVERSITY
RECINTO UNIVERSITARIO DE MAYAGUEZ UNIVERSIDAD DE PUERTO RICO

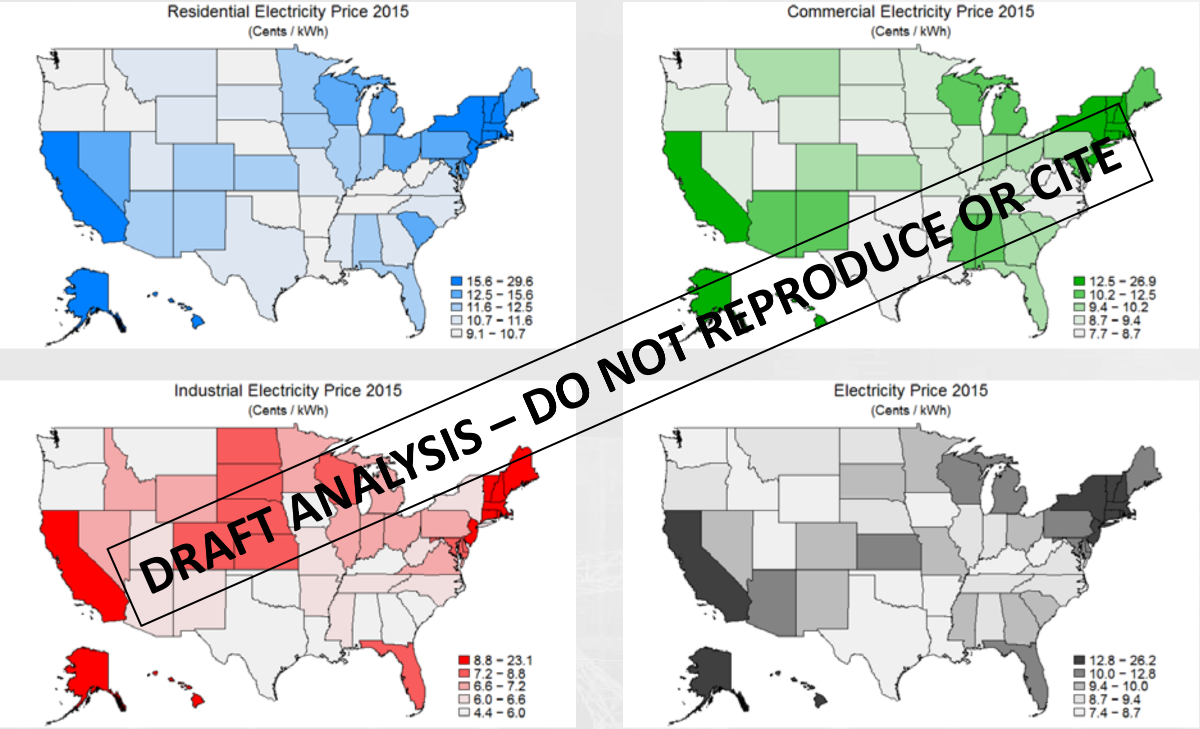
- Report results using common metrics

Price, V/VAR, Actuations, ANSI C84.1 violations, total load, appliance load, …

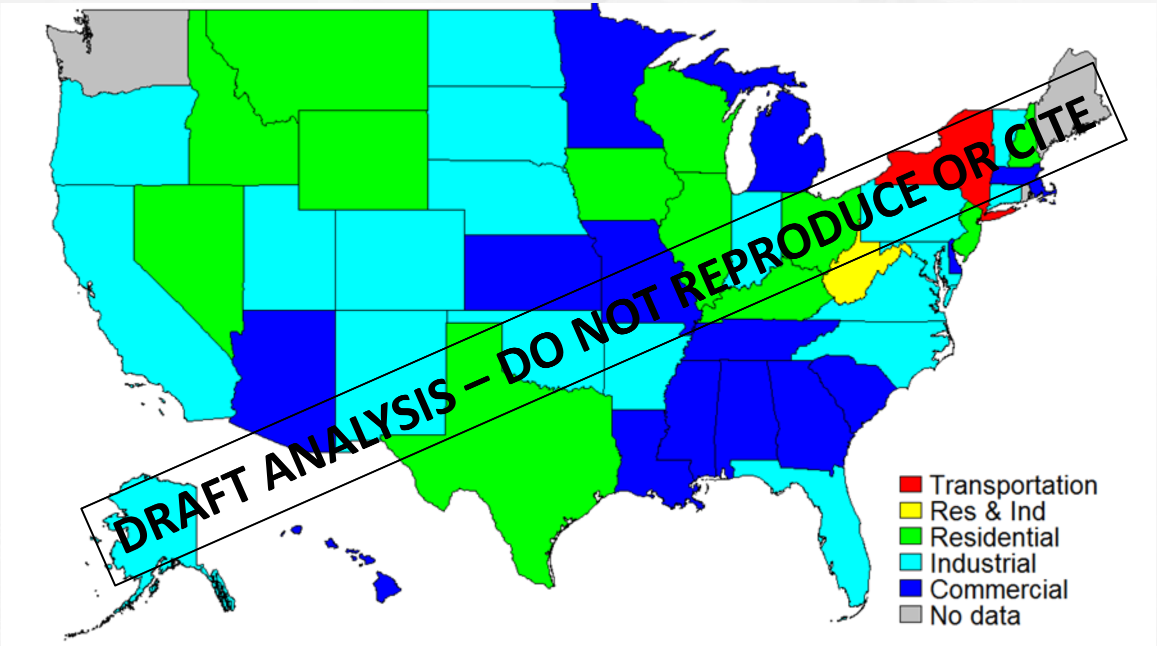
Research: Operations and Economics

New study: The Economics of Interoperability in Smart Grid Operations

Average Price of Electricity by State and End Consumer Group



Sector with Lowest Unit Cost of Demand Response



NIST Smart Grid Program – Current Budget

Smart Grid Program	FY17 $(K)
Experimental Facilities: Smart Grid Test Bed	**$2,469**
Smart Grid System Testbed Facility (SL SGP) - Boynton	
Power Conditioning Systems for Renewables, Storage, and Microgrids (PML) - Hefner	
National Coordination + Strategy	**$2,771**
Smart Grid Secretariat (EL SGP) - Gopstein	
Smart Electric Power Alliance (EL SGP) - Nguyen	
Smart Grid Testing and Certification (EL SGP) - Nguyen	
Research Projects	**$3,295**
Cybersecurity for Smart Grid Systems (ITL) - Hastings	
Smart Grid Communication Networks (CTL) - Griffith	
Smart Grid Communication Networks (ITL) - Gharavi	
Precision Timing for Grid Systems (ITL) - Li-Baboud	
Wide-area Monitoring and Control of Smart Grid (PML) - FitzPatrick	
Electromagnetic Compatibility (CTL) - Ladbury	
Building Integration with Smarg Grid (EL) - (*not incl. $300k EIB) - Holmberg/Gopstein	
Quantifying Key Economic Issues in the Smart Grid (EL AEO) - O'Fallon	
TOTAL	**$8,535**

Smart Grid Interoperability and Building-to-Grid Integration

Steven T. Bushby

Group Leader, Engineering Laboratory
NIST Embedded Intelligence in Buildings Program

There is no Smart Grid without Smart Buildings!

- 72% of electricity is consumed in buildings (40% commercial, 32% residential)
- Increased building automation capabilities and building-scale renewable generation make building interactions increasingly important to the grid
- As the nation migrates to electric vehicles, they will be plugged in to buildings

Buildings will no longer be a dumb load at the end of the wire. They will become an integral part of the grid.

Building Resources Potentially Available to the Grid


Ice Storage

- Generation
- Electrical and thermal storage
- DR to reduce peaks
- Fast DR for some ancillary services
- Load forecasts to improve planning

The scale in homes is much smaller but there are many of them.

Facility Smart Grid Information Model – An Example of NIST's Impact

- Examples of NIST capabilities relevant to this effort are:
  - Technical leadership
  - Ability to bring together diverse stakeholders and standards development organizations (SDOs)
  - Leverage leadership positions in national and international standards organizations
  - Ability to coordinate with technical experts in the private sector and other federal agencies

Today's Automation and Control Technology

- Industrial – Ubiquitous, mature, capable but generally not configured to support grid needs
- Large Commercial –
  - Installed base slow to change (20 year life)
  - BACnet the dominant technology being installed today
  - Strong trend towards greater system integration and more sophisticated control strategies
- Small Commercial and Residential
  - Limited automation and control – mostly thermostats

The Problems

- Control technology and maturity varies by building sector
- Utilities and energy service providers want to interact with all building types in the same way
- Different SDOs have jurisdiction over different building sectors (AHAM, ASHRAE, ISA, NEMA)
- We need solutions that are accepted internationally
- Standards for buildings need to fit within the context of other smart grid standards and activities.
- Regulators want to enable innovation while ensuring resilience and reliability

The Solution

Develop an information model standard that is applicable across the building space and provides a common evolutionary path for automation and control technologies in each space

- Create a multi-SDO collaboration
- Build a balanced team of experts that represent the various stakeholders
  – Commercial/Institutional/Industrial Producer
  – Appliance, Residential Automation, and Consumer Electronics Producer
  – Utility
  – Consumers – Residential, Commercial, and Industrial
  – General Interest
- Conduct domestic outreach during development to get early feedback
- Conduct international outreach to build support for adoption of the results as an international standard
- Leverage electronic meetings to increase participation and accelerate progress

The Result

ASHRAE NEMA FSGIM
Facility Smart Grid Information Model
Standard 201

ISO 17800

ISO 17800

PURPOSE: The purpose of this standard is to define an abstract, object-oriented information model to enable appliances and control systems in homes, buildings, and industrial facilities to manage electrical loads and generation sources in response to communication with a “smart” electrical grid and to communicate information about those electrical loads to utility and other electrical service providers.

FSGIM

Facility Smart Grid Information Model

Standard 201

ISO 17800

The model will support a wide range of energy management applications and electrical service provider interactions including:

(a) on-site generation,
(b) demand response,
(c) electrical storage,
(d) peak demand management,
(e) forward power usage estimation,
(f) load shedding capability estimation,
(g) end load monitoring (sub metering),
(h) power quality of service monitoring,
(i) utilization of historical energy consumption data, and
(j) direct load control.

How Do You Model Device Energy Management?

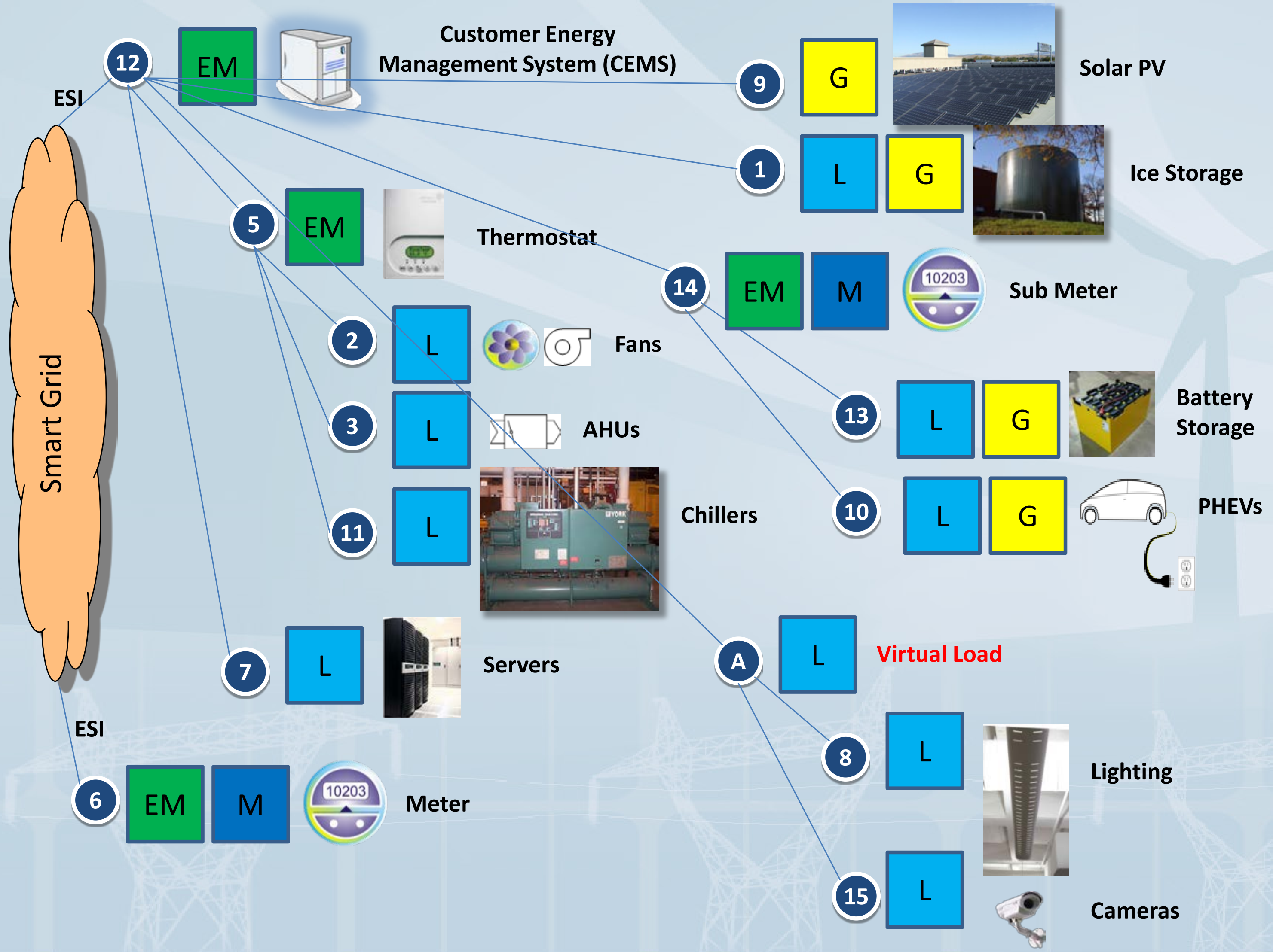
Imagine modeling all devices behind the ESI as either an energy manager, energy meter, energy generator, or energy load.

Generator	Load
Meter	Energy Manager

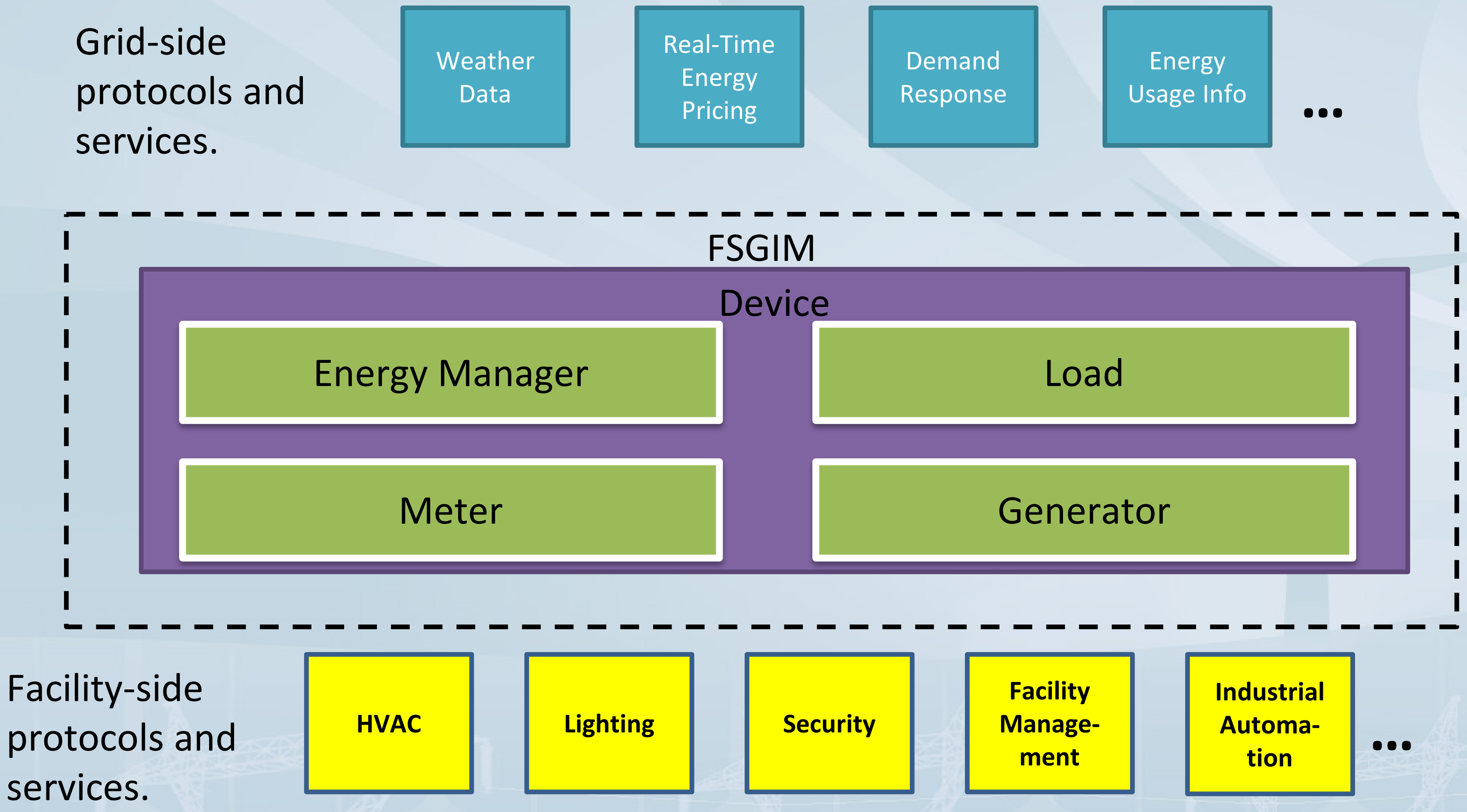
Examples might be:

- **EMS = Energy Manager**
- **Smart Appliance = Energy Manager + Load**
- **Battery = Generator + Load**
- **Premise sub-meter = Meter**

Composition of Devices from Components



FSGIM Overview



Early Impact of the FSGIM

- Compatible with Green Button, OpenADR and weather information services
- Provides standard aggregations that will work in a multi-vendor environment
- Can represent load curves for predicting energy and power consumption or selecting control points

Control technology standards groups are beginning to develop technology specific implementations of the FSGIM

Securing Grid Edge Devices

Nelson Hastings
Group Leader, Cybersecurity and Privacy Applications Group
Applied Cybersecurity Division
Information Technology Laboratory

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

Security of Grid Edge Devices

- Grid edge devices include Smart Meters, Inverters, Thermostats, HVAC systems, …
- Securing these devices is critical to scaling control systems that may leverage grid edge devices.
- The NISTIR 7628 provides Guidelines for Smart Grid Cyber Security.
- Ideally we would like a strategy to decompose these system level guidelines to device specifications.

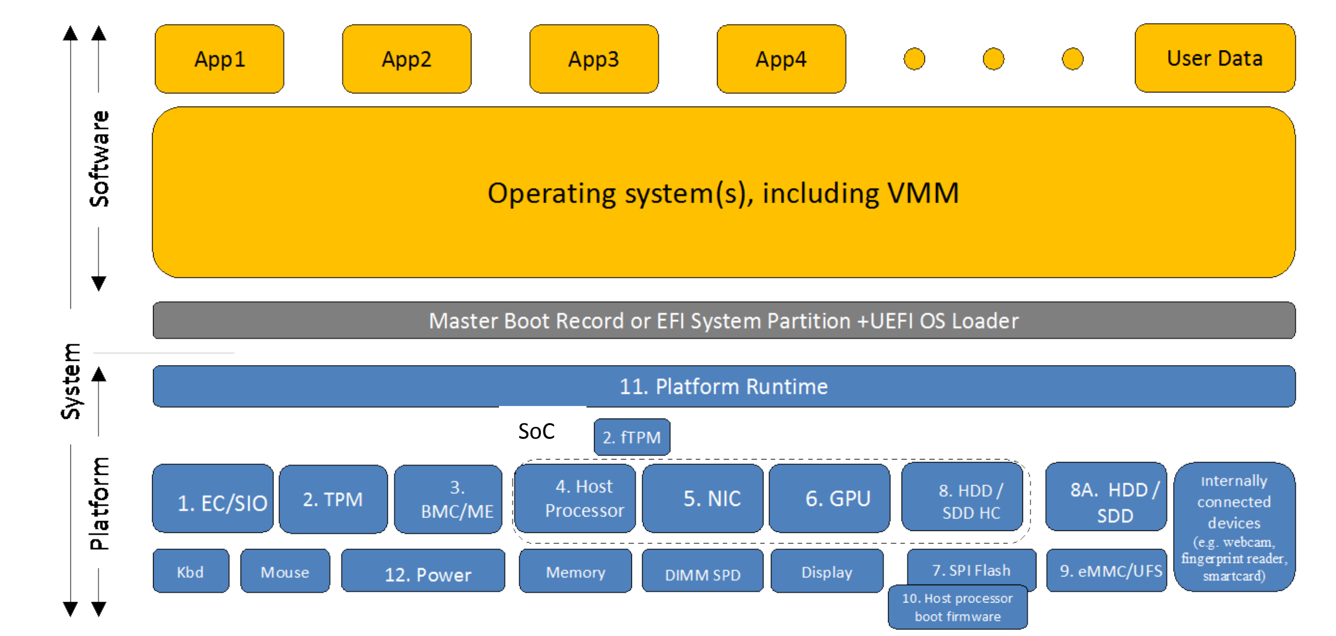
Cybersecurity Efforts

- Profiling Performance of Grid Edge Devices
- Secure Publish-Subscribe Communications

Profiling Performance of Grid Edge Devices

- We are currently developing technology to profile the performance impact of security solutions on grid edge devices.
- The eventual goal is to balance cybersecurity tools across a DER architecture, minimizing system level risk exposure.
- Diversity in design, legacy and communication protocols pose a challenge – requiring continuing engagement with device manufacturers.

Grid Edge Device Test Infrastructure

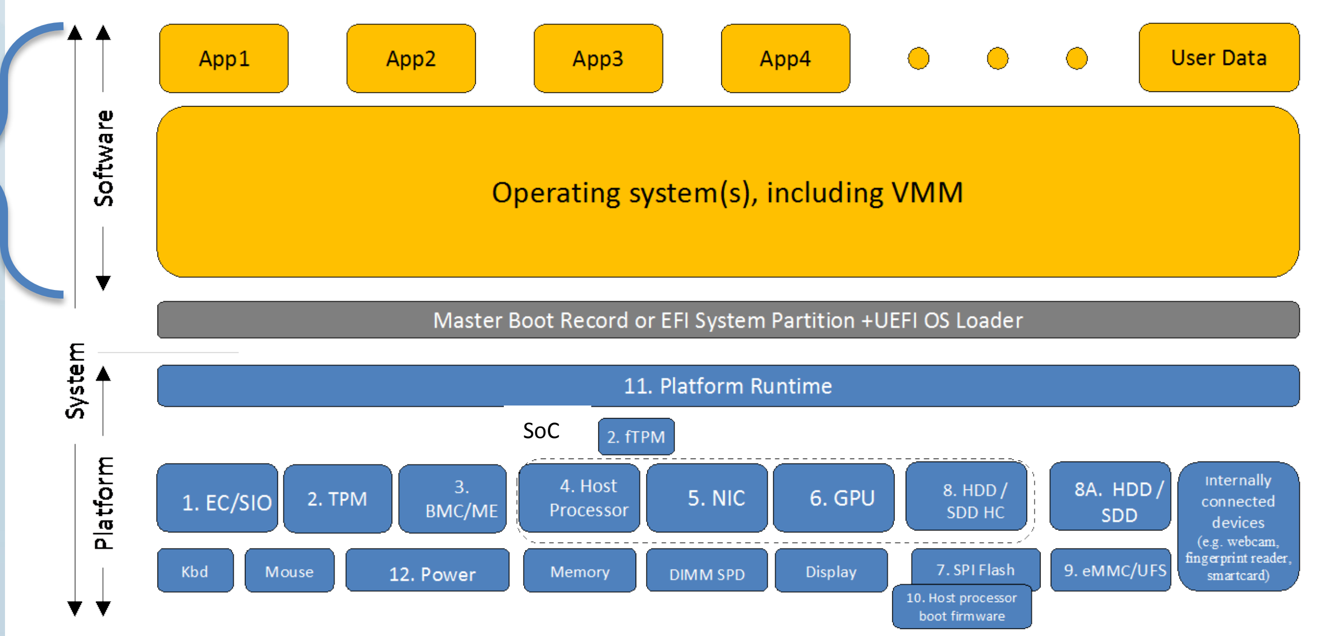


Draft NIST SP 800-193 Platform Firmware Resiliency Guidelines

Classes of Test Devices

- Smart Meters
- Inverters
- EV Charging Stations
- Thermostats

Grid Device Test Infrastructure - Software



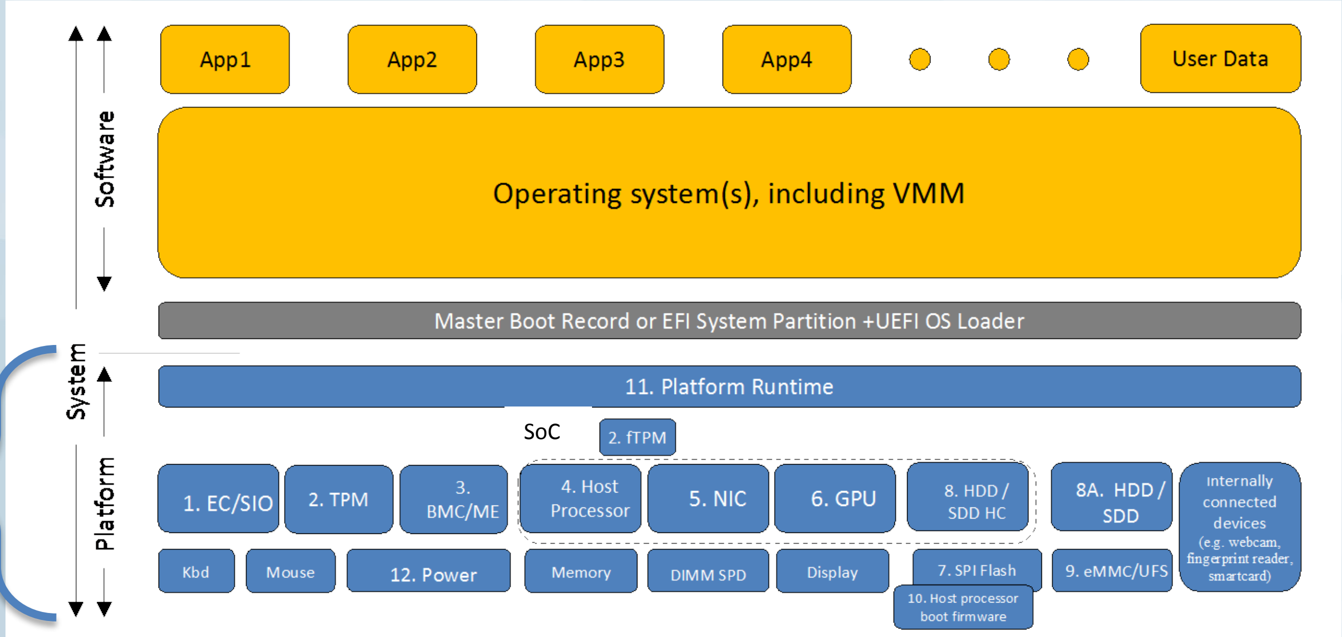
Draft NIST SP 800-193 Platform Firmware Resiliency Guidelines

Performance statistical profiling of applications

– Contribution of different security routines in App/OS space to execution cost

– Profile various software events (instructions, cache misses, etc.)

Grid Device Test Infrastructure – Hardware/Firmware



Draft NIST SP 800-193 Platform Firmware Resiliency Guidelines

Hardware/Firmware in the loop testing

– Contribution of different hardware/firmware security tools (crypto, MAC, Network)

– Profile various hardware events (clock cycles, network use, buffers, etc.)

– Use hardware probing and network monitoring to sample pub-sub protocols, hardware interrupts, etc.

Results Matrix

- We plan to construct a matrix of hardware platforms commonly used in smart grid devices with performance metrics of the encryption libraries that are enabled on them.
- The test will baseline performance of various devices by measuring the performance different encryption algorithms in bytes/second and bytes/cycle.
- This will catalog expected performance impacts by enabling security features on a wide swath of smart grid devices.

Secure Publish-Subscribe Communications

- Review the NAESB RMQ.26 standard for implementing Open Field Message Bus (OpenFMB)
- Actively participating in the SEPA OpenFMB Cybersecurity Task Force (CTF)
- Perform a security review of NAESB RMQ.26 and corresponding OpenFMB CTF output
- Design and build a proof of concept implementation of OpenFMB

Collaboration

- National Renewable Energy Lab (NREL)
- OpenFMB CTF Members:
  - Avista
  - Coergon
  - Duke Energy
  - Electric Power Research Institute
  - FREEDM Systems
  - General Electric Company
  - Green Energy Corp
  - Itron, Inc.
  - Landis+Gyr – Toshiba
  - OMNETRIC Corp.
  - Real-Time Innovations, Inc.
  - Red Hat
  - Xanthus Consulting International
  - Xcel Energy Inc.

Timeline

- Profiling Performance of Grid Edge Devices
  - Q4 FY17 – Design test plan
  - Q1 FY18 – Complete design and procure equipment as needed
  - Q2 FY18 – Conduct test and collect data
  - Q3-Q4 FY18 – Produce data set from results
  - Q3-Q4 FY18 – Create document recording test architecture, results, and implications
- Secure Publish-Subscribe Communications
  - Ongoing – SEPA OpenFMB CTF participation
  - Q1-Q4 FY18 – Perform security review of NAESB RMQ.26
  - Q2-Q4 FY18 – Design and implement PoC implementation of OpenFMB

Mitigating the impact of stochasticity in future power systems

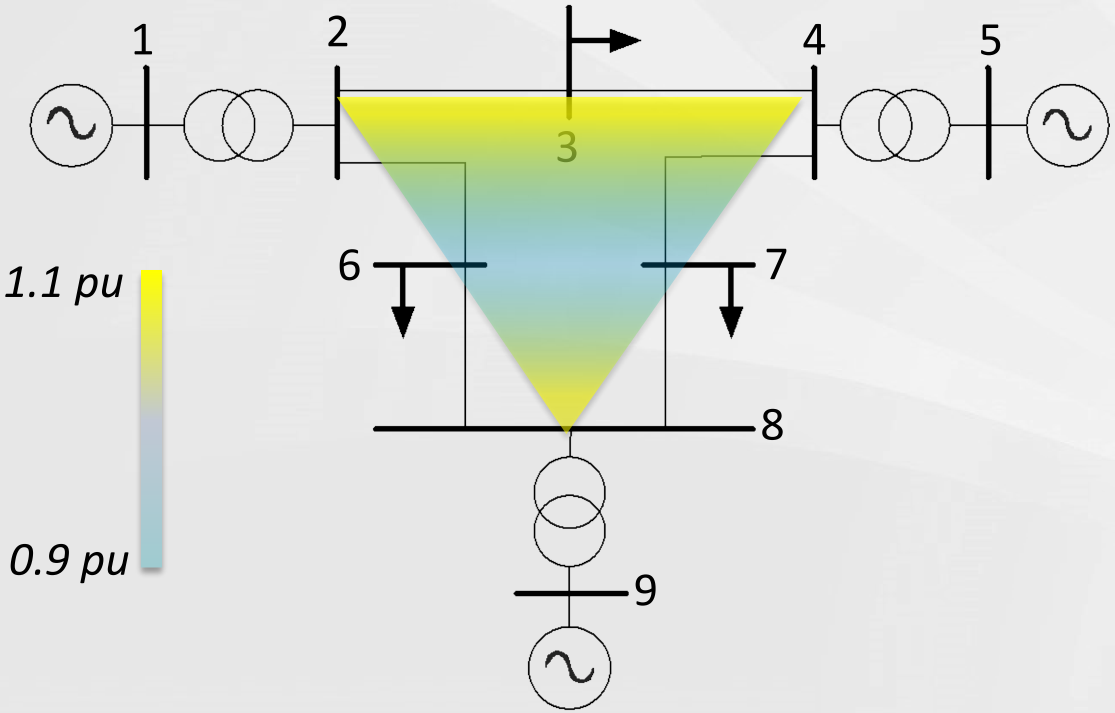
Dhananjay (DJ) Anand

Federal Advisory Committee Meeting

08/17/2017

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

Uncertainty and Variability in Distribution Circuits



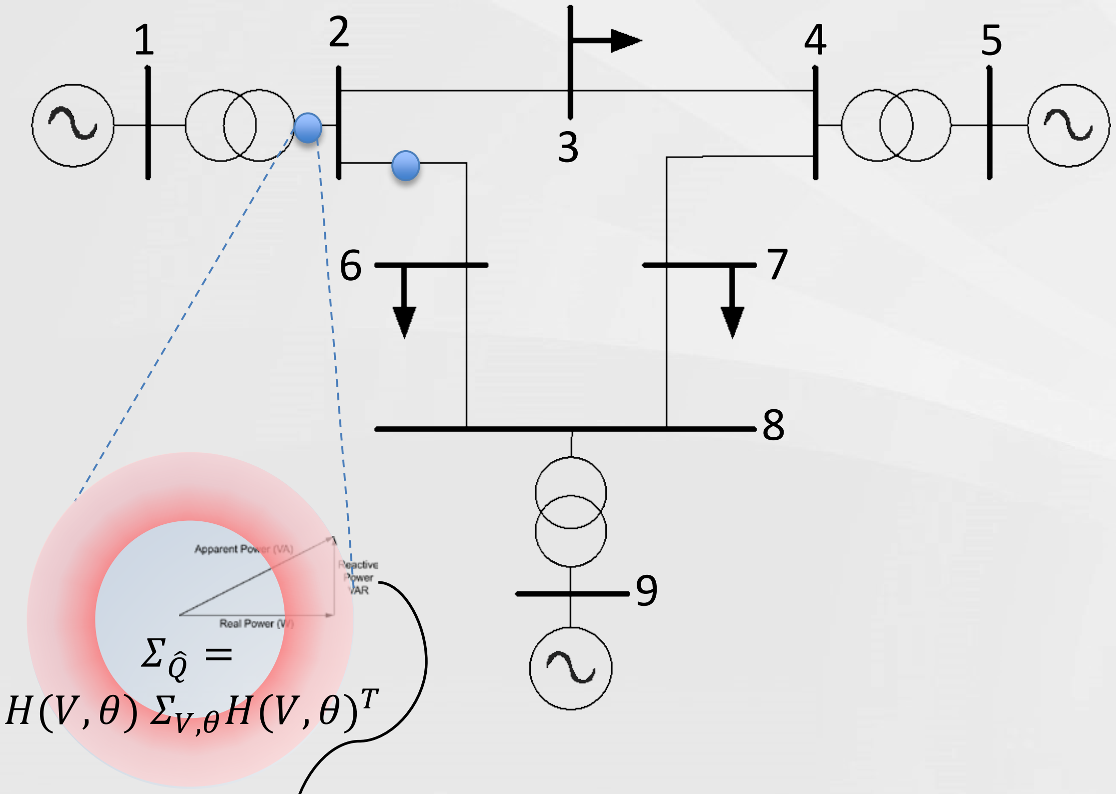
Epistemic Uncertainty

- **Uncertainty in circuit parameters**
- **Lack of observability on circuit buses**
- **Limited measurement of terminal loads**
- **Limited modeling of generation sources**

Aleatory Variability

- **Stochastic generation sources**
- **Aggregate statistical behavior of flexible loads**
- **Exogenous circuit parameters**
- **Quasi-equilibria in a system with non-convex objectives**

Uncertainty and Variability in Distribution Circuits



Epistemic Uncertainty

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- **Limited modeling of generation sources**

Aleatory Variability

- **Stochastic generation sources**
- **Aggregate statistical behavior of flexible loads**
- **Exogenous circuit parameters**
- **Quasi-equilibria in a system with non-convex objectives**

$$\begin{bmatrix} \hat{Q}_{12} \\ \hat{Q}_{26} \end{bmatrix} = \begin{bmatrix} V_2 V_3 B_{23} \cos(\theta_2 - \theta_3) + V_2 V_6 B_{26} \cos(\theta_2 - \theta_6) \\ V_2 V_6 B_{26} \cos(\theta_2 - \theta_6) \end{bmatrix}$$

$$H(X) := \frac{\partial h(X)}{\partial X}$$

Parameter Sensitivity : $\|H(X)\|$

Unobservable dynamics: $\|\mathcal{R}(H(X))\|$

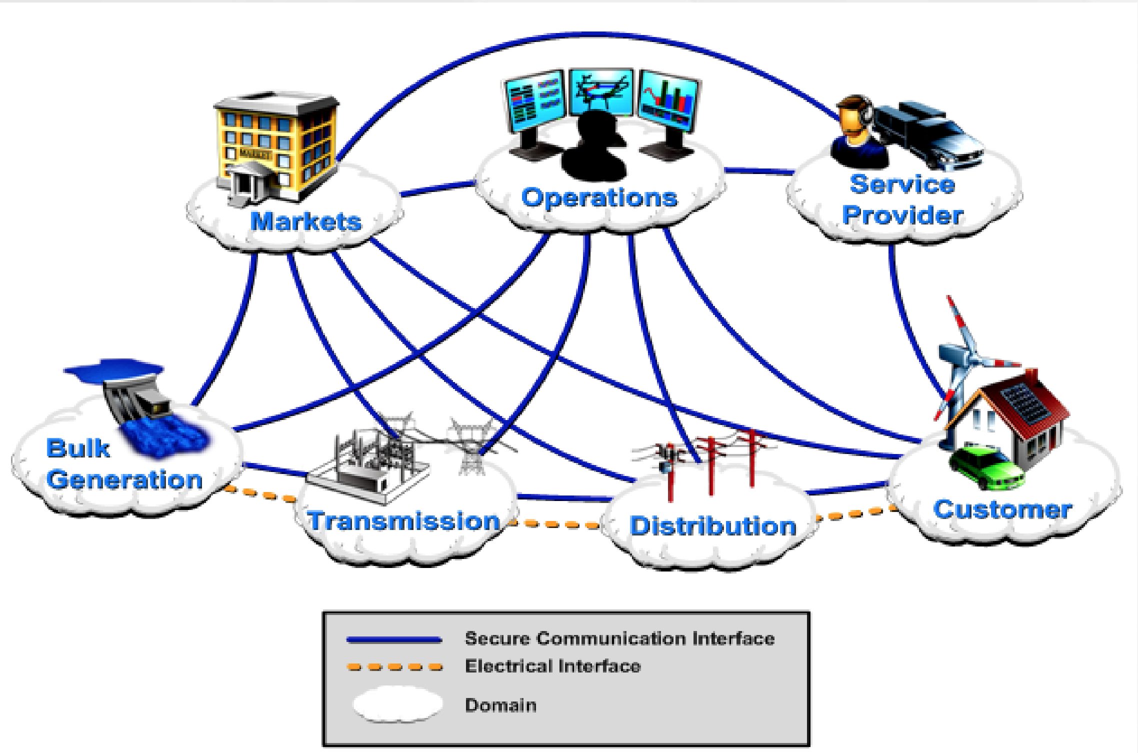
$$S = \Sigma_i \lambda_i \boldsymbol{x_i}$$

$$\Sigma\, \lambda_i = 1\,,\, \lambda_i \geq 0$$

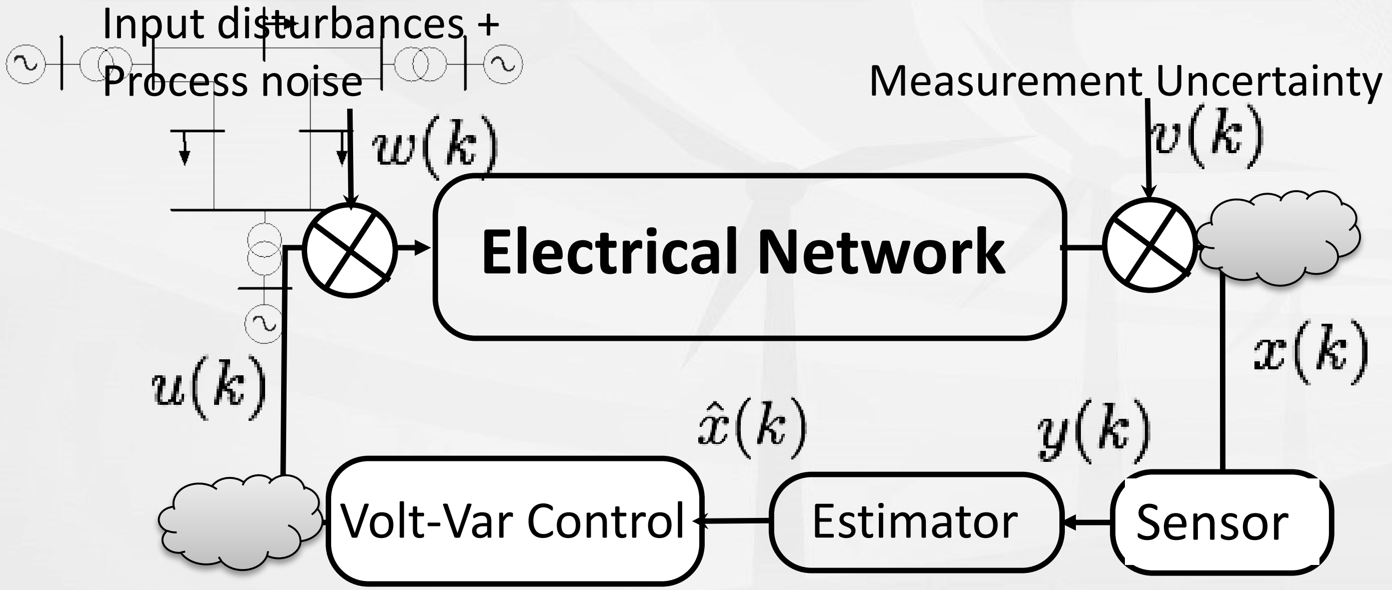
$$\mathbb{E}(Q|X) = \sum_{Q \in S} Q \cdot P(Q|X)\ ;$$

$$P(Q|X) = \frac{P(X|Q)P(Q)}{P(X)}$$

Advancing to measurement and validation of ‘systems’



Physical processes ↔ Communication networks ↔ Control algorithms

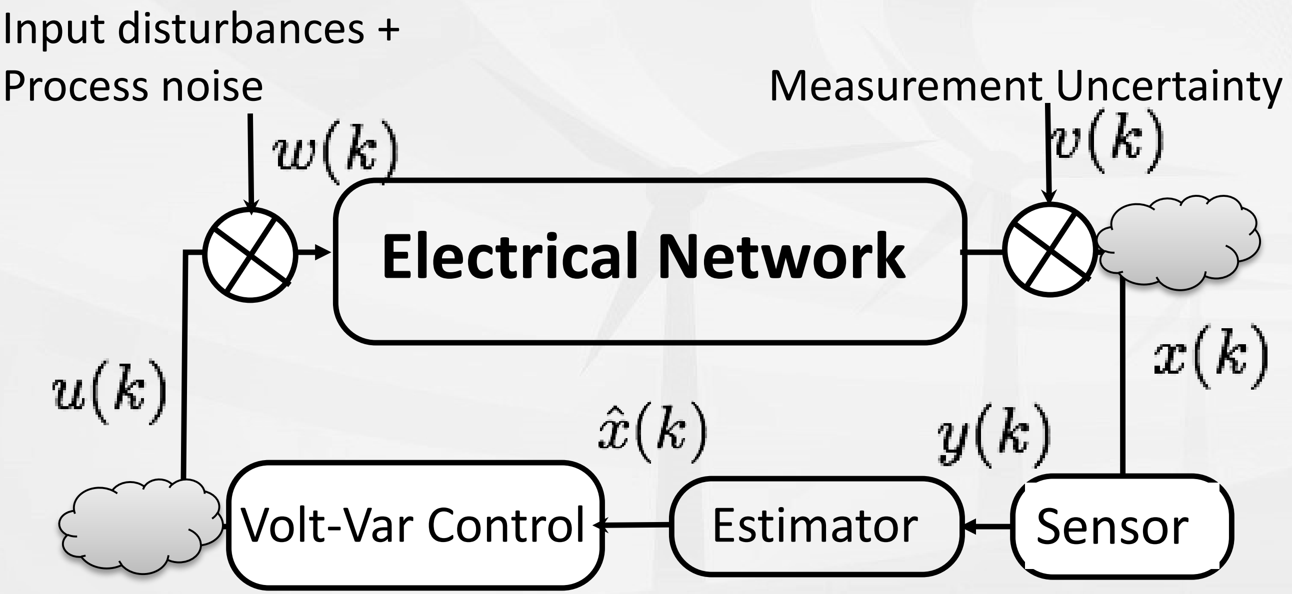


$$\begin{bmatrix}\hat{Q}_{12}\\ \hat{Q}_{26}\end{bmatrix} = \begin{bmatrix}V_2V_3B_{23}\cos(\theta_2-\theta_3)+V_2V_6B_{26}\cos(\theta_2-\theta_6)\\ V_2V_6B_{26}\cos(\theta_2-\theta_6)\end{bmatrix} + \begin{bmatrix}\varepsilon_1(V,I,\phi,\theta,\cdots)\\ \varepsilon_2(V,I,\phi,\theta,\cdots)\end{bmatrix} + \begin{bmatrix}\mathbb{E}(Q_{12}|X)\\ \mathbb{E}(Q_{26}|X)\end{bmatrix}$$

Challenges in factoring systemic uncertainty

- Dynamics are non-linear, hybrid and have multiple degrees of freedom.
- Communication models include stochastic loss and delay parameters.
- Control algorithms tend to use reduced order approximations resulting in state dependent uncertainty.

- Computational burden would be prohibitive for traditional Monte Carlo methods.
- Finite order stochastic formulations are needed for Sensitivity Analysis.
- Partial derivatives of system outputs (or parameters) with respect to the uncertain quantities tend to be numerically ill-posed.
- Bounds on the validity of model approximations form high order polytopes.
- Stochastic excitation of continuous dynamics interact with switched or delayed systems.



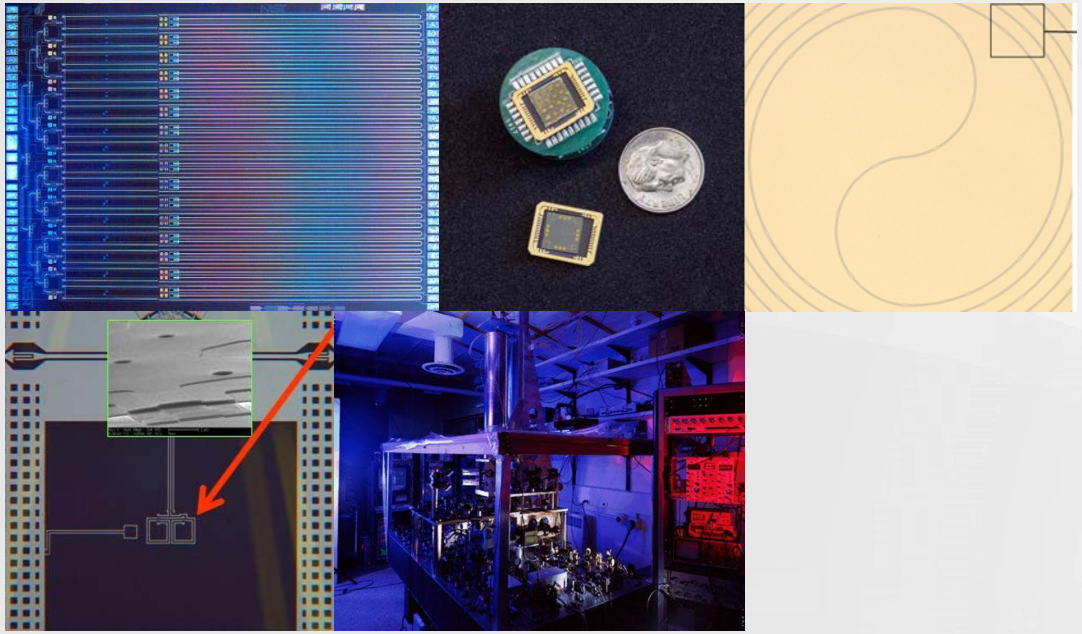
$$\begin{bmatrix}\hat{Q}_{12}\\ \hat{Q}_{26}\end{bmatrix} = \begin{bmatrix}V_2V_3B_{23}\cos(\theta_2-\theta_3)+V_2V_6B_{26}\cos(\theta_2-\theta_6)\\ V_2V_6B_{26}\cos(\theta_2-\theta_6)\end{bmatrix} + \begin{bmatrix}\varepsilon_1(V,I,\phi,\theta,\cdots)\\ \varepsilon_2(V,I,\phi,\theta,\cdots)\end{bmatrix} + \begin{bmatrix}\mathbb{E}(Q_{12}|X)\\ \mathbb{E}(Q_{26}|X)\end{bmatrix}$$

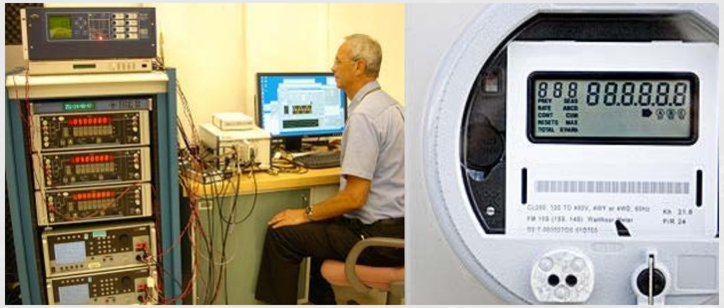
We plan to adopt three concurrent strategies

1. Minimize uncertainty within each component – leveraging current efforts.
2. Characterize the stochastic properties of the residual uncertainty to improve forecasts and model based estimates.
3. Propagate the uncertainty through interacting components while retaining analytical capabilities.

NIST contributions towards addressing uncertainty

Improved measurements





Epistemic Uncertainty

- **Uncertainty in circuit parameters**
  - NIST programmable Josephson voltage standard
  - NIST quantum Hall resistance standard
  - Maxwell-Wien bridge inductance standards
  - Calculable capacitor reference standard
  - Atomic standards for frequency
- **Lack of observability on circuit buses**
  - Synchrometrology
- **Limited measurement of terminal loads**
  - Improved energy/power metrology at grid edge
- **Limited modeling of generation sources**
  - Quantum characterization of solar PV cells
  - Electrical Performance of PV modules

NIST Efforts in physics based modeling and validation

Better modeling

Aleatory Variability

- **Stochastic generation sources (PV)**
  - Models of PV modules
  - NOAA sourced irradiance spectra
- **Aggregate statistical behavior of flexible loads**
  - Occupant and Latent Load Simulator (NZERTF)
- **Exogenous circuit parameters**
  - Reference models for transducers
  - Transformer loss models
  - Models for solid state switching devices
- **Quasi-equilibria in a system with non-convex objectives**
  - NIST solver for 2D elliptic PDEs on distributed memory parallel computers and multicore computers (PHAML)

We plan to adopt three concurrent strategies

1. Minimize uncertainty within each component – leveraging current efforts.
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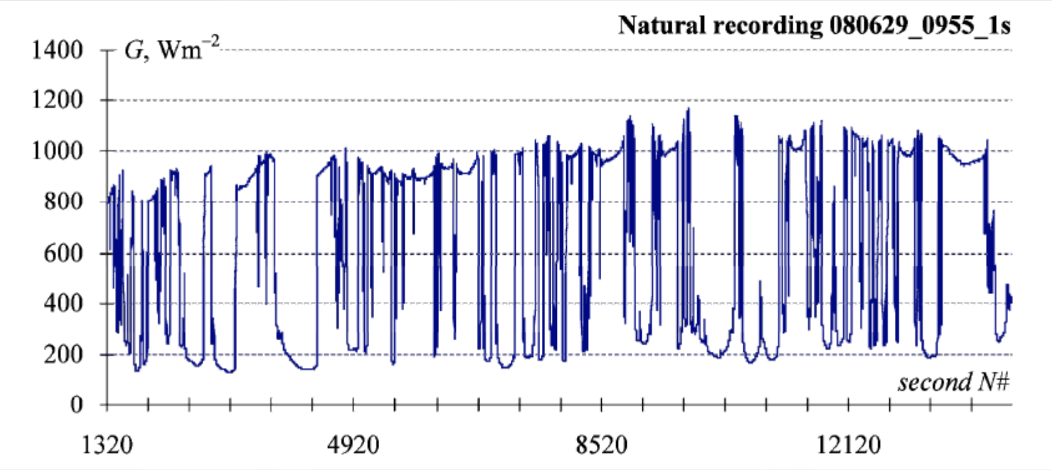
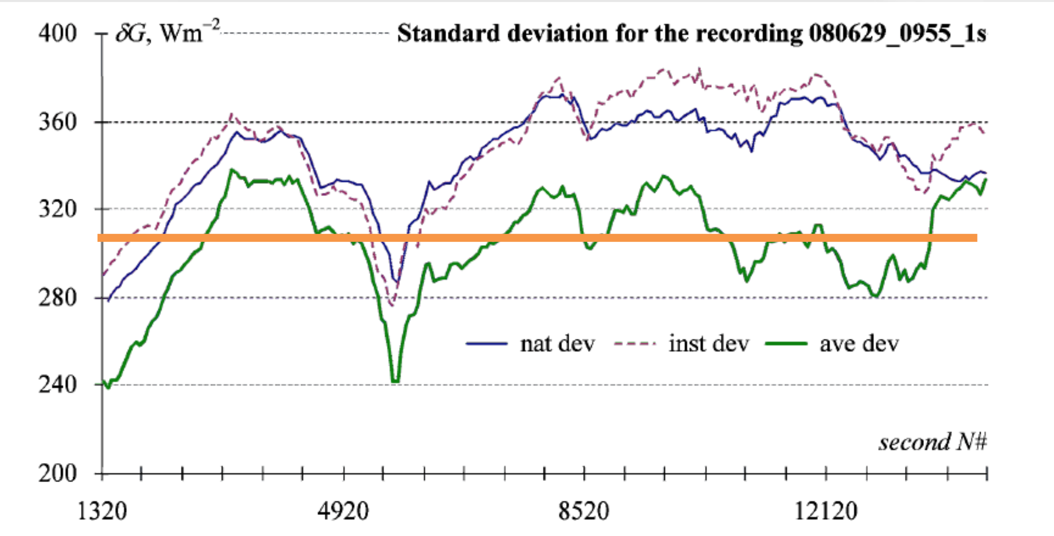
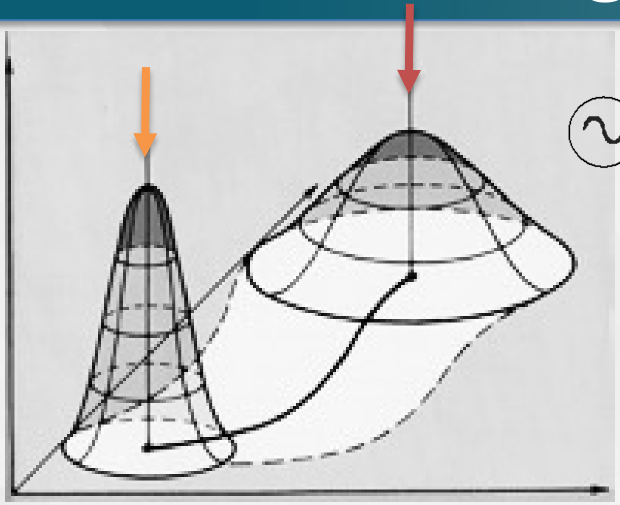
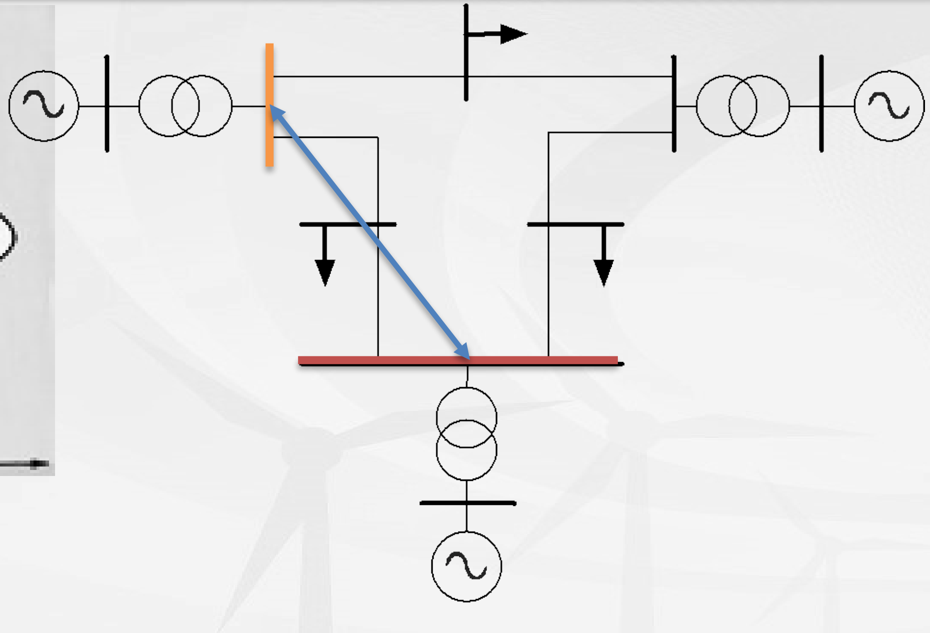
3. Propagate the uncertainty through interacting components while retaining analytical capabilities.

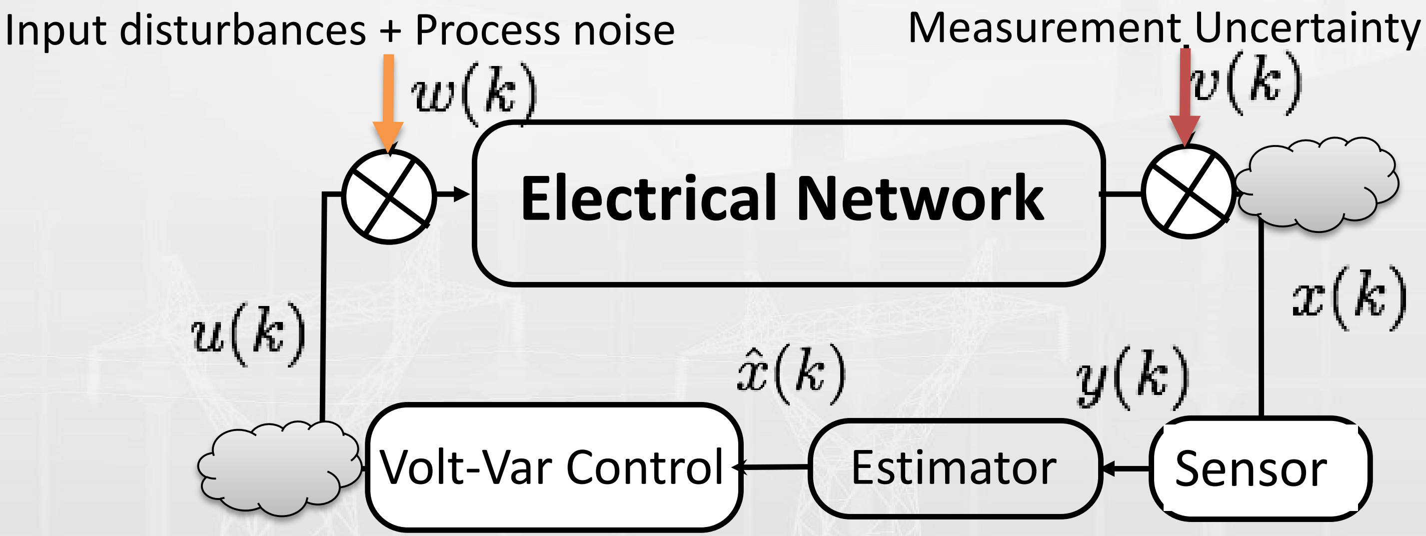
Example: Voltage regulation with high PV penetration





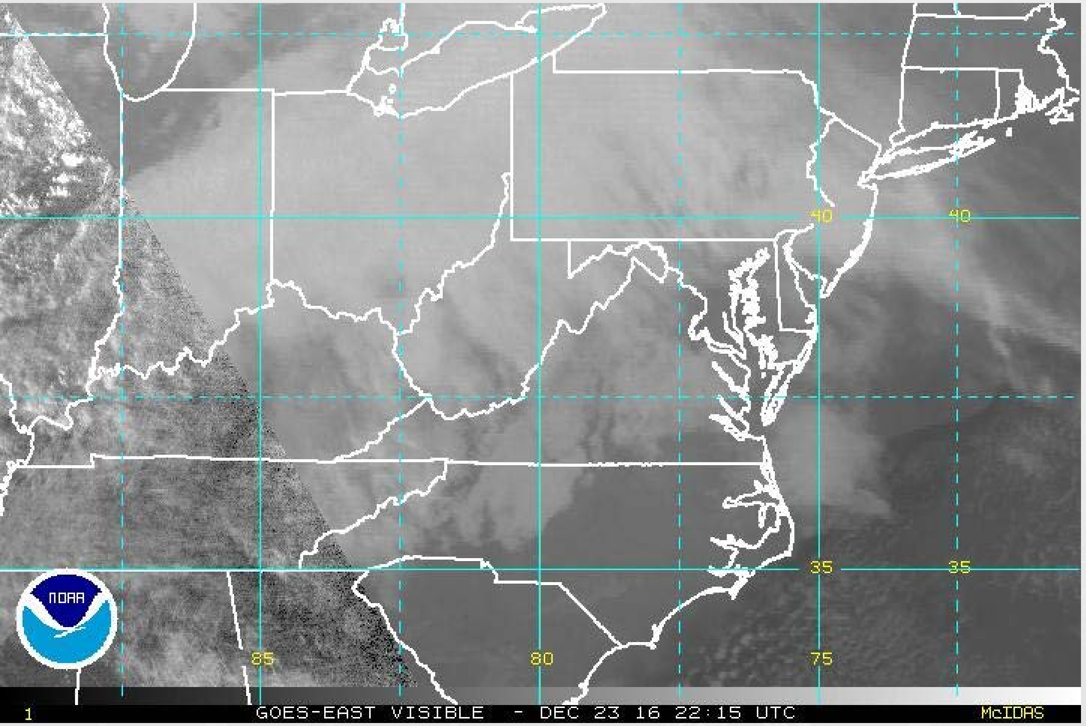






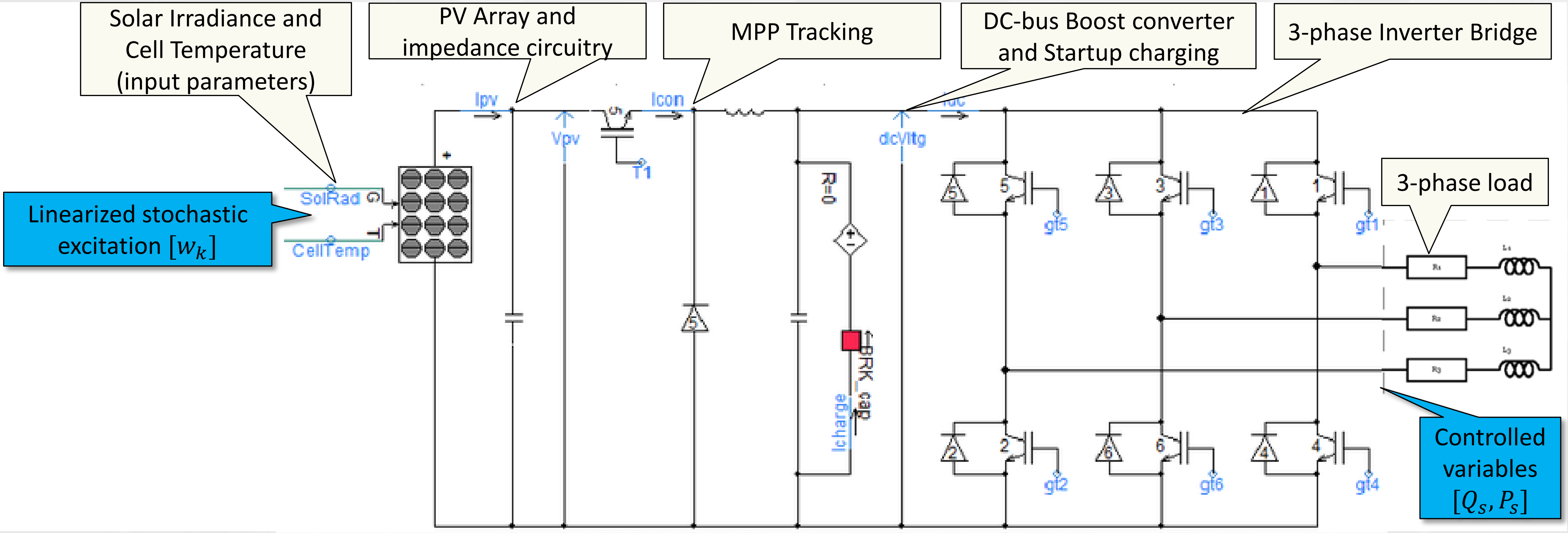
Improve analytical approximations for $w(k)$

Track, predict and linearize insolation estimates over $10^1 - 10^3$ second horizon.



Improve analytical approximations for $w(k)$ (linearization)

Disturbance characterization is non-trivial



We plan to adopt three concurrent strategies

1. Minimize uncertainty within each component – leveraging current efforts.
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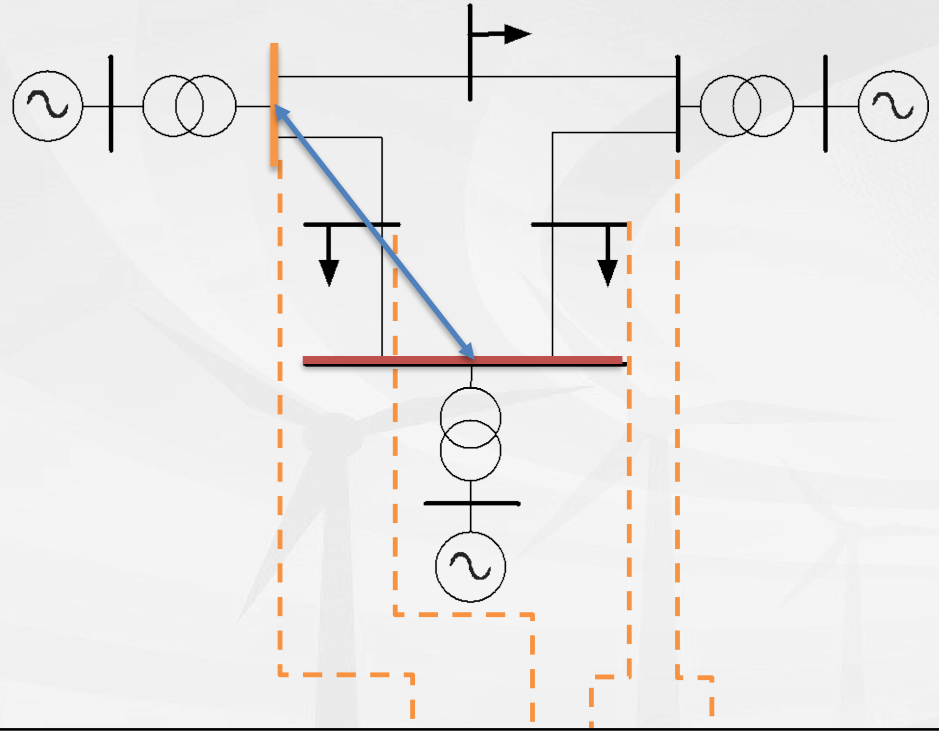
Uncertainty propagation through physics and time

A reduced order stochastic formulation will allow us to propagate (dynamic evolution of a projection) in order to minimize uncertainty of the **current** *as well as* the **future state**.



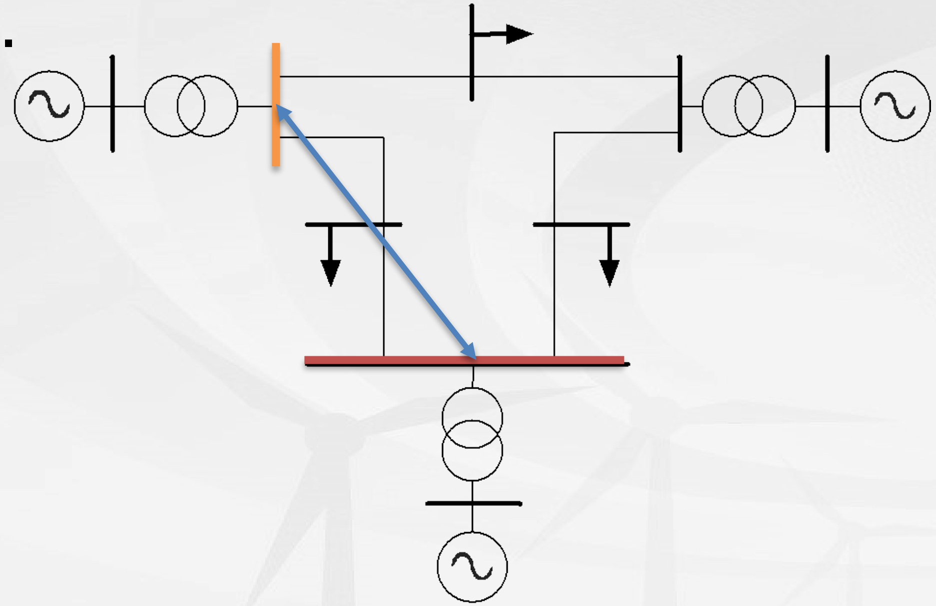
An existing method to represent the coupling between multiple Stochastic Differential Equations is the FPK equation.

A PDE that describes the time evolution of the probability density function of a trajectory under the influence of random forces.

Electrical power systems present some unique pitfalls!

Our proposed finite order stochastic formulation

Gaussian mixture models bounded by convex hulls.

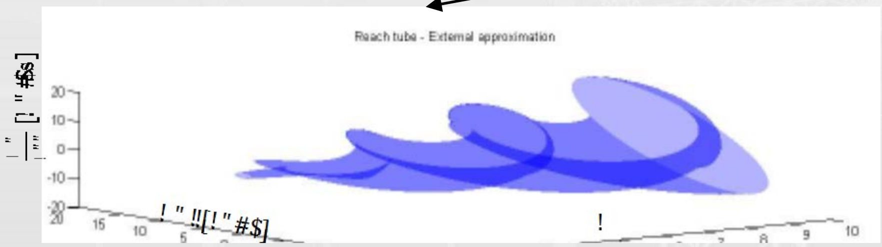


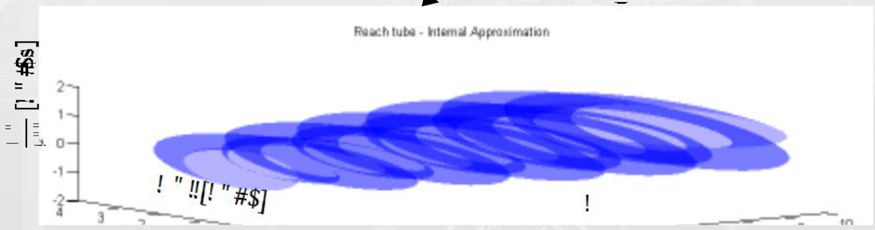
The approach is amenable to **a-posteriori adaptation** in response to measurements.

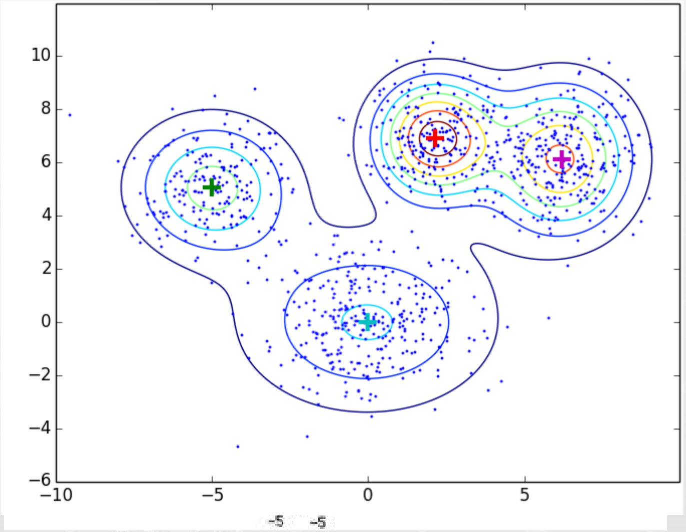
Able to leverage both the **FPK formulation** as well as the **geometric propagation** of convex hulls through switched or hybrid dynamical systems.

$$\varepsilon(V, I, \phi, \theta, \cdots)$$

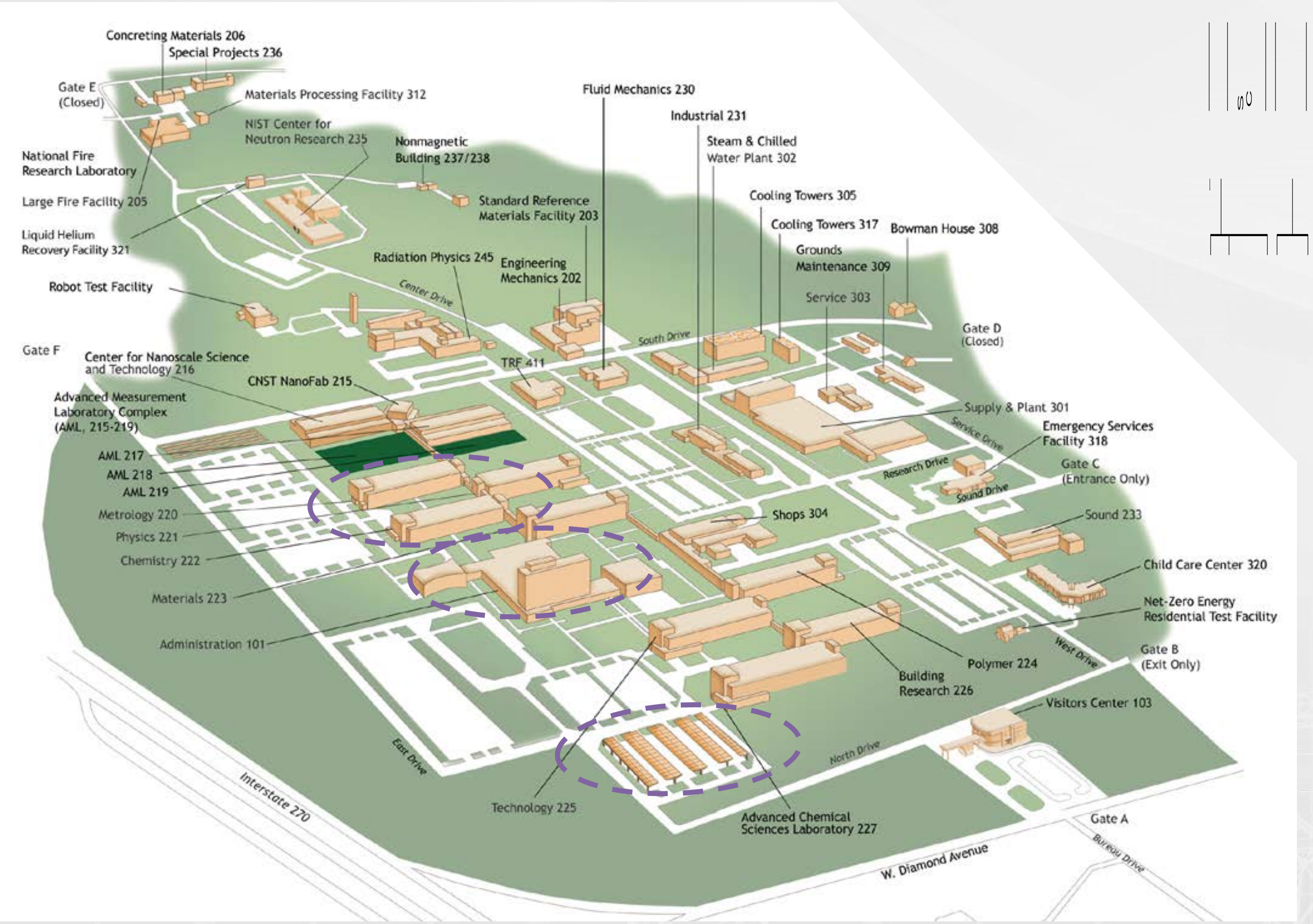
$$\mathbb{E}(Q|Z^1_{\in\mathbb{Z}^+}) \qquad \mathbb{E}(Q|Z^2_{\in\mathbb{Z}^+})$$

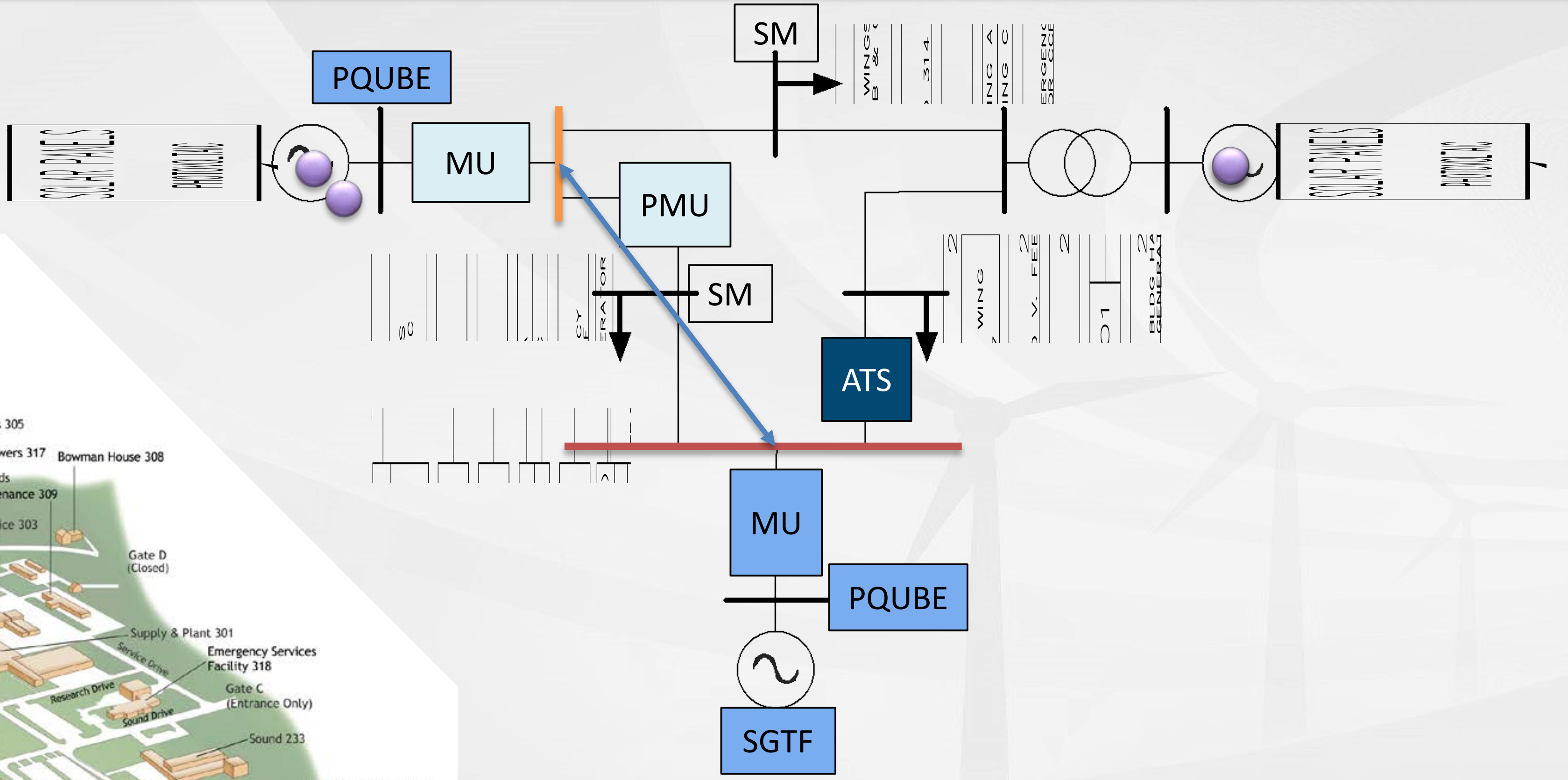






Validation using NIST campus’ distribution circuit





Thank you

1. Minimize uncertainty within each component.
2. Characterize the stochastic properties of the residual uncertainty to improve forecasts and model based estimates.
3. Propagate the uncertainty through interacting components while retaining analytical capabilities.

NIST Smart Grid Advisory Committee SEPA Update - 2017

Sharon Allan
Chief Innovation Officer
August 15, 2017

Smart Electric Power Alliance

History of SGIP >> SEPA

The Timeline . . .

Smart Electric Power Alliance

2017 Priority Action Plan Closures:

- PAP-15: Harmonized Power Line Carrier
- PAP-17: Facility Smart Grid Information Standard
- PAP-20: Green Button ESPI Evolution
- PAP-21: Weather Information
- PAP-23: IEC 61850 Testing Profiles
- PAP-26: Distributed Intelligence

Sept 2009
NIST SG Interoperability Framework 1.0

Nov 2009
NIST establishes SGIP

July 2011
First 6 Entries In the CoS

Feb 2012
NIST SG Interoperability Framework 2.0

Dec 2012
SGIP 2.0, Inc

2013
- First SGIP2.0 election held
- Exec Dir Hired
- First Tech conference held

Sept 2014
NIST SG Interoperability Framework 3.0

2014
- Exec Dir replaced with CEO
- Vendor contracts terminated and

March 2015
BoD reduced from 22 to 12

2015
- Launched OpenFMB
- Prioritized focus
- Contract for 2016 - 2018 Cooperative

2016
- Rebrand
- 3 websites launched
- Launched Grid Mgmt Group
- Awarded 3

Feb 2017
SGIP closes 6 PAPs

April 2017
- SGIP merges with SEPA
- 81 Entries in CoS

SGIP – 2017
Thru March Summary

6 Priority Action Plan Closures

- PAP-15: Harmonized Power Line Carrier
- PAP-17: Facility Smart Grid Information Standard
- PAP-20: Green Button ESPI Evolution
- PAP-21: Weather Information
- PAP-23: IEC 61850 Testing Profiles
- PAP-26: Distributed Intelligence

3 SGIP WHITE PAPERS PUBLISHED

New Committees/ Subgroups Formed

- Technical Advisory Council (TAC)
- Catalog of Test Programs (CoTP)
- OpenFMB Management Services Task Force

The Catalog of Standards Visualization Tool

- The Catalog of Standards Visualization Tool went live in February 2017.
- 81 Standard in CoS

Working Groups

- 350+ Meetings Held
- 1650+ Participants
- 285+ Hours of Meeting & Collaboration

Webinar Participant Geographic Regions

Algeria, Australia, Bangladesh, Brazil, Canada, China, Colombia, Ecuador, France, India, Japan, Korea (South), Malaysia, Mexico, New Zealand, Portugal, Romania, Singapore, South Africa, Spain, Turkey, United Kingdom, and United States

25 Countries

2017 Educational Webinars

- Cyber-Physical Resiliency Webinar
- Economic Value of the Integration of Consumption Preferences in Electric System Planning Webinar
- Evaluation of the Electromagnetic Phenomena Issues on Smart Grid Reliability Webinar
- H/B/I2G DEWG Smart Grid System Security with Broadcast Communications
- Orange Button Webinar -
- Orange Button Year Two Update Webinar
- Smart Grid Cybersecurity Committee Webinar: A Comparison of How Key Cybersecurity Standards Affect Smart Grid

- 7 Webinars Held
- 560+ Total Attendees
- 1177 Total Registrants

Priority Action Plan Status

Smart Electric Power Alliance

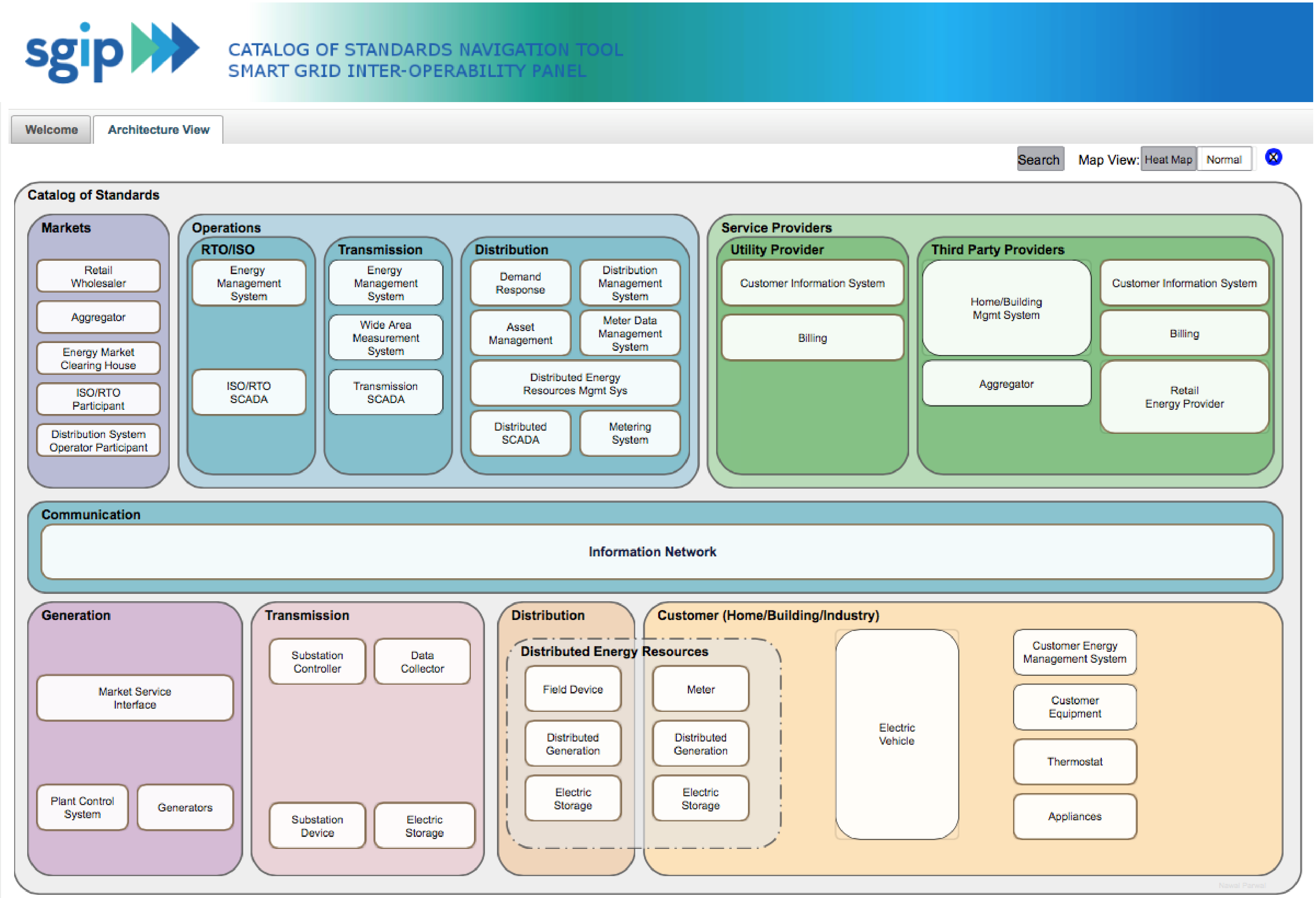
3 PAPs Remain Open

PAP Number	PAP Name	PAP Status	PAP Next Step
22	EV Fueling Submetering Requirements	OPEN	1) Awaiting NEMA EVSE specification publication (estimated within two months); 2) Planning to publish EVSE application whitepaper
24	Microgrid Operational Interfaces	OPEN	Ongoing work coordinated with IEEE SA. Awaiting report of results of balloting for approval of IEEE 2030.7 and 2030.8. Also developing white paper on Technical Implications of Regulatory Environment for Microgrids.
25	Orange Button: Harmonized Financial Data	OPEN	PAP 25 scope included in Orange Button DOE project. This PAP will close when Orange Button is complete and closed.

24 PAPs Have Been Closed

PAP Number	PAP Name	PAP Status
0	Meter Upgradeability Standard	CLOSED
1	Role of IP in the Smart Grid	CLOSED
2	Wireless Communications for the Smart Grid	CLOSED
3	Common Price Communication Model	CLOSED
4	Common Schedule Communication Mechanism	CLOSED
5	Standard Meter Data Profiles	CLOSED
6	Common Semantic Model for Meter Data Tables	CLOSED
7	Energy Storage Interconnection Guidelines DER/Electric Storage Interconnection & Object Model Std	CLOSED
8	CIM/61850 for Distribution Grid Management	CLOSED
9	Standard DR and DER Signals	CLOSED
10	Standard Energy Usage Information	CLOSED
11	Common Object Models for Electric Transportation	CLOSED
12	Mapping IEEE 1815 (DNP3) to IEC 61850	CLOSED
13	Harmonization of IEEE C37.118 with IEC 61850 and Precision Time Synchronization	CLOSED
14	Transmission and Distribution Power Systems Model Mapping	CLOSED
15	Harmonize Power Line Carrier Standards for Appliance Communications in the Home	CLOSED
16	Wind Plant Communications	CLOSED
17	Facility Smart Grid Information Standard	CLOSED
18	SEP 1.x to SEP 2 Transition and Coexistence	CLOSED
19	Wholesale Demand Response (DR) Communicatiion Protocol	CLOSED
20	Green Button ESPI Evolution	CLOSED
21	Weather Information	CLOSED
23	Testing Profile for IEC 61850, Communication Networks and Systems in Substations	CLOSED
26	OpenFMB: Distributed Intelligence	CLOSED

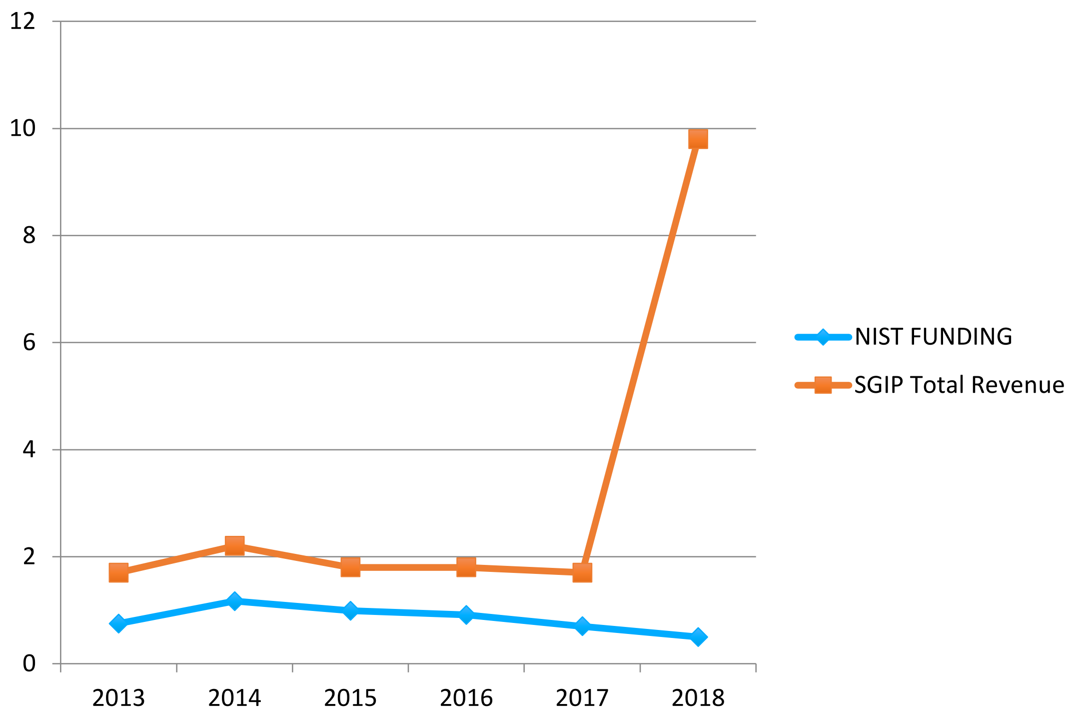
CoS is available via the Web



10+ new candidate standards have been suggested, SIFs not submitted yet

The Journey

Smart Electric Power Alliance



- Over the course of the last 3 years we have been keeping Revenue flat by diversifying sources as NIST funding decreased
- SEPA is a step change in Revenue

SEPA Staff is a total of 48 with SGIP Combined Revenues near $10M

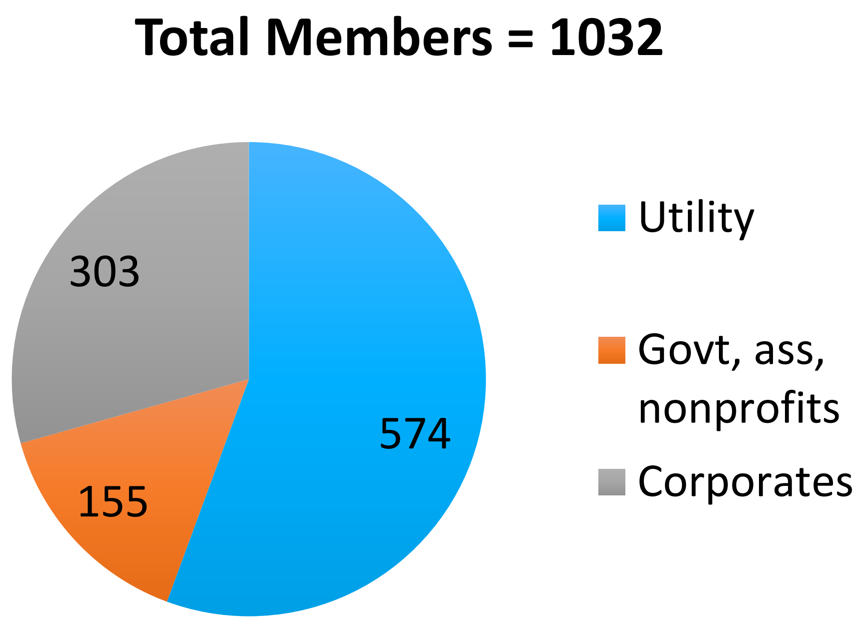
SEPA Mission & Membership

On April 1, 2017, SGIP merged with the Smart Electric Power Alliance (SEPA)

Mission

To facilitate the electric power sector's smart transition to a clean energy future through education, research, standards, and collaboration.

Membership



The SEPA Board

Smart Electric Power Alliance

Bruce Edelston, VP of Energy Policy, Southern Company
Caroline Choi, SVP Regulatory Affairs, Southern Calif Edison
Jill Anderson, EVP, NY Power Authority
Jim Albert, SVP, HECO
Matt Handel, VP of DG and Storage, NextEra Energy
Jim Rogers, Former Chairman of Duke
Raiford Smith, VP Emerging Technologies, Entergy
Joe Hoagland, VP Stakeholder Engagement, TVA
Paul Lau, Chief Strategy Officer, SMUD
Rob Caldwell, President Renewables & Storage, Duke
David Forfia, Dir IT Transformation, ERCOT
John Hewa, VP Corp Services, Rappahannock
Mark Nielson, VP Service, Deleware Electric Coop
Karen Butterfield, COO, STEM
Ron Binz, Binz Consulting
Seth Frader-Thompson, CEO, Energyhub
Steve Malnight, SVP Strategy & Policy, PG&E
Tom Starrs, VP, Sunpower

2017 Ex-Officios and members of the TAC (Tech Adv Council)

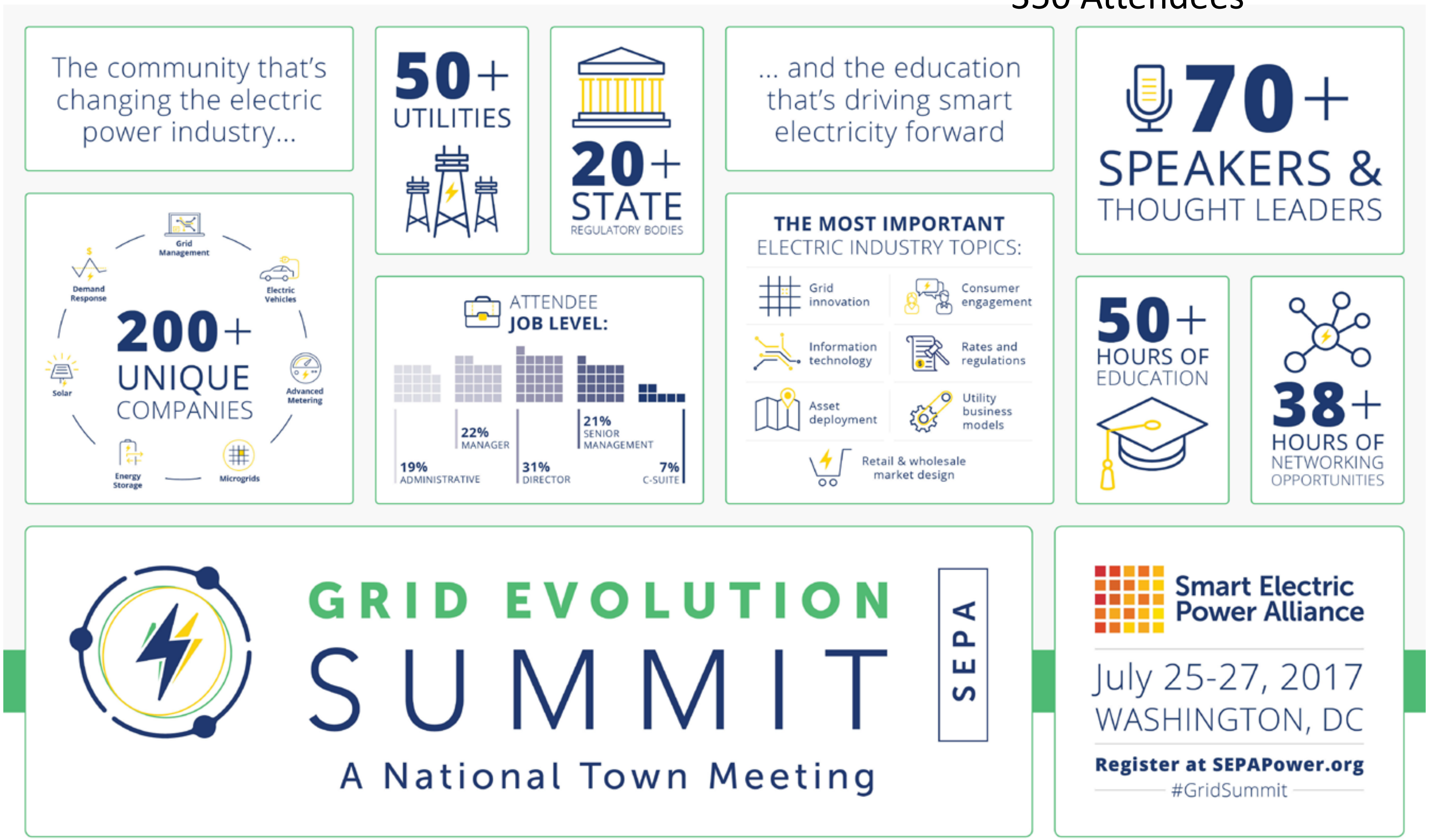
Andres Carvallo, CMG
David Wollman, NIST
Robby Simposn, GE
Nick Wagner, Iowa PUB
Michael Bates – Intel
Aaron Snyder – Enernex
Bill Ash – IEEE
Tony Thomas - NRECA

Grid Evolution Summit

July 2017

Smart Electric Power Alliance

350 Attendees



Speakers Included:

- Avi Gopstein
- Cuong Nguyen
- Suzanne Lightman
- Nelson Hastings
- Tim Polk
- David Holmberg
- Dr. Greer

✓ 11 Working Group & Committee Meetings

✓ One Meet & Greet Technical Working Group Networking Breakfast

SEPA's focus for 2017 is to complete the integration

Smart Electric Power Alliance

- Integrate Web sites
- Integrate Accounting and Time Tracking
- Integrate Events ✓
- Integrate Working Groups
- Launch the TAC ✓
- Continue to support PAPs/CoS
- Expand reach of '51st State'
- Continue to execute on existing programs ✓

SEPA appreciates the opportunity to work with NIST and looks forward to continuing our efforts together

Smart Electric
Power Alliance

Interoperability Framework Discussion

Avi Gopstein

Smart Grid Program Manager

Smart Grid and Cyber-Physical Systems Program Office
National Institute of Standards and Technology

U.S. Department of Commerce

August 17, 2017

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

Energy Independence and Security Act

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…*"

NIST Smart Grid Interoperability Framework

This publication is available free of charge from http://dx.doi.org/10.6028/NIST.SP.1108r3

NIST Special Publication 1108r3

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0

Smart Grid and Cyber-Physical Systems Program Office
and Energy and Environment Division,
Engineering Laboratory

in collaboration with
Quantum Measurement Division,
Semiconductor and Dimensional Metrology Division,
and Electromagnetics Division,
Physical Measurement Laboratory
and
Advanced Network Technologies Division
and Computer Security Division,
Information Technology Laboratory

http://dx.doi.org/10.6028/NIST.SP.1108r3

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

- Ongoing effort to “coordinate development of a framework that includes protocols and model standards for information management to achieve interoperability of Smart Grid devices and systems.”
- Includes smart grid conceptual reference model and conceptual architectural framework.

Interoperability Frameworks to date

NIST Special Publication 1108

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0

Office of the National Coordinator for Smart Grid Interoperability

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

2010

NIST Special Publication 1108R2

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 2.0

Office of the National Coordinator for Smart Grid Interoperability,
Engineering Laboratory
in collaboration with
Physical Measurement Laboratory
and
Information Technology Laboratory

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

2012

This publication is available free of charge from http://dx.doi.org/10.6028/NIST.SP.1108r3

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and Computer Security Division,
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http://dx.doi.org/10.6028/NIST.SP.1108r3

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

2014

Interoperability Framework V1

NIST Special Publication 1108

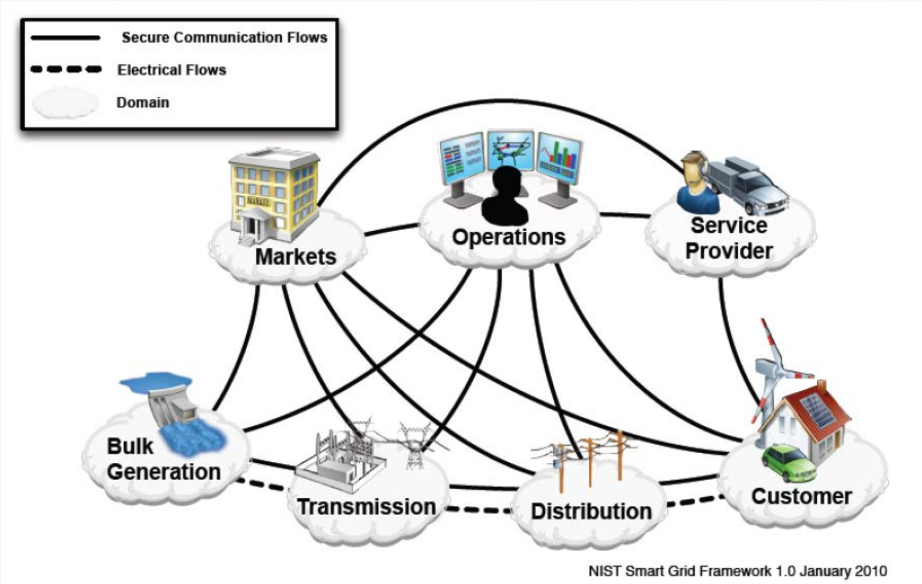
NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0

Office of the National Coordinator for Smart Grid Interoperability

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

2010

Introduced grid domains

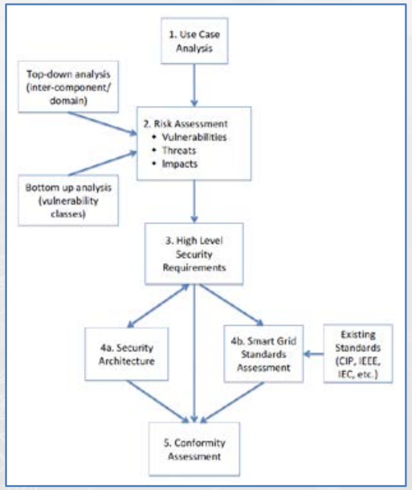


Explored network information exchange

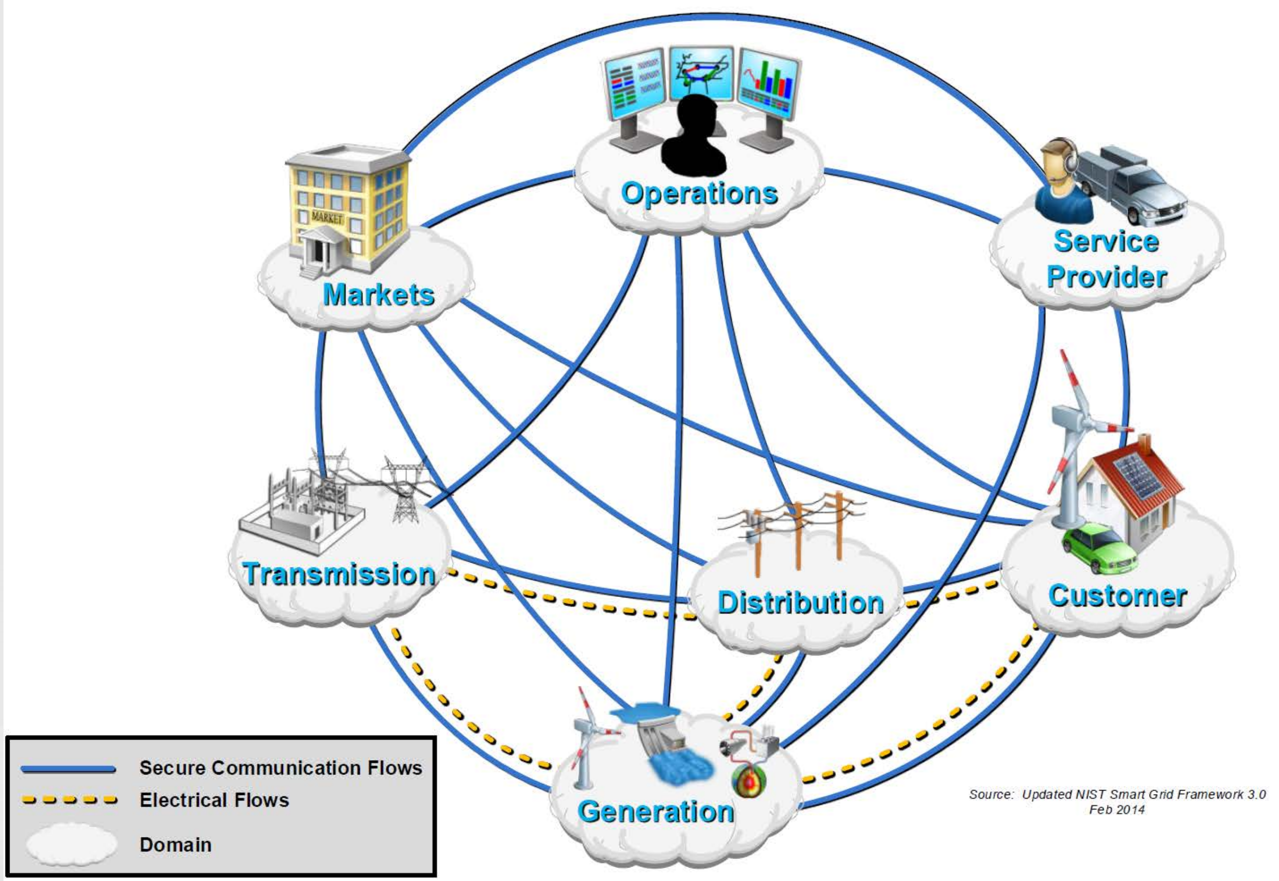
Identified 25 standards

	Standard	Application	Comments
Standards and Specifications			
1	ANSI/ASHRAE 135-2008/ISO 16484-5 BACnet - A Data Communication Protocol for Building Automation and Control Networks http://resourcecenter.ashrae.org/store/ashrae/newstore.cgi?itemid=30853&view=item&page=1&loginid=39839941&priority=none&words=135-2008&method=and&	BACnet defines an information model and messages for building system communications at a customer's site. BACnet incorporates a range of networking technologies to provide scalability from very small systems to multi-building operations that span wide geographic areas using IP protocols.	Open, mature standard with conformance testing developed and maintained by an SDO. BACnet is adopted internationally as EN ISO 16484-5 and used in more than 30 countries. This standard serves as a customer side communication protocol at the facility interface and is relevant to the Price, DR/DER, and Energy Usage PAPs (see Sec. 5.5 - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP03PriceProduct , Sec. 5.4 - http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP09DRDER, and Sec. 5.3- http://collaborate.nist.gov/twiki-sggrid/bin/view/SmartGrid/PAP10EnergyUsagetoEMS).
2	ANSI C12 Suite : ANSI C12.1 http-p://webstore.ansi.org/RecordDetail.aspx?sku=ANSI+C12.1-2008 ANSI C12.18/IEEE P1701/MC1218 http://webstore.ansi.org/FindStandards.aspx?SearchString=c12.18&SearchOption=0	Performance and safety type tests for revenue meters. Protocol and optical interface for measurement devices.	Open, mostly mature standards. It is recognized that ANSI C12.19 is an extremely flexible revenue metering model that allows such a wide range of options that requests for actionable information from a meter, such as usage in kilowatt hours, requires complex programming to secure this information. ANSI C12.19 2008 has a mechanism by which table choices can be described, termed Exchange Data Language (EDL), that can be used to constrain oft-utilized information into a well-known form. A Priority Action Plan (PAP) has been set up to establish common data tables for meter information that will greatly reduce the time for

… and cyber

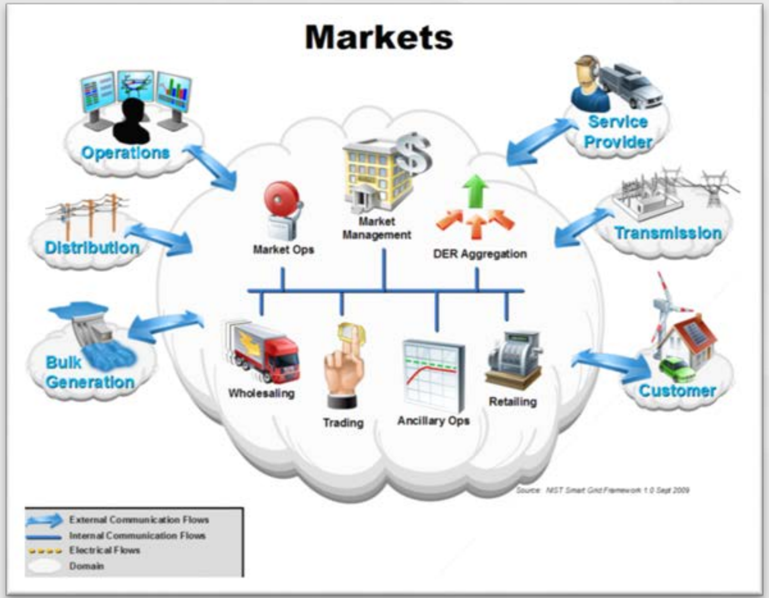


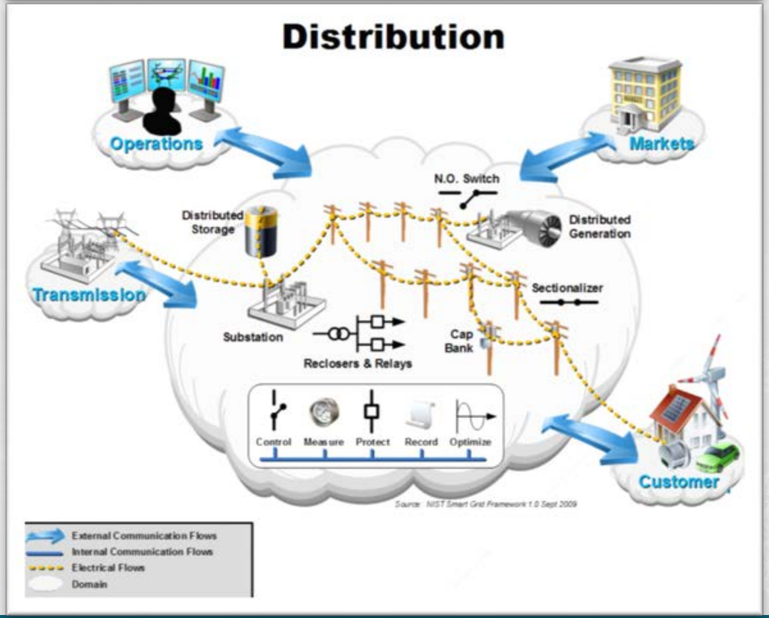
Smart Grid Conceptual Model (2014)

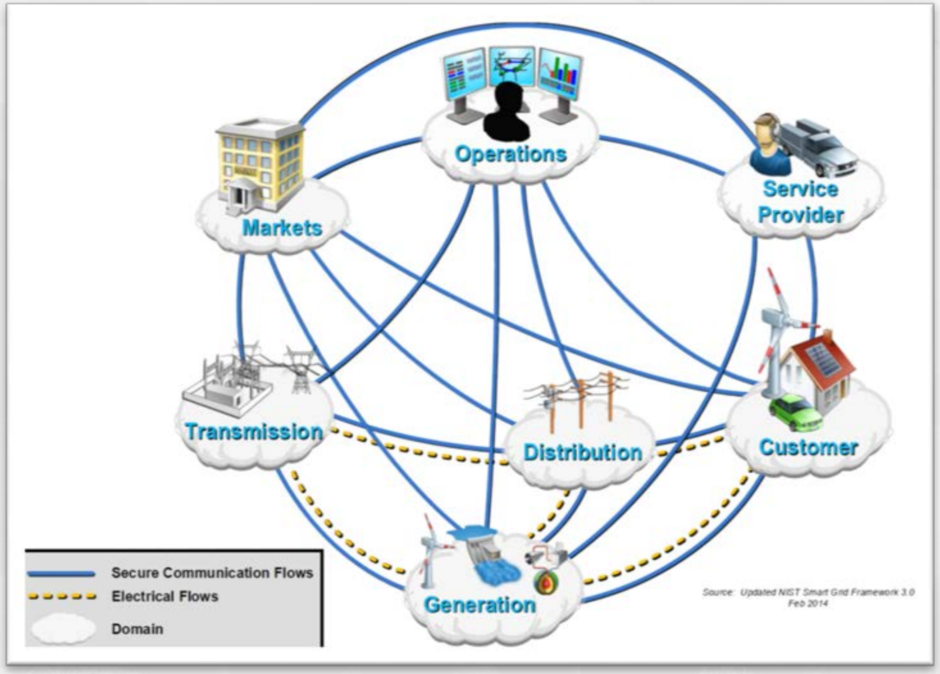


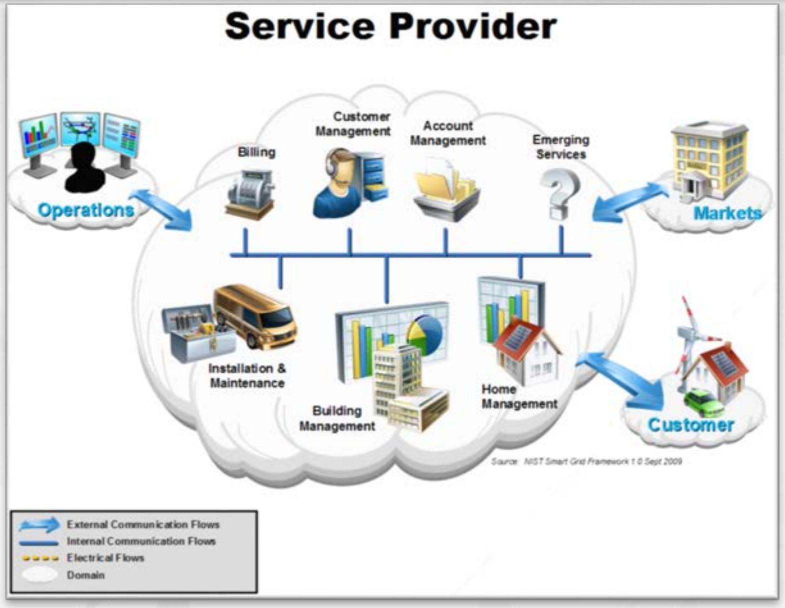
	Domain	Roles/Services in the Domain
1	Customer	The end users of electricity. May also generate, store, and manage the use of energy. Traditionally, three customer types are discussed, each with its own domain: residential, commercial, and industrial.
2	Markets	The operators and participants in electricity markets.
3	Service Provider	The organizations providing services to electrical customers and to utilities.
4	Operations	The managers of the movement of electricity.
5	Generation	The generators of electricity. May also store energy for later distribution. This domain includes traditional generation sources (traditionally referred to as generation) and distributed energy resources (DER). At a logical level, "generation" includes coal, nuclear, and large-scale hydro generation usually attached to transmission. DER (at a logical level) is associated with customer- and distribution-domain-provided generation and storage, and with service-provider-aggregated energy resources.
6	Transmission	The carriers of bulk electricity over long distances. May also store and generate electricity.
7	Distribution	The distributors of electricity to and from customers. May also store and generate electricity.

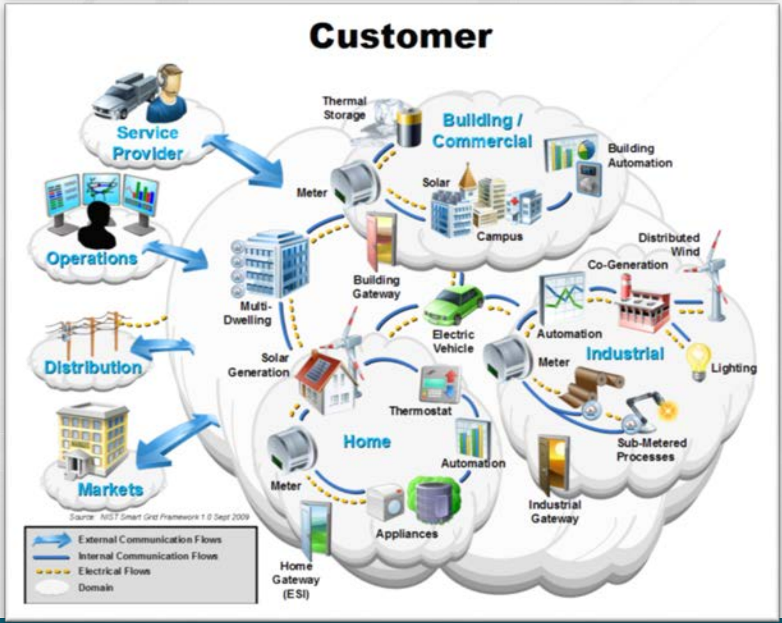
Smart Grid Conceptual Model (2014)



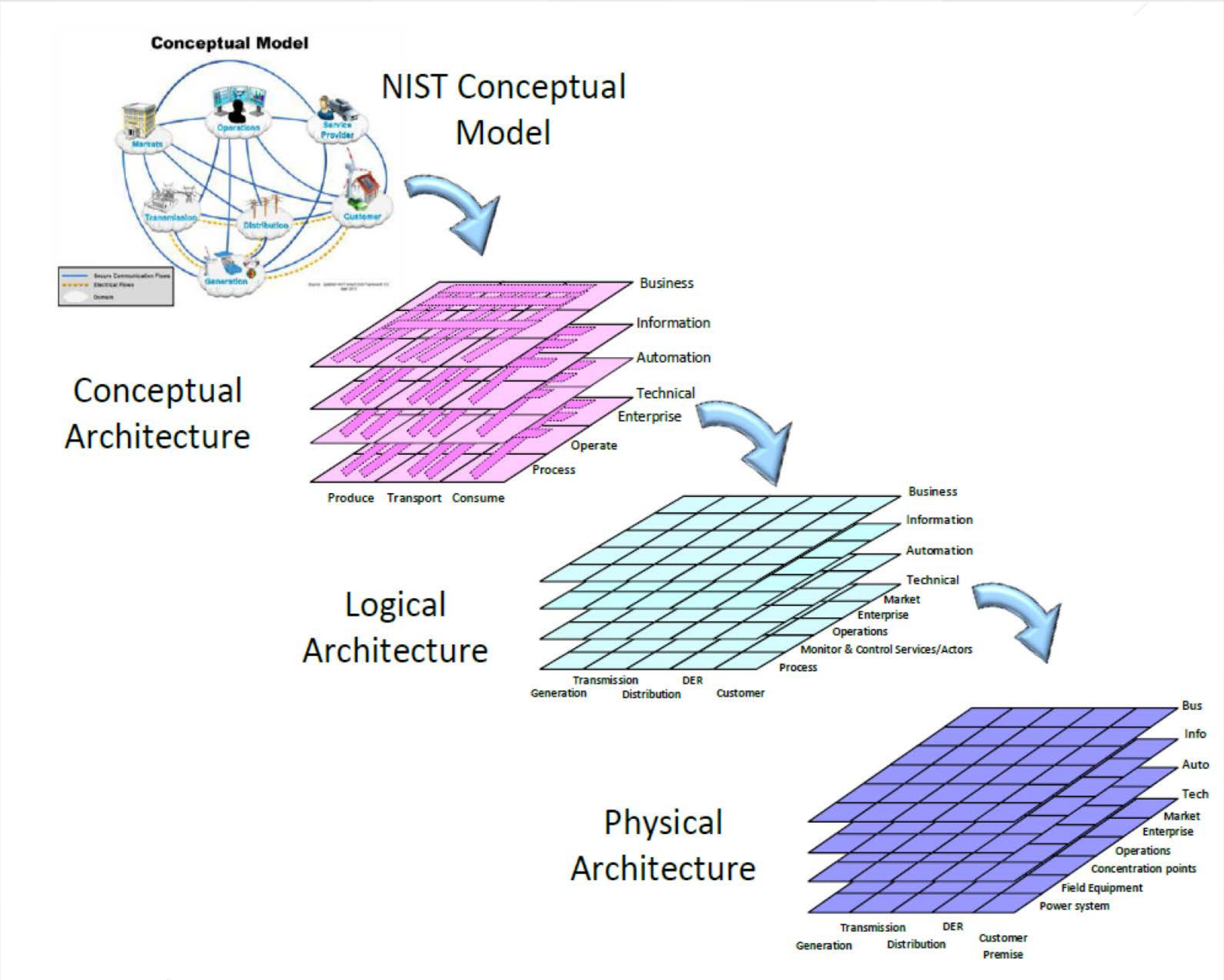








Smart Grid Conceptual Model (2014)



SGAM Layers & Planes

- Conceptual
- Logical
- Physical
- Implementation

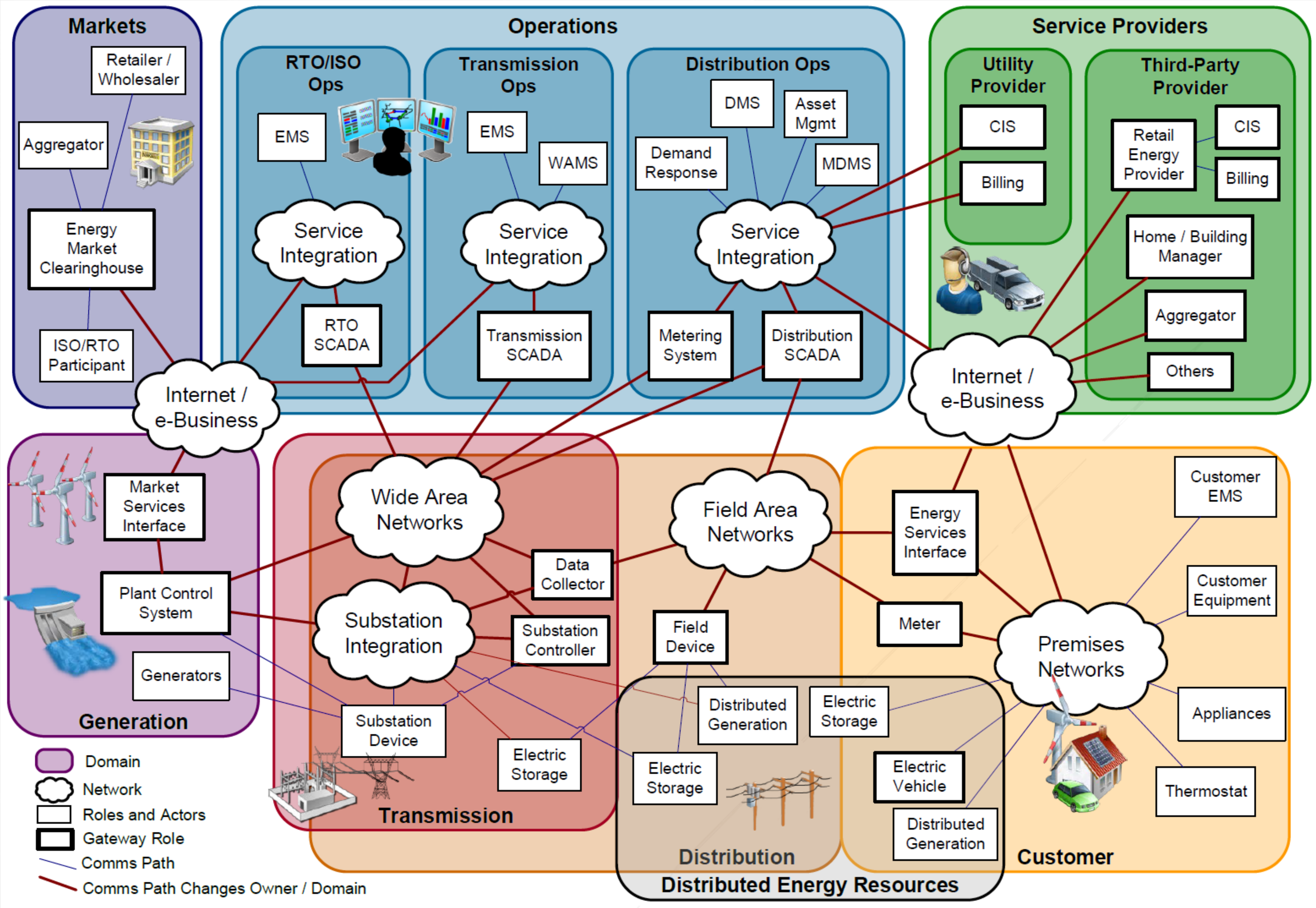
Business

Information

Automation

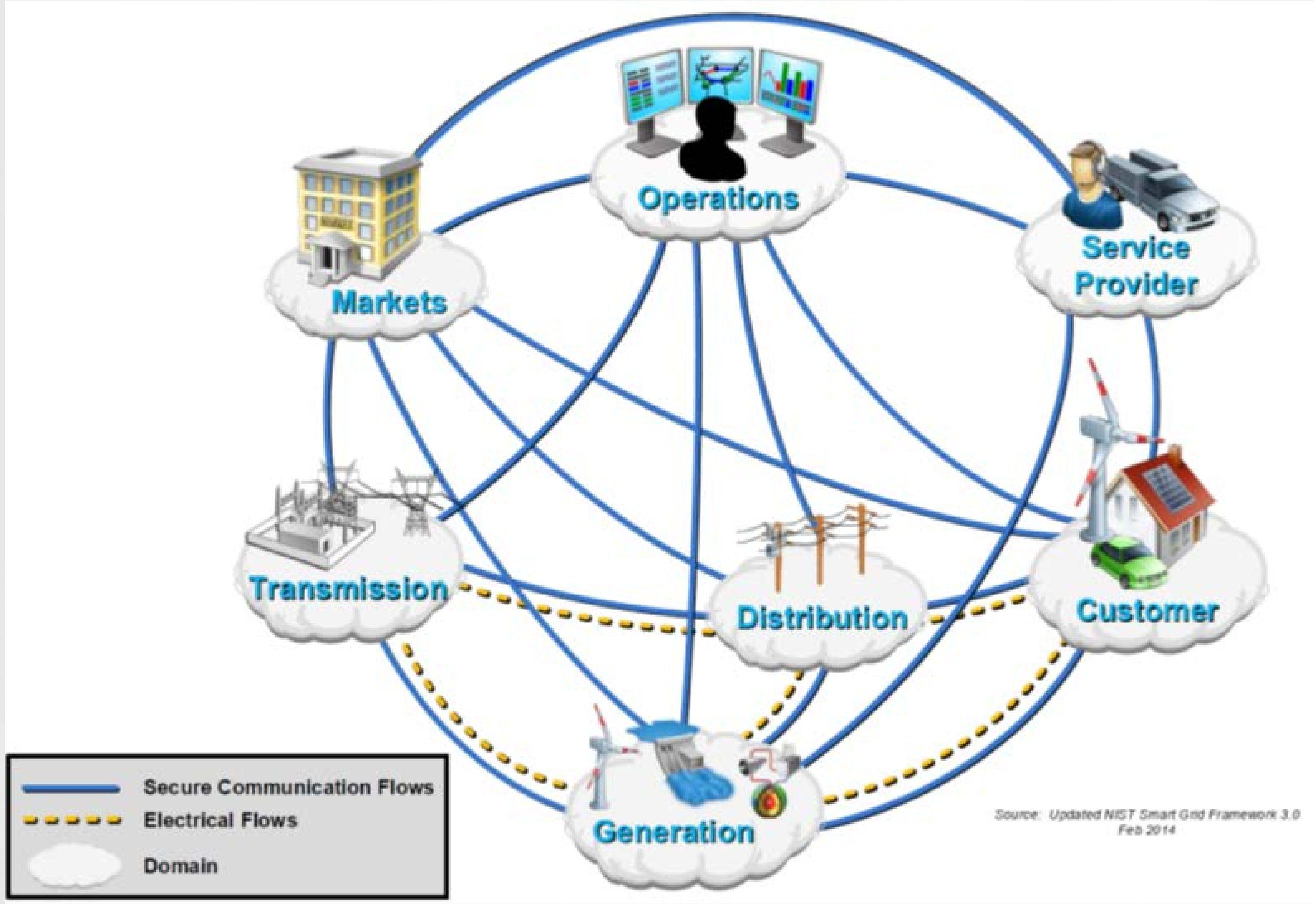
Technical

Smart Grid Conceptual Model (2014)



Logical model of legacy systems mapped onto conceptual domains for smart grid information networks

What has changed? (2017)



Questions to be addressed

- New domains?
- New interactions?
- New scales?
- Expanded mappings?
- New roles?
- Updated economics?

Future Activity (2018)

- NIST Smart Grid Interoperability Framework V4
- Number of viable Architectures expanding
  - Architecture is the integrated representation of possibility
  - No single model is adequate
- Significant impacts on:
  - Operations
  - Economics
  - Cybersecurity
  - Testing & Certification
- Current research
- Stakeholder engagement, feedback, and collaboration