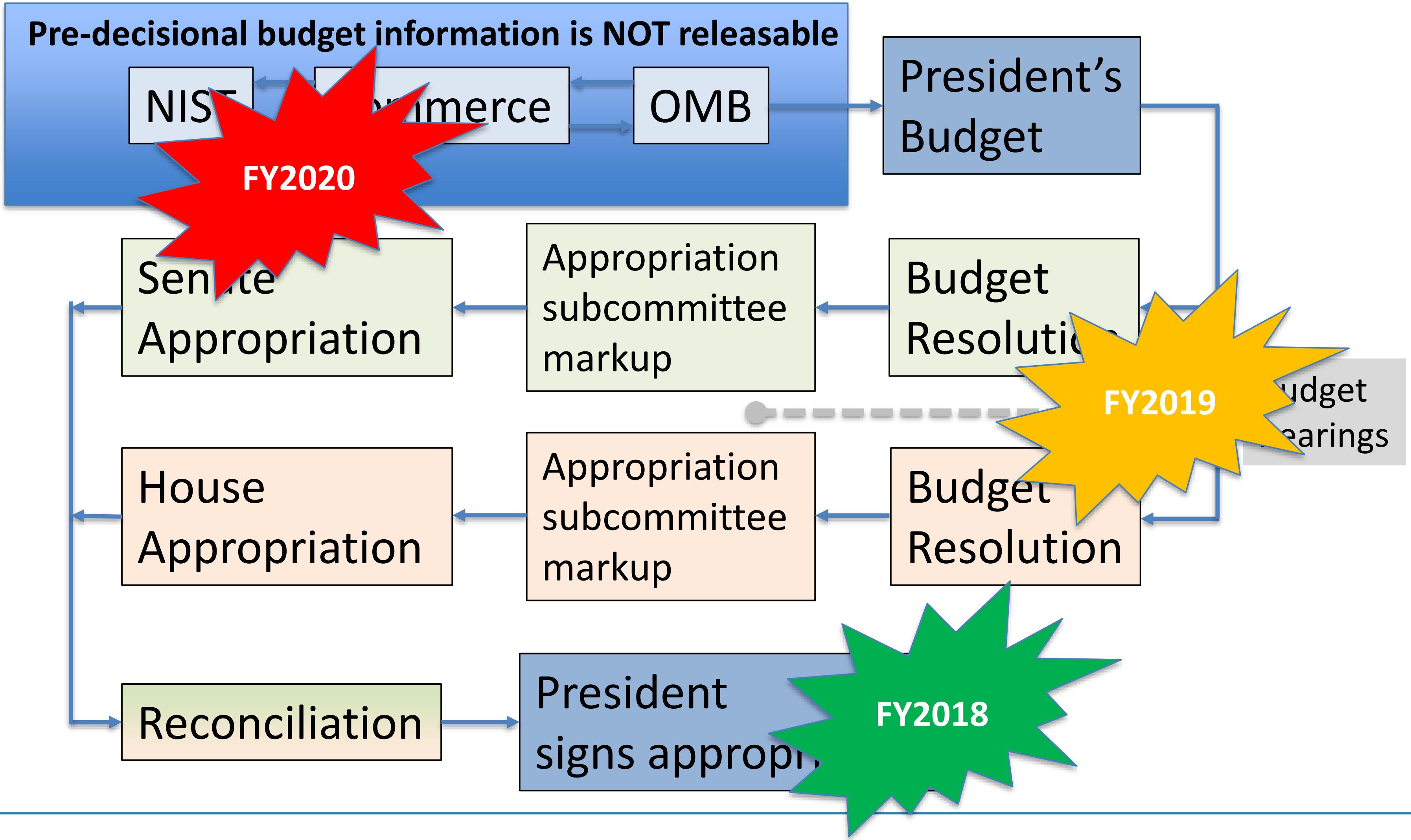
National Institute of Standards and Technology
Budget Overview

Smart Grid Advisory Committee

Budget Process



FY2018 Omnibus – First the Good News $1.198 B (+$256.5 M)

- $724.5 million for NIST's Laboratory Programs—an increase of $34.5 million over FY 2017.
- $140 million for the Manufacturing Extension Partnership—an increase of $12 million over FY 2017.
- $15 million for Manufacturing USA—a decrease of $10 million from FY 2017.
- $319 million for NIST construction programs—an increase of $210 million.

- NIST Lab Increase +$34.5M
- $22.2M Targeted Investments
  - Internet of Things Cybersecurity (+$2.0 M)
  - Forensic Science and the Organization of Scientific Area Committees ($4.0 M)
  - Metals-based Additive Manufacturing Grants ($5.0 M)
  - Disaster Resilient Buildings Grants ($5.0 M)
  - Plastics and Polymeric Materials Grants ($5.0 M)
- $11.3 M will support NIST Priorities

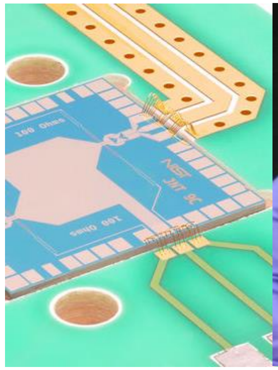
Strategic Opportunities for the Future: Applying New Technologies to Revolutionize Mission Delivery

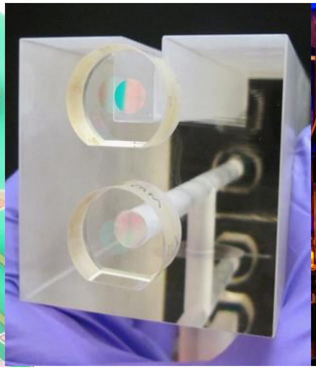
Artificial Intelligence realizing the promise of data-driven innovations for mission critical research

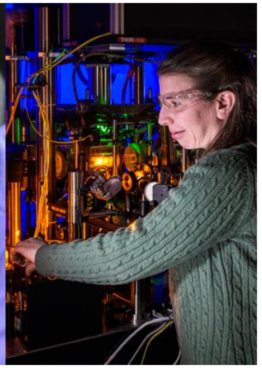
- improving confidence in AI
- driving applications of AI
- computing infrastructure

Quantum Science building new classes of quantum reference standards and tools

- practical quantum SI devices
- quantum science & metrology
- quantum engineering







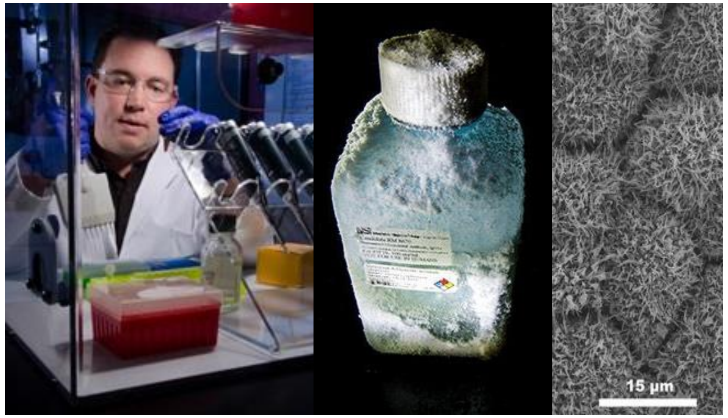
Strategic Opportunities for the Future: Providing a Foundation of Trust in Emerging Industries

Bioeconomy uncovering fundamental principles that drive the development of next-generation bio-based products

- synthetic biology
- new biopharmaceuticals
- microbiome

Internet of Things realizing the full potential of connecting humans, systems and devices

- connectivity
- interoperability
- trust



Preserving the NIST Research Mission

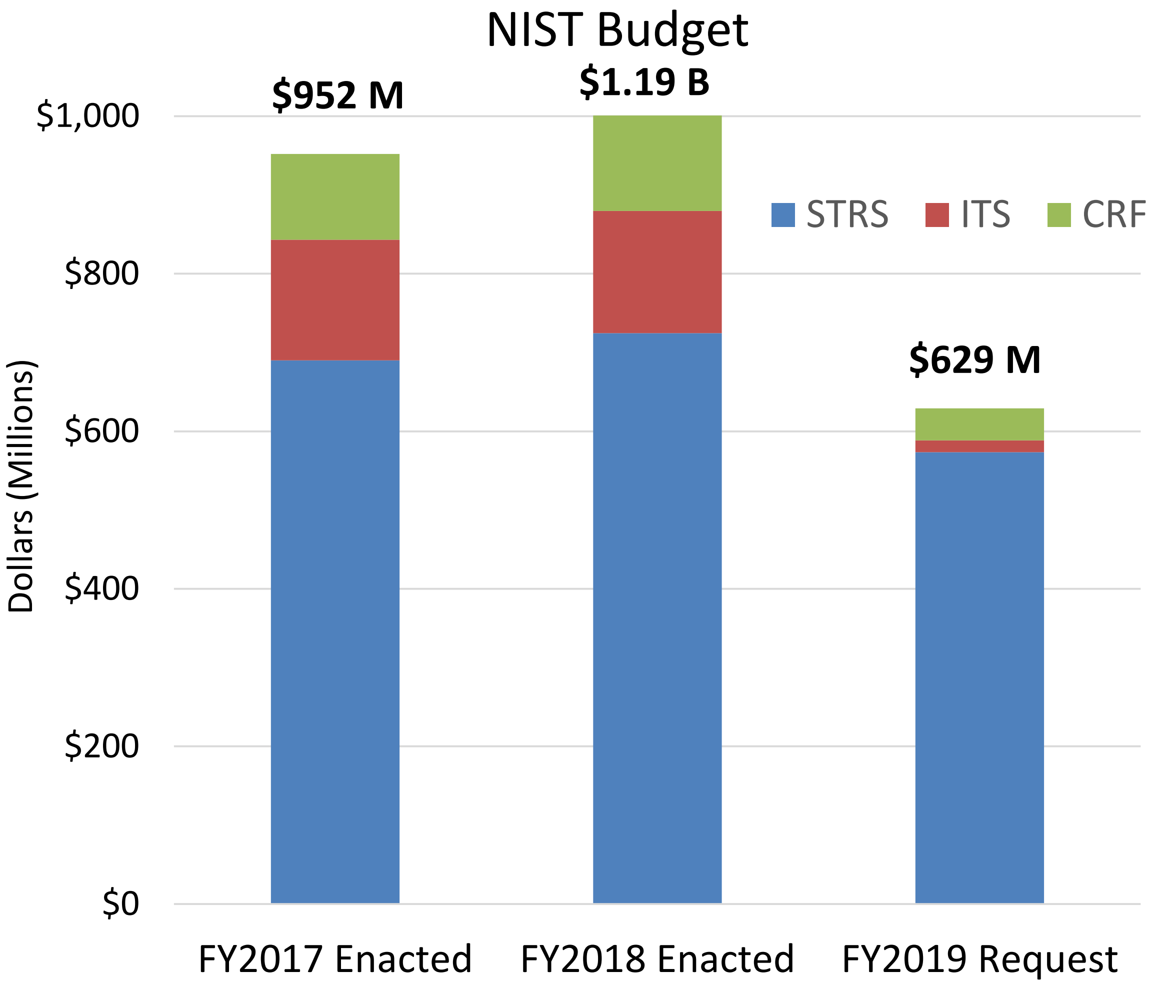
The FY 2019 budget request reflects the Administration’s priority to rebuild the military, make critical investments in the nation’s security, and keep the nation on a responsible fiscal path.

Funds will maintain research capabilities in measurement science so that the Institute can continue to meet its central mission to provide the measurements and standards that accelerate innovation.

The NIST mission is 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

Summary of FY 2019 Budget Request

- Scientific and Technical Research Services (STRS) $573.4 million, a $151.1million reduction (-20.8%)
  - Cuts across all laboratory programs
- Industrial Technology Services (ITS) $15.1 million, a $139.9 million reduction (-90.1%)
  - Eliminates Federal Funding for the Hollings Manufacturing Extension Partnership Program
  - Maintains funding for NIMBL and network coordination
- Construction of Research Facilities (CRF) $40.5 million, a $278.5 million reduction (-87.3%)
  - No new funding for major renovations of infrastructure
  - Remaining funding focused on safety and maintenance



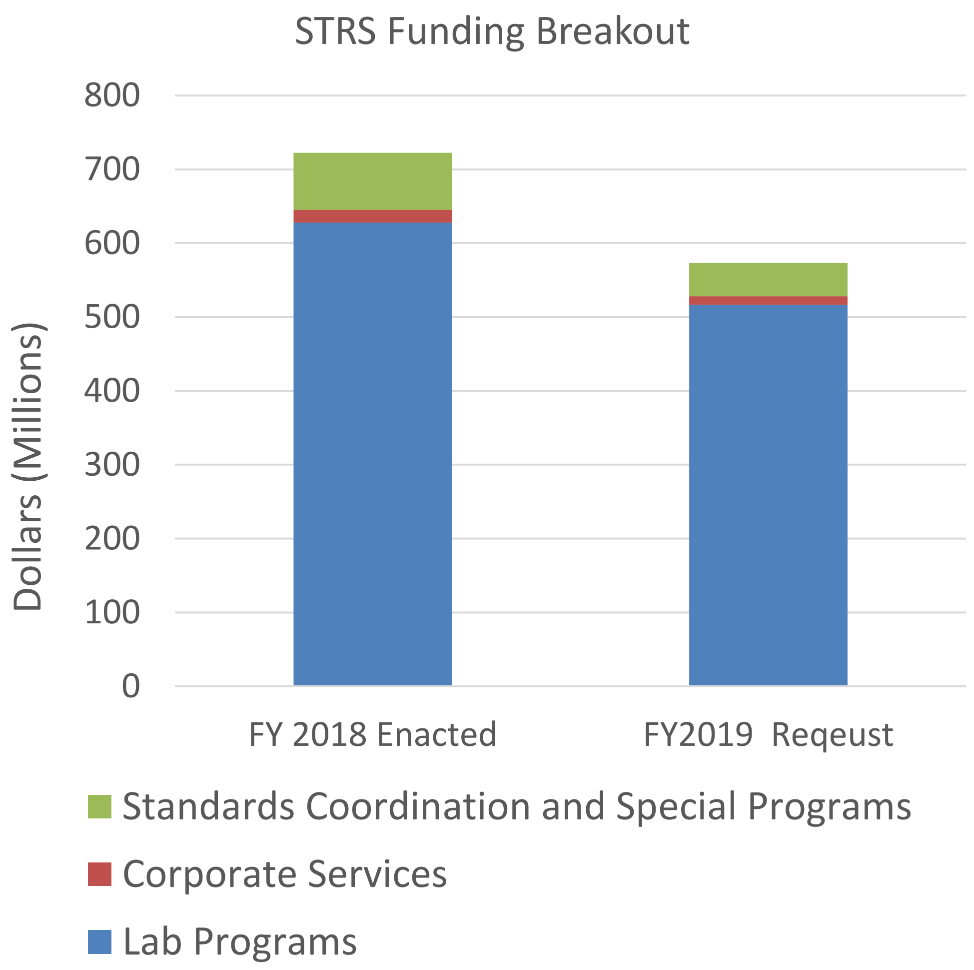
NIST FY 2019 Budget Submission (Dollars in millions)

	FY 2017 Enacted	FY 2018 Enacted		+/(-) Over FY 2017 Enacted	% Over FY 2017 Enacted	FY 2019 Request	+/(-) Over FY 2018 Enacted	% Over FY 2018 Enacted
STRS	**$690.0**	**$724.5**		**$34.5**	**5.0%**	**$573.4**	**($151.1)**	**-20.9%**
Laboratory Programs	604.7	TBD		N/A	N/A	516.6	N/A	N/A
Corporate Services	17.3	TBD		N/A	N/A	11.6	N/A	N/A
Stds Coord & Special Pgms	68.0	TBD		N/A	N/A	45.2	N/A	N/A
ITS	**$153.0**	**$155.0**		**$2.0**	**1.3%**	**$15.1**	**($139.9)**	**-90.3%**
Hollings Mfg Ext Partnership	128.0	140.0		12.0	9.4%	0.0	(140.0)	-100.0%
NNMI/Manufacturing USA	25.0	15.0	*	(10.0)	-40.0%	15.1	0.1	0.7%
CRF	**$109.0**	**$319.0**		**$210.0**	**192.7%**	**$40.5**	**($278.5)**	**-87.3%**
Construc & Major Renovations	60.0	270.0		210.0	350.0%	0.0	(270.0)	-100.0%
Saf, Cap, Maint & Maj Repairs	49.0	49.0		0.0	0.0%	40.5	(8.5)	-17.3%
Total, NIST Discretionary	**952.0**	**1,198.5**		**$246.5**	**25.9%**	**629.0**	**(569.5)**	**-47.5%**

* Bill language provides National Network for Manufacturing Innovation (NNMI) for $15M while Manuf. USA for $5M, but the combination of both is only $15M.

STRS Summary: $573.4 M (-$151.1 M and -400 Positions)

- FY2019 request reduces laboratory programs by 16.3%
  - Laboratories $516.6M (-$111.4 M), a 17.7% reduction
  - Corporate Services $11.6M (-$5.7 M), a 33% reduction
  - Standards Coordination and Special Programs Office $45.2M (-$31.7 M), a 41.2% reduction
- Objective – preserve internal NIST R&D capabilities with a focus on future measurement challenges. Reduction criteria include:
  - External grant focused efforts
  - Approaching technological maturity
  - Less need for leading-edge NIST measurements

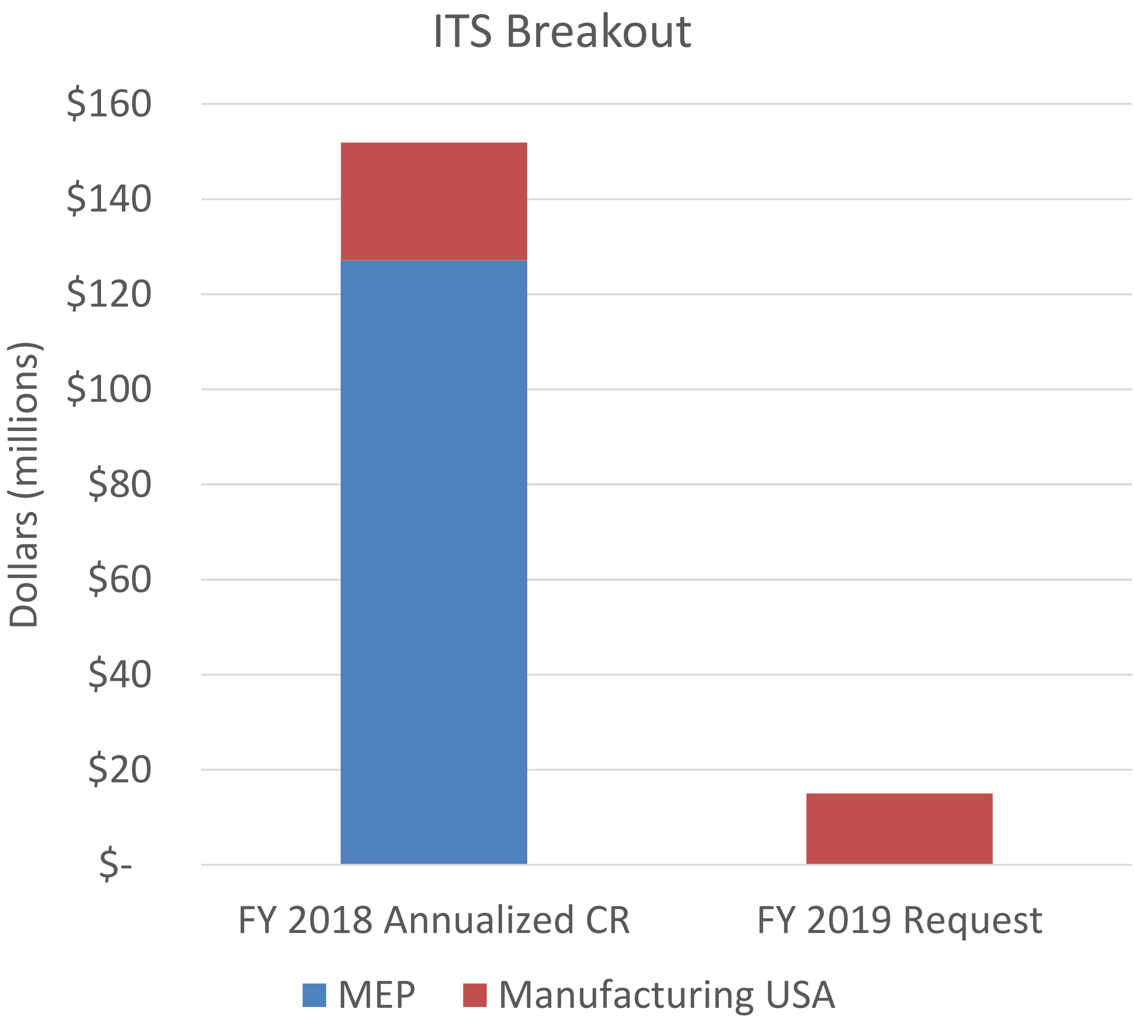


Summary of STRS Reductions By Focus Area

	FY 2018 Enacted	FY 2019 Request	Difference	
Advanced Communications, Networks, and Scientific Data Systems	$69.9 M	$54.2 M	-$15.7M	-22.4%
Advanced Manufacturing and Material Measurements	$172.7 M	$135.5 M	-$37.2 M	-21.5%
Cybersecurity and Privacy	$83.2 M	$78.4 M	-$4.8 M	-5.7%
Exploratory Measurement Science	$58.3 M	$58.3 M	-$0.0 M	0%
Fundamental Measurement, Quantum Science, and Measurement Dissemination	$184.0 M	$127.0 M	-$57.0 M	-30.9%
Health and Bioscience	$26.4 M	$16.5 M	-$9.9 M	-37.5%
NIST User Facilities	$58.3 M	$44.3 M	-$14.0 M	-24.0%
Physical Infrastructure and Resilience	$69.8 M	$58.8 M	-$11.0 M	-15.7%
Totals:	**$722.6 M**	**$573.0 M**	**-$149.6 M**	**-20.7%**

ITS Summary: $15.1 M (-$139.9 M and -81 Positions)

- The Administration's FY 2019 Budget prioritizes rebuilding the military and making critical investments in the nation's security. To accomplish this, the Budget identifies savings and efficiencies needed to keep the nation on a responsible fiscal path, including:
  - Proposes elimination of the MEP program
  - Provide funding for continued coordination of existing Manufacturing USA network activities
  - Maintain funding for NIST's institute in Manufacturing USA (NIIMBL)
  - Baldrige continues operations with Foundation support

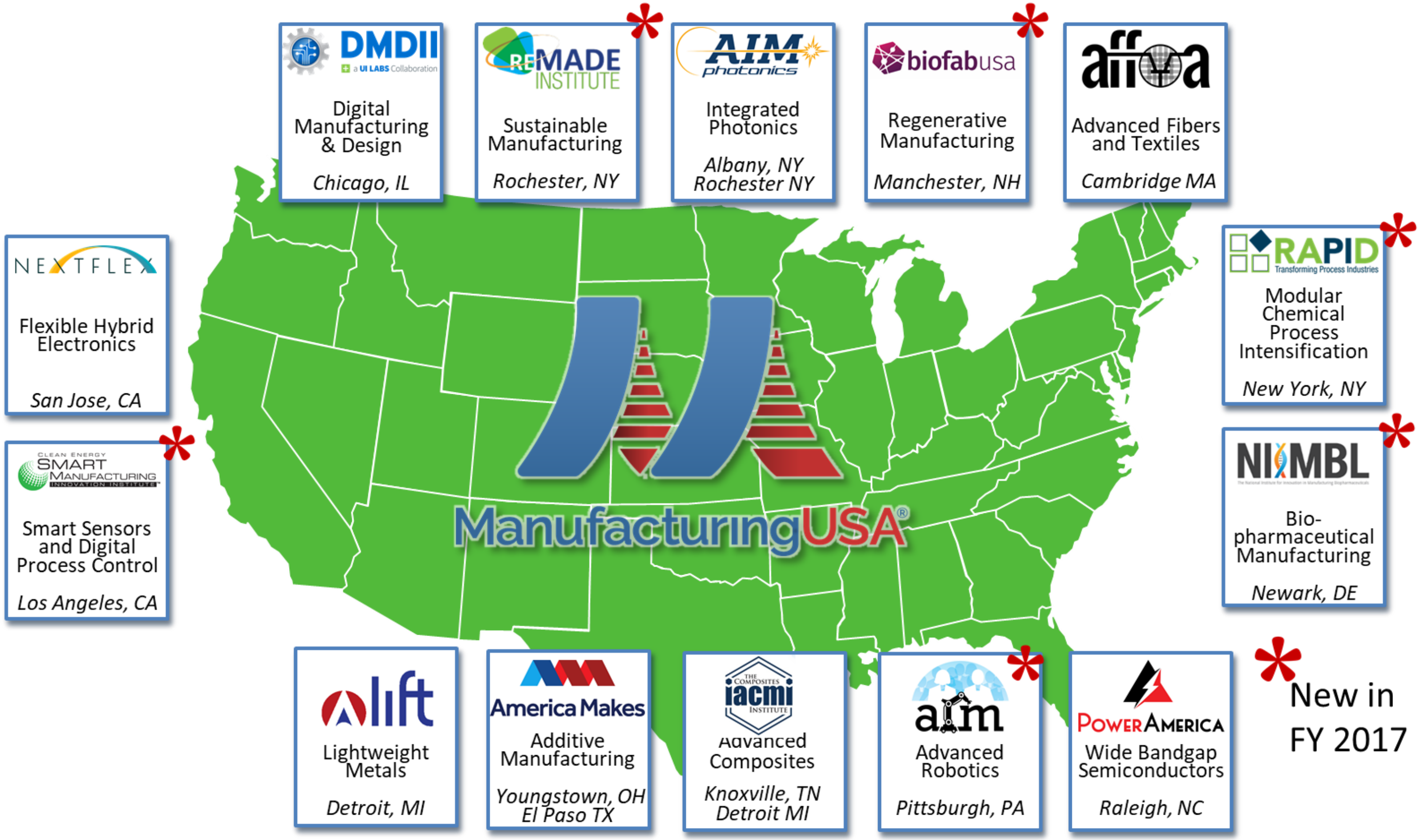


Hollings Manufacturing Extension Partnership: $0 (-$140.0 M and -81 Positions)

- The FY 2019 request:
  - Eliminates federal funding for the program
  - The reduction will impact 1,300 non-federal technical experts in the Centers and affect over 2,500 partners in all centers and nearly 600 field offices.
  - Over 9,000 clients will have to find services elsewhere

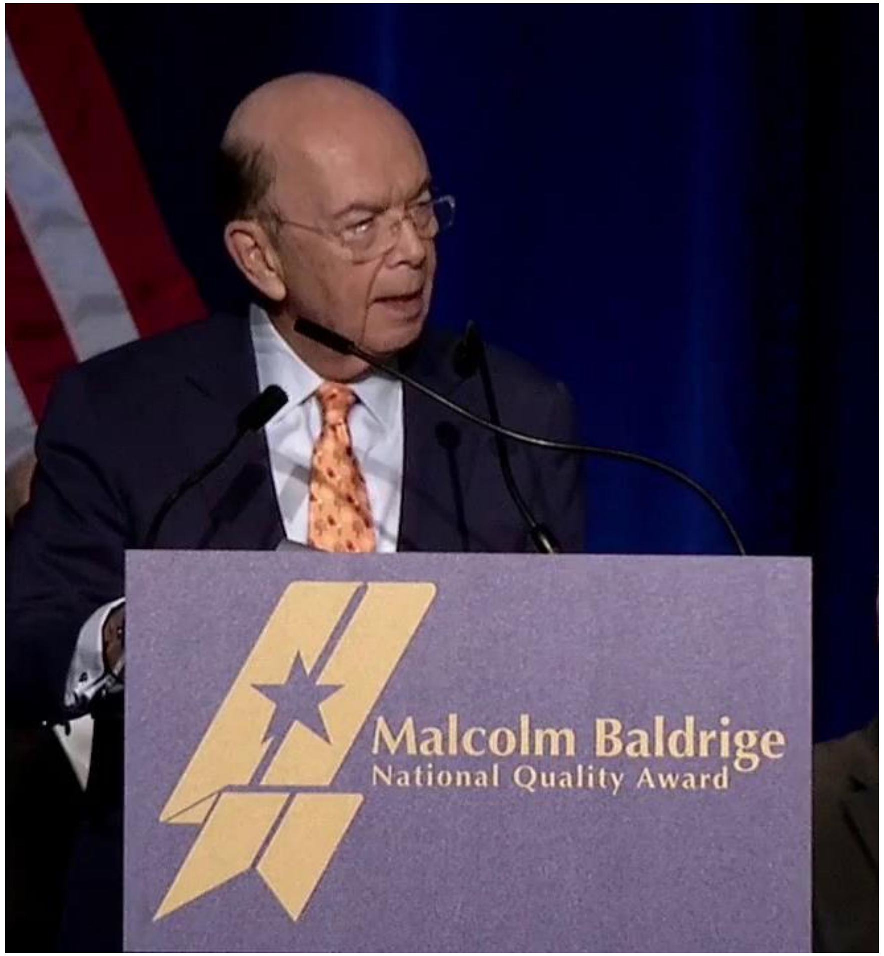
Manufacturing USA: $15.1 million (-$10.0 M)

- Funds coordination of the Manufacturing USA network by NIST
- Continues funding the only NIST/Department of Commerce Institute in the network
  - The National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL) is centered in DE with industry and academic members across the country



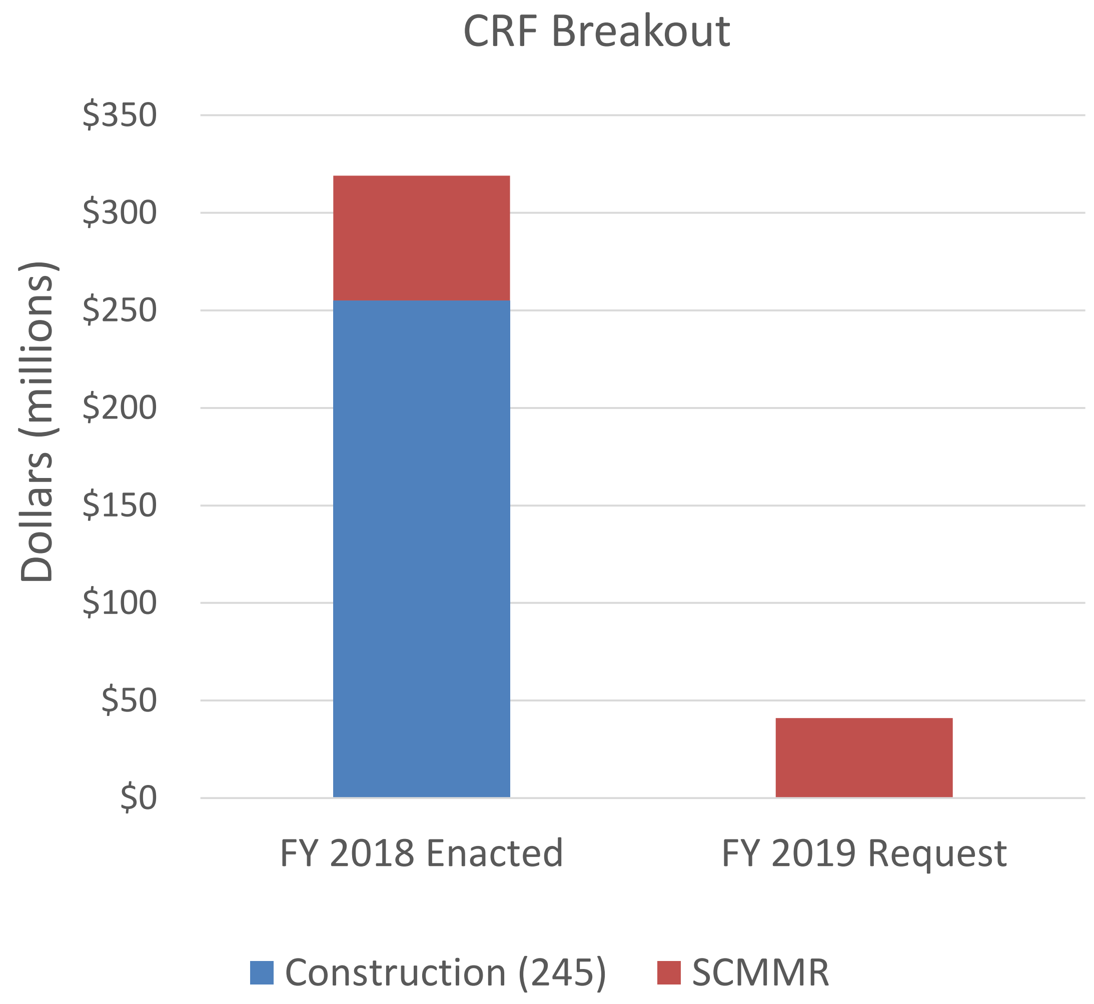
Baldrige Performance Excellence Program (2.2M in FY2018)

- 2017 Winners, to be presented in April 2018
  - Bristol Tennessee Essential Services, Bristol, TN, *small business sector*
  - Stellar Solutions, Palo Alto, CA, *small business sector*
  - City of Fort Collins, Fort Collins, CO, *nonprofit sector*
  - Adventist Health Castle, Kailua, HI, *health care sector*
  - Southcentral Foundation, Anchorage, AK, *health care sector*
- Baldrige Cybersecurity Excellence Builder
  - self-assessment tool to help organizations better understand effectiveness of their cybersecurity risk management efforts and in the context of their organizational objectives



Construction of Research Facilities: $40.5 M (-$278.5 M)

- No new funding for major renovations of NIST infrastructure
  - Boulder – Delays new work for Building 1 renovation
- Focus on Safety, Capacity, Maintenance, and Major Repairs ($40.5M, 16.1% reduction)
  - Remaining funds will focus on maintenance and major repairs to address the highest priority issues
  - Anticipate increased facilities deficiencies including infrastructural systems failures
    - NIST loses 50,000 gallons of water a day due leaky steam pipes
  - Anticipate more renovations being paid for with programmatic funds



What to watch for next

- Markups for FY2019
  - House – May
  - Senate – June
- Expected Outcome Similar to FY2018

- FY2020 – 2 Year Budget Deal Expires

Additional Details on STRS Cuts

https://www.nist.gov/fy-2019-presidential-budget-request-summary/scientific-and-technical-research-and-services

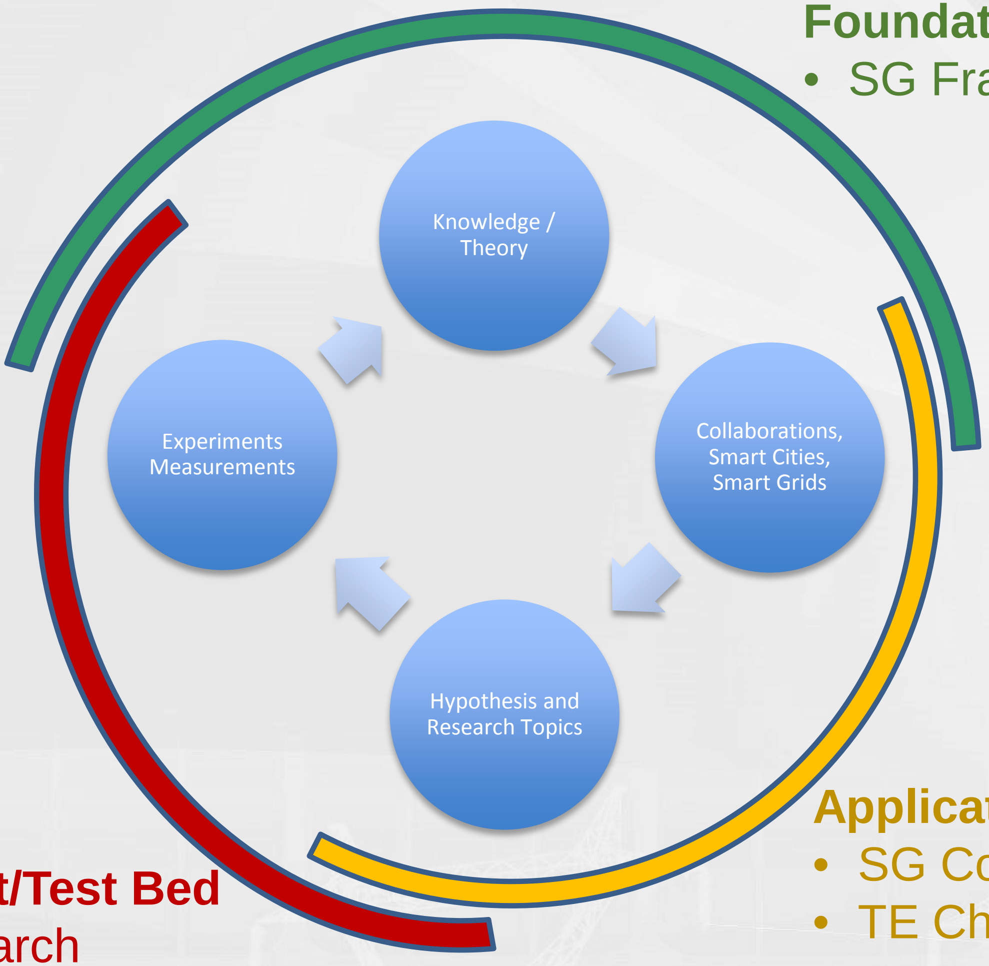
Smart Grid Program Update & Research Portfolio

Avi Gopstein and Paul Boynton
Smart Grid Program and Testbed managers
NIST Smart Grid Program

Federal Advisory Committee Meeting
April 24, 2018

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

Review: Smart Grid Program Overview



Foundations
- SG Framework

Applications
- SG Coordination
- 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

Review: NIST Smart Grid Program – Budgetary Structure

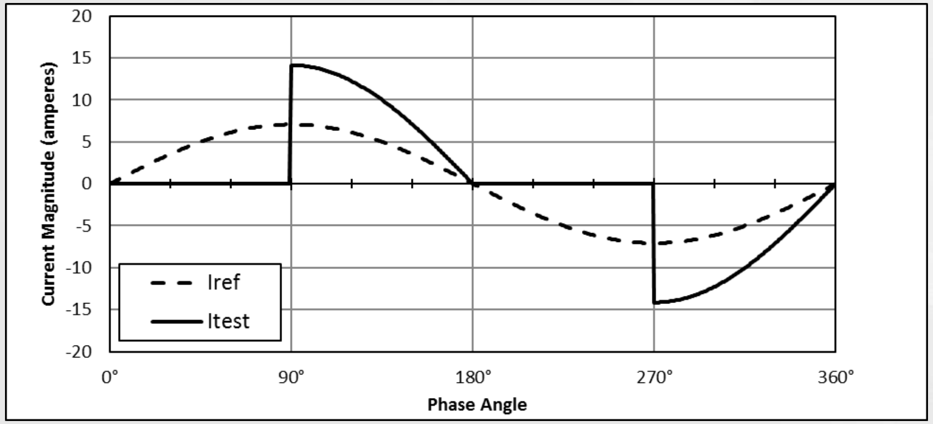
Smart Grid Program	
Smart Grid Test Bed	Experimental Facilities
Smart Grid System Testbed Facility (SL SGP) - Boynton	
Power Conditioning Systems for Renewables, Storage, and Microgrids (PML) - Hefner	
National Coordination + Strategy	Coordination
Smart Grid Secretariat (EL SGP) - Gopstein	
Smart Electric Power Alliance (EL SGP) - Nguyen	
Smart Grid Testing and Certification (EL SGP) - Nguyen	
Smart Grid Projects	Research
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	
Building Integration with Smart Grid (EL) - Holmberg/Gopstein	
Quantifying Key Economic Issues in the Smart Grid (EL AEO) - O'Fallon	

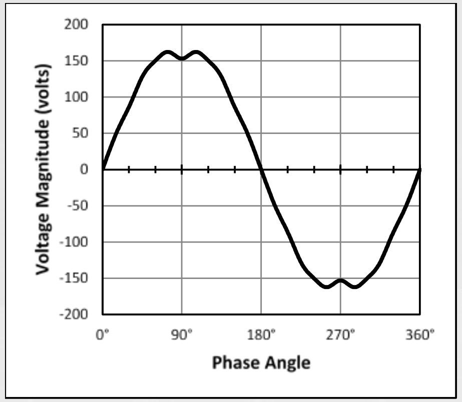
Research: Common Themes

- Monitoring and Control
- Cybersecurity
- Communications and Timing
- Operations and Economics

Research: Monitoring and Control (distributed sensors)

What is in ANSI C12.20-2015

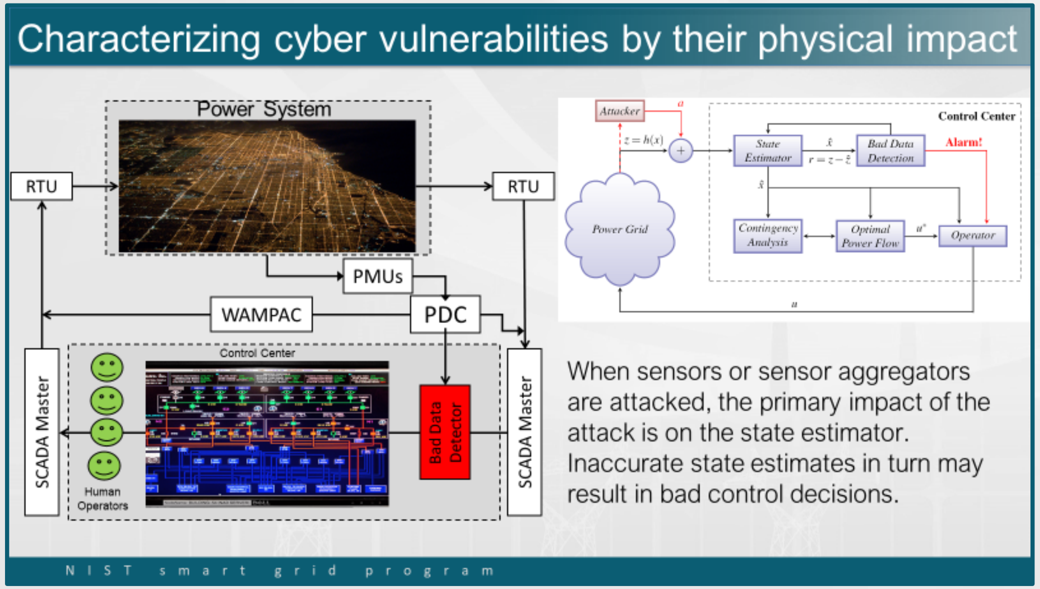




Harmonic	Voltage Amplitude % V_{ref}	Phase	Current Amplitude % I_{ref}	Phase	Demand
1	100	0	100	0	100.00
3	3.8	0	30	180	-1.140
5	2.4	180	18	0	-0.432
7	1.7	0	14	180	-0.238
11	1.1	0	9	180	-0.099
13	0.8	180	5	0	-0.040
				Total Demand	98.051

What we're doing

Research: Cybersecurity



- Draft smart grid cybersecurity risk profile
- Working to expand content to multiple architectures
- Foundational activity, will inform future research projects

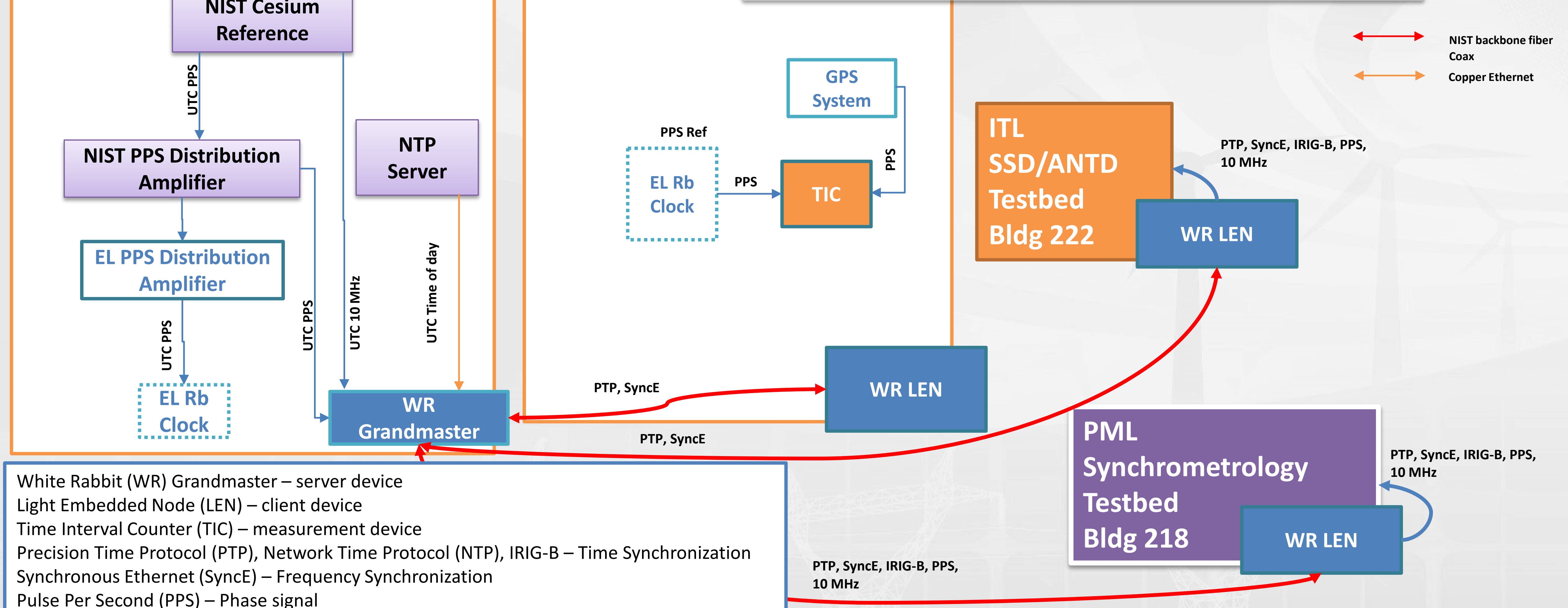
Protect – The Protect Function is critical to limit the impact of a potential cybersecurity event Identity Management and Access Control, Awareness and Training, Information Protection Processes, Maintenance, and Protective Technology are the priority security focus areas. Identity Management and Access Control identifies and regulates personnel ingress and egress. Awareness and Training and the Protection Processes prepare the workforce to achieve cyber security. Protective technology implements security decisions.

Table 3 PROTECT Smart Grid Profile

Category		Maintain Safety	Maintain Reliability	Maintain Resilience	Support Grid Modernization	Considerations for Utilities
		Subcategories				
PR	Access Control	PR.AC-1	PR.AC-1	PR.AC-1	PR.AC-1	Basic activity.
		PR.AC-2	PR.AC-2	PR.AC-2	PR.AC-2	Basic activity. Power system owners/operators should control physical access to the power system, including modernized and distributed grid components. Power system owners/operators should consider the limitations of maintaining physical access to devices on other premises, especially those devices that are owned by a 3rd party.
		PR.AC-3	PR.AC-3	PR.AC-3	PR.AC-3	Basic activity. Many grid components are maintained remotely and such access should be secured. For modernized environments, consider the limitations of managing remote access to devices that are owned by a 3rd party, such as distributed resources.
		PR.AC-4	PR.AC-4	PR.AC-4	PR.AC-4	Basic activity. Least privilege is important for limiting damage when the power system is being restored (resilience) It is also important to limit permissions/authorizations of connected devices; excessive permissions risk safety and reliability. Grid modernization efforts will need to consider least privilege during design and in operation. Consider the limitations of managing access permissions to DER devices owned by another party.
		PR.AC-5	PR.AC-5	PR.AC-5	PR.AC-5	Basic activity. Network segmentation is important for containing potential incidents (safety, reliability), and limiting damage from

Research: Communications and Timing

Objective: Dynamic calibration of GNSS receiver as time source to provide independent 100 ns or better accuracy to UTC for distributed measurement labs.



White Rabbit (WR) Grandmaster – server device
Light Embedded Node (LEN) – client device
Time Interval Counter (TIC) – measurement device
Precision Time Protocol (PTP), Network Time Protocol (NTP), IRIG-B – Time Synchronization
Synchronous Ethernet (SyncE) – Frequency Synchronization
Pulse Per Second (PPS) – Phase signal
10 MHz – Frequency signal

Research: Operations & Economics

Key themes

- NIST Smart Grid Program technical leadership is reinforced when based upon current research exploring complex issues
- Completion of the testbed is already allowing for a more integrated approach to research across many skillsets
- The testbed is critical to our overall success

NIST Smart Grid Testbed

Paul Boynton

Testbed Manager, Engineering Laboratory
NIST Smart Grid Program

Smart Grid Federal Advisory Committee Meeting

April 24, 2018

Technically Diverse Cross-OU Testbed Staff

Engineering Laboratory

- Chris Greer (SG/CPS Program Office Director)
- Dave Wollman (SG/CPS Program Office Deputy)
- Avi Gopstein (Smart Grid Program Manager)
- Paul Boynton (Testbed Manager)
- DJ Anand (Dynamics and Controls)
- Hasnae Bilil (Safety, Capability Assessment)
- Marty Burns (Transactive Energy, Federation)
- Kang Lee (Smart Sensors)
- Cuong Nguyen (Safety, Timing)
- Tom Roth (Federation)
- Eugene Song (Smart Sensors)

Physical Measurement Laboratory

- Tam Duong (Microgrid/DER Interconnect)
- Jerry FitzPatrick (Smart Sensors)
- Allan Goldstein (PMUs)
- Al Hefner (Microgrid/DER Interconnect)
- Tom Nelson (Smart Meters)
- Jose Ortiz (Microgrid/DER Interconnect)
- Richard Steiner (Smart Meters)

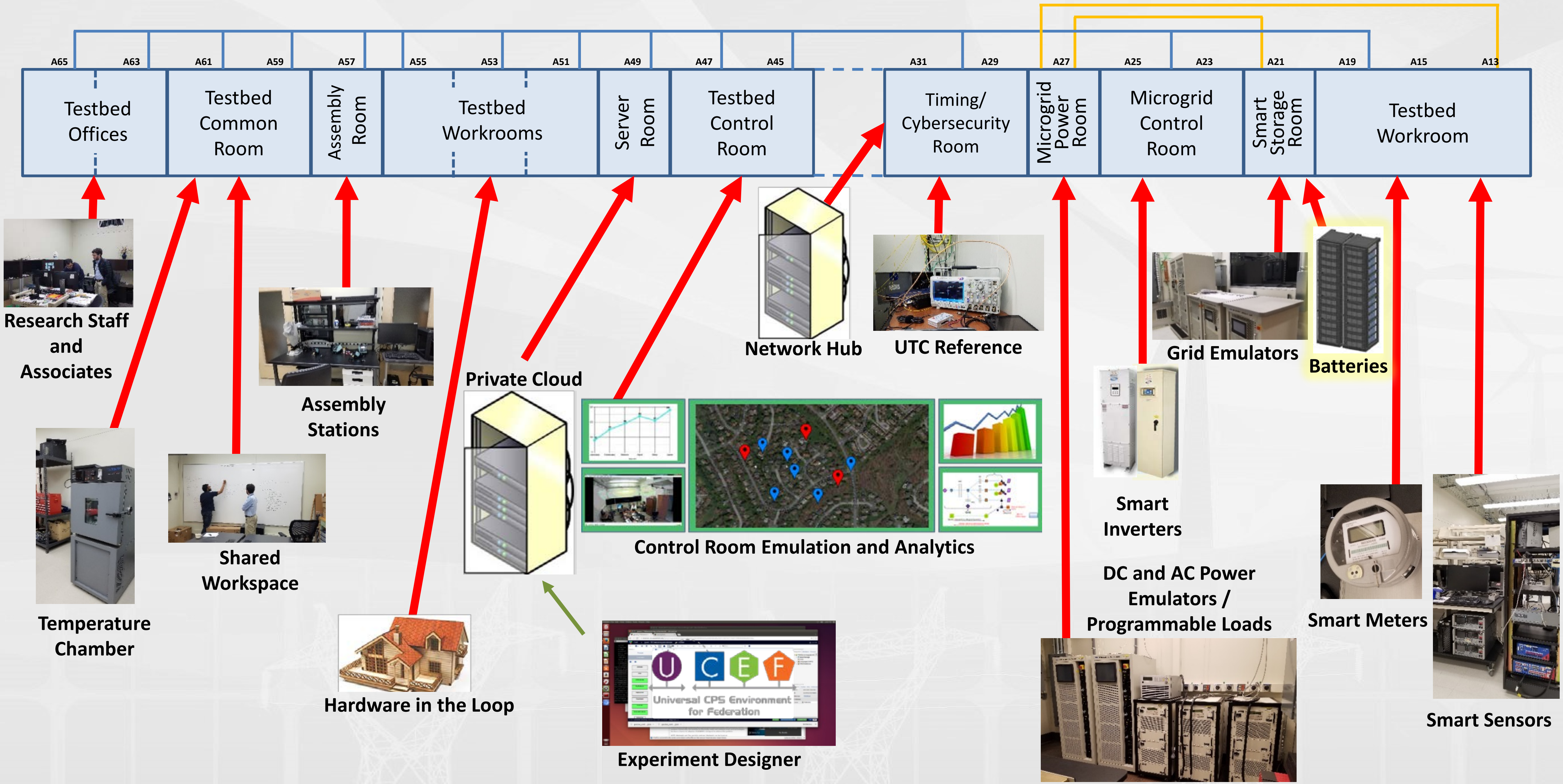
Information Technology Laboratory

- Mike Bartock (Cybersecurity)
- Kevin Brady (Cybersecurity)
- Nelson Hastings (Cybersecurity)
- Ya-Shian Li-Baboud (Timing/Synchronization)
- Jeff Marron (Cybersecurity)
- Eric Simmon (Cybersecurity

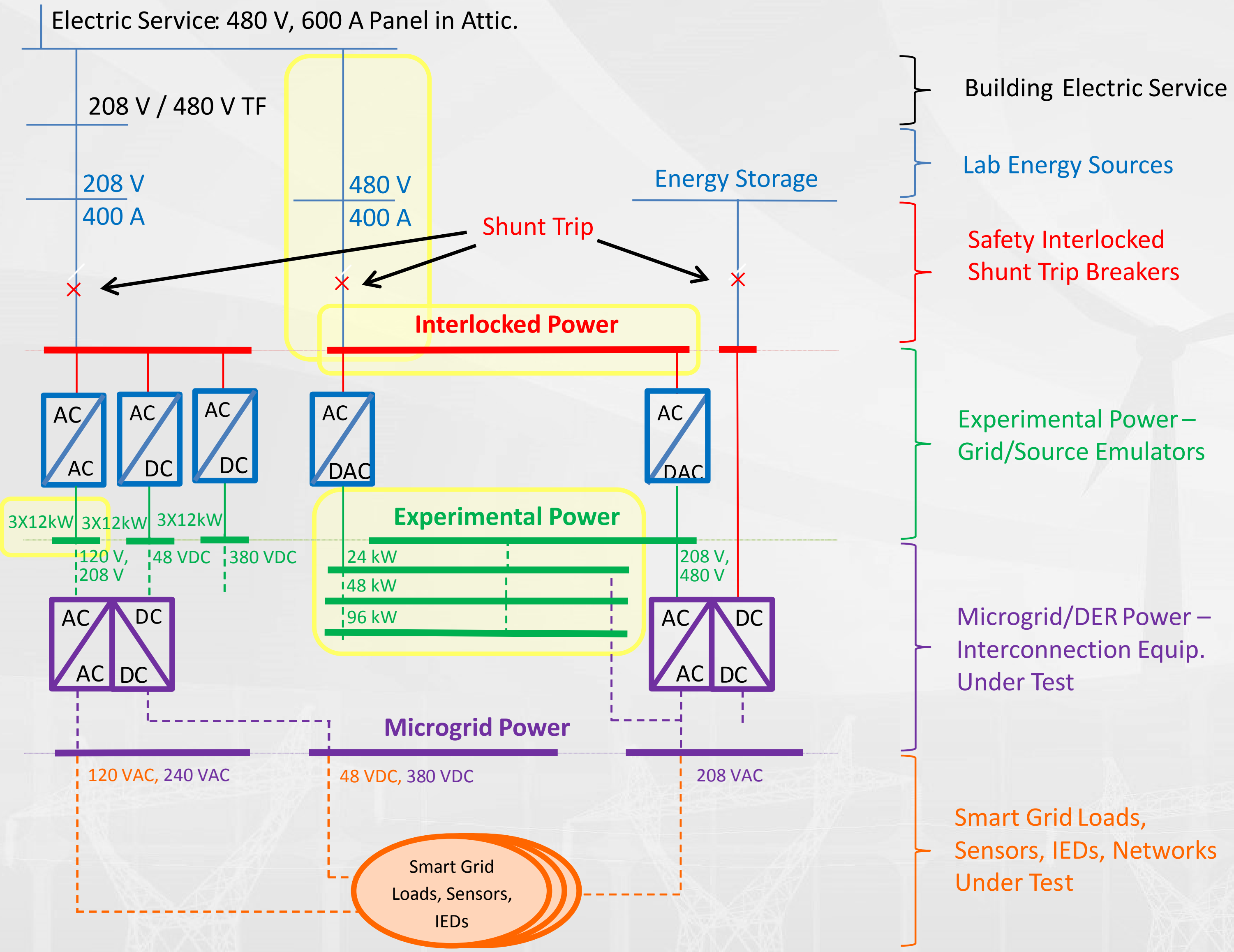
Communication Technology Laboratory

- Wei Wu (Network Communications)

Testbed Locations—Building 220 Basement



Testbed Electrical Power Capability



Emulation of real-life Smart Grid / Microgrid

Regenerative AC/DC Grid Emulator

Smart AC power emulator

Smart DC power emulator

Voltage harmonics

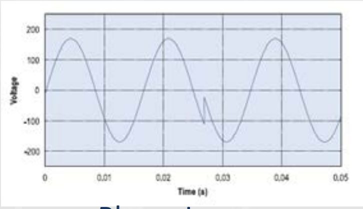
- Grid Emulator & Smart Power Source (AC/DC)
  - Broad voltage range **0-600V**
  - 3 different power capabilities of regenerative grid emulators at NIST's SG test-bed

    96kW, 48kW & 24kW
  - Possibility of running several 3-phase and 1-phase tests and experiments.
  - Emulation of all waveform of real main grid

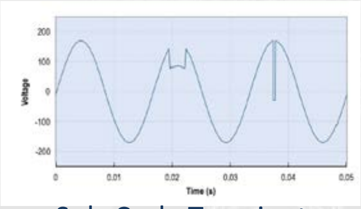
    Voltage harmonics, sub-cycle transients, phase jump and abnormal voltage sags and drops.
  - Smart AC power source with wide range of harmonics emulation

    Frequency 20-5000Hz

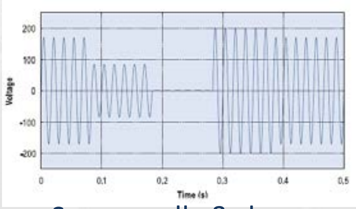
    Power range 3x18kW
  - DC power emulator



Phase Jump



Sub-Cycle Transients

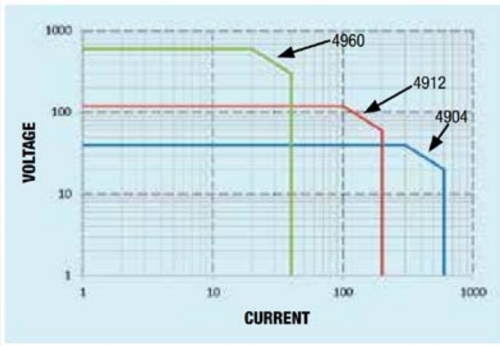


Sags, swells & drops

- Battery Pack Test System & Custom DER's Power Emulator
  - Installed power of

    2x36kW
  - 2 different voltage range

    0-120V & 0-600V
  - Three possibilities of regenerative load/source operating modes,
    - Constant Voltage (CV),
    - Constant Current (CC),
    - Constant Resistance (CR),
    - Constant Power (CP),



  - Custom waveform/profile generation
  - Microsecond voltage, current & mode transition
  - Capability of emulating any generation profile

Emulating PV, wind-power, battery, ...

Smart grid testbed : Beyond emulation

Impact on STANDARDS

IEEE Standards

MEASUREMENTS

INDUSTRY & TECHNOLOGY SUPPORT

- Standards testing and verification

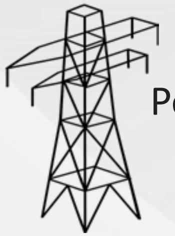
  The SG test-bed enables required foundations for testing and verifying several DER related standards,

  For instance,
  - IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces
  - IEEE Standard for Synchrophasor Measurements for Power Systems

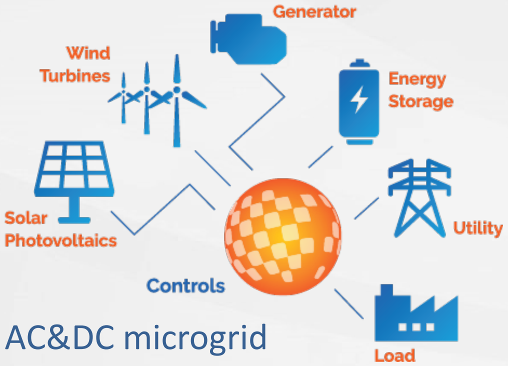
- Measurement & Characterization
  - Electrical characteristics measurements, voltage, current, active and reactive power, harmonics, uncertainties
  - Analysis and simulation of dynamic performance of PMU
  - Measurement innovation
  - Measurement calibration

- Industry and Technology Support

  The test-bed provides the possibility of testing DER related devices, such as,
  - Batteries
  - EV-batteries
  - Inverters
  - Controllers



Power System Dynamics

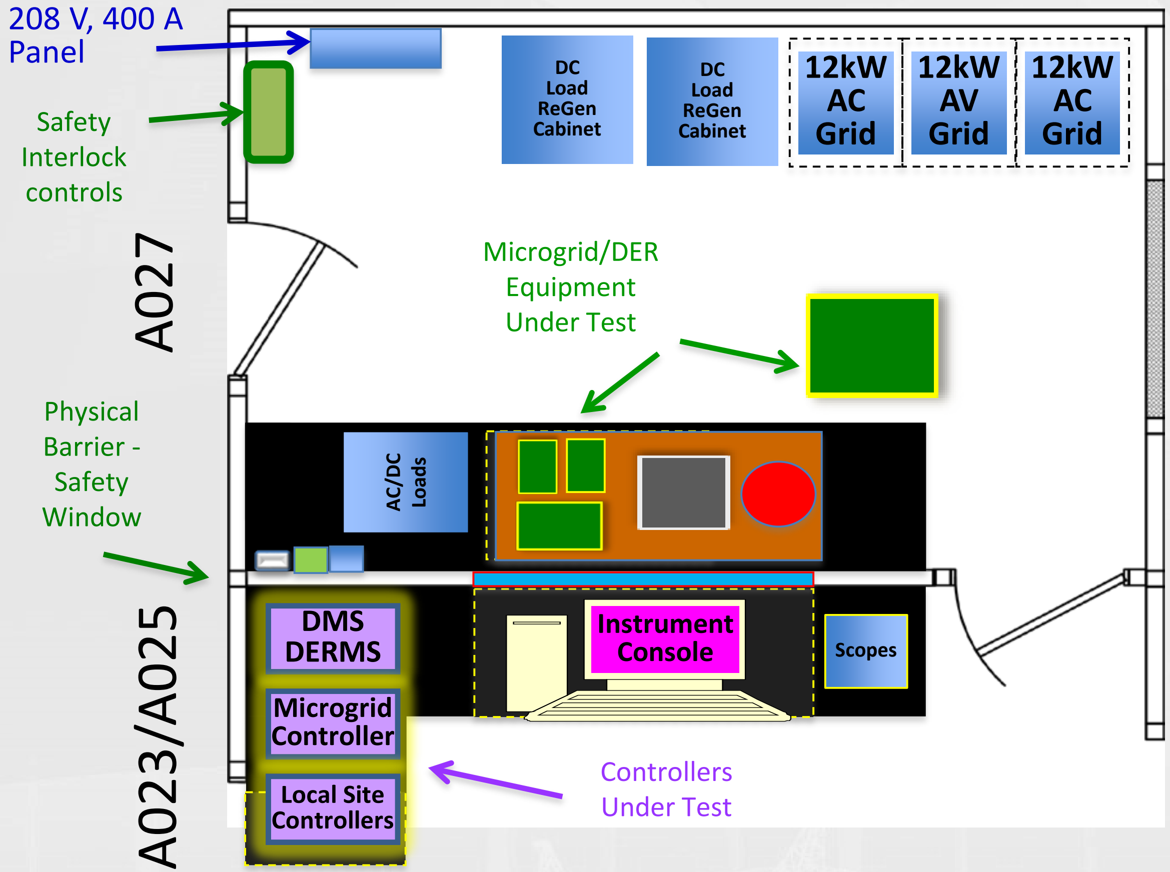


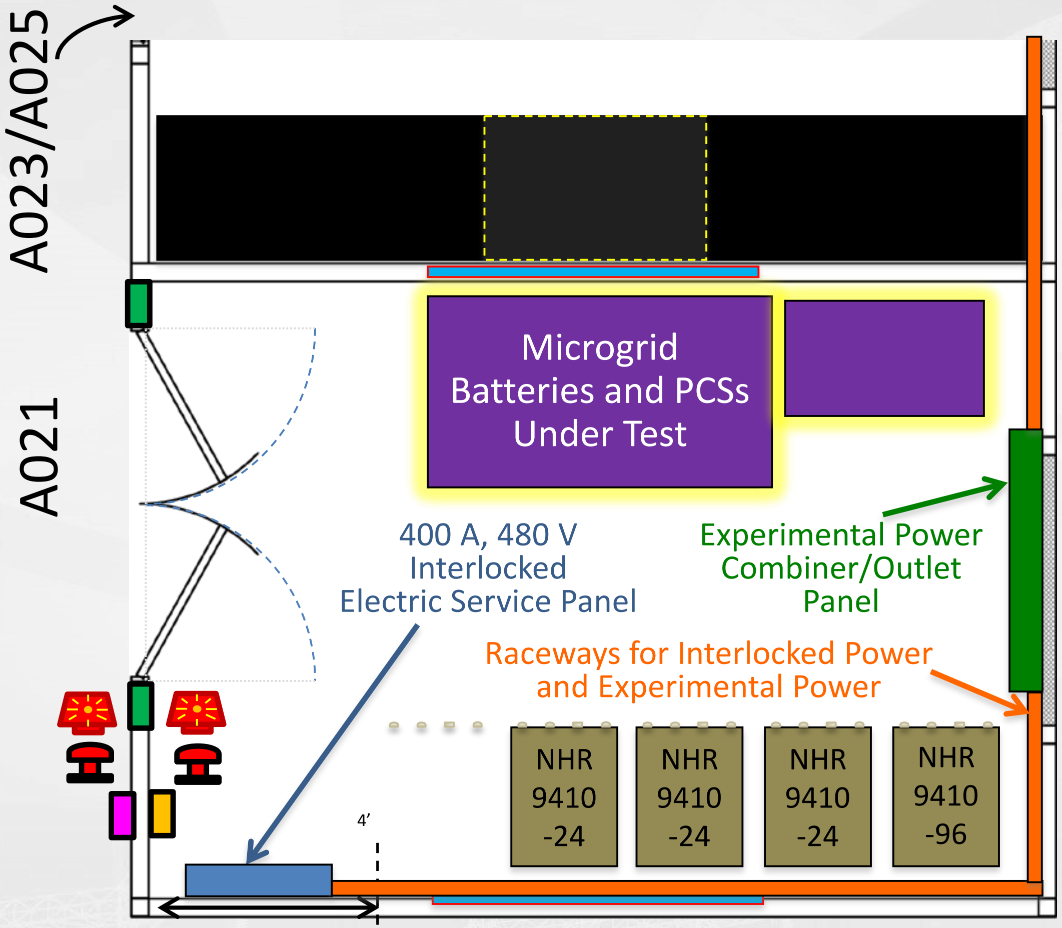
AC&DC microgrid control

Control strategies of EV's Charging

- Research scopes
  - Dynamics emulation and analysis of power systems with high level penetration of DER
  - Harmonics analysis and DER integration
  - DER contribution in voltage signal quality
  - AC&DC Microgrid related research, i.e. load side management
  - PV- based electrical vehicles station, EV's charging strategy and contribution on DER uncertainties control

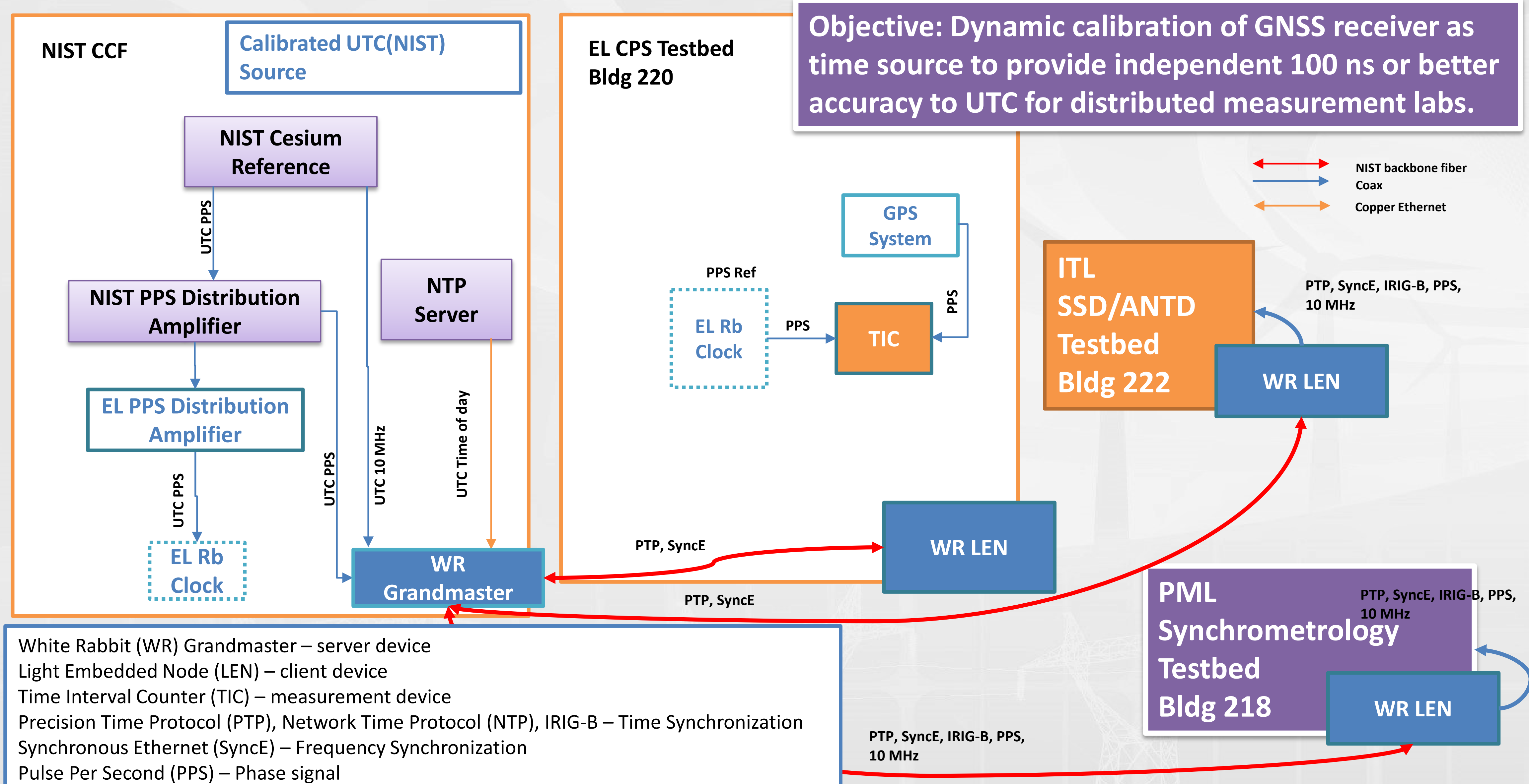
Testbed Electrical Power Layout





Traceable time infrastructure

Objective: Dynamic calibration of GNSS receiver as time source to provide independent 100 ns or better accuracy to UTC for distributed measurement labs.



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Why is timing important in the testbed?

Distributed Metrology

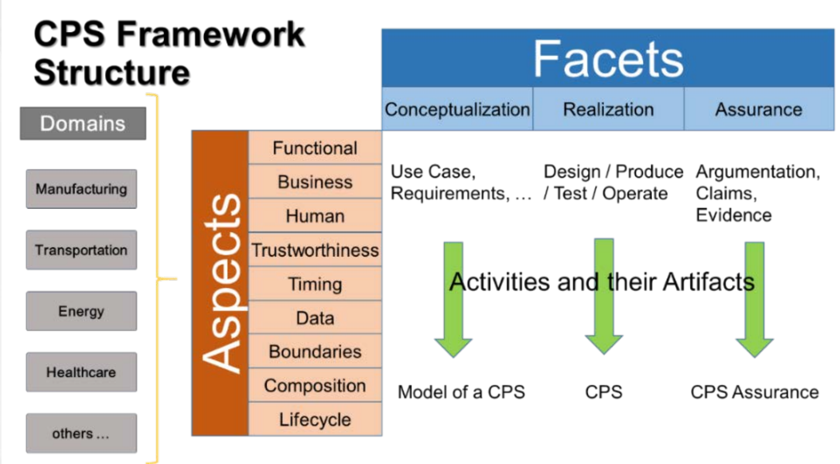
- State estimation and measurement
- Reliably acquiring accurate time

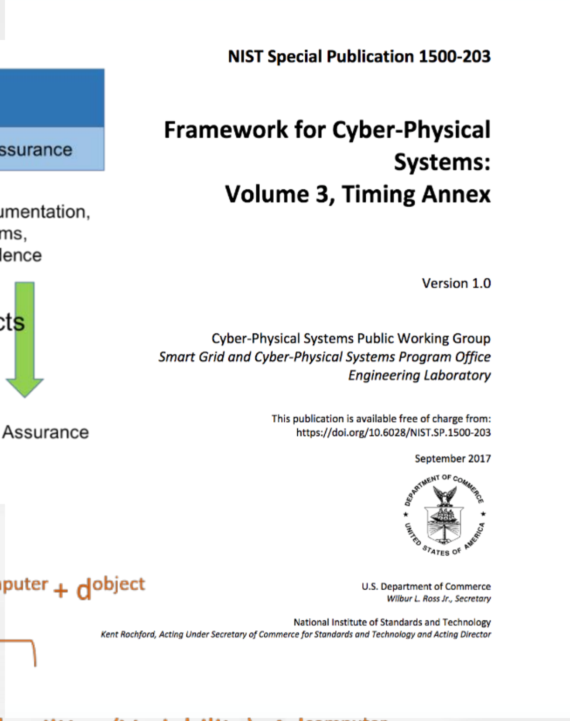
Time Aware Networks and Systems

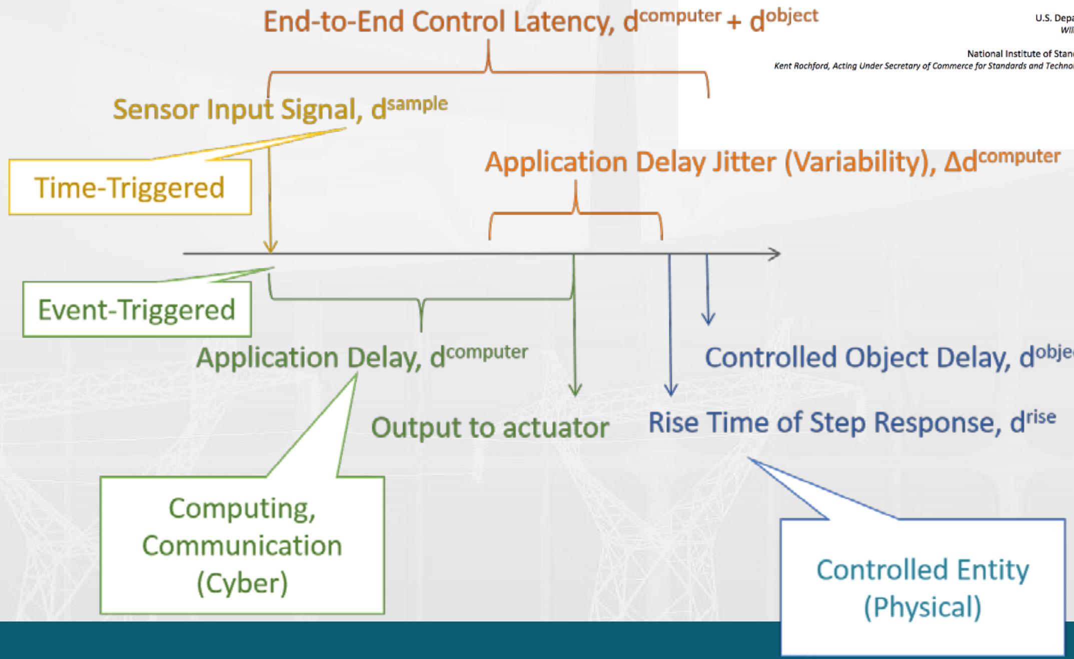
- Common system clock to meet real-time demands
- "Now" is uncertain
- Integration of logical and physical time (HiL)

Autonomous Systems

- Continuous observation
- Rapid adaptation to changes
- Physical environments are highly variable, uncertain
- Resources available "now"

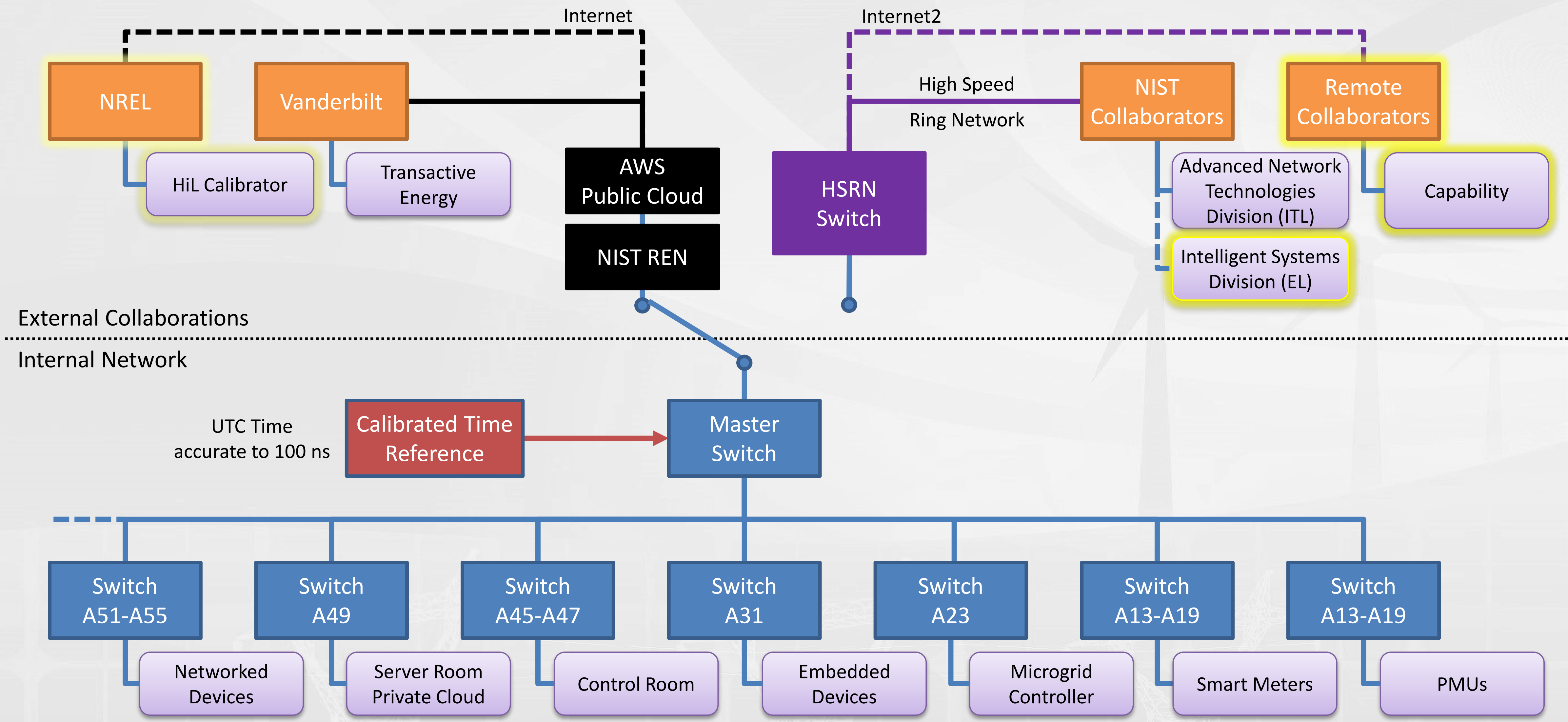






Needs
Challenges

Testbed Network



Testbed Safety

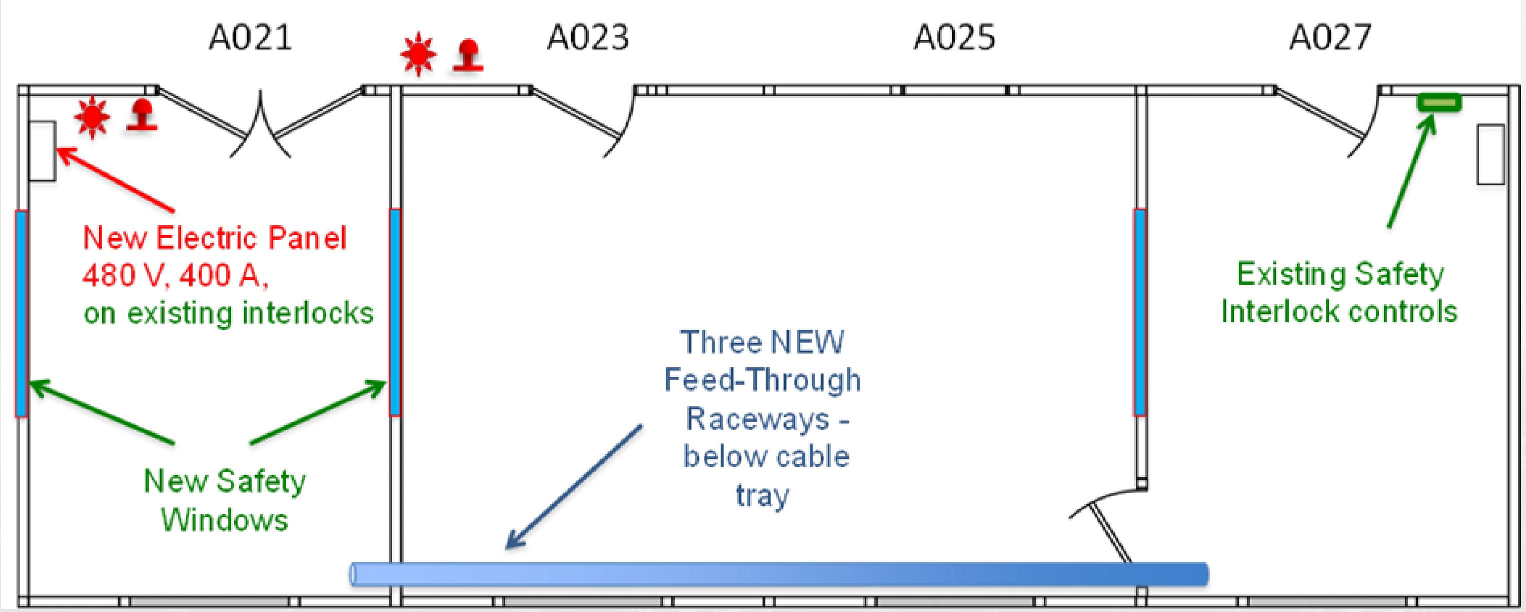
- **Hazard Avoidance—**Several hazard-avoidance safety measures are being implemented for the testbed to reduce the risk of fire and injury.

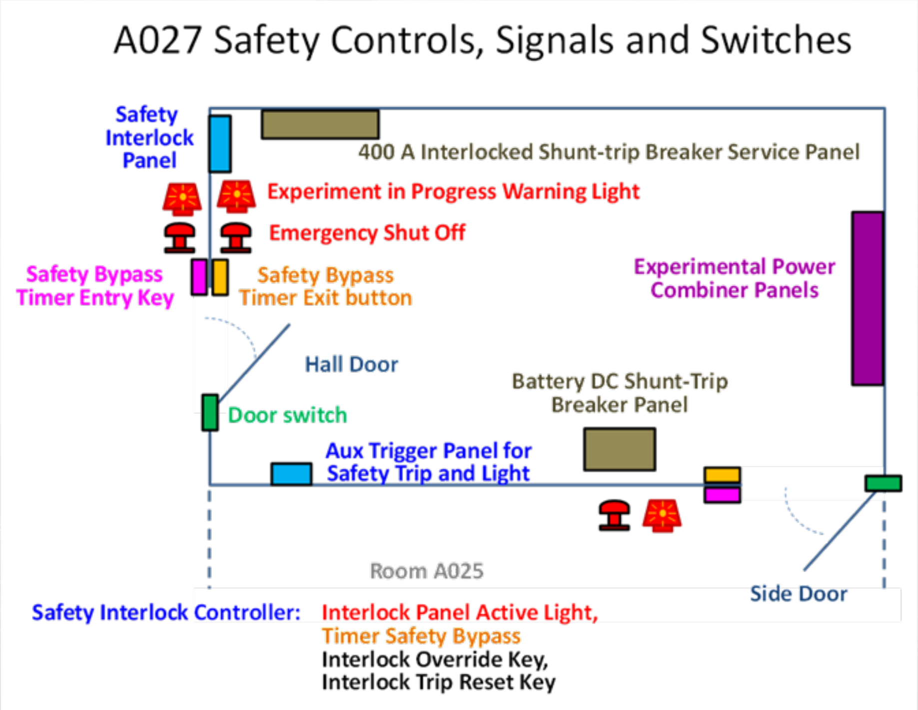
- **Physical Barrier—**The primary hazard mitigation equipment involves physical barriers to prevent persons from being exposed to potential hazards including arc flash (primary potential hazard), electrical voltage contact, and hot surface contact.

NISTSafety

Testbed Safety

- **Emergency Shutdown and Experiment in Progress Warning Lights—** The primary electrical safety system involves an interlocked Emergency Shutdown system that deactivates all sources of hazards when triggered, and an Experiment in Progress Warning light that indicates that there is an experiment in progress.

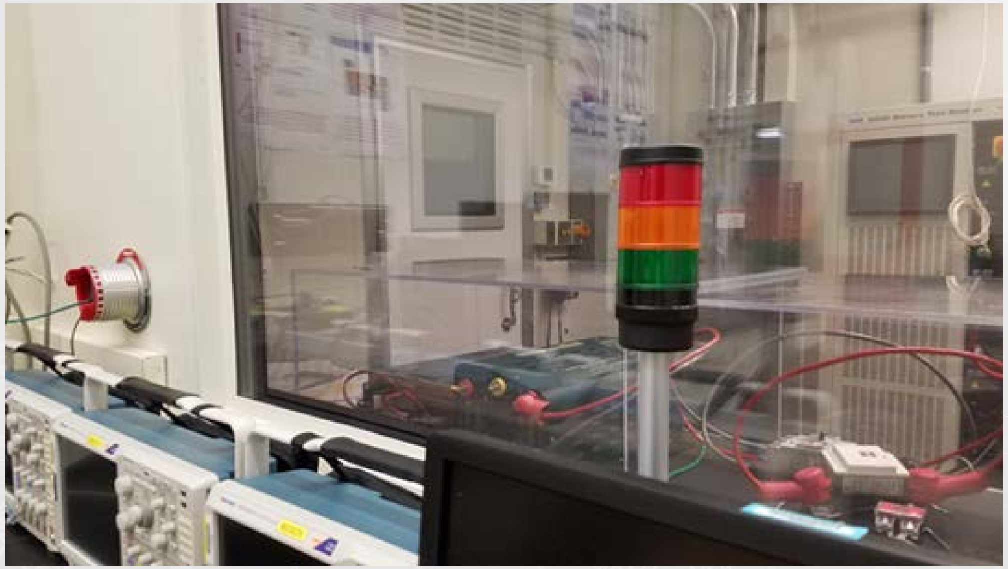




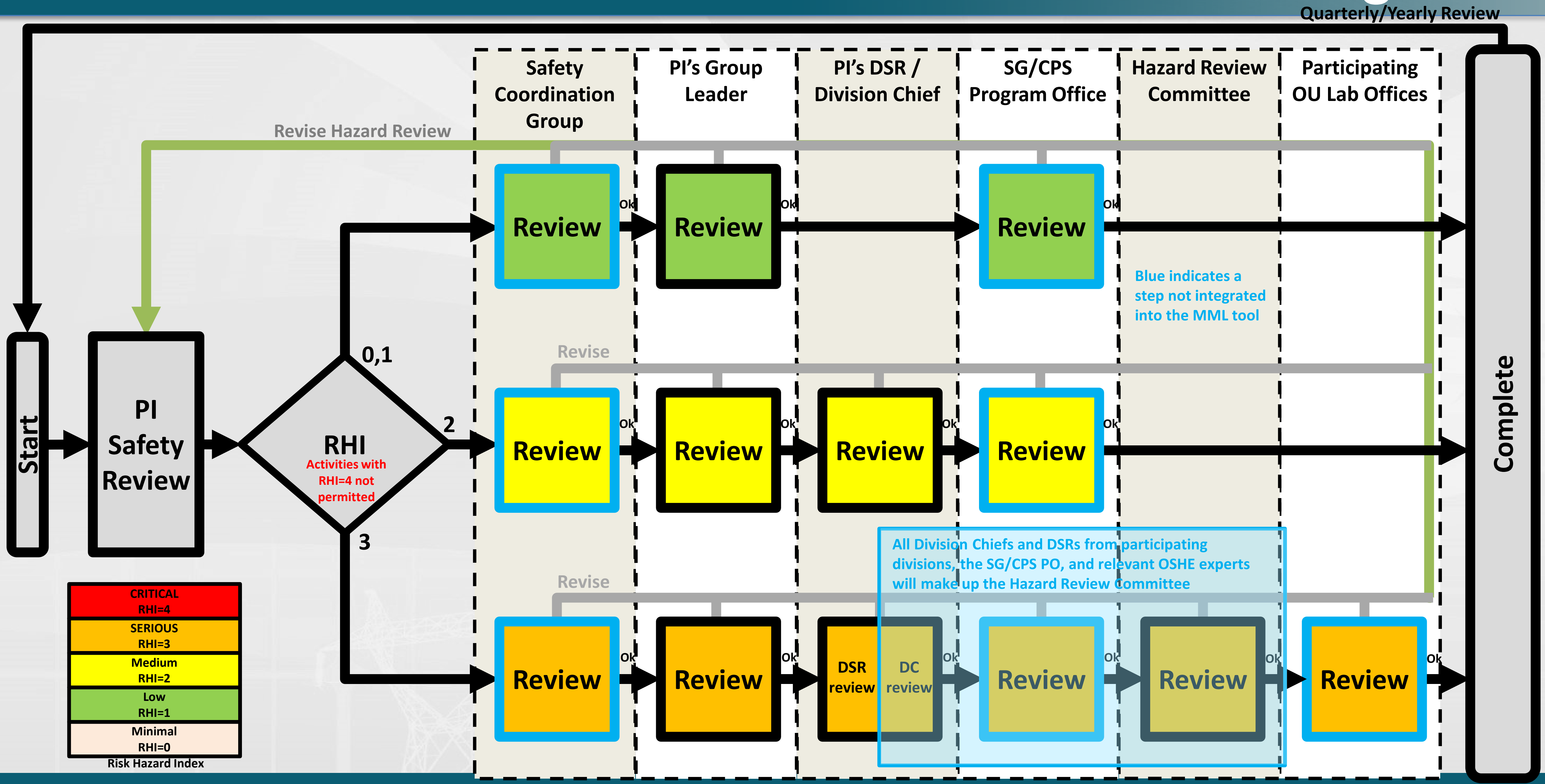
Testbed Safety

- **Operator Warning Light and Status Sensing System**—This system is an independent redundant safety warning system that monitors operation of the emergency shutdown systems panel tripped-signal and timer-bypass-signal, and provides additional triggers for emergency shutdown.

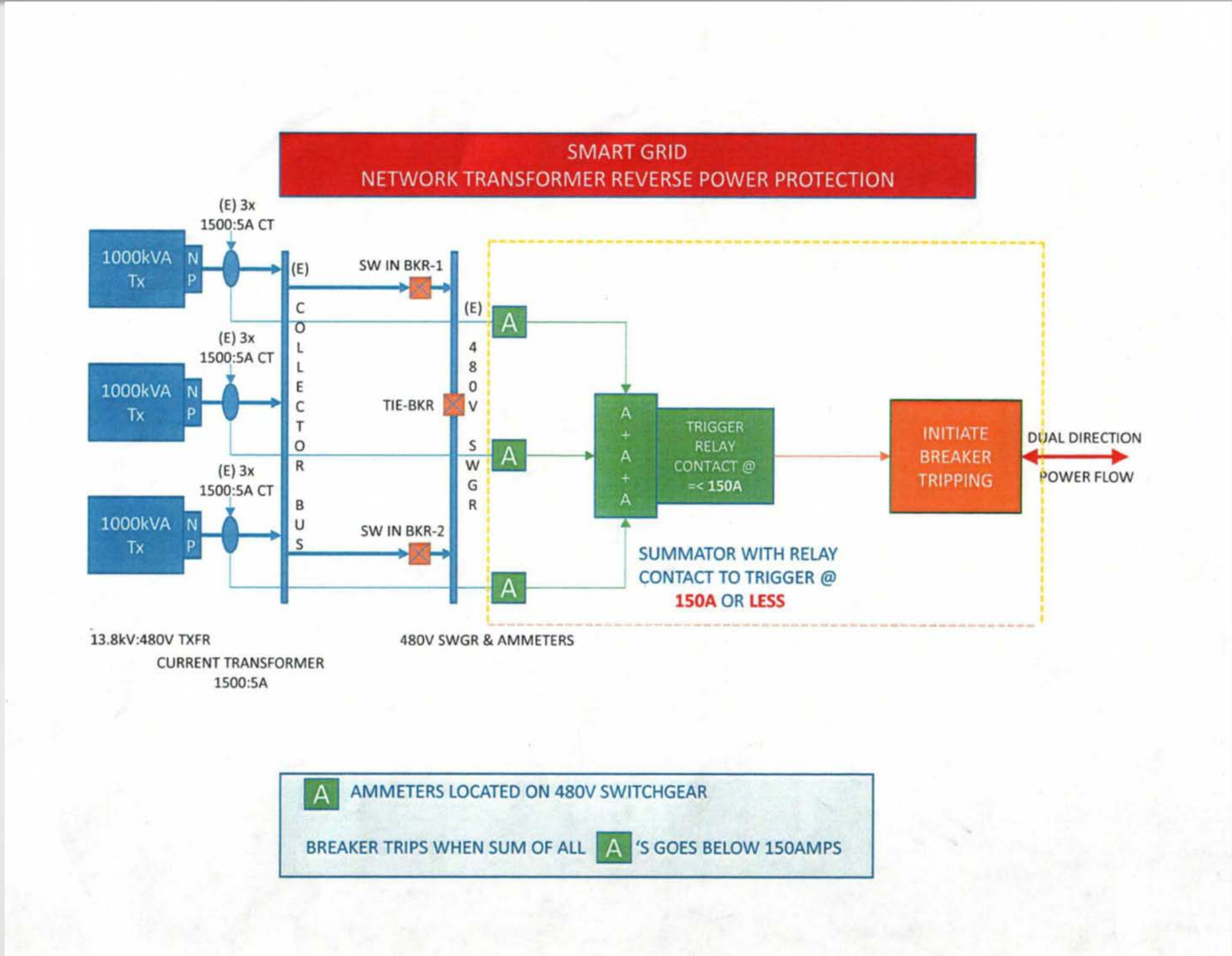
Red = power connected & power on
Yellow (warning) = power connected | power on | safety system malfunction detected
Green = safety systems are operational & power not connected & power not on



Testbed Enhanced Multi-OU Hazard Review Logic



Network Protection Switch



Timeline

Milestone	Quarter
Research begun in expanded space	1QFY18
Finalizing Safety Interlock System	
Hazard reviews for high-power equipment	2QFY18
Testbed Safety Best Practices Document	
Testbed Capabilities Document	3QFY18
Testbed Project Platform	
Installation of Additional Equipment	4QFY18
Equipment Commissioning Complete	1QFY19
Network Protection Switch Installed	2QFY19

The old adage about the last mile…

…we are close to having full functionality

Grid Edge Device Security

Mike Bartock
IT Specialist
Computer Security Division
Information Technology Laboratory

NIST
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.

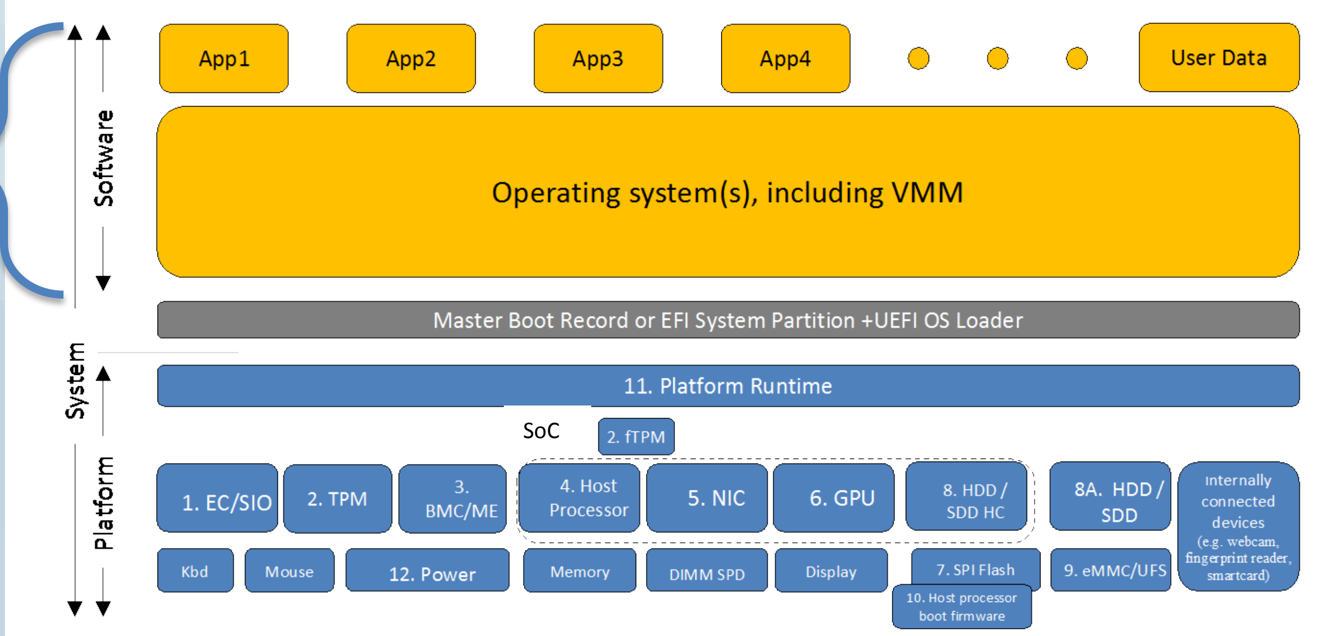
Cybersecurity Efforts

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

Profiling Performance of Grid Edge Devices

- We are currently developing techniques to profile the performance impact of security solutions on grid edge devices.
- The 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 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.)

Results Matrix

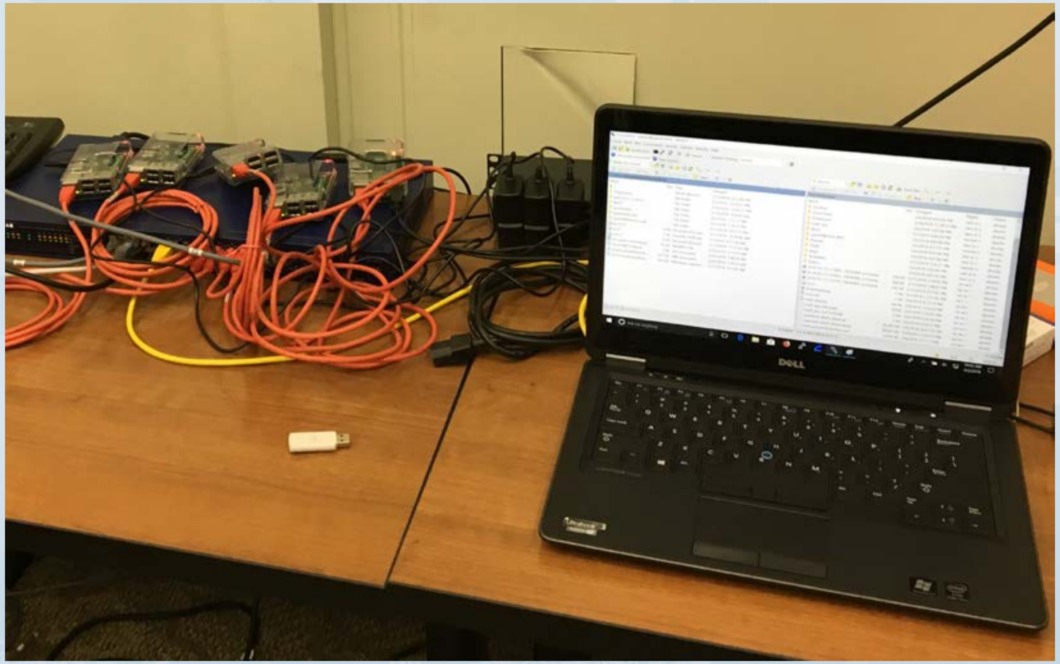
- Construct a matrix of hardware platforms commonly used in smart grid devices with performance metrics of the encryption libraries that are enabled on them.
- Baseline performance of various devices by measuring the performance different encryption algorithms in bytes/second and bytes/cycle.
- This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

Publish-Subscribe Communications

- Reviewed the NAESB RMQ.26 standard for implementing Open Field Message Bus (OpenFMB)
- Participated in the SEPA OpenFMB Cybersecurity Task Force
- Performed a security review of NAESB RMQ.26 and corresponding OpenFMB CTF output
- Built proof of concept implementation of OpenFMB

OpenFMB PoC Implementation

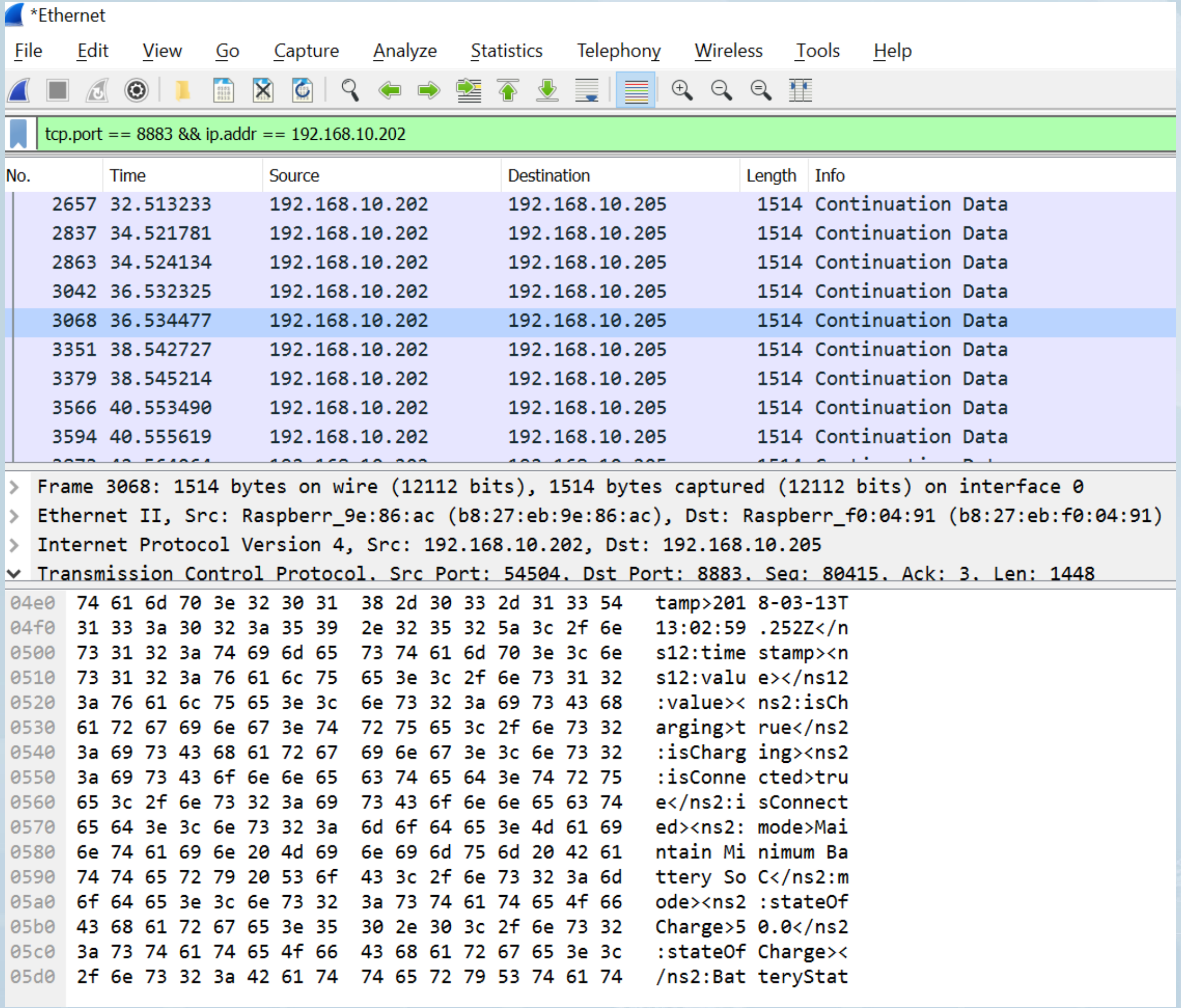
- Raspberry Pi 2 – 900MHz quad-core ARM Cortex-A7 CPU
- Ubuntu Linux Operating System
- OpenSSL Crypto Library
- Mosquitto MQTT Broker and Client
- Java Simulation of Grid Devices
- Netgear GS724Tv4 24-Port Gigabit Smart Managed Pro Switch
- Laptops: Windows 10

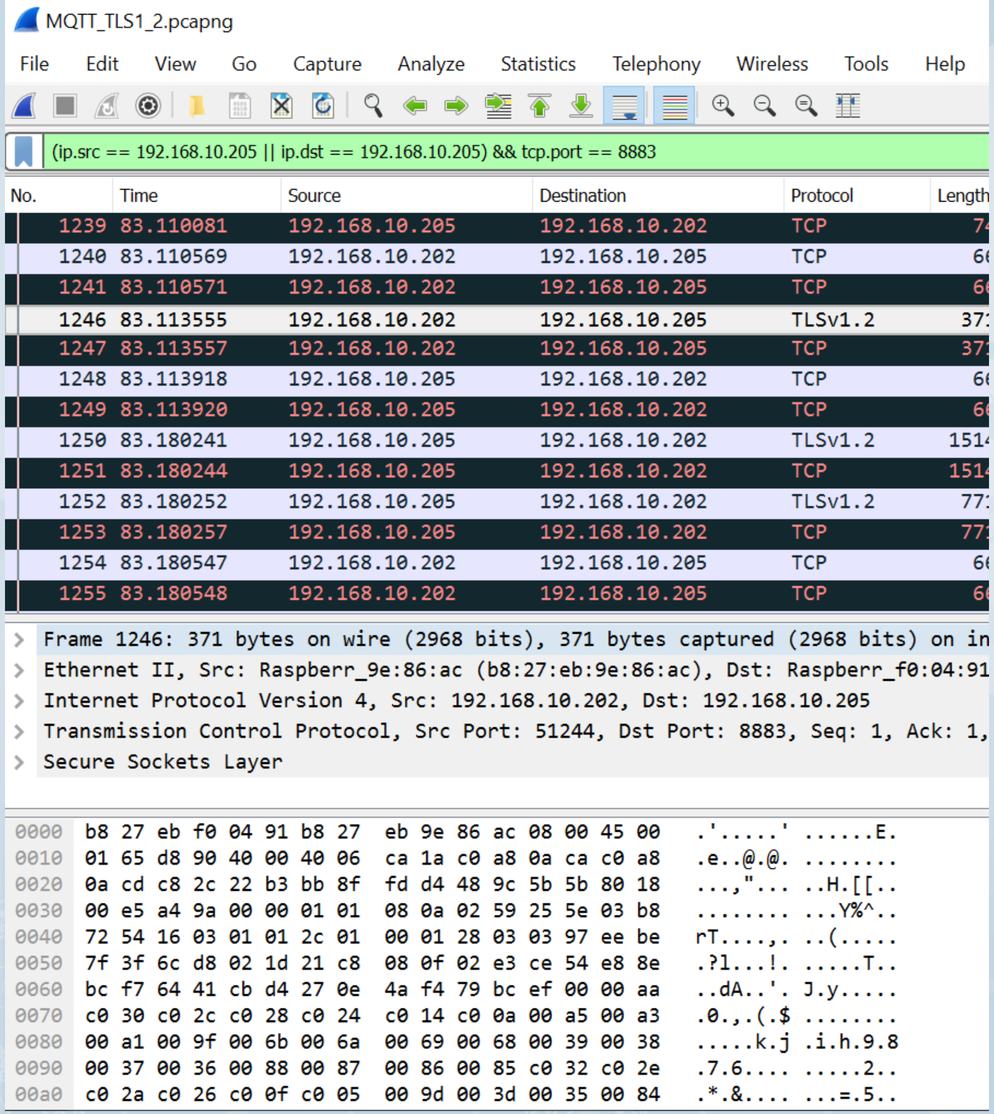


OpenFMB PoC Implementation Outcomes

- Enabled Operating System access controls
- Turned on certificate based TLS encryption for network traffic
- Performed certificate based device authentication
- Limited access to information within the publish-subscribe messaging

OpenFMB PoC Implementation Outcomes





OpenFMB PoC Implementation Outcomes

Preliminary Performance Results

$MQTT_{Init}$ --> $MQTT_{SUBACK}$

Authentication / Encryption	None	TLS 1.2
None	.002855	.108071
Username & Password	.003223	.108458
X509 Certificate	N/A	.201232

$MQTT_{PUB}$ --> $MQTT_{SUB\_RECV}$

Authentication / Encryption	None	TLS 1.2
None	.003242	.109013
Username & Password	.003216	.108034
X509 Certificate	N/A	.186208

Next Steps

- Research to improve performance
  - Investigate keeping TLS sessions alive for publishing message
  - Use different key exchange methods to establish TLS session
- Obtain grid devices that support OpenFMB
- Publish findings in a NIST document

Q & A

Overview of NIST participation at UCAIug IEC 61850 IOP

Cuong Nguyen

NIST Smart Grid Program

NIST Smart Grid Advisory Committee Meeting
April 24, 2018

What is the UCAIug IEC 61850 Interoperability Plugfest?

Objective: Identify issues related to the interoperation of substation automation equipment from different vendors.

- Interoperation has been identified as an impediment to adoption of modern sensors, relaying and control equipment.
- All profess to comply to the **IEC 61850** Substation communication protocol.
- Sponsored by UCAIug
- Several parallel testing events:
  - **Integrated Application**
  - **Time Sync**
  - Cyber Security
  - Substation Configuration Language (SCL)
  - **GOOSE and R-GOOSE**
  - **SV and R-SV**
  - **MMS**
- Recreate both *normal* and *stressed* environments?
- Over 208 attendees including system integrators, vendors, and utilities

NIST Motivation

- Advancing interoperation is a stated goal of the smart grid program
- Metrology for these advanced systems require custom tools
- Engagement with industry engineers on implementation issues
- Interop events highlight standards ambiguities
- Industry interest in testing and certification is difficult to gauge
- Peer pressure inspires participation with best of breed equipment
- NIST test capability in the area had not been benchmarked against industry leading practice

NIST participation

Testing events:

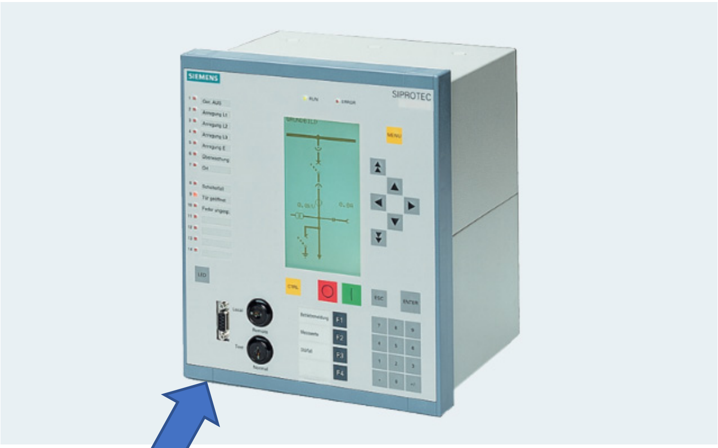
- **Integrated Application**
- **Time Sync**
- Cyber Security
- Substation Configuration Language (SCL)
- **GOOSE and R-GOOSE**
- **SV and R-SV**
- **MMS**

Major project components:

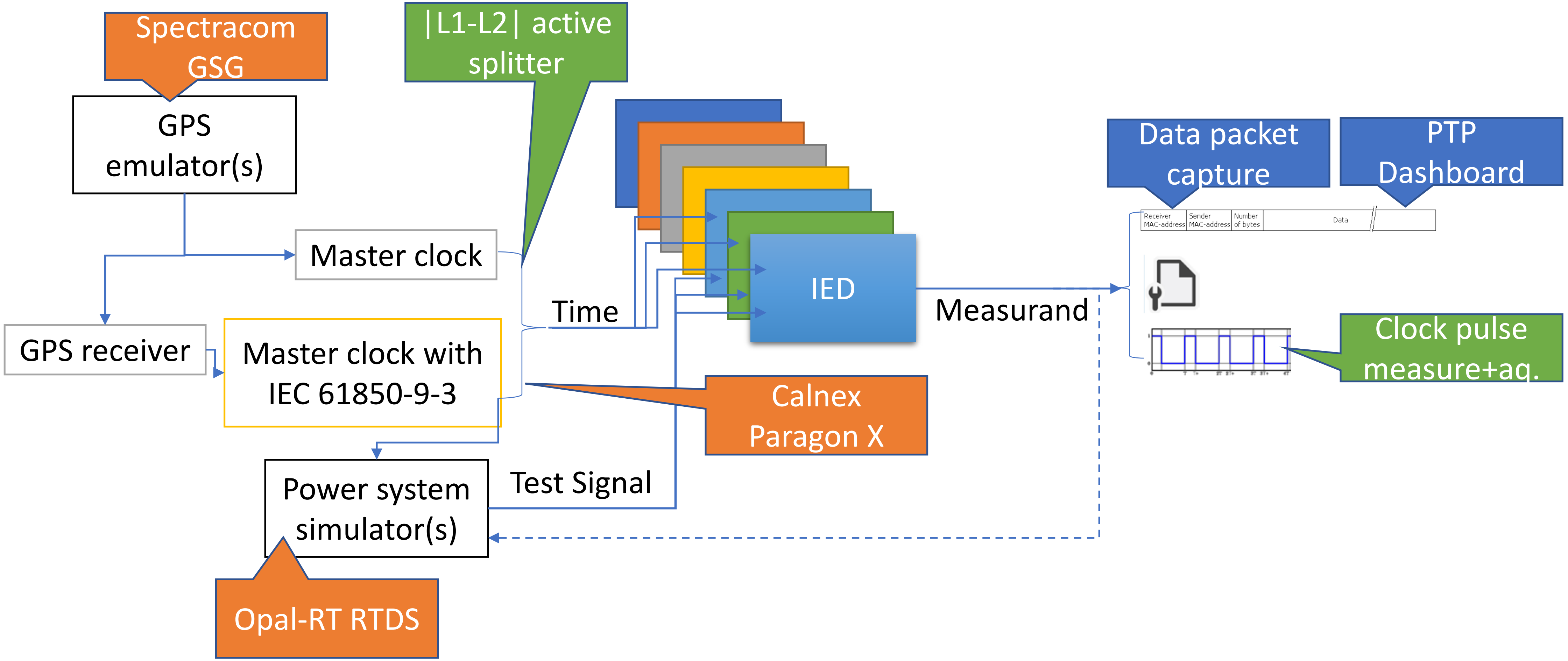
1. Capture 61850 SV, GOOSE, MMS packets from a diverse set of vendor devices
2. Build a dashboard to visualize and analyze the contents of timing packets on the network
3. Build a device to measure time differences between devices
4. Prototype a Hardware in the loop test system for 61850 compliant IEDs
5. Capture variations in the latency of network time messages
6. Provide a GPS emulation capability and emulate signals to participating devices

Devices being tested

- PDC/ SCADA
- PMU/ AMU
- Relay
- IED
- TC/BC
- GPS receiver
- Clock



Test Equipment Provided By NIST



NIST Team

Team Members	
Allen Goldstein, Ya-Shian Li-Baboud, Jerry FitzPatrick	Project management
Cuong Nguyen	Official witness, Lead for onsite team
Kang Lee, Eugene Song	Test and capture 61850 packet data at integrated testing
Kevin Brady Jr. , DJ Anand	Test apparatus engineering and support

Timing Test Observations

- Device Conformance Issues
  - Devices had some conformance issue with respect to the configuration parameters
  - Issues can be resolved with firmware fix and upgrade
- Device Interoperability
  - Compatibility between clocks
  - Network supported multiple domains without interference
- Synchronization Performance
  - Accuracy exceeds standard's requirements
- Standards Issues
  - Need to define behaviors of grandmaster and boundary clock at start up
- Testing Issues
  - Future tests need sniffing device capable of logging the exact moment of the leap second
  - Need better tools

Overview of NIST participation at UCAIug IEC 61850 IOP

Thank you!

Stakeholder Engagement

NIST Smart Grid Advisory Committee

Dr. David Wollman
Deputy Director, SG and CPS Program Office

April 24, 2017

Stakeholder Engagement

- Stakeholder:
  - a person entrusted with the stakes of bettors.
  - a person with an interest or concern in something, especially a business.
  - Stakeholders can affect or be affected by an organization's actions, objectives and policies.

Source: Merriam-Webster, Google

- **EISA (2007) SEC. 1305. SMART GRID INTEROPERABILITY FRAMEWORK.**

  ..National Institute of Standards and Technology shall have primary responsibility to coordinate the development of a framework that includes protocols and model standards for information management to achieve interoperability of smart grid devices and systems. …

  (1) [NIST] shall seek input and cooperation from the Commission, OEDER and its Smart Grid Task Force, the Smart Grid Advisory Committee, other relevant Federal and State agencies; and

  (2) [NIST] shall also solicit input and cooperation from private entities interested in such protocols and standards, including but not limited to the Gridwise Architecture Council, the International Electrical and Electronics Engineers, the National Electric Reliability Organization recognized by the Federal Energy Regulatory Commission, and National Electrical Manufacturer's Association.

NIST's EISA SG Stakeholders

- Some initial motivations:
  - Curiosity (many organizations did not know much about NIST)
  - Fear of regulation
  - Funding (ARRA) and future work (consultants…)
  - International marketplace
  - Networking (discussions with peers/experts)
  - Mutual interests (desire to engage critical mass of participants to make rapid progress)

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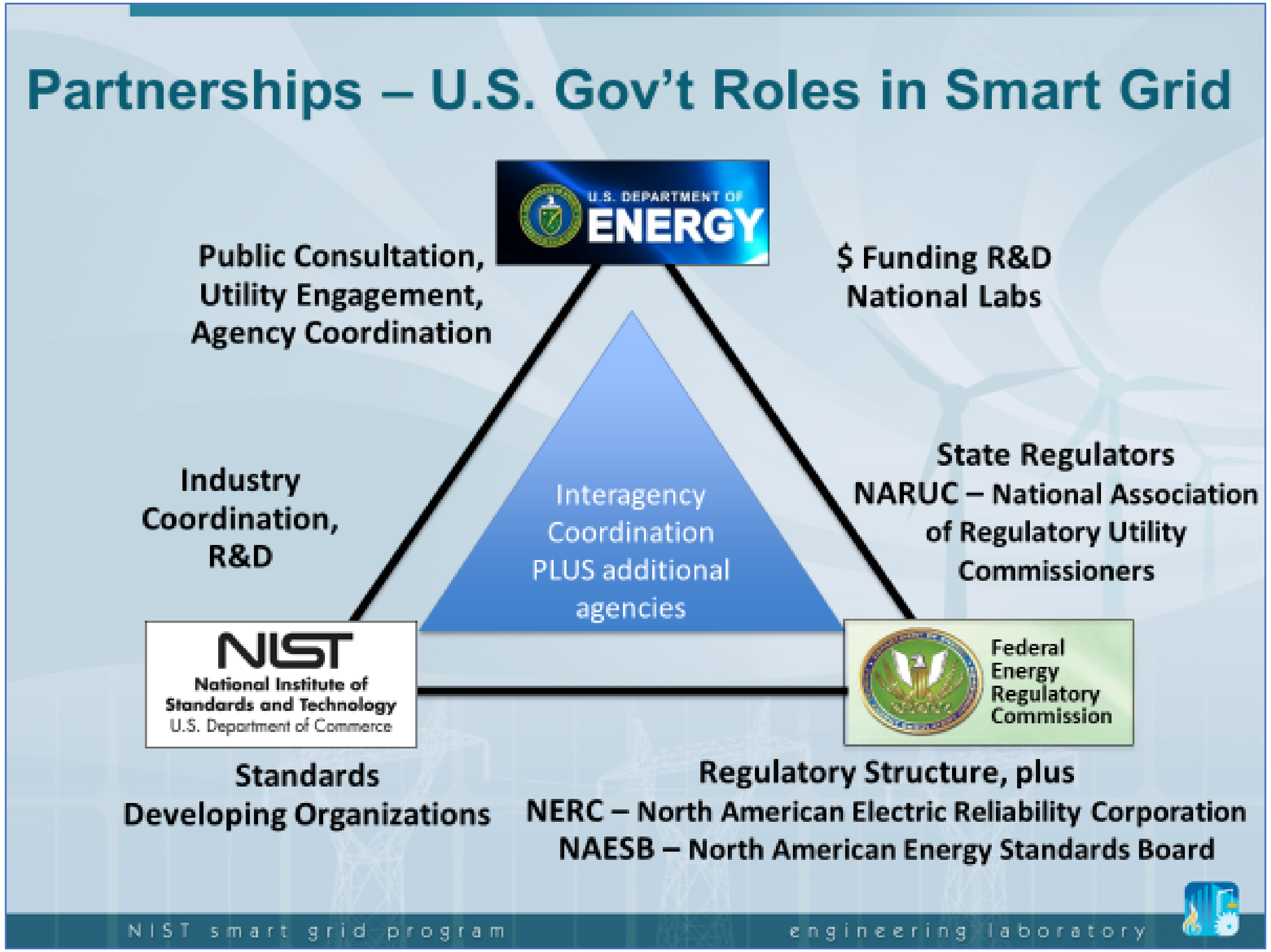

NIST interagency coordination at multiple leadership levels with DOE, FERC and other agencies (including through Smart Grid Task Force)

NIST's EISA SG Stakeholders

NIST smart grid leadership extended to coordination with international standards organizations, new leadership role for NIST

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  - Curiosity (many organizations did not know much about NIST)
  - Fear of regulation
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  - International marketplace
  - Networking (discussions with peers/experts)
  - Mutual interests (desire to engage critical mass of participants to make rapid progress)

Smart Grid Interoperability Panel (SGIP)

22 SGIP Stakeholder Categories

1	Appliance and consumer electronics providers
2	Commercial and Industrial equipment manufacturers and automation vendors
3	Consumers – Residential, Commercial and Industrial
4	Electric transportation industry Stakeholders
5	Electric utility companies – Investor Owned Utilities (IOU) and Publicly Owned Utilities
6	Electric utility companies - Municipal (MUNI)
7	Electric utility companies - Rural Electric Association (REA)
8	Electricity and financial market traders (includes aggregators)
9	Independent power producers
10	Information and communication technologies (ICT) Infrastructure and Service Providers
11	Information technology (IT) application developers and integrators
12	Power equipment manufacturers and vendors
13	Professional societies, users groups, trade associations and industry consortia
14	R&D organizations and academia
15	Relevant Federal Government Agencies
16	Renewable Power Producers
17	Retail Service Providers
18	Standard and specification development organizations (SDOs)
19	State and local regulators
20	Testing and Certification Vendors
21	Transmission operators and Independent System Operators
22	Venture Capital

5 in SGIP 2.0

- Manufacturers
- Asset Owners
- Service Providers & System Administrators
- Consumers, Policy and Government
- SDOs and Consortia

For comparison, DOE Stakeholder Categories included Consumer Advocates, Utilities, Technology Providers, Policymakers, Regulators, Environmental Groups

Types of Stakeholder Engagement

Some representative perspectives on stakeholder engagement

- NIST researchers
  - Personal (expert peers) networks
  - Publication-based collaborations and conferences/workshops organization
- NIST program managers/division chiefs
  - Mix of personal networks and organizational networks
  - Interactions with multiple levels from peer program managers up to leadership
  - Workshop/conference leadership and sponsorship, and funding initiatives
- NIST senior leadership
  - Organizational networks and personal contacts with peer senior leadership
  - Official responsibilities (legislation, executive orders)
  - Congressional and Executive – Budgets
  - Strategic engagement

- Examples: mix of leadership, technical involvement in SDOs
  - IEC Strategy Group 3 – NIST liaison (NIST hosted SyC Smart Energy in March2018)
  - USNC – NIST participation
  - IEEE – NIST liaison, ISGT & PES, PMU ICAP T&C, …
  - CEN-CENELEC-ETSI SG-Coordination Group (later SEG-CG) – NIST liaison
  - ITU-T Focus Group on Smart Grid – NIST liaison (ending)
  - NEMA – multiple levels, CEO+program managers, IPRM, metering stds.
  - NAESB – NIST member of BoD
  - ASHRAE – NIST in leadership positions
  - ANSI – multiple levels of interaction
- Additional examples: Utilities, SEPA, Industry Organizations, Research Orgs, National Labs, Grid 3.0, ...

Stakeholder Engagement for a Purpose

- Examples of NIST smart grid cooperative agreements:
  - Broad-based stakeholder organizations (example: SEPA)
  - Defined constituent-based organizations (example: NARUC)
  - Project-related organizations (example: Green Button Alliance)

Some context:

EISA: Broad range of stakeholders,
Varied technical activities,
Smart Grid Framework interactions,
Pre-SDO standards requirements,
Committee products, etc.

State regulators are key stakeholder group, in particular for distribution grid, educational vehicle (e.g. cybersecurity)

Transition to industry-based leadership of Green Button Initiative (NIST has provided technical foundation)

Committee Input on Stakeholder Engagement

Do the 3 forms of stakeholder engagement (technical activities, educational activities, standards development activities) cover reasonable vectors of interaction with stakeholders? (Note: explicitly not including research activities for now)

What level of stakeholder engagement is necessary for NIST to achieve smart grid objectives?

How extensive does stakeholder engagement need to be in general (or is it always situational)?

How much (effort, time, influence, …) can one realistically expect from other organizations?

Is stakeholder engagement "rewarded" within organizations (performance plans, etc.)?

Can one ever hope to engage consumers? (proxy organizations – consumer advocates, regulators, etc.)

Interoperability Framework 4.0 Themes and Reference Cases

Avi Gopstein

Smart Grid Program Manager
Smart Grid and Cyber-Physical Systems Program Office

National Institute of Standards and Technology

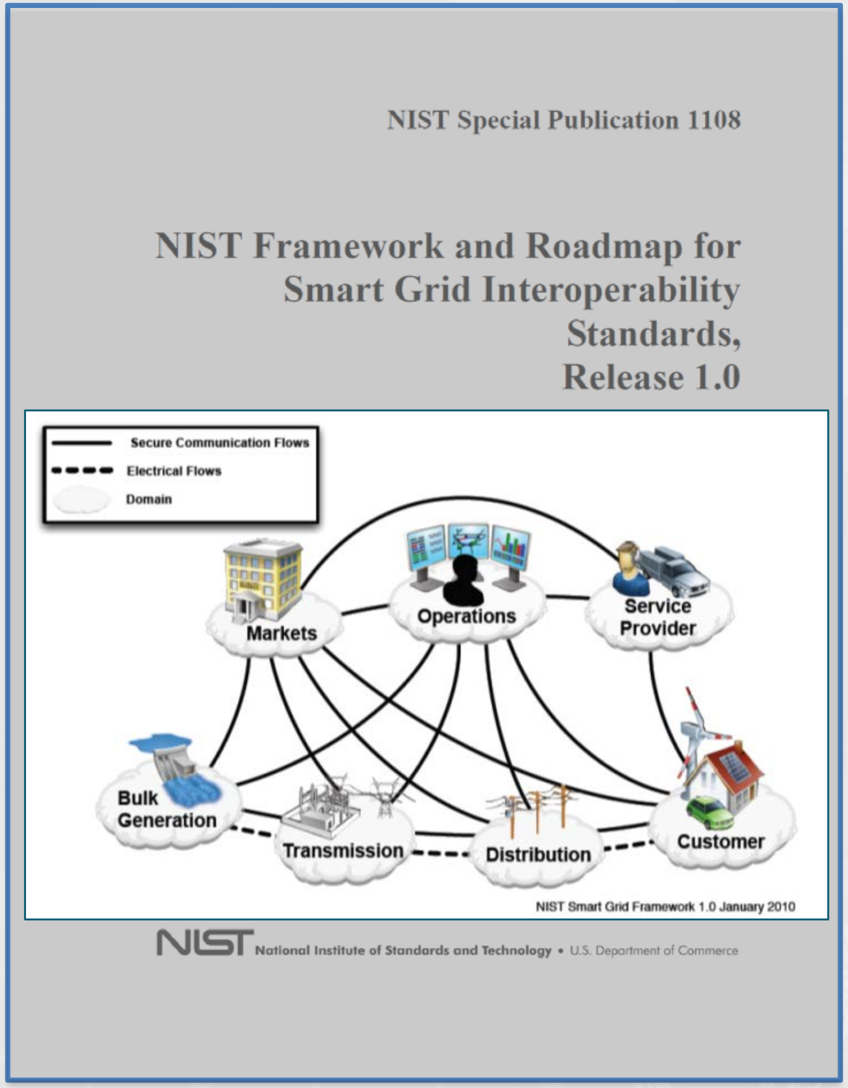
U.S. Department of Commerce

April 25, 2018

Review: 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…"*

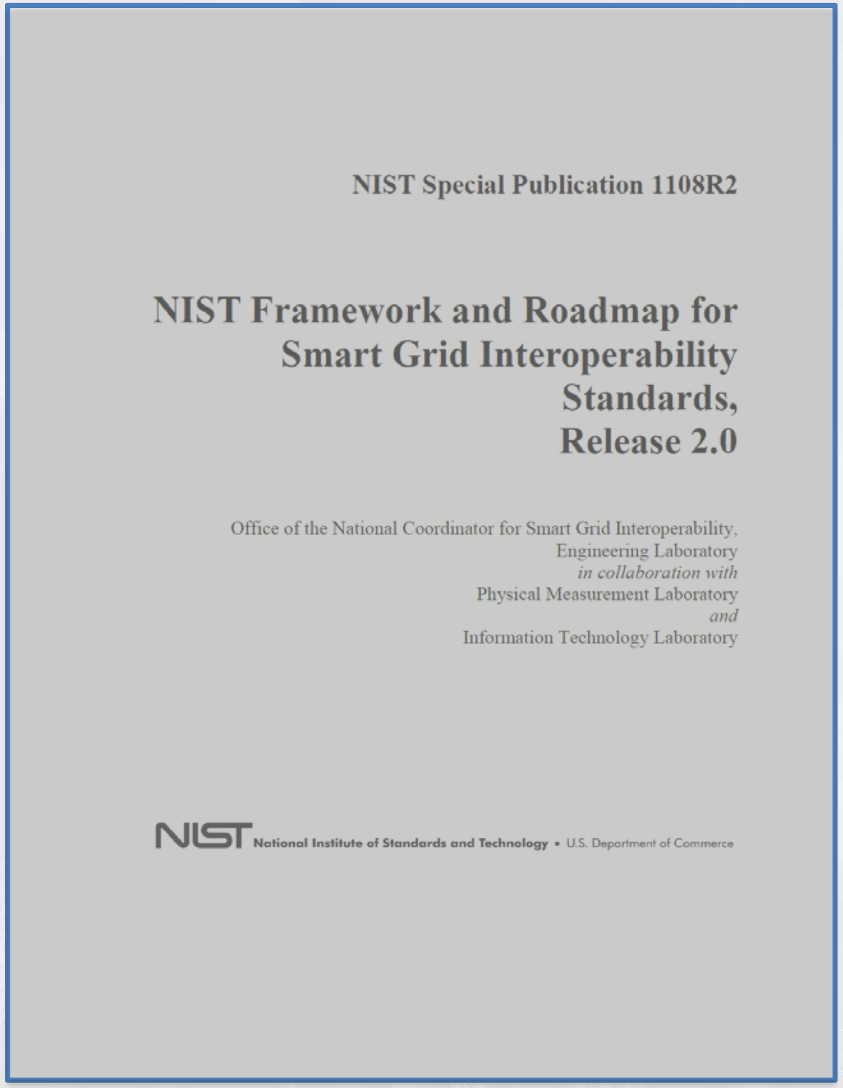
Review: Interoperability Frameworks to date


NIST Special Publication 1108

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

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

2010

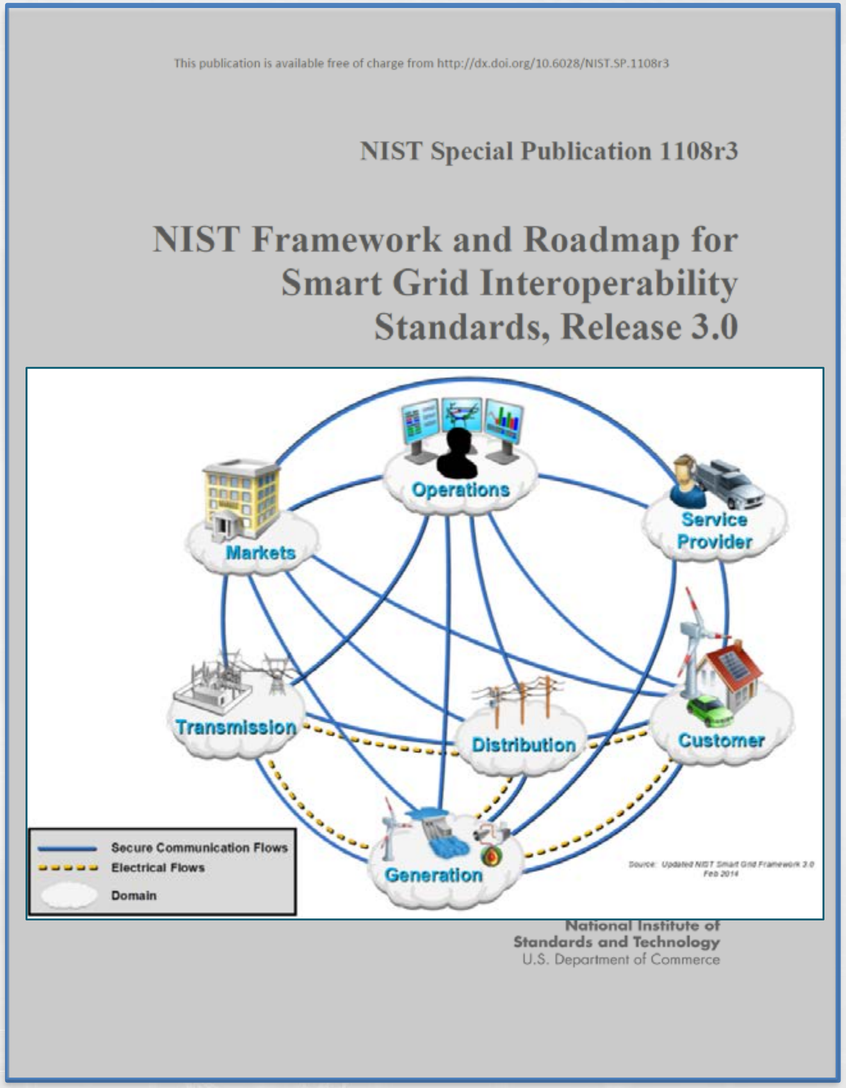

NIST Special Publication 1108R2

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

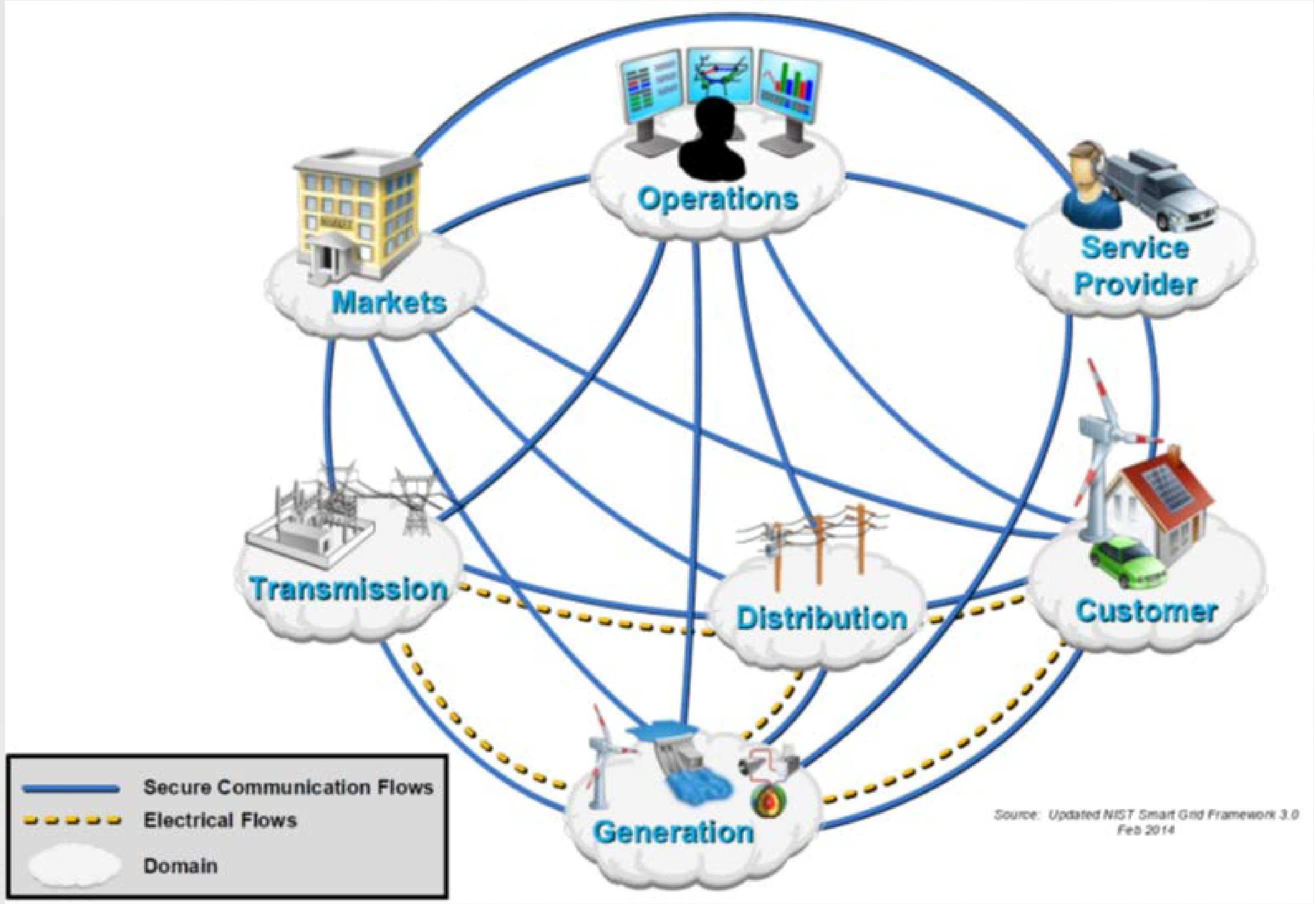
NIST Special Publication 1108r3

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

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

2014

Review: What has changed since 2014?

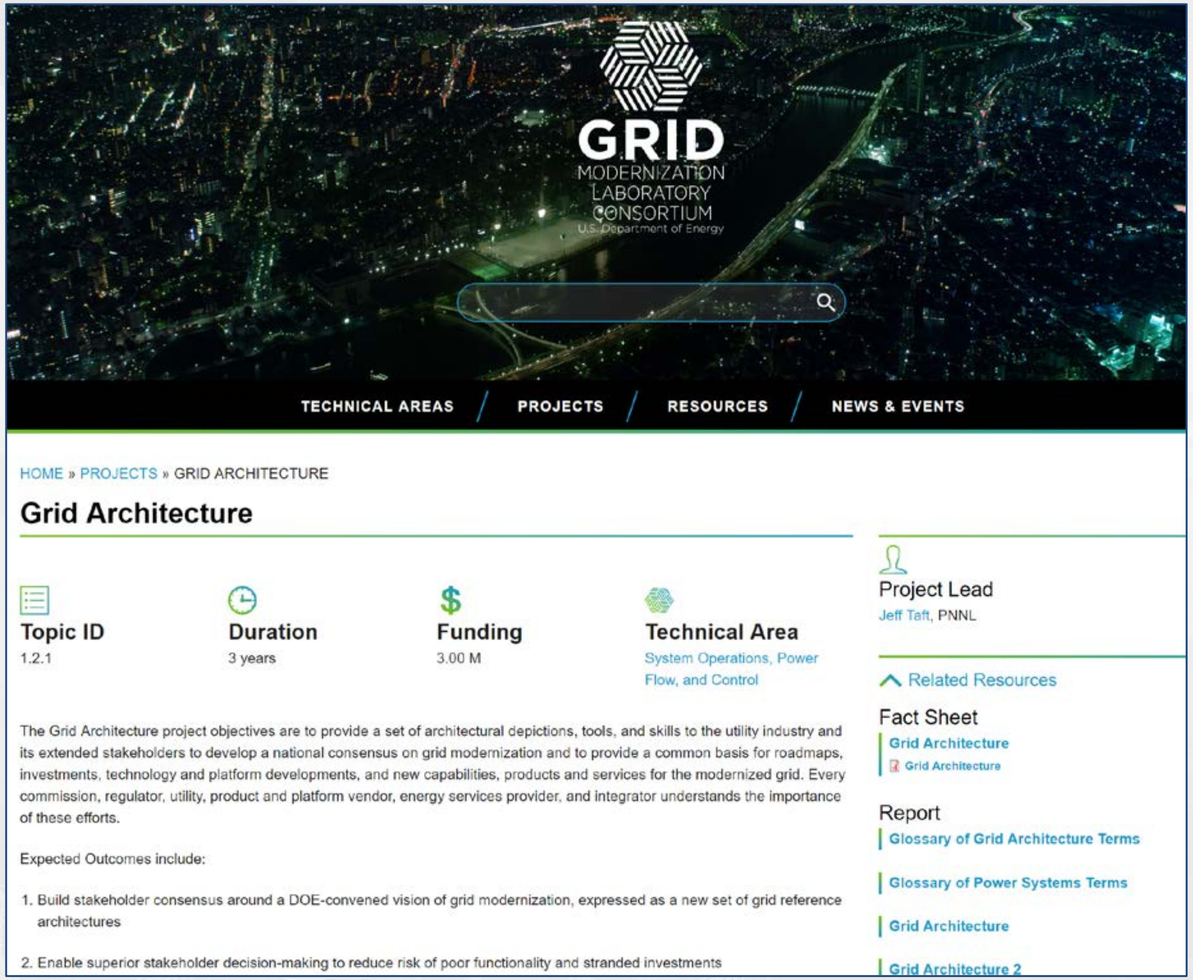


Questions to be addressed

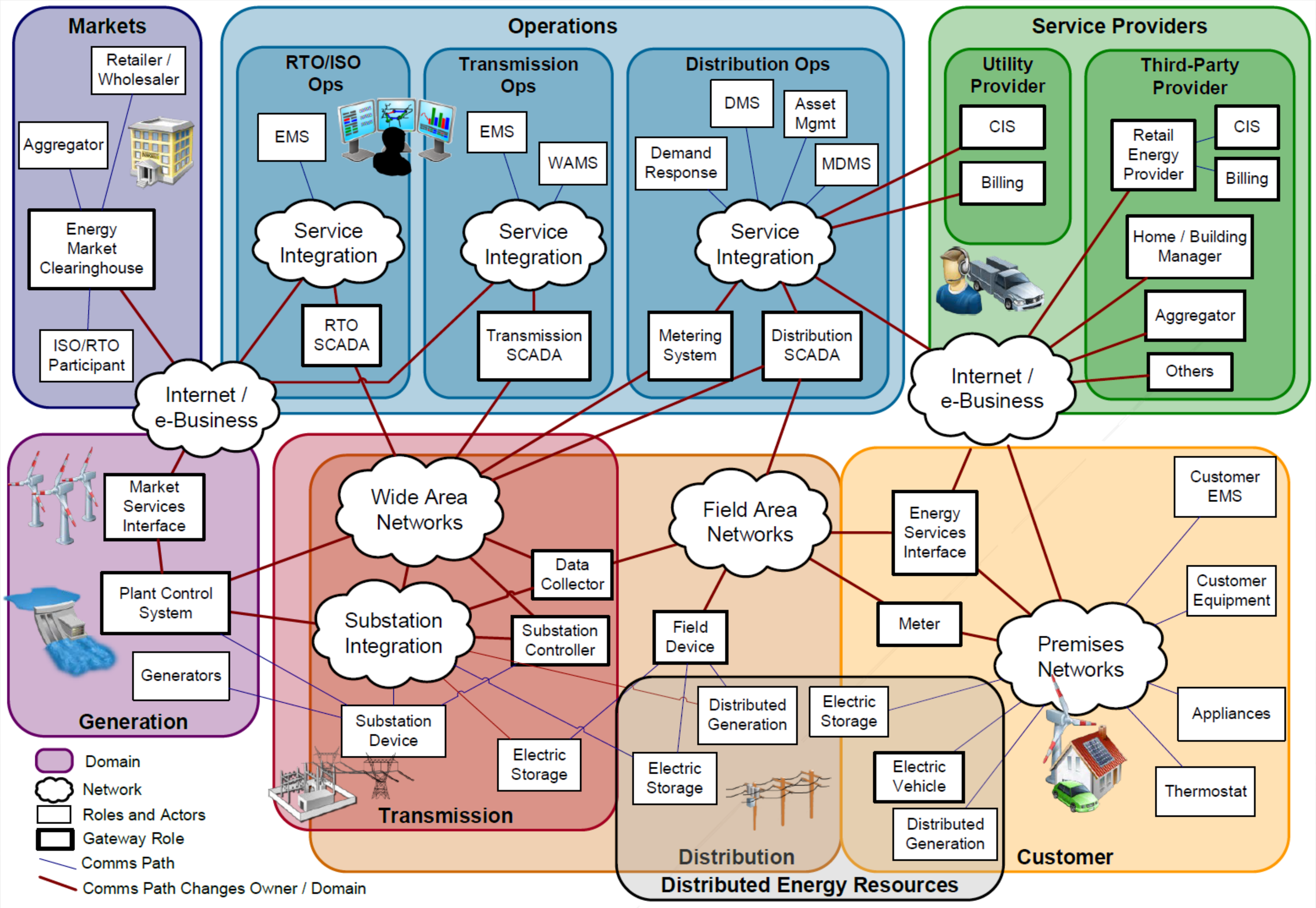
- New domains?
- New interactions?
- New scales?
- Expanded mappings?
- New roles?
- Updated economics?

NIST perspective

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



Review: Legacy Utility Communications

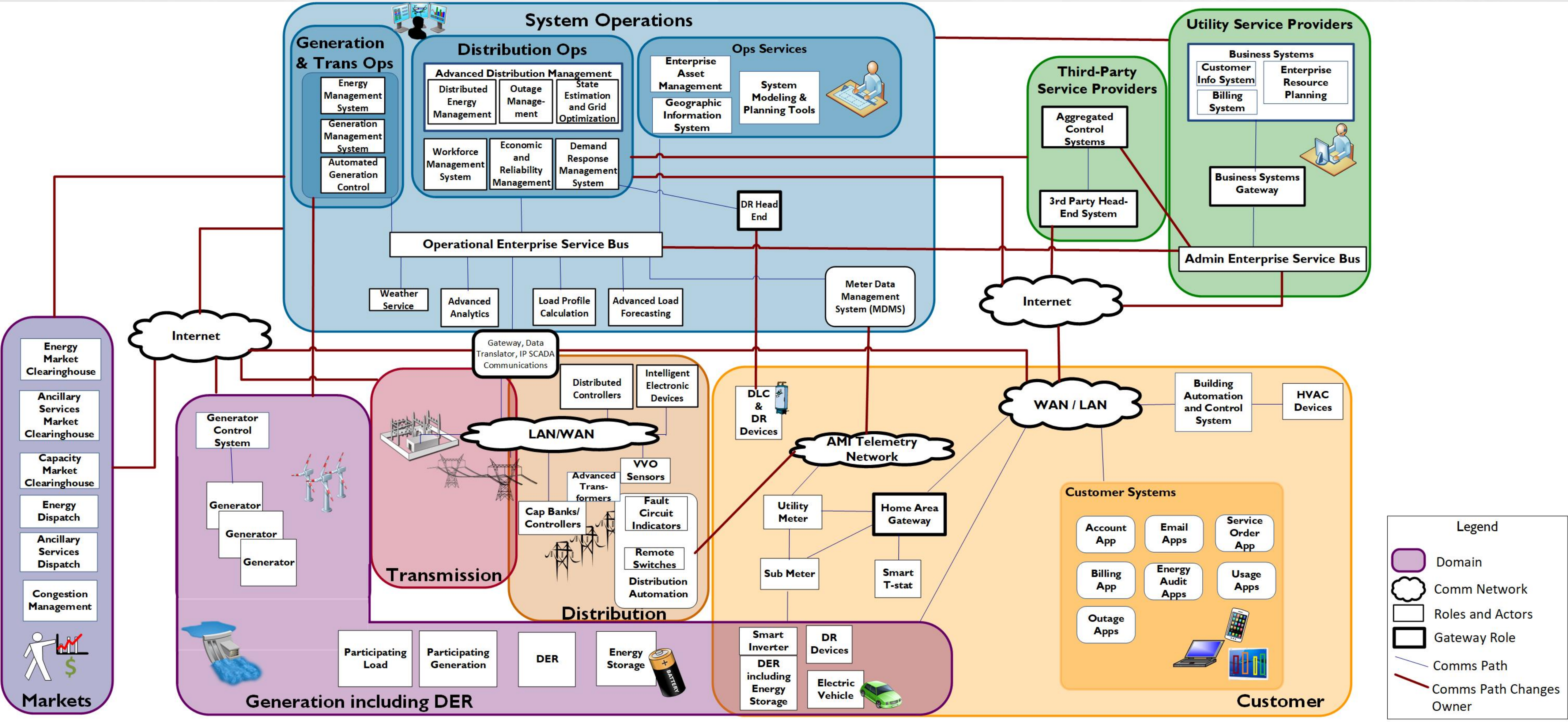


Logical model of legacy systems mapped onto conceptual domains for smart grid information networks

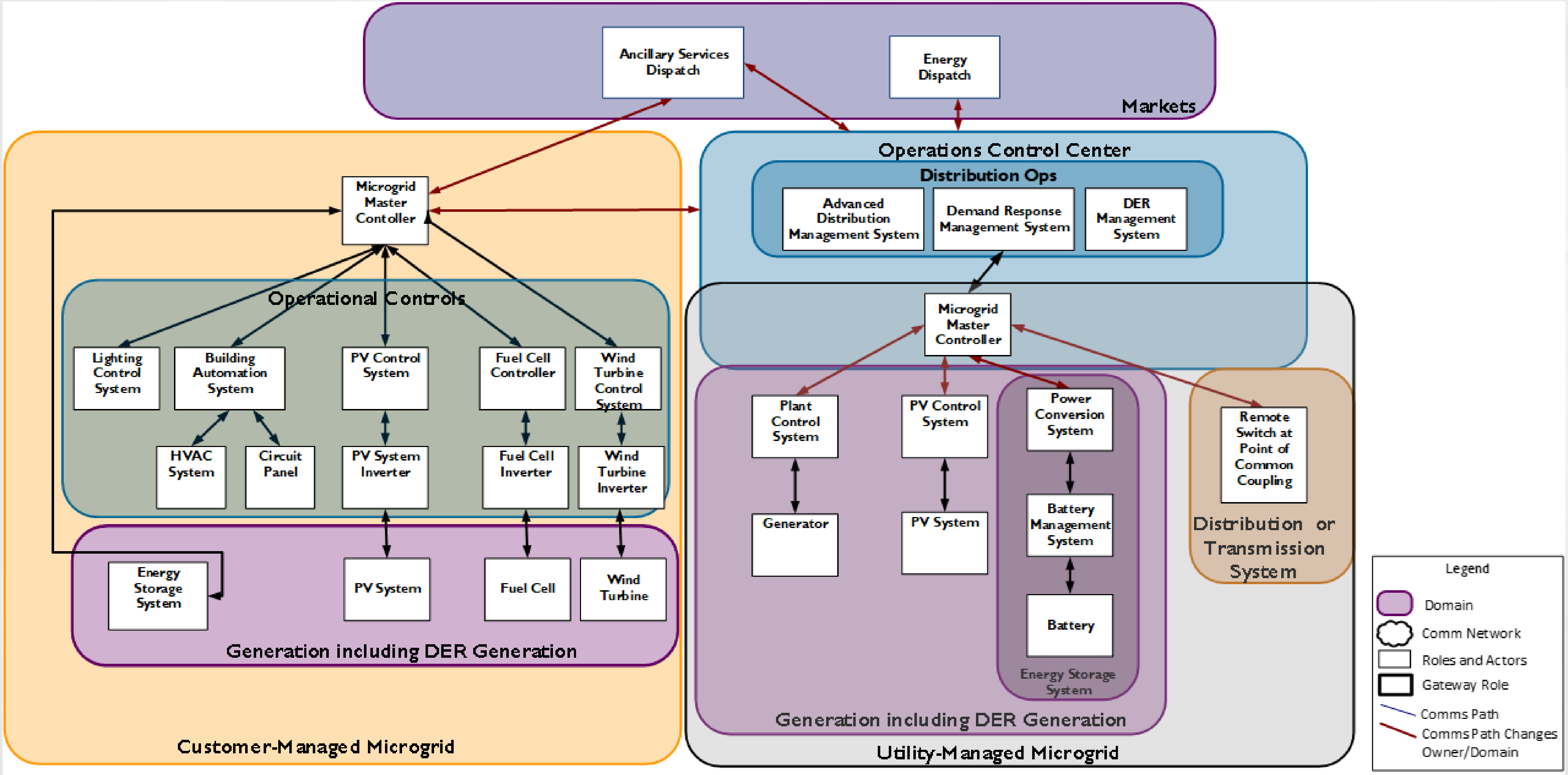
Framework 4.0 includes four examples:

- Legacy utility architecture
- High-DER architecture
- Microgrid architecture
- Advanced Bulk architecture

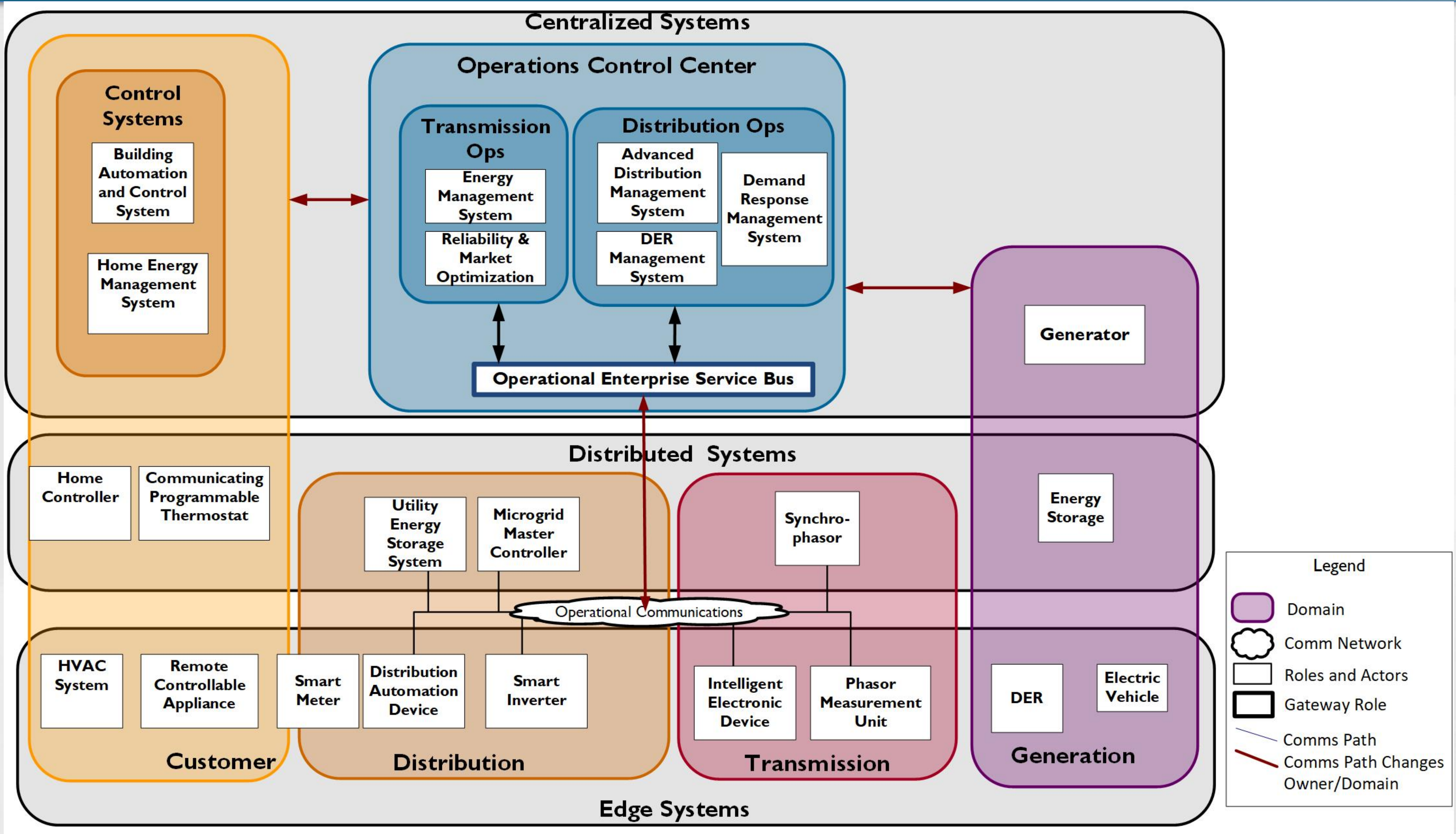
High-DER Architecture Communications Example



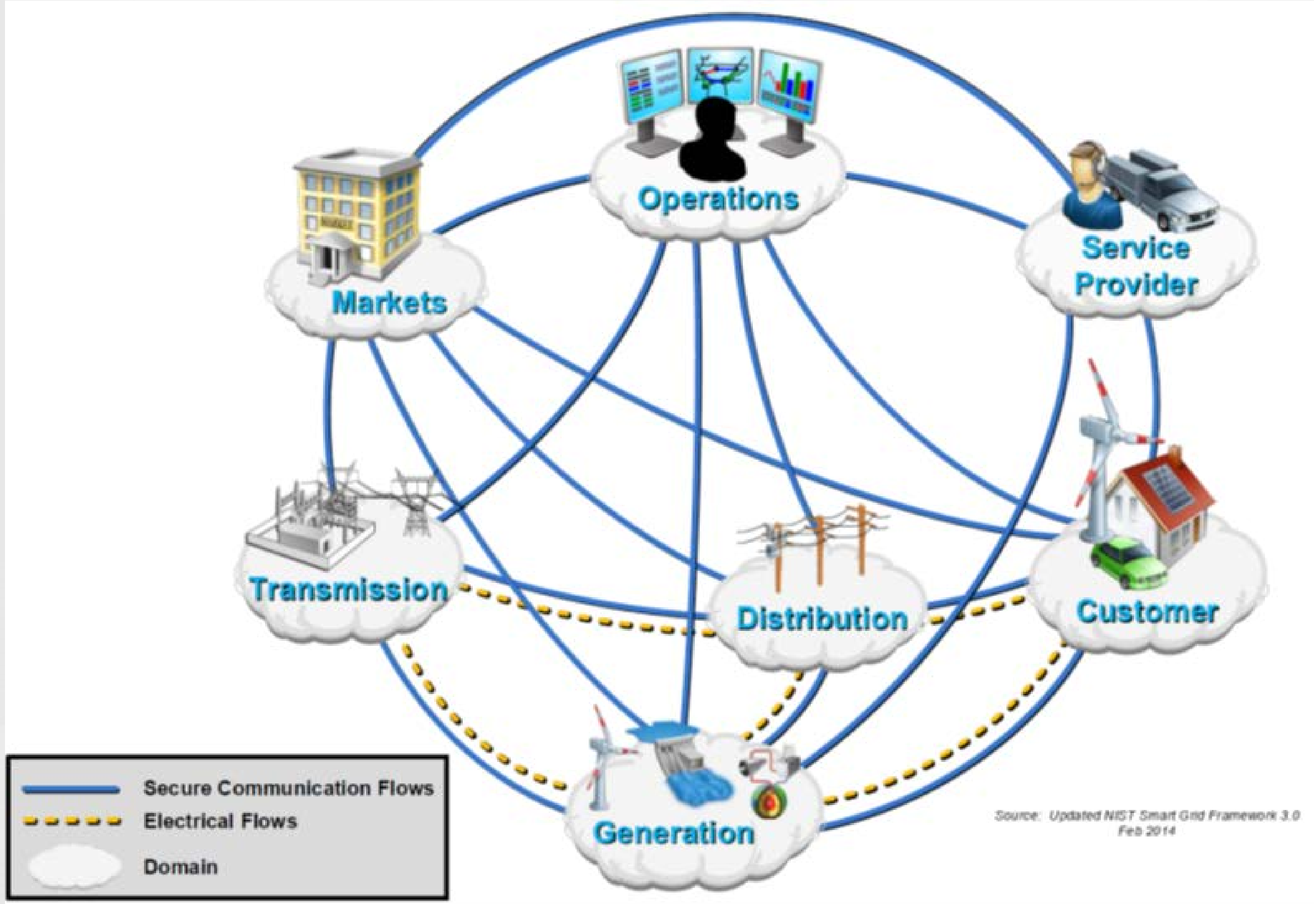
Microgrid Architecture Communications Example



Advanced Bulk Grid Architecture Example



Review: What has changed since 2014?

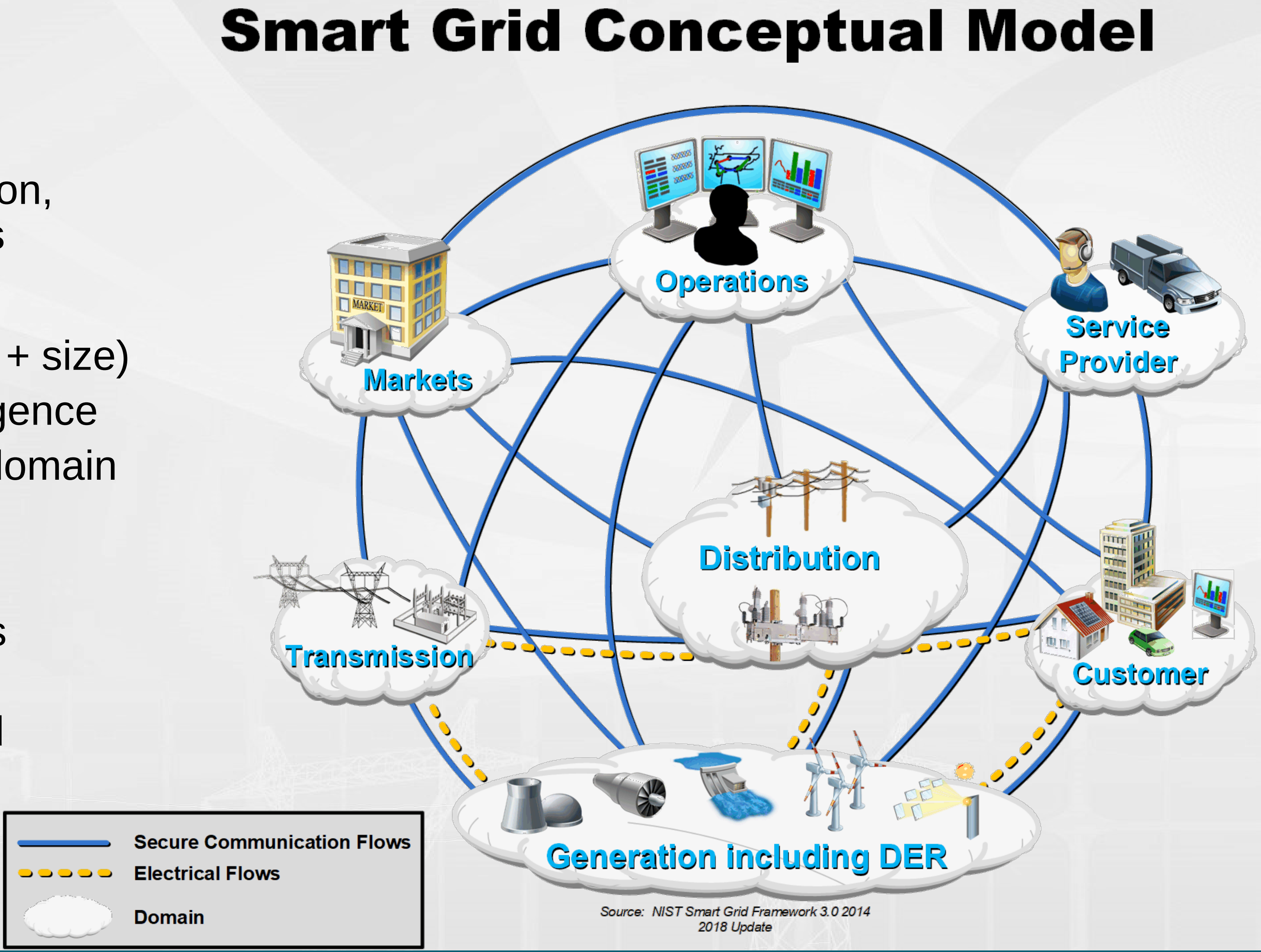


Questions to be addressed

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

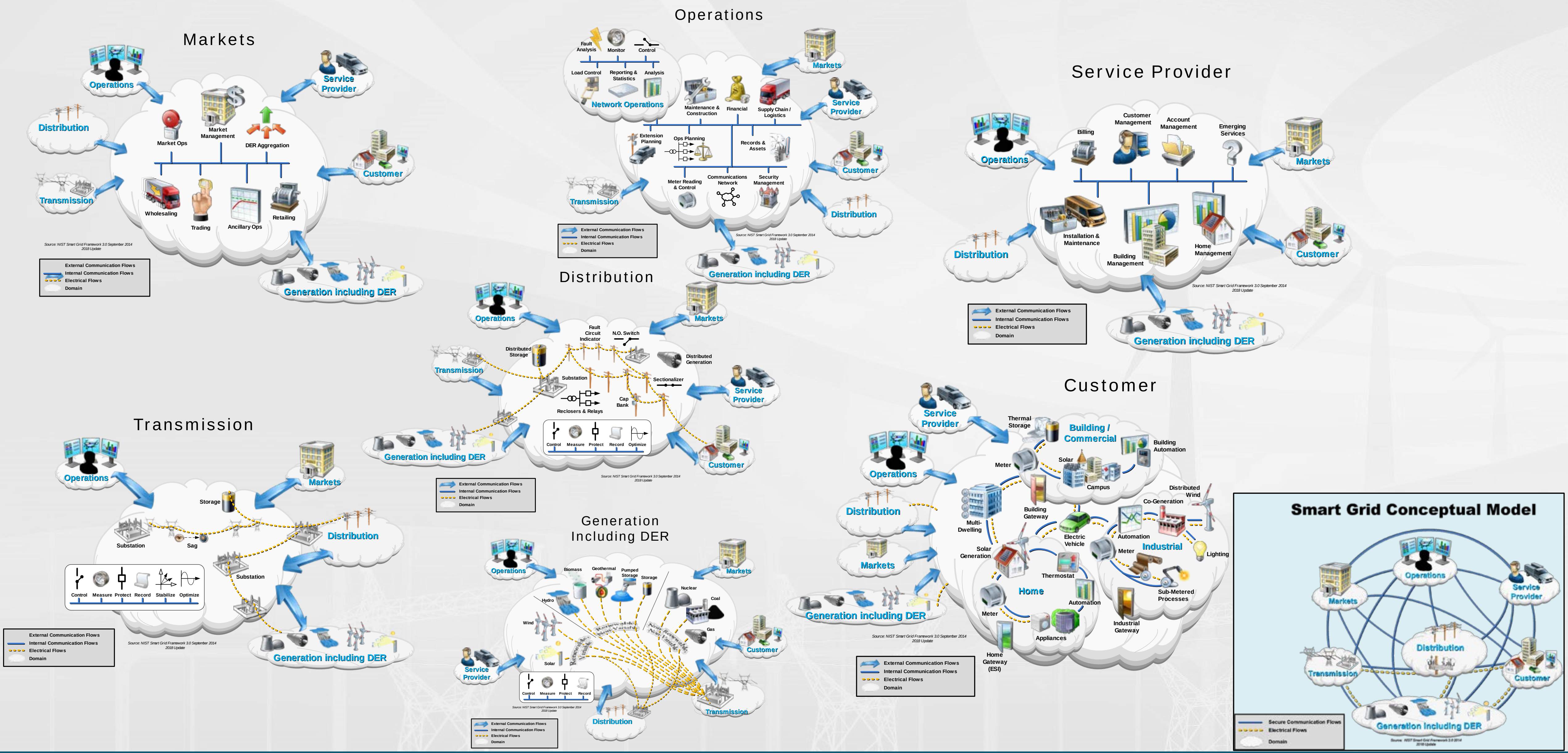
Updated Smart Grid Conceptual Model

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



Source: NIST Smart Grid Framework 3.0 2014
2018 Update

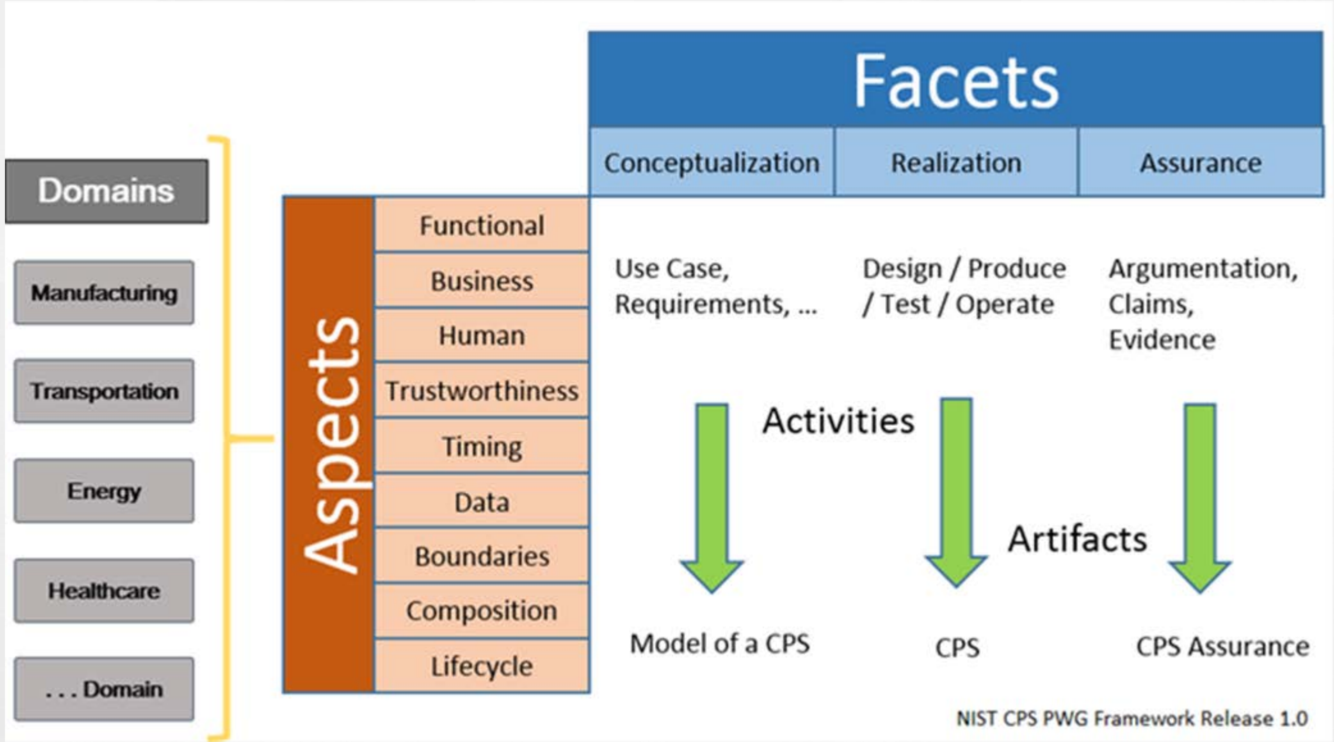
Updated Smart Grid Conceptual Model Domains



The CPS Framework—A Tool for the Smart Grid

Jargon surrounds the electrical grid:

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



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

CPS Aspects and Concerns

- **Functional**
  - Actuation
  - Communication
  - Controllability
  - Functionality
  - Manageability
  - Measurability
  - Monitorability
  - Performance
  - Sensing
- **Business**
  - Enterprise
  - Cost
  - Environment
  - Policy
  - Quality
  - Regulatory
  - Time to Market
  - Utility
- **Human**
  - Human Factors
  - Usability
- **Trustworthiness**
  - Privacy
  - Reliability
  - Resilience
  - Safety
  - Security
- **Timing**
  - Synchronization
  - Time Awareness
- **Data**
  - Data Semantics
  - Relationship between Data
- **Boundaries**
  - Behavioral
  - Networkability
  - Responsibility
- **Composition**
  - Adaptability
  - Complexity
  - Constructivity
  - Discoverability
- **Lifecycle**
  - Deployability
  - Disposability
  - Engineerability
  - Operability

INTELLIGENCE

Note: Illustrative only

Description of CPS Concerns for the Smart Grid

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

Framework Themes through Architecture Examples

- Architecture affects what we think about grid
  - Cybersecurity
  - Operations
  - Economics
- We can use the architecture examples to explore
  - Common trends
  - Changing responsibilities
  - Unique considerations
- Architecture helps us understand value streams
  - Who is the customer in a High-DER architecture?
  - The role of interoperability in unlocking this value
- Testing & Certification growing importance
  - Claimed conformance vs actual performance
  - Actuation and controllability in every device
  - Diversified ownership, unified operation
- CPS ontology allows description and specification

Cybersecurity Themes for the Smart Grid

Jeff Marron

IT Specialist - Security, Information Technology Laboratory
NIST Smart Grid Program

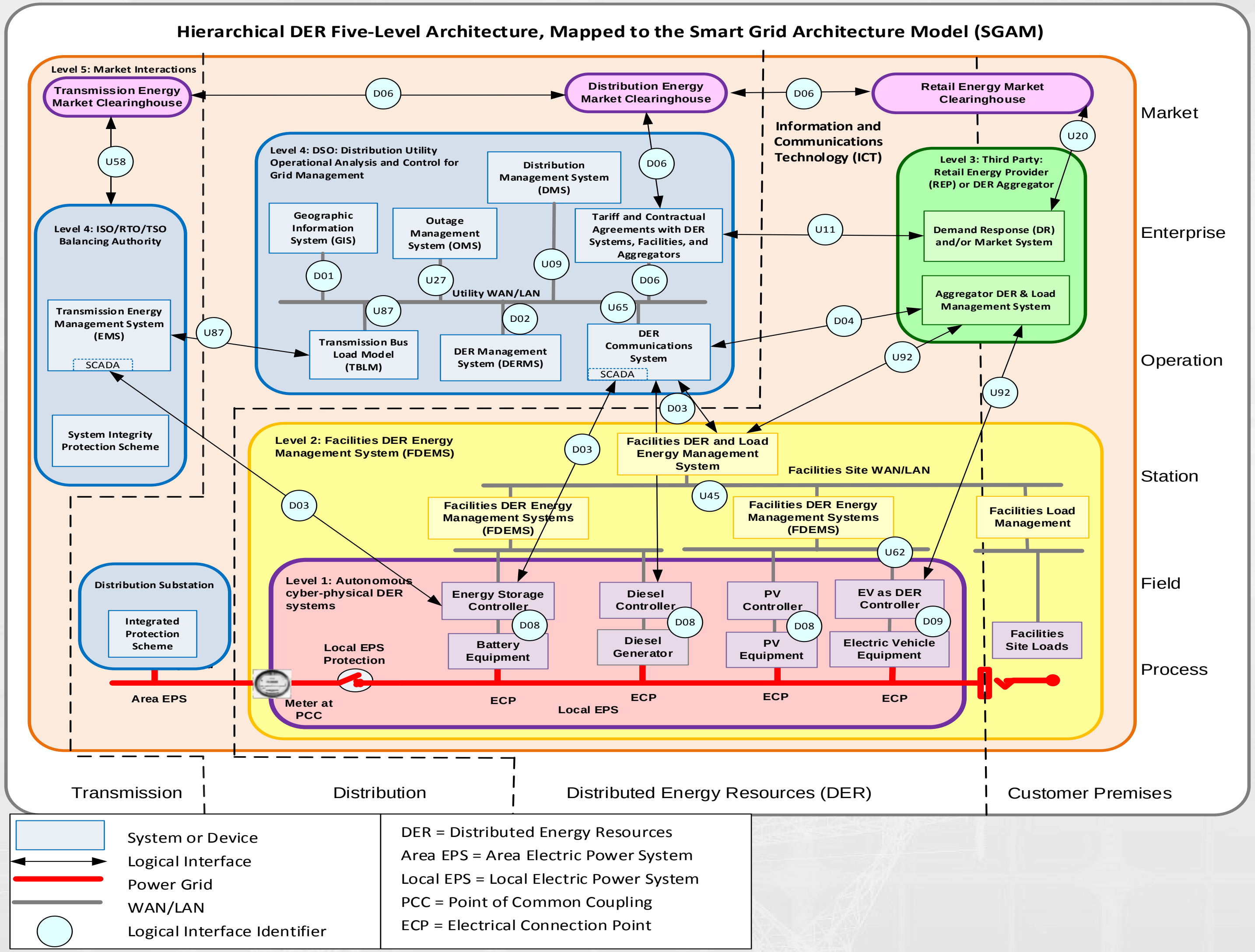
Smart Grid Federal Advisory Committee

April 25, 2018

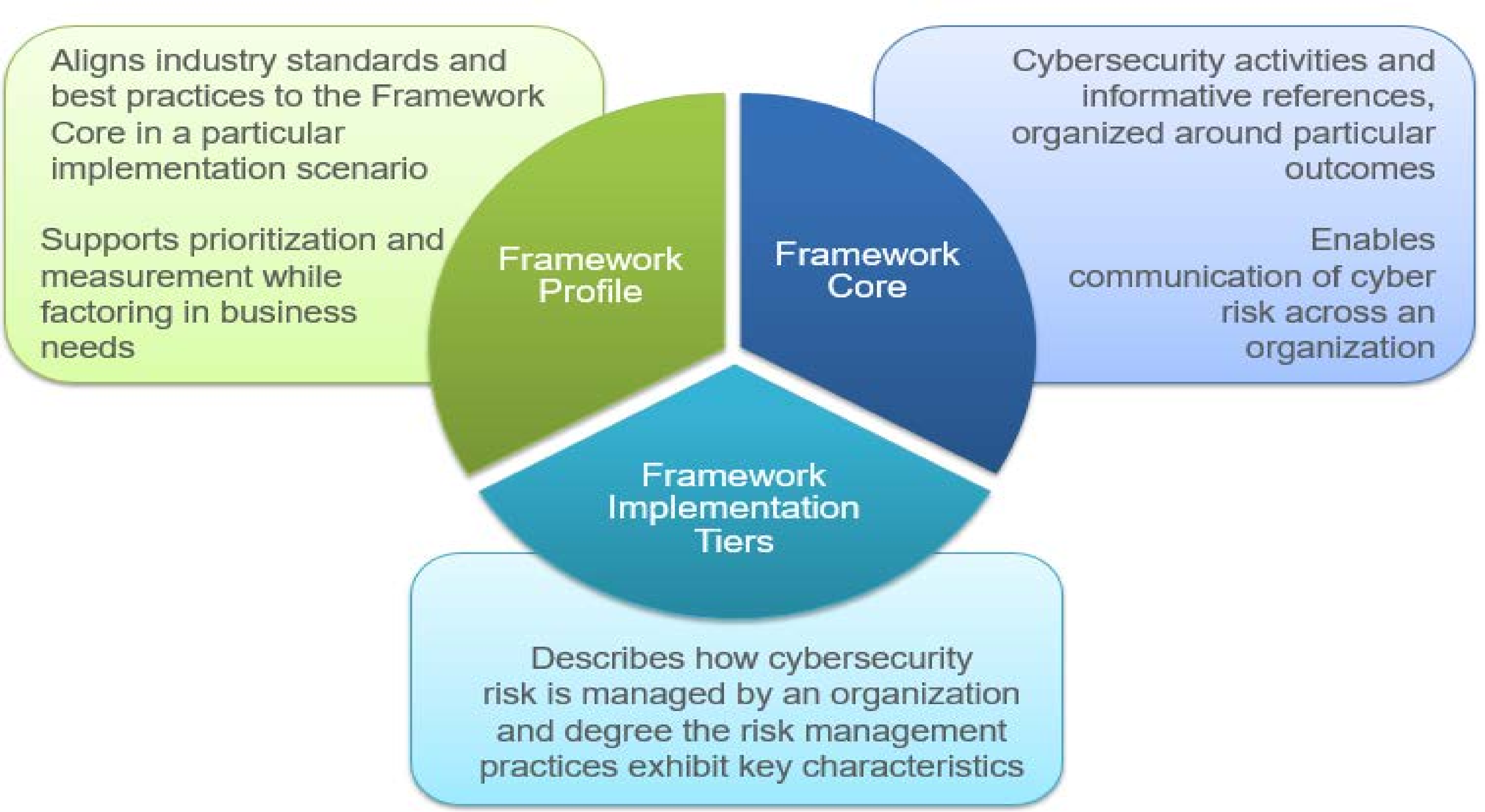
NIST
National Institute of Standards and Technology
U.S. Department of Commerce

Smart Grid – Increased benefits, increased cyber risks

- Communications risks
  - Known problem in IT
  - New application in Smart Grid
    - Logical Interface Categories (LIC)
    - Sheer volume of control paths
- Issues with Distributed Energy Resources (DER)
  - Device ownership
  - Trust
  - Data integrity



Cybersecurity Framework



Evaluation of Cyber Considerations for Power Systems

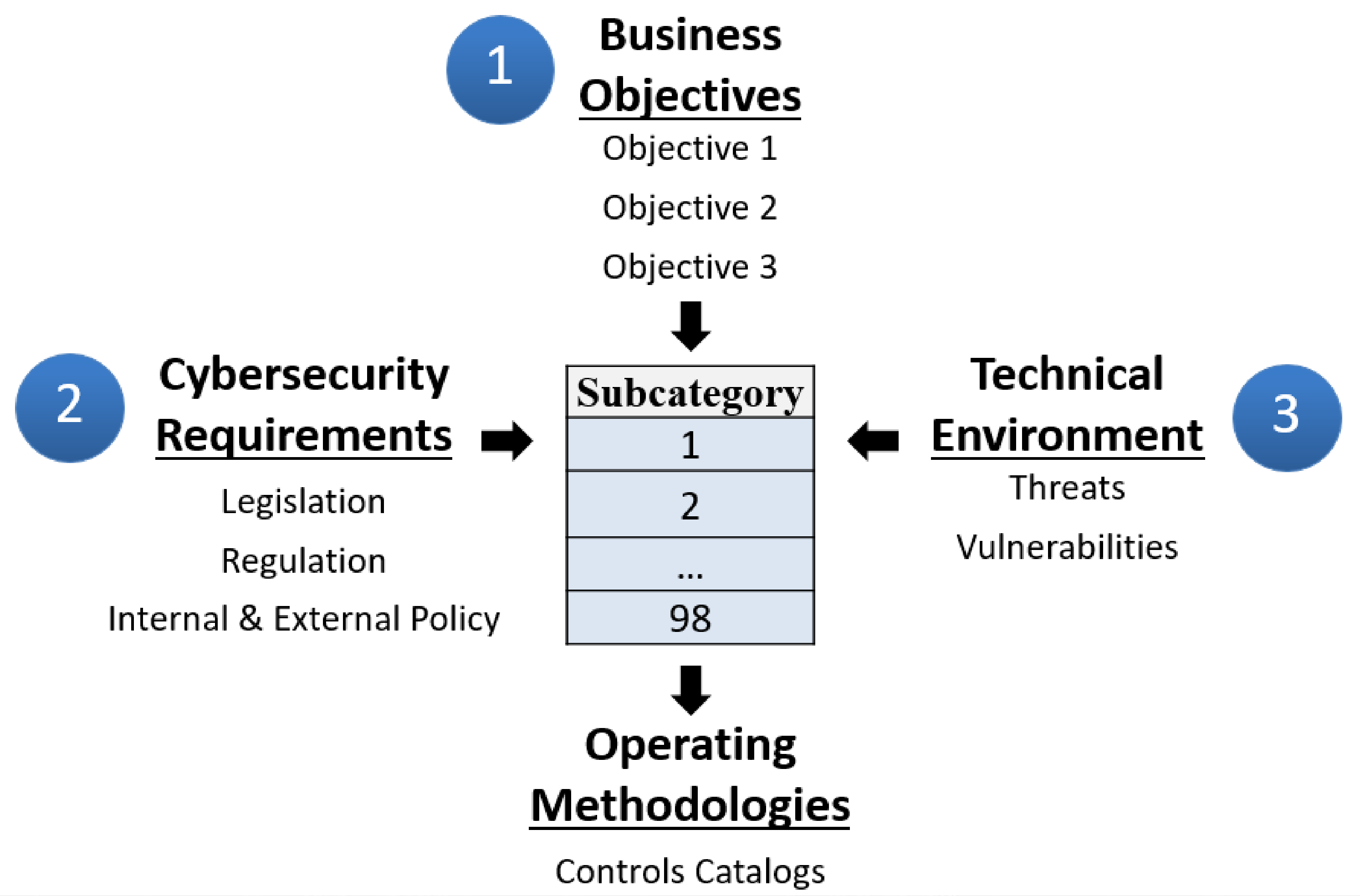
- Architectural considerations
  - Business/mission requirements similar across architectures
  - Responsibilities may change, however
  - Considerations for cybersecurity activities

Table 2 IDENTIFY Smart Grid Profile

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

Smart Grid Profile

- Power System Owners/Operators prioritize cybersecurity activities to:
  - Support business/mission requirements
  - Meet regulatory requirements
  - Match technical environment
  - Adhere to organizational budget and risk appetite



Future Work Options

- Explore risk of increased distributed energy assets
- Explore device authentication on resource-constrained devices
- Explore risks of DDoS to the grid from DER concentrations
- Explore cyber risks of each communication path (LIC)
- Explore the Smart Grid CSF Profile's role

Interface	Entity #1	Entity #2	Logical Interface Security	Protection against Attacks
Level 1: Autonomous Cyber-Physical Systems				
D08	4a: DER Controller of DER Devices (single or in aggregate)	4b: DER Device or Unit (e.g. PV, Storage, Diesel, Turbine)	LIC #3: Interface between control systems and equipment with high availability, without compute nor bandwidth constraints	Communications between DER components and their DER controller typically uses ModBus. Cybersecurity protection of this protocol is not feasible, so physical security, such as locked rooms or cabinets should be used. If necessary, a VPN can be used to secure the transport of ModBus messages.
D08	4a: Utility-Scale DER System or Plant (e.g. large storage system)	4b: DER Device or Unit (e.g. PV, Storage, Diesel, Turbine)	LIC #3: Interface between control systems and equipment with high availability, without compute nor bandwidth constraints	Communications between DER components and their DER controller typically uses ModBus. Cybersecurity of this protocol is not feasible, so physical security, such as locked rooms or cabinets should be used. If necessary, a VPN can be used to secure the transport of ModBus messages.

Framework Theme: Operations

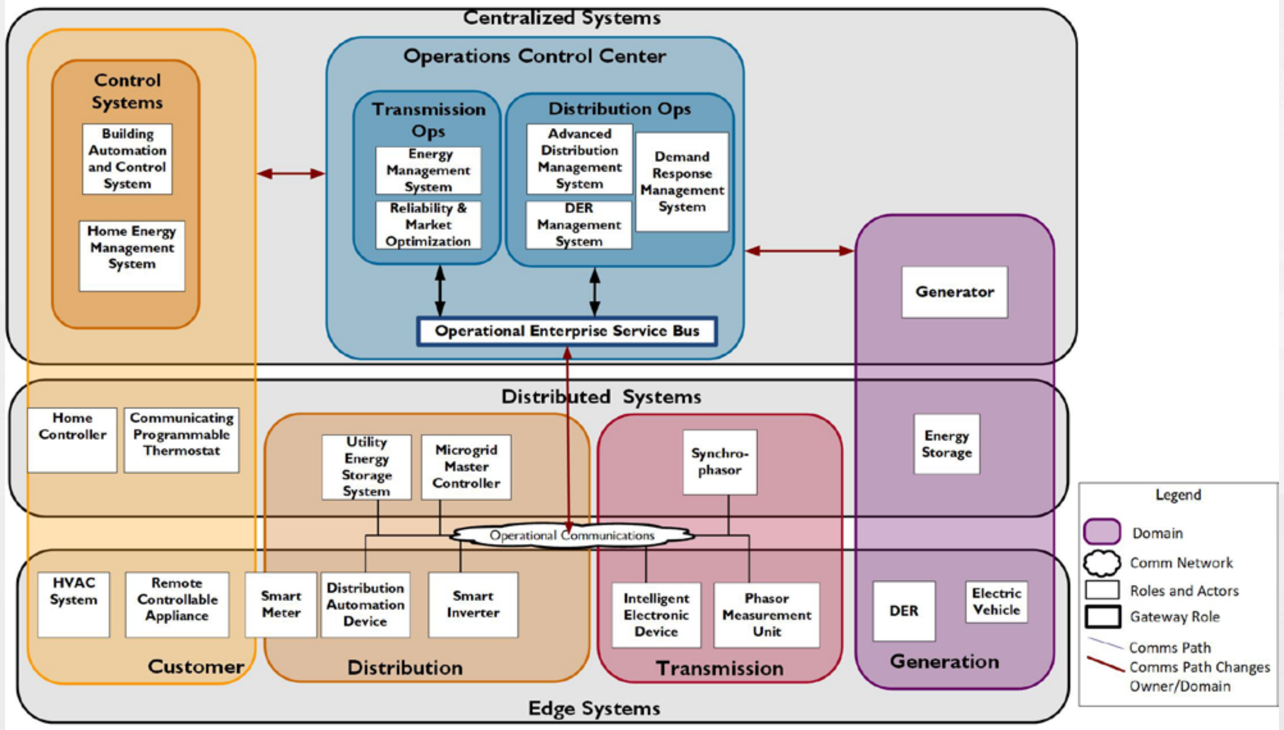
Avi Gopstein
Smart Grid Program Manager

April 25, 2018

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

Key Message: Migrating to grid edge

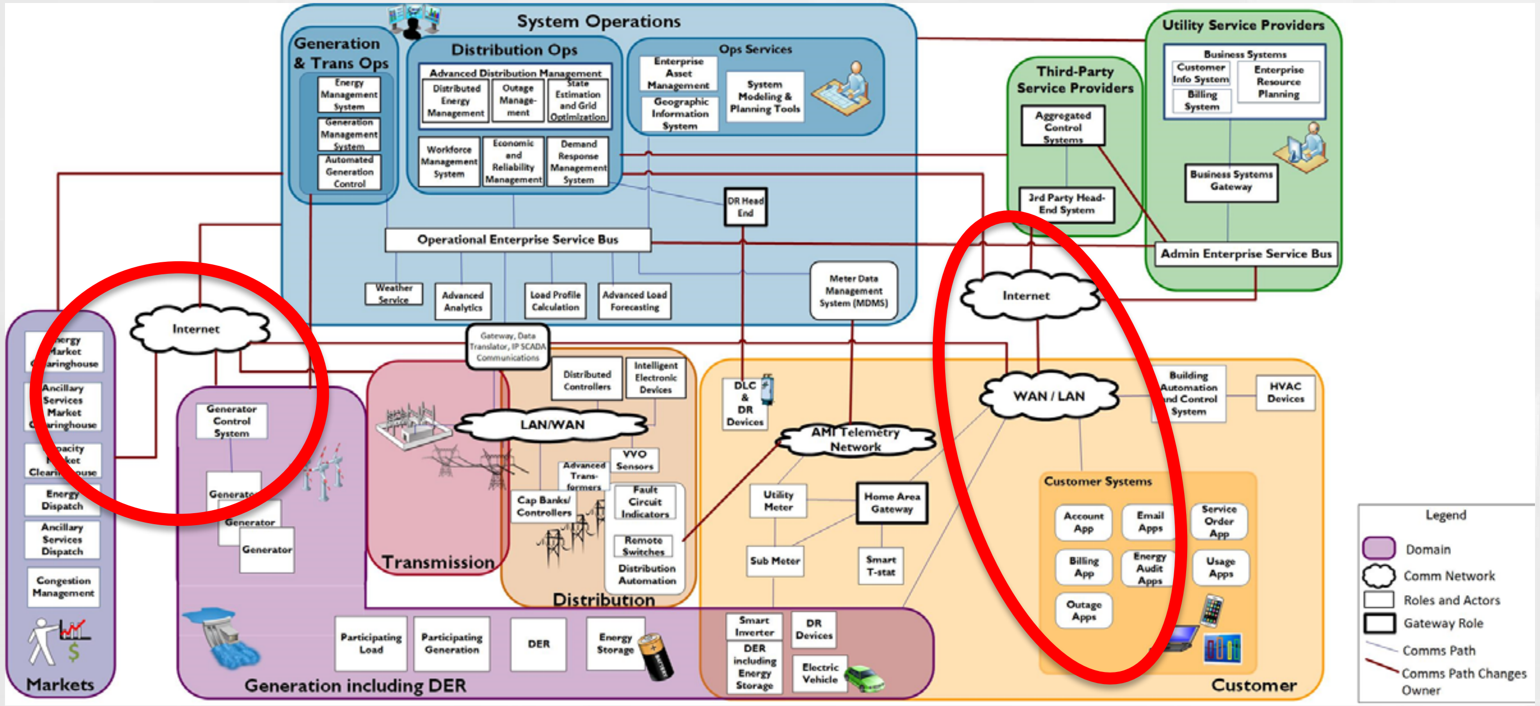
- Sensing, actuation and control is moving towards the grid edge
  - Common trend across all architectures
  - Occurring in each domain
    - Transmission edge: PMUs and IEDs
    - Distribution edge: distribution automation devices & smart inverters
    - Customer edge: remote controllable appliances
  - Operational efficiencies can be gained through local management



Advanced Bulk Architecture Example

Key Message: Shared infrastructure

- As DERs increase, shared infrastructure becomes more important



- Shared infrastructure increases need for predictability
  - Physical predictability (e.g., IEEE 1547)
  - Communications predictability (e.g., IEC 61850)
- Shared infrastructure has benefits, possible risks

Key Message: No single architecture

- Grid architectures are not mutually exclusive
- The examples allow us to explore technical aspects of interoperability
- No single architecture is "correct"

Interruptible programs: the power to reduce your energy costs

RATE 70/71 GEN-SET/CURTAILMENT HISTORY

SUMMER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIODS IN HOURS
2008	9	64	7.1
2009	2	14	7
2010	8	62.5	7.8
2011	7	59.5	8.5
2012	3	21	7
2013	6	33	5.5
2014	3	16.5	5.5
2015	3	19	6.3
2016	4	24	6
2017	1	6	6

WINTER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIODS IN HOURS
2006-07	0	0	0
2007-08	0	0	0
2008-09	0	0	0
2009-10	0	0	0
2010-11	0	0	0
2011-12	0	0	0
2012-13	0	0	0
2013-14	0	0	0
2014-15	0	0	0
2015-16	0	0	0

The Interruptible Rate 70/71 program allows Dakota Electric to reduce its capacity and energy requirements during peak load conditions by interrupting all or a portion of a members' electric load. Scheduled interruption times can be found at http://lmguide.grenergy.com/GetSchedule.do and range from 4 to 10 hours per day based on system needs. Interruptions for system emergency can occur at anytime.

Programs subject to terms, conditions and change without notice.

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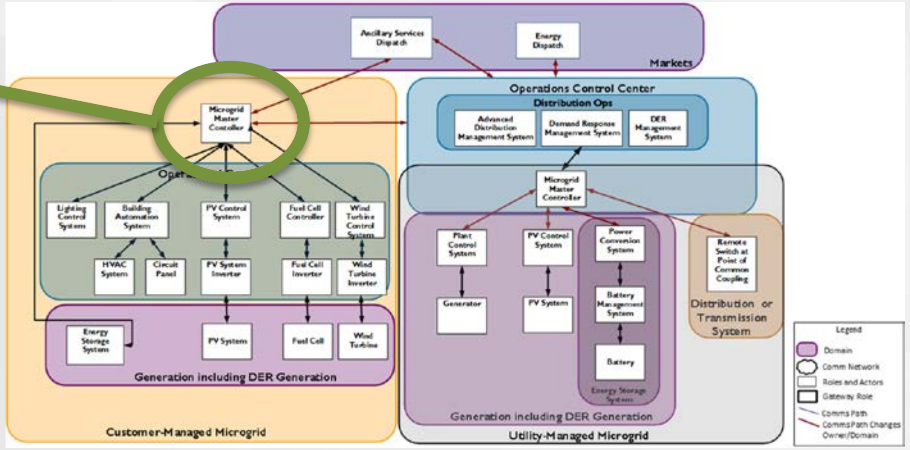
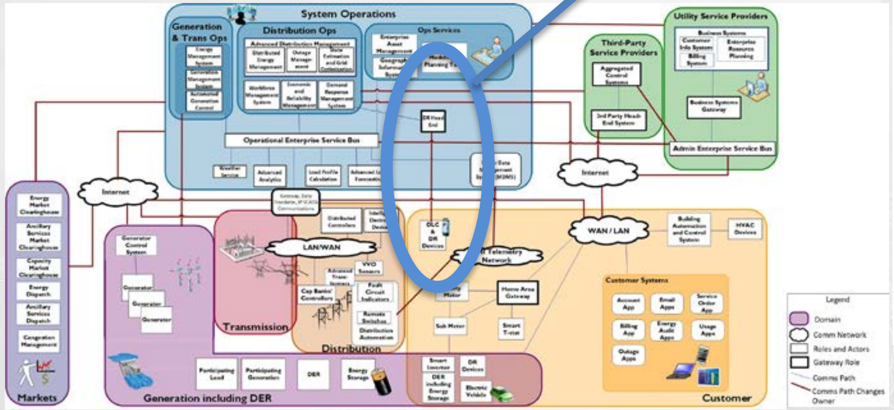
ENERGY WISE MN

10/17





ENERGY WISE for your Home

LOAD CONTROL SUMMARY

SUMMER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIOD (in hours)
2008	27	175	6.5
2009	16	90	6
2010	20	126	6
2011	17	102	6
2012	15	72	5
2013	15	65	4
2014	12	44	3.5
2015	10	37	3.7
2016	14	50	3.5
2017	14	53	4.8

WINTER

YEAR	NUMBER OF CONTROL PERIODS	TOTAL HOURS CONTROLLED	AVERAGE LENGTH OF CONTROL PERIOD (in hours)
2007-08	31	115	3.7
2008-09	29	133	4.5
2009-10	25	114	4.5
2010-11	24	104	5.0
2011-12	9	35	4.0
2012-13	12	39	4.0
2013-14	20	79	4.0
2014-15	12	42	3.5
2015-16	12	42	3.5
2016-17	12	42	3.5

Heating and cooling loads will be controlled during peak periods, typically on the hottest and coldest days of the month. The average length of control has been 3 to 6 hours, usually occurring between 2 p.m. and 11 p.m. Hours controlled reflect air conditioning and heating loads. The summer control period includes May through September, and the winter period includes October through April. Water heaters are typically controlled from Monday through Friday for 4 to 5 hours in the evening from June through August and December through February.

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ENERGY WISE MN

Key Message: Diversified ownership

Diversifying asset ownership

- Common to all architecture examples

Demands increased interoperability

Requires Trustworthiness

- Extends beyond cybersecurity
  - Trustworthiness.Reliability
  - Trustworthiness.Resilience
  - Trustworthiness.Safety
- Architecture defines trustworthiness requirements
  - Device level trustworthiness
  - Microgrid level trustworthiness
  - Service provider level trustworthiness

Needs cost-effective Testing and Certification for assuredness

Grid operation is highly interdependent with market structure, which in turn is limited by the nature of grid operations. Operations and market evolve coincidently and interdependently.

Interoperability Economics in the Context of the Smart Grid

Cheyney O'Fallon, Ph.D.

Economist, Engineering Laboratory
NIST Smart Grid Program

Federal Advisory Committee Meeting

April 25th, 2018

Interoperability Value Proposition

Interoperability improvements create new opportunities
for organizations across the electric power sector: Customers, Firms, and System Operators.

Realizing the potential of interoperability improvements entails strategic and operational hurdles

Strategic

1. Move beyond using interoperability improvement to capture and lock-in market share
2. Pivot to using interoperability improvement to catalyze innovation and expand markets for electricity services
3. The benefits from interoperability improvements should be distributed across stakeholder groups.

Operational

1. Move beyond interoperability within individual device classes
2. Need to improve interoperability between systems and systems of systems to create new value networks
3. Interoperability between diverse resources and capabilities will enable subsequent innovation in service delivery

Interoperability Value Proposition

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

1) Interoperability and Specificity

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

Organizational Strategy

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

Smart Grid Context

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

Value chains and value networks

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

2) Interoperability and Customer Empowerment

Interoperability is crucial to customer empowerment.

1. Enabling customers to be better informed regarding their own electricity-use decisions.
   a. Improved utilization of current assets
   b. Better decision making with respect to technological adoption
   c. Accurate signals are critical to economic efficiency

2. Enabling a plug-and-play environment.
   a. Expectation that devices purchased will work with rest of the system
   b. Devices can be selected for customer optimality
   c. Reduced transaction costs of integrating customer equipment

3. Informational improvements may contribute to greater customer agency
   – The cost of "political organization" may fall for some stakeholders connected through interoperable systems.

3) Complexity and Cost Structures

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

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

} **Impact on Cost Structures**

Transaction costs are rising in salience

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

Interoperability strategies can directly address cost escalation due to complexity

4) Testing and Certification

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

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

5) Trust and Assurance

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

1. Uncertainty impacts investment decisions

2. Assurances provided by testing and certification can mitigate certain types of uncertainty that could slow technology adoption

3. Testing and certification can mitigate the transaction costs that may “impede” or “completely block” the formation of markets for new services.
   - Informational Costs
   - Costs of troubleshooting and integrating new technology
   - Coordination Costs
   - Labor Costs

Known Gaps – A Call for Committee Perspectives

Motivating Question: What is the value of enhanced interoperability?

1. Interoperability *best practices*.

2. *Information asymmetries* as barriers to action (including tech adoption).

3. Grid value-network *fragmentation* and *transaction cost* structures.

4. Diversity of interoperability *testing and certification* needs across stakeholder groups.

5. Characterizing *trustworthiness* and its role in organizational strategy.

Thank You

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U.S. Department of Commerce

Framework Theme: Testing and Certification

Eugene Song and Cuong Nguyen

NIST Smart Grid Program

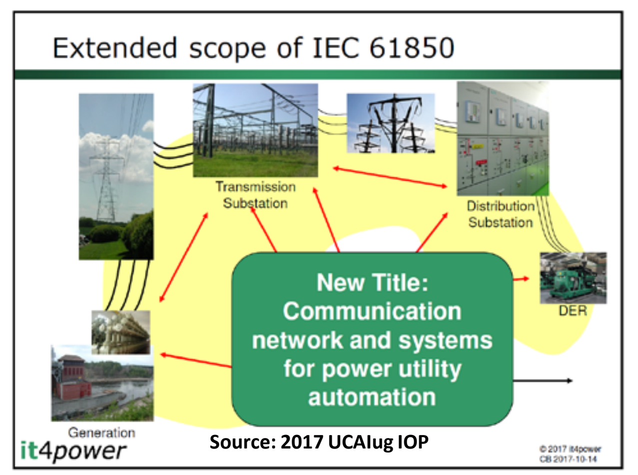
NIST Smart Grid Advisory Committee Meeting
April 25, 2018

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

Agenda

1. Motivations to Identify and Evaluate SG Standards
2. How Do We Identify SG Standards?
3. How Do We Evaluate SG Standards?
4. Preliminary Statistic Data Analysis Result
5. IEEE P1547 Standard
6. California Rule 21 – Specification
7. Interoperability Profile
8. Summary

1. Motivations to Identify and Evaluate SG Standards



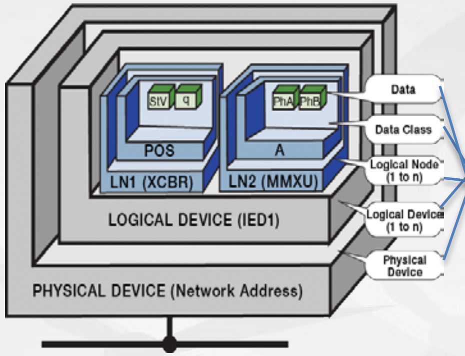
IEC 61850 Applies for all Domains & Some Subdomains:

- Generation
- Transmission
- Distribution
- Customer
- Market
- Operations
- Service providers

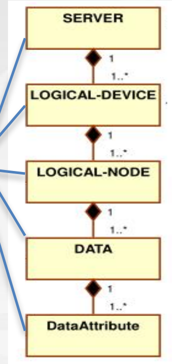
IEC 61850:

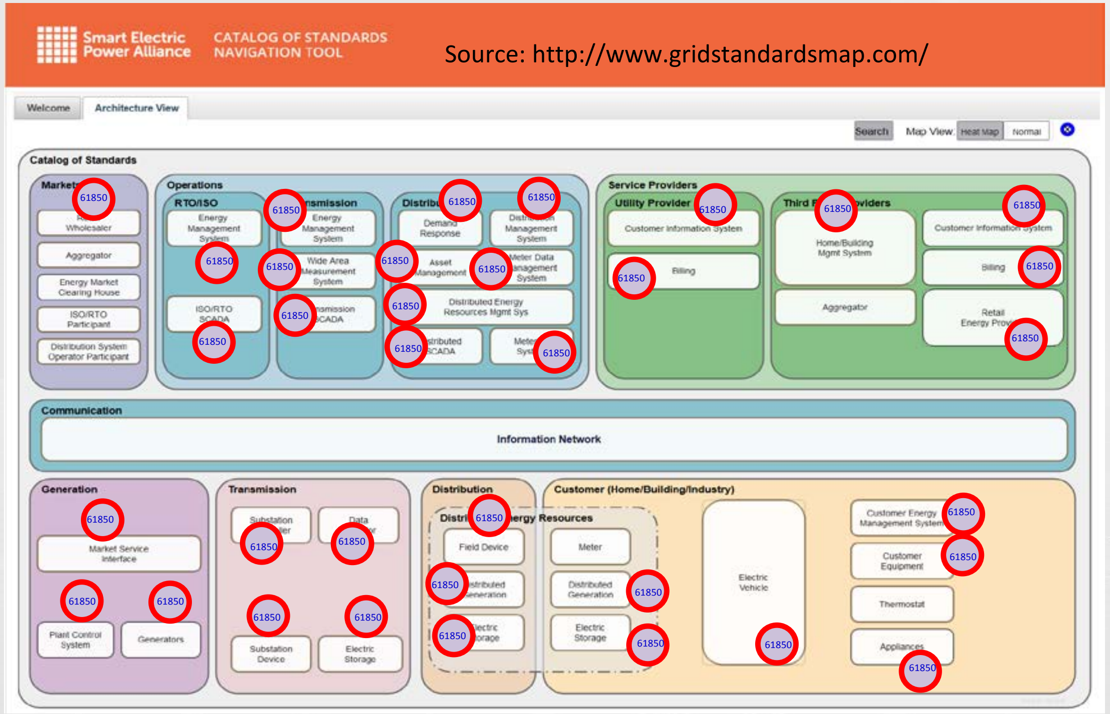
- ✓ Information Model
- ✓ Communication protocols
- ✓ Performance
- ✓ Test method
- ✓ Communication Mapping
- ✓ Model Mapping
- ✓ Guideline & Practice

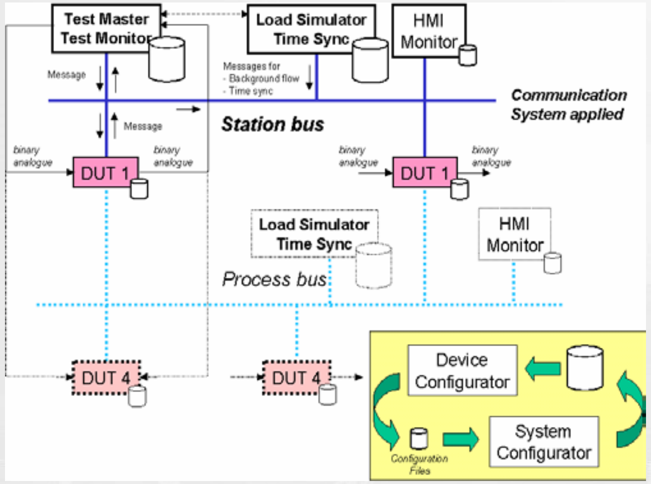
IEC 61850 Device Structure



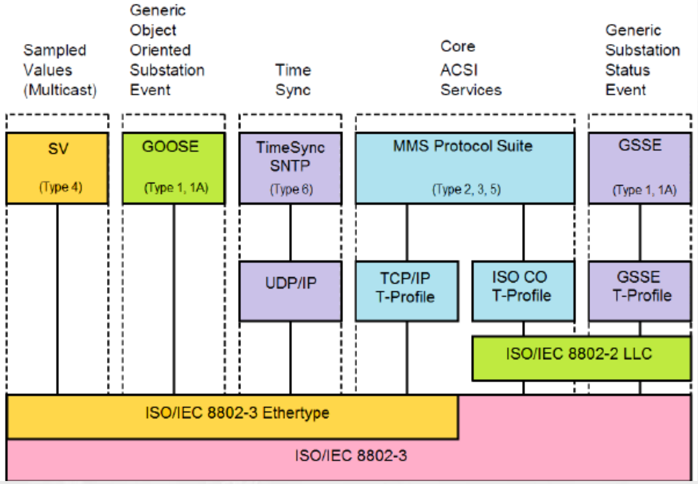
IEC 61850 Object Model







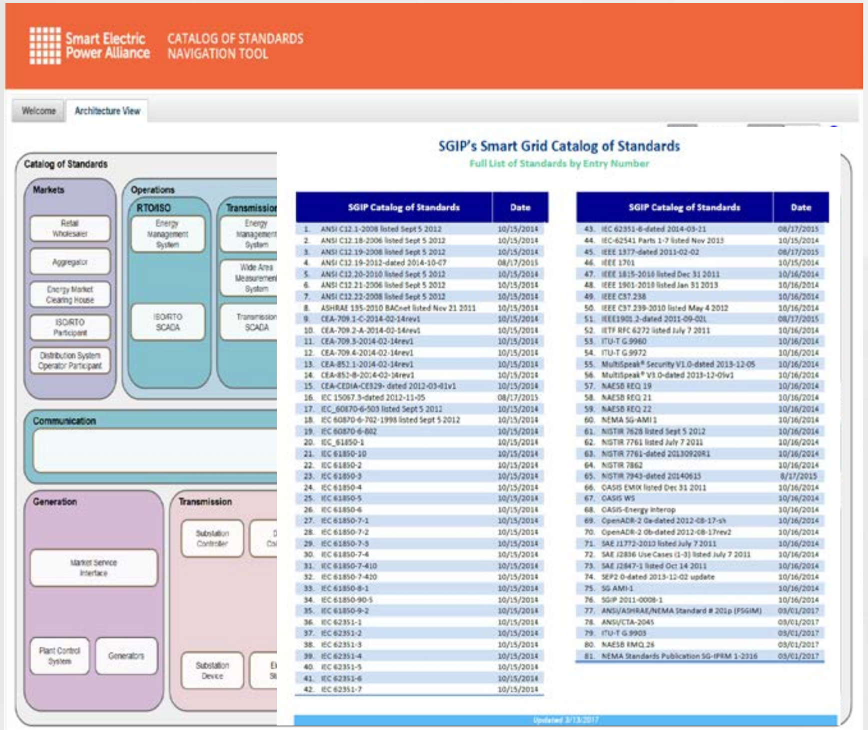
Testing Method in IEC 61850



Communication Protocols in IEC 61850

2. How Do We Identify SG Standards

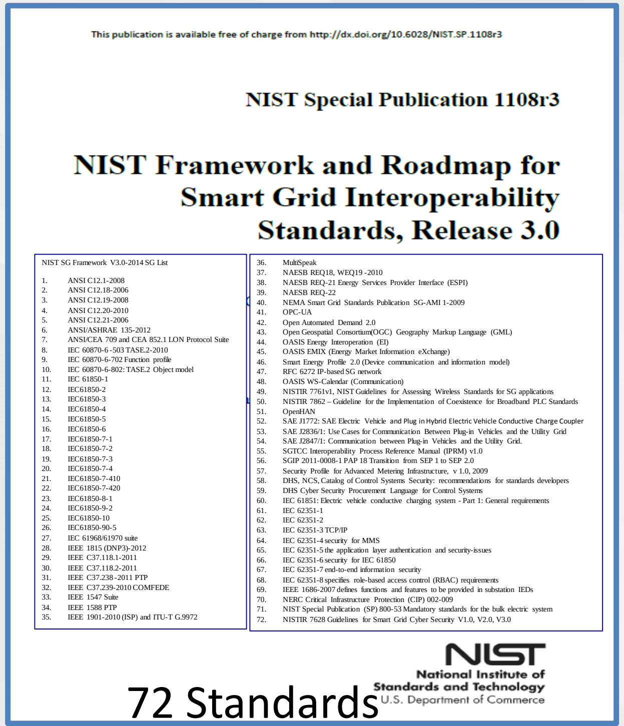
SEPA/SGIP SG CoS List



81 Standards

Source: http://www.gridstandardsmap.com/

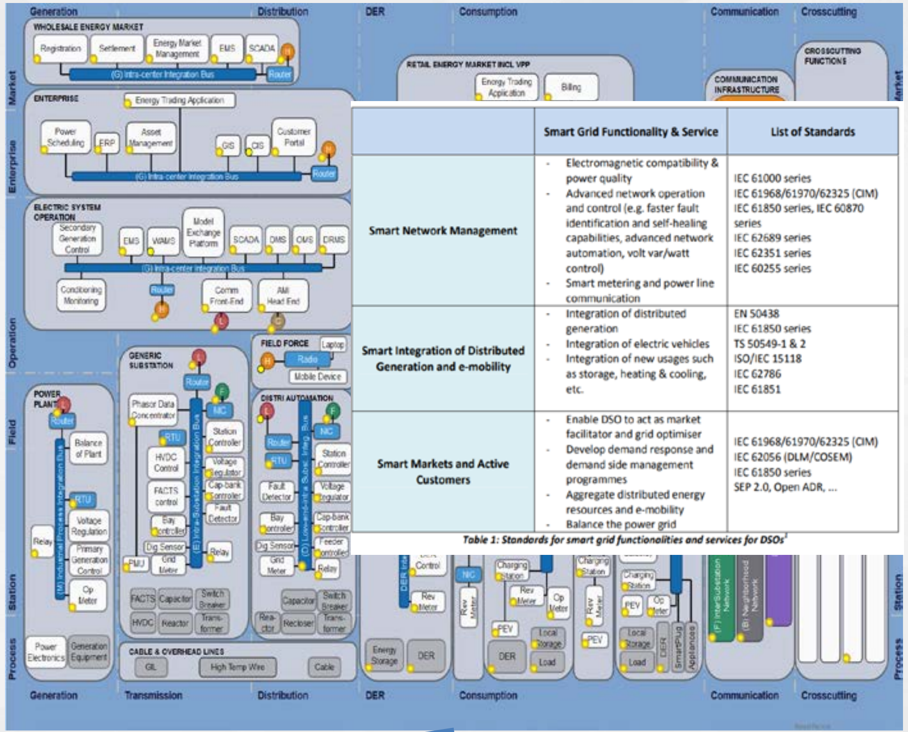
Identified SG Standard List of NIST Framework R3.0



72 Standards

https://www.nist.gov/news-events/news/2014/10/nist-releases-final-version-smart-grid-framework-update-30

IEC SG CoS & DSO Priority List



16 Standards

Source:
http://smartgridstandardsmap.com/
https://www.edsoforsmartgrids.eu/wp-content/uploads/public/DSO-Priorities-Smart-Gird-Standardisation.pdf

New Standards:

- New Standards
- New versions of old standards

Identified SG Standards for NIST Framework R4.0 (257 Standards)

3. How Do We Evaluate SG standards for T&C

No. | Standard Family | Standard No. | Name | Information Model | Communication | Performance | Test method | Communication Mapping | Model Mapping | Guideline & Practice | Security | (Types) | Description | Characteristics | Domain, subdomain and components | Use Cases | T&C | NIST 3.0 | SEPA CoS | IEC CoS

	P3	Standard Family	Standard No.	Name	Information Model	Communication	Performance	Test method	Communication Mapping	Model Mapping	Guideline & Practice	Security	(Types)	Description	Characteristics	Domain, subdomain and components	Use Cases	T&C	NIST 3.0	SEPA CoS	IEC CoS
1																					
5			ANSI C12.1-2014	ANSI C12.1-2014: Electric Meters - Code for Electricity Metering https://webstore.ansi.org/RecordDetail.aspx?sku=ANSI%20C12.1-2014			x						Measurment performance	This standard establishes acceptable performance criteria for new types of ac watthour meters, demand meters, demand registers, pulse devices, and auxiliary devices. It describes acceptable in-service performance levels for meters and devices used in revenue metering. It also includes information on related subjects, such as recommended measurement standards, installation	This Code for Electricity Metering is designed as a reference for those concerned with the art of electricity metering, such as utilities, manufacturers, and regulatory bodies.	• Operations/distribution operations/Metering system • Transmission/substation Devices • DERs / (Field Device, meter) • Customers/Meter	personnel to determine if an outage is still valid. The OMS Poll is a multicast which can be initiated manually or automatically. • Outage Management System Poll Unicast • Outage Notification: This use case addresses the Outage Notification	x			
6			ANSI C12.18-2006	ANSI C12.18-2006: American National Standard for Protocol Specification for ANSI Type 2 Optical Port. https://www.smartgrid.gov/document/ansi_c1218_2006ieee_p1701mc1218_protocol_specification_ansi_type_2_optical_port	x	x	x					x	Communication, information model, performance, security	This standard describes the criteria required for communications between a C12.18 Device and a C12.18 Client via an optical port. The C12.18 Client may be a handheld reader, a portable computer, a master station system or some other electronic communications device. This Standard provides details for a complete implementation of an OSI 7-layer model. The protocol specified in this document was designed to transport data in Table format. The Table definitions are in ANSI C12.19 Utility Industry End Device Data Tables.	The C12.18 Client may be a handheld reader, a portable computer, a master station system or some other electronic communications device. The C12.18 Device is An electronic communication apparatus that implements an ANSI Type 2 Optical Port for communication according to the protocol specification of this Standard. Point-to-point communications is defined as communication between C12.18 Client (reader or master) and C12.18 Device (server or apparatus) through a single optical interface.	• Operations/distribution operations/Metering system • Transmission/substation Devices • DERs / (Field Device, meter) • Customers/Meter	message generated by the Smart Meter and how this message gets generated into a trouble ticket. • Outage Restoration Notification: Utility implements integrated management of Distributed Energy Resources • Performing Real Time Price Option: This use case addresses the process of computing the Real Time Price (RTP) signals for the Smart Grid Dispatch.		x	x	
			ANSI C12.19-2008	ANSI C12.19-2008: American National Standard for Utility Industry End Device Data Tables. https://www.smartgrid.gov/document/ansi_c1219_2008ieee_p1377mc12	x								Information model	This standard provides a common data structure for use in transferring data to and from utility End Devices, typically meters. The standard data structure is defined as sets of tables. The tables are grouped together into sections called decades. Each decade pertains to a particular feature-set and related function such as Time-ofuse, Load Profile, etc. Table data is transferred from or to the	This Standard defines a Table structure for utility application data to be passed between an End Device and any other device.	• Operations/distribution operations/Metering system • Transmission/substation Devices • DERs / (Field Device, meter) • Customers/Meter	• Remote Programming Smart Meter: Meter Remote Connect & Disconnect: This use case addresses the messages exchanged between customer information system (CIS) and Smart Meter through		x	x	
257			IEC 62053-23	IEC 62053-23 Electricity metering equipment (a.c.) - Particular requirements - Part 23: Static meters for reactive energy (classes 2 and 3) https://webstore.iec.ch/publication/6384			x							This standard applies only to newly manufactured static var-hour meters of accuracy classes 2 and 3, for the measurement of alternating current electrical reactive energy in 50 Hz or 60 Hz networks and it applies to their type tests only. For practical reasons, this standard is based on a conventional definition of reactive energy for sinusoidal currents and voltages containing the fundamental frequency only.				x			
258		IEC 62054	IEC 62054-21	IEC 62054-21: Electricity metering (a.c.) – Tariff and load control – Part 21: Particular requirements for time switches https://webstore.iec.ch/preview/info_iec62054-21%7Bed1.0%7Den.pdf										This standard specifies particular requirements for the type test of newly manufactured indoor time switches with operation reserve that are used to control electrical loads, multi-tariff registers and maximum demand devices of electricity metering equipment.				x			
259	Total	33	257		55	123	28	15	11	8	34	31						48	91	72	99

Sheet1

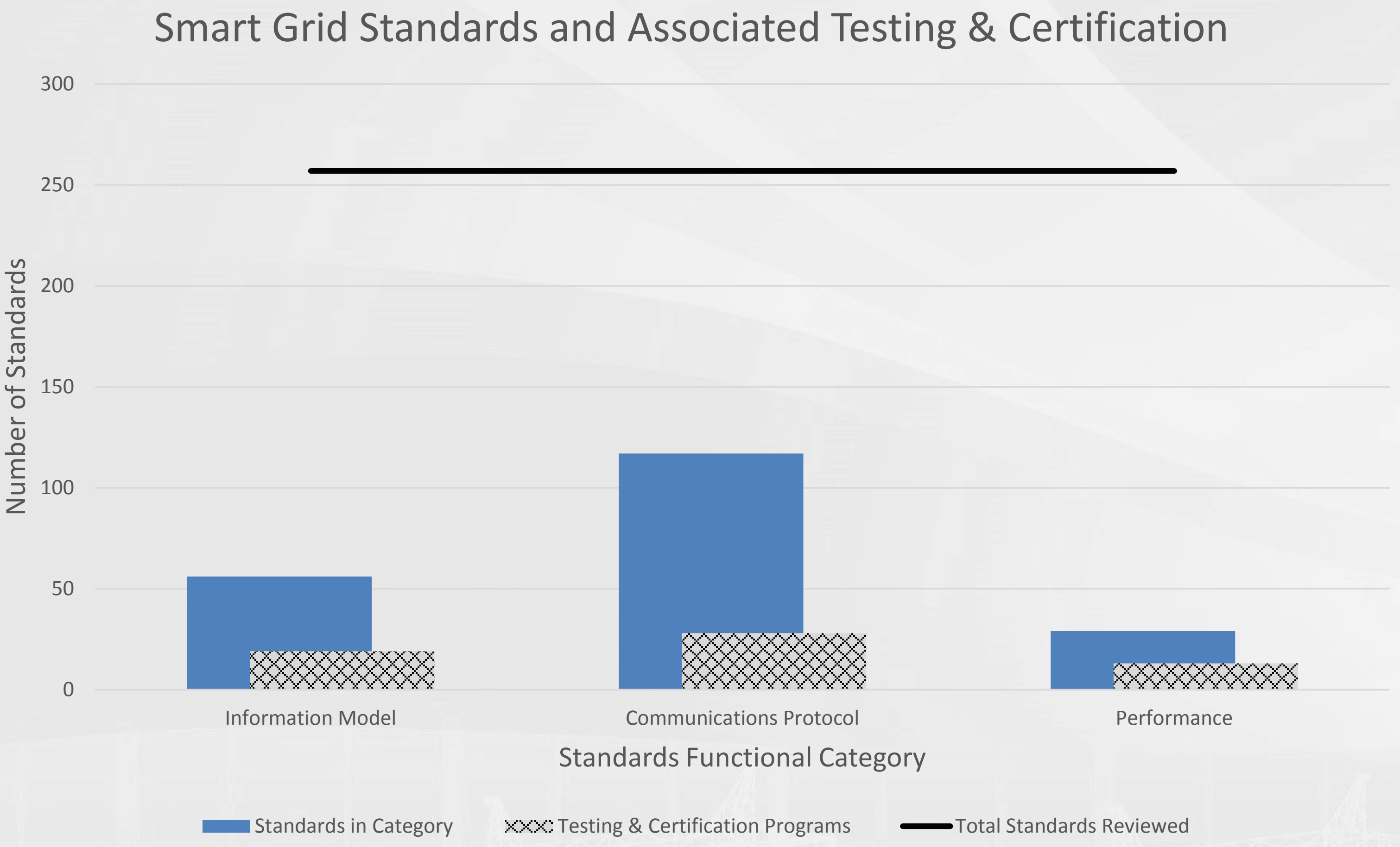
Ready Calculate 85%

Sheet1

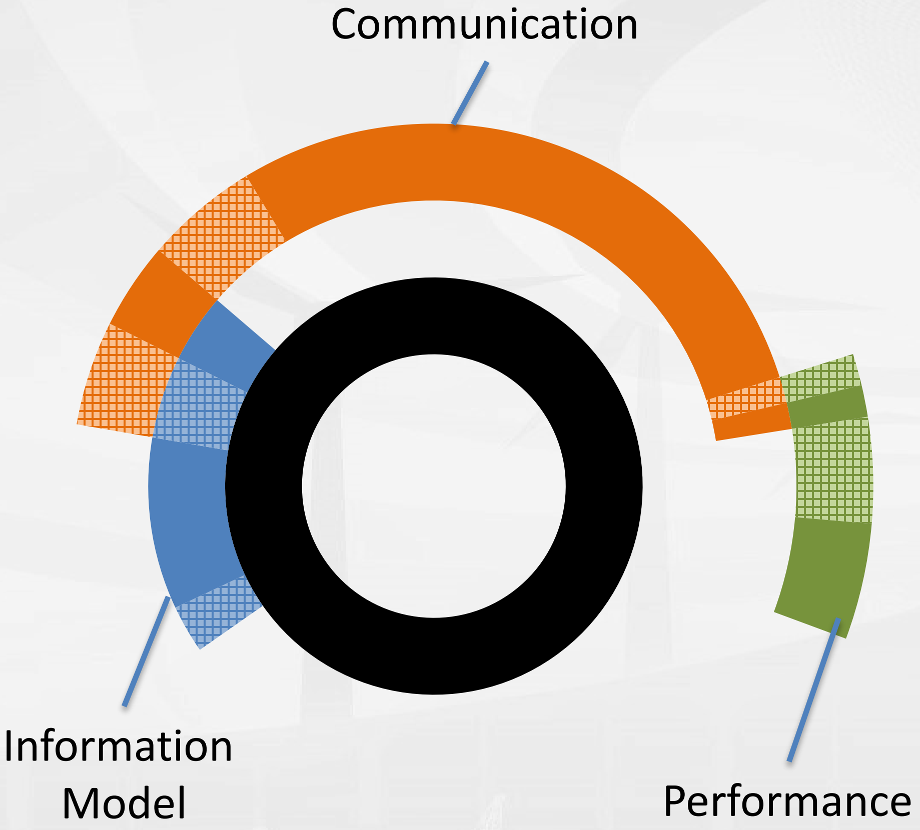
Ready 84%

1 ~ 257

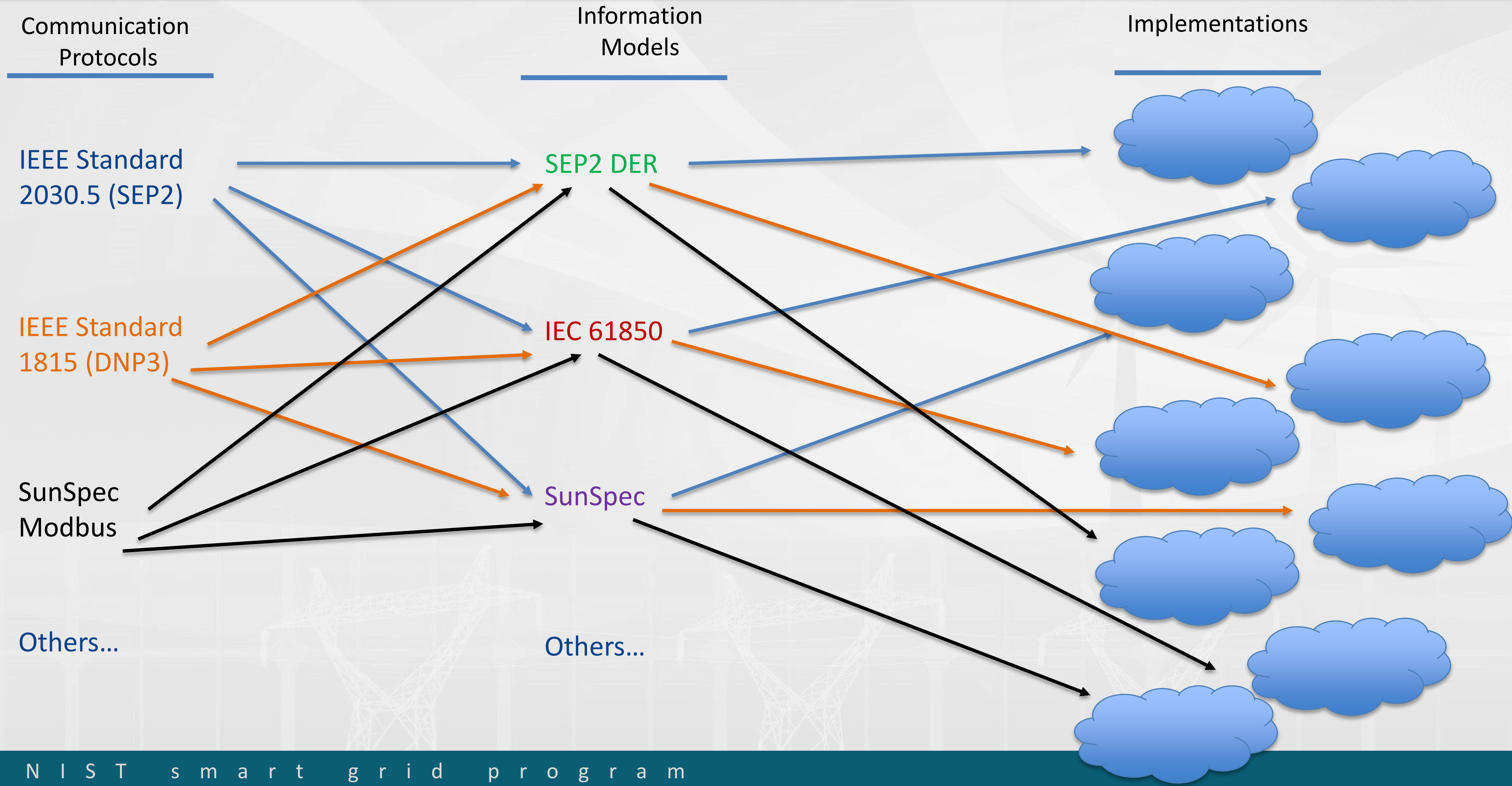
4. Preliminary Statistic Data Analysis Result



19/56 28/117 13/29



5. IEEE P1547 Standard

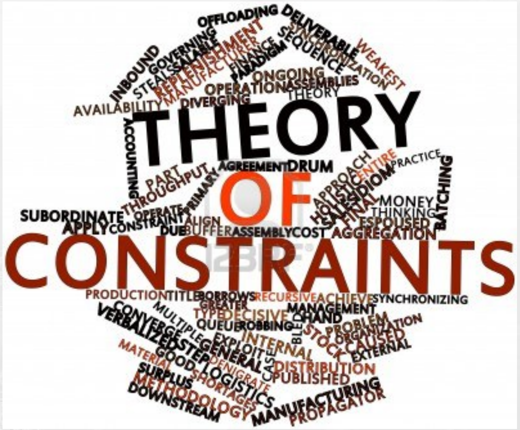


6. California Rule 21 – Specification

Communication Protocols	Information Models	Implementation
IEEE Standard 2030.5 (SEP2)	SEP2 DER	
IEEE Standard 1815 (DNP3)	IEC 61850	Rule 21
SunSpec Modbus	SunSpec	
Others…	Others…	

7. Interoperability Profile

- A profile is a description of a well-defined subset of the standard that has been agreed upon by a user community, testing authority or standards body.
- The specification and use of profiles allows the interoperability gap to be narrowed by reducing the degrees of freedom of implementation flexibility in the context of interest by the device supplier, implementer and system owner.
- Interoperability profile can
  - Narrows constraints and provides uniformity
  - Supports multi-vendor interoperability
  - Lowers cost of system integration



8. Summary

1. Motivations to Identify and Analyze SG Standards
2. Identification of SG Standards based on four SG standard sources
3. Evaluation of Identified SG Standards based on the metrics
4. Provided Preliminary Data Analysis Result (only 18.6% T&C)
   - T&C is critical to accelerate, achieve and assure interoperability.
   - T&C has a very long way to go
5. IEEE P1547 Standard
6. California Rule 21 – Specification
7. Interoperability Profile

Questions?

Interoperability Framework Stakeholder Engagement

Avi Gopstein

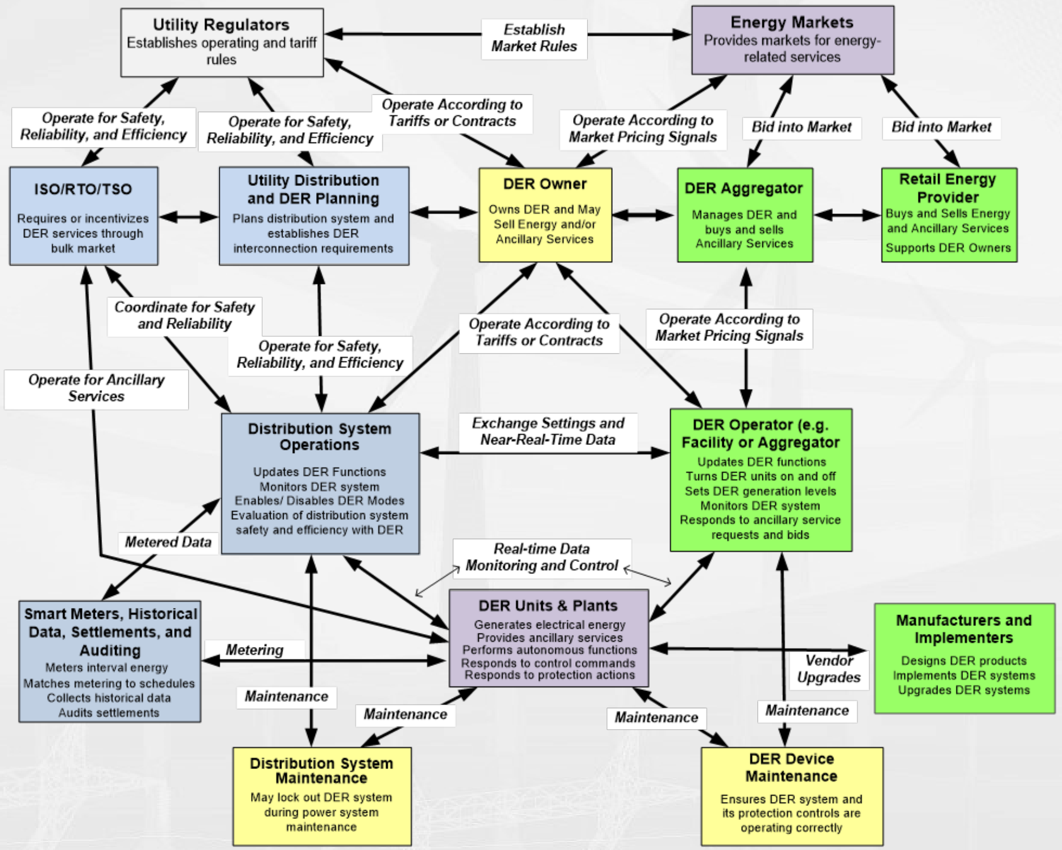
Smart Grid Program Manager

April 25, 2018

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

Context

- Significant reworking of the Interoperability Framework
  – New basis vectors
- Stakeholders are quite varied:
- Tight timeline
  – First workshop June 6, 2018
  – Public draft November 1, 2018
- Value derives from adoption
- Requires:
  – Agreement on approach
  – Pre-pub. dissemination of content
  – Multiple feedback channels



Illustrative example of stakeholders in a High-DER Architecture example

Workshop 1: Framework Introduction

Date: June 5, 2018
Location: NIST

Topic: Introducing Interoperability Framework 4.0
Content:

- Updated smart grid conceptual model
- Architecture Examples & relationship to:
  - ► Operations
  - ► Cybersecurity
  - ► Economics
  - ► Testing & Certification
- CPS Aspects/Concerns description

Illustrative Questions:

- What is missing from the architectural examples?
- How does the updated conceptual model help you understand the importance and challenge of interoperability, where could it be improved?
- Which CPS concerns are most critical to the grid modernization discussion?

Workshop 2: Cybersecurity for the Smart Grid

Date: June 6, 2018

Location: NIST

Topic: Cybersecurity needs for the smart grid

Content:

- New interactions (NISTIR 7628 spaghetti diagram)
- Cybersecurity risk profile
- Relationship between bulk & distribution requirements

Illustrative Questions:

- As consumers take ownership of grid assets, what happens to a high-level risk profile focused on power-system owner-operators and their business/mission requirements?
- What additional work needs to be done for the grid profile?

Workshop 3: Testing & Certification

Date: July 9, 2018
Location: Washington, DC
Partner: SEPA

Topic: Testing & certification needs for interoperability
Content:

- Explore underlying drivers for the current state of testing and certification
- Propose an idea of interoperability profiles for smart grid standards as a means to accelerate the development of testing and certification programs.

Illustrative questions:

- What is limiting the development and use of T&C in the smart grid ecosystem?
- What essential elements are needed to formulate an interoperability T&C program?
- How would you prioritize operational interfaces for T&C development?

Workshops 4-7: Economis and Operations

Dates: July – September

Locations: West, Midwest, Northeast, and Southeast regions

Partner: NARUC

Topic: Locally specific operational and economic issues

Content:

NIST will provide an overview of key framework topics to the local community, and learn about issues and concerns relevant to the respective commissions and their stakeholders. Partner commissions to be identified to explore the range of architecture-driven interoperability examples.

Illustrative Questions:

- TBD

Requests of the committee

Provide direct feedback:

- Example logical communications diagrams (architecture charts)
  - Overall review
  - Interface prioritization
- Smart Grid aspects and concerns matrix / prioritized concerns

Participate in one workshop

Fall SGFAC meeting:

- Virtual meeting (September/October)
- Provide feedback on Workshops

Other?

  - Coordinated review?
  - Content contribution?