NIST Smart Grid Program

Measurement Challenges and Opportunities for Developing Smart Grid Testbeds

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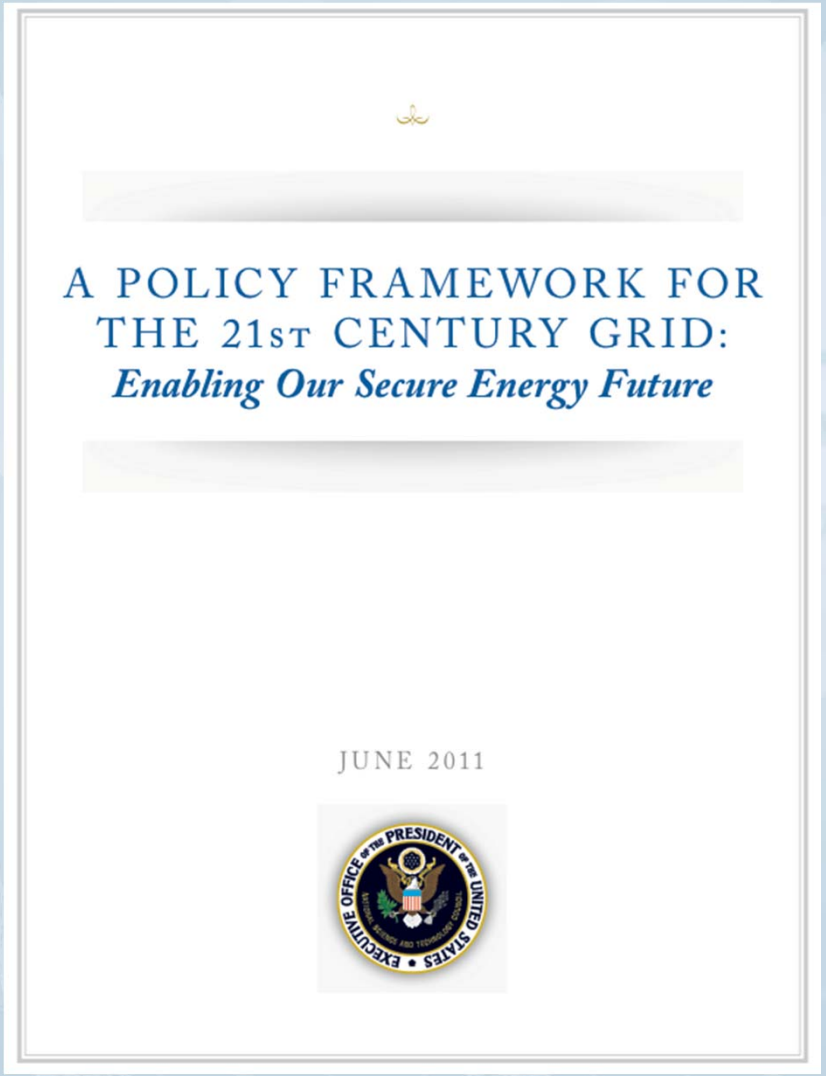
Smart Grid – A U.S. National Policy

- "It is the policy of the United States to support the modernization of the Nation's electricity [system]… to achieve…a Smart Grid."

- *Congress, Energy Independence and Security Act of 2007*



http://www.whitehouse.gov/ostp

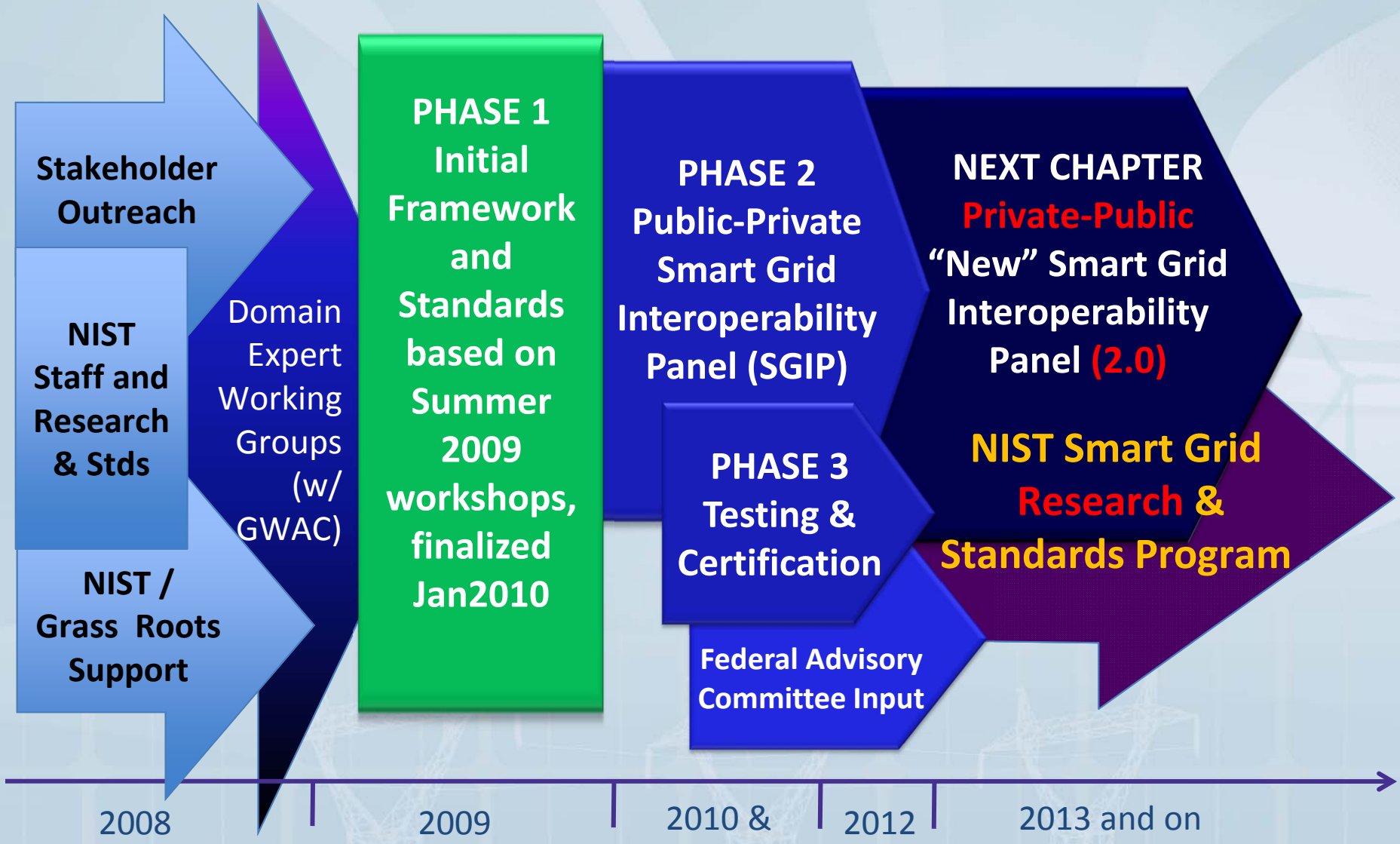
Standards – Key Aspect of US Policy

The Energy Independence and Security Act gives NIST

"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…"

- Congress directed that the framework be "flexible, uniform, and technology neutral"
- Use of these standards is a criteria for federal Smart Grid Investment Grants
- Input to federal and state regulators

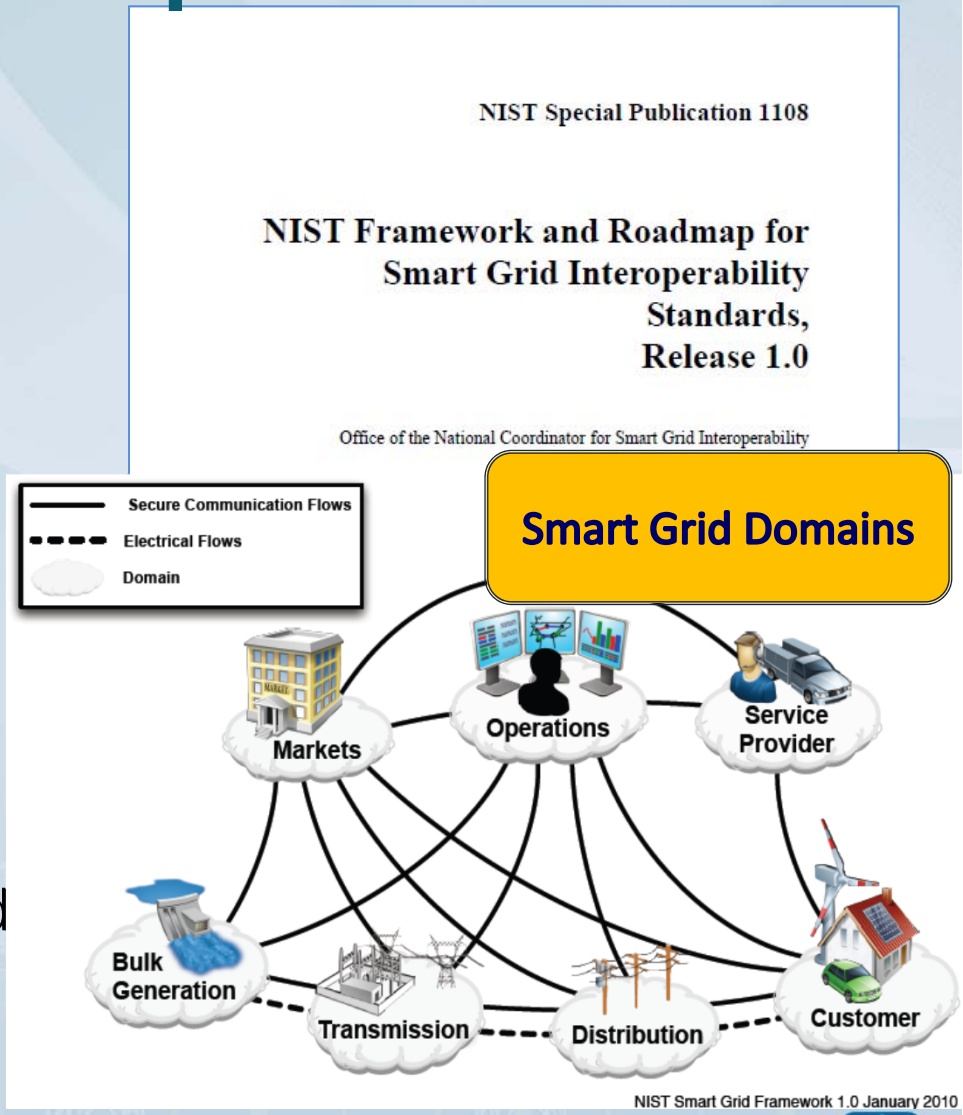
NIST Smart Grid Interoperability Plan



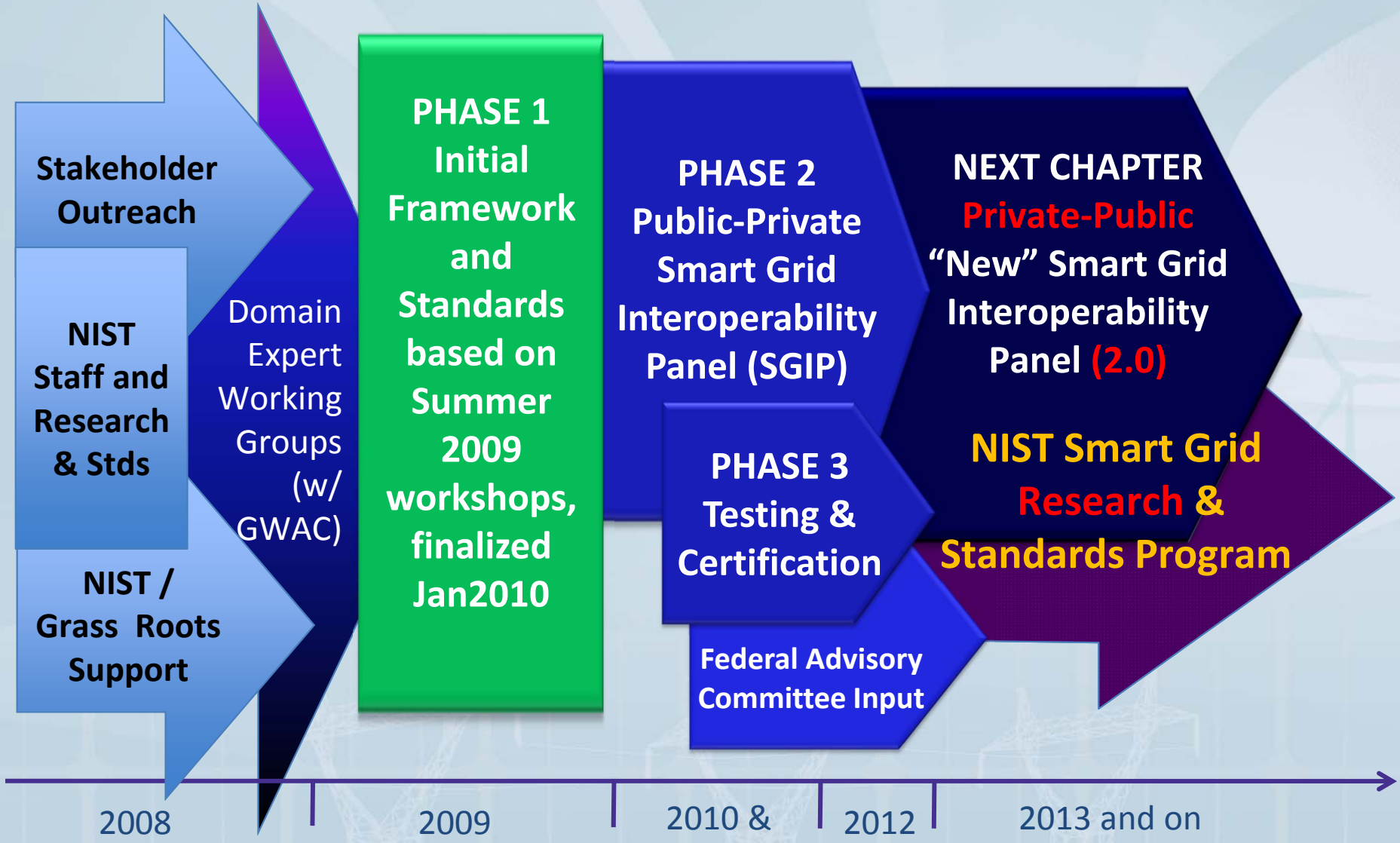
NIST Smart Grid Framework and Roadmap

- Release 1 - January 2010
- Release 2 - February 2012
- Release 3 – September 2014
- Smart Grid vision & reference model
- Identifies 100 key standards
- Cybersecurity guidelines
- Testing and certification framework
- Provided a foundation for IEC, IEEE, ITU, and other national and regional standardization efforts

http://www.nist.gov/smartgrid/



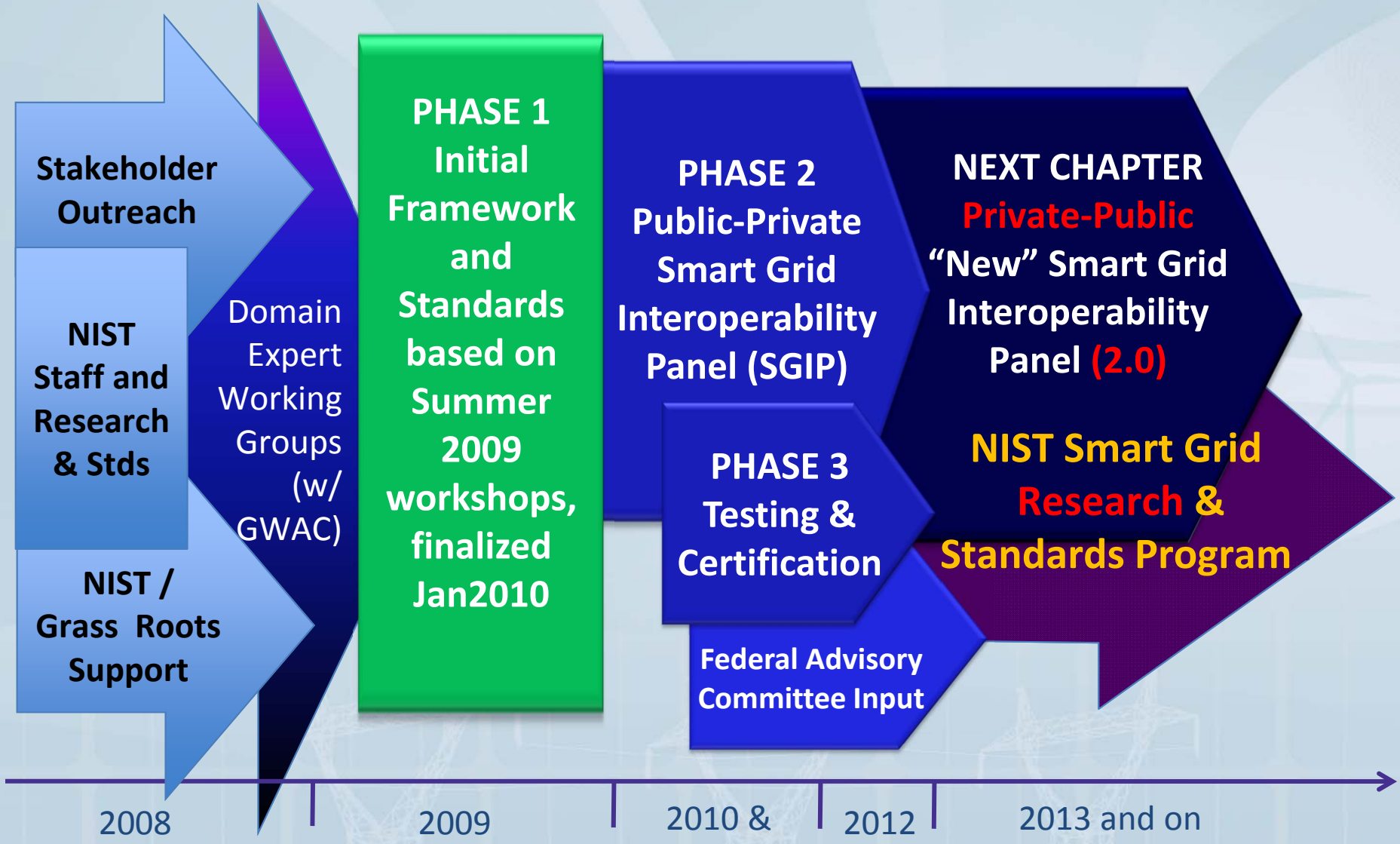
NIST Smart Grid Interoperability Plan



Smart Grid Interoperability Panel (SGIP) Background

- Established in 2009 by NIST as a public/private partnership organization to support NIST in its EISA role
- Began transitioning to member-funded, non-profit organization SGIP 2.0, Inc. in Dec. 2012, operational April 1, 2013 (public/private now private/public)
- Mission
  - In support of NIST, provide a framework that is mandated by EISA for coordinating all Smart Grid stakeholders in an effort to accelerate standards harmonization and advance the interoperability of Smart Grid devices and systems
- SGIP fulfills this mission by:
  - Facilitating standards development for Smart Grid interoperability
  - Identifying necessary testing and certification requirements
  - Overseeing the performance of these activities & continuing momentum
  - Informing and educating Smart Grid industry stakeholders on interoperability
  - Conducting outreach to establish global interoperability alignment

NIST Smart Grid Interoperability Plan



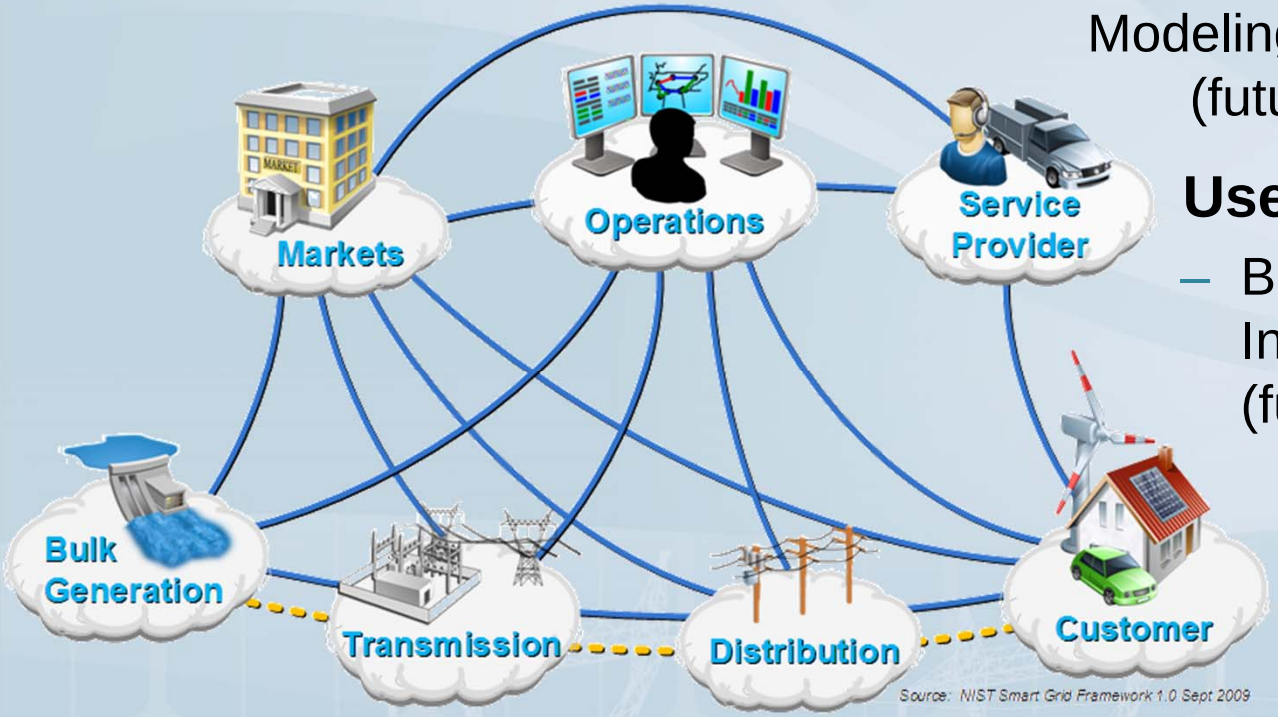
NIST Smart Grid Program

Smart Grid Coordination

- Secretariat; Smart Grid Interoperability Panel; Program Development

Smart Grid System Performance

- Cybersecurity; Timing; Communications
- EMC; Smart Grid Testbed; Testing and Certification; Systems Modeling and Simulation (future work)



User-to-Grid

- Building Integration; Industrial Integration (future work)

Distributed Energy Resources and Microgrids

- Power conditioning; storage (future work)

Transmission and Distribution Operations

- Wide Area Modeling and Control (PMUs); Advanced Metering

NIST Smart Grid Measurement Research Thrusts

Cross-cutting Systems Aspects

- Architecture and System Modeling
- Testing and Certification Methods
- Communication Networks
- Cybersecurity
- Electromagnetic Compatibility
- Precision Timing for Smart Grid Systems
- Smart Grid Testbed

Transmission and Distribution

- Advanced Metering in Smart Distribution Grids
- Wide Area Monitoring and Control

Distributed Resources

- Power Conditioning Systems for Renewables, Microgrids and Storage

Customer Domain

- Building Integration with Smart Grid
- Industrial Integration with Smart Grid

Smart Grid Testbeds

- Workshop; March 13-14, 2014 in Gaithersburg, Maryland.
- http://www.nist.gov/smartgrid/upload/SG-Testbed-Workshop-Report-FINAL-12-8-2014.pdf
- Testbed owners/operators and other key stakeholders from industry, utilities, academia, and the national laboratories
  - *Smart grid measurement and characterization problems not currently addressed by testbeds*
  - *Key attributes and design elements of composable/modular smart grid testbeds*
  - *Design elements/considerations for interconnected smart grid testbeds*

Needs/Opportunities

- **Security –** Developing advanced security mechanisms; also needs to know how to return the system to a secure operational state if new technologies fail to operate as expected.

- **Pre-Integration Development –** Identifying problems earlier in the development process; testing concepts and prototypes in a controlled testbed environment rather than relying solely on simulations.

- **Integration –** Seamlessly integrating individual components (i.e. electrical, communication, IT) at the system level.

Needs/Opportunities

- **Development of Standards –** Serving as a platform for standards development, especially for establishing the interoperability of components.

- **Customer Engagement –** Gauging customer's acceptance of new, advanced, and sometimes more complex technologies.

- **Safety –** Serving as experimental grounds for system interaction to understand / characterize interactions between components / users.

Challenges to Developing and Operating Testbeds

- **Technologies and Simulations for Complex Grid Systems—** Smart grid systems involve numerous combinations of components, users, and suppliers, and countless interactions between these elements
- **Limits to Knowledge and Data –** Limited information is available for the purpose of developing solutions.
- **Stakeholder Communications and Engagement –** There are no broadly accepted mechanisms for coordination among smart grid testbed owners and operators.
- **Testbed Operating Standards and Protocols—**Test conditions vary substantially between testbed systems

Challenges to Developing Modular/Composable Testbeds

- **Technical Complexity–** high level of complexity and scale; latency in communications, developing adequate connection architectures, incorporating security/protection devices, modeling/testing in real time.
- **Business/Economic–** high-cost of testbed components
- **Policy, Regulation and Standards –** example: current and future requirements for security and data privacy.
- **Institutional/Workforce –** lack of guidance and/or governance for conducting R&D and specifically in testbed environments

Challenges to Developing Interconnected Testbeds

- **Shared Infrastructure and Needs–** need to share infrastructure between testbeds.
- **Data and Knowledge –** Data sharing is critical to creating useful outputs from interconnected testbeds
- **Incentives/Business Models –** stakeholder community is relatively conservative and exhibits a general inertia to change
- **Testbed Awareness –** no accessible, central inventory or repository of testbeds exists, resulting in limited awareness of the capabilities that are currently available as well as potentially some duplication of effort.
- **Workforce –** Developing and maintaining the skilled workforce

Smart Grid Testbed Workshop
Key Findings

- Lack of coordination and awareness among testbeds
- Lack of central understanding of priorities for R&D
- Need for the creation of an accessible inventory of testbeds
- A range of testbed scenarios needed (modular/composable and interconnected)
  - *Increasing the Penetration of Renewable Power through Various Approaches*
  - *Application of Data Analytics to Utility Big Data to Create Actionable Information*
  - *Architecture for Federation of Interconnected Testbeds*
  - *Multi-Level Control Architecture Testbeds*

Smart Grid Testbed Workshop Key Findings

- Priorities for developing/expanding testbeds include:
  - Hardware and device development and integration
  - Testing of data security and compatibility of Advanced Metering Infrastructure (AMI) and Home Area Network (HAN) devices
  - Support systems for viable renewable power sources, including storage, demand response, communications, and infrastructure.
  - Integration of renewables across multiple smart grid domains, including distribution, demand responses, markets, and validated in federated testbeds
  - Data analytics for actionable information from large volumes of utility data and a wide range of datasets
  - Architectures for federation of interconnected testbeds, including frameworks for applications and interoperability
  - Multi-level control architectures needed to support changes in conventional grid control paradigms

Additional Testing Gaps

- Additional testing gaps
  - System of System Interoperability and Integration
  - Multi-Vendor Testing
  - Communications Testing
  - Environmental Testing
  - DER Testing
  - Microgrid Testing
  - PMU Testing
  - Big Data Testing
  - Governance Techniques and Best Practices

NIST Smart Grid Interoperability Testbed

- Measurements will include eight areas:
  - micgrogrid PCS/interconnection
  - synchrophasor metrology,
  - cybersecurity,
  - precision time synchronization,
  - electric power metering,
  - modeling/evaluation of SG communications,
  - sensor interfaces,
  - energy storage.

Microgrid/PCS Interoperability Lab is designed to:

- Addresses metrology needed for interoperability of advanced microgrid devices and systems
- Incorporates elements of many of the projects in the NIST smart grid portfolio
- Focused on unique NIST mission of Smart Grid interoperability and leverages SGIP activities
- Extensible to all aspects of multilevel distributed control
- Coordinated with other agencies and industry programs
- Aligned with partner testbed architectures to enable interchangeability of devices between testbeds
- Network connectivity to enable multi-lab co-simulation

Testing Microgrid/DER Interconnection/Control

- **Interconnection standard** defines operational interface functional requirement (electrical and communication) at the point-of-common-coupling (PCC) required for safe, stable system operation and for meeting equipment vendor value proposition needs.
- **Conformance testing** ensures that requirements of interconnection standards are met by equipment (interconnection equipment and controller) at the PCC for sufficient combinations of conditions at the PCC. Further tests are required at commissioning.
- ***Interoperability testing*** *emulates boundary conditions (communication and electrical) around a collection of devices for a sufficient combination of device states and boundary conditions. This can serve as a basis to verify and validate that standards are consistent and accurate.*
- **Demonstration testing** enables equipment or collection of devices to be interconnected to electric utility's distribution system/power grid without potential for adverse impacts on other customers on the grid.
- **Impact studies** use standard test and monitoring procedures to evaluate the impact of equipment or collection of devices t integrated with the utility's distribution system/power grid in a way that might impact other customers.

NIST Smart Grid Interoperability Testbed

SGIP Smart Grid Interoperability

NIST Measurement Science

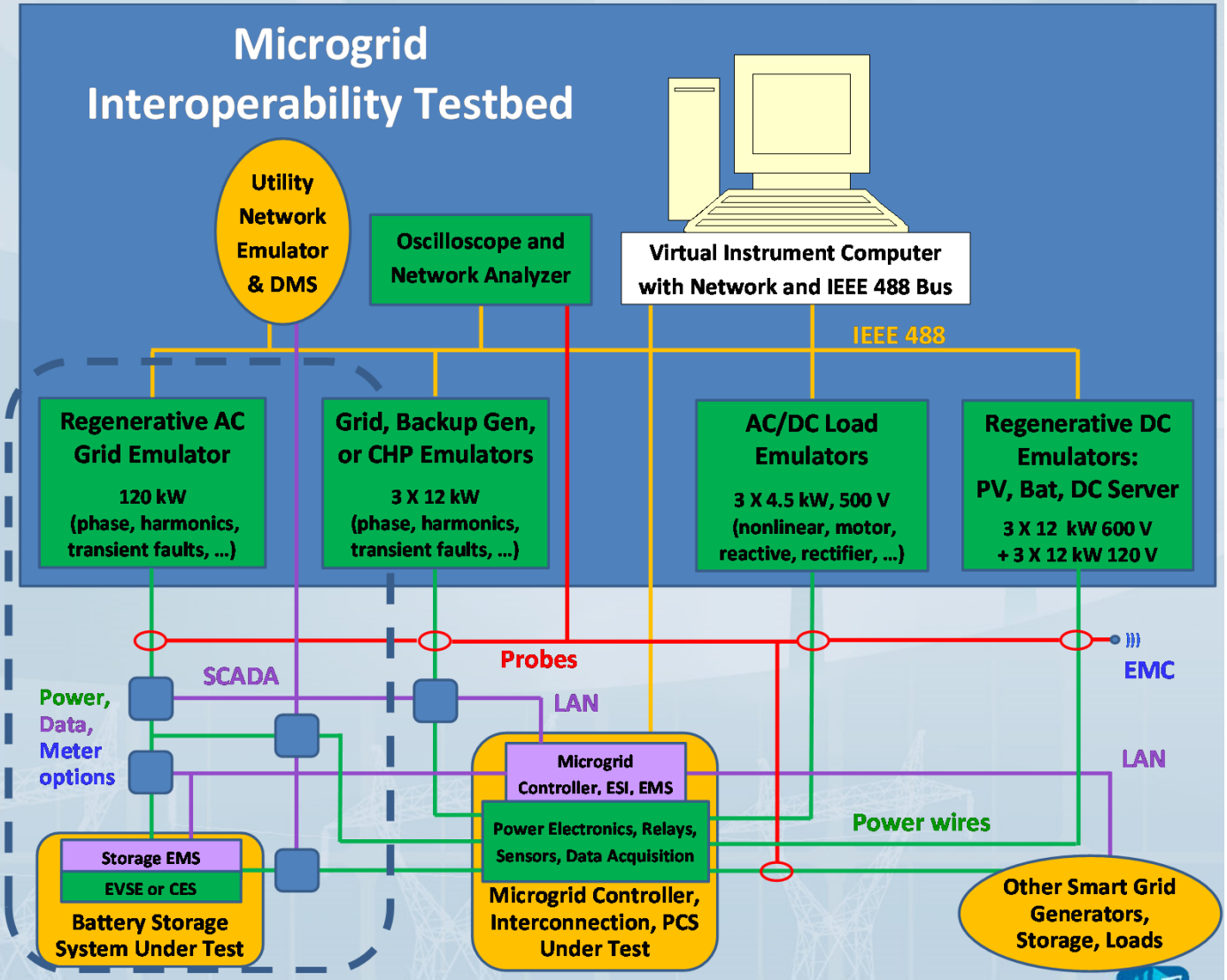
DOE/DOD Labs, Test & Certification

ESI, EMS, Microgrid & Storage functions

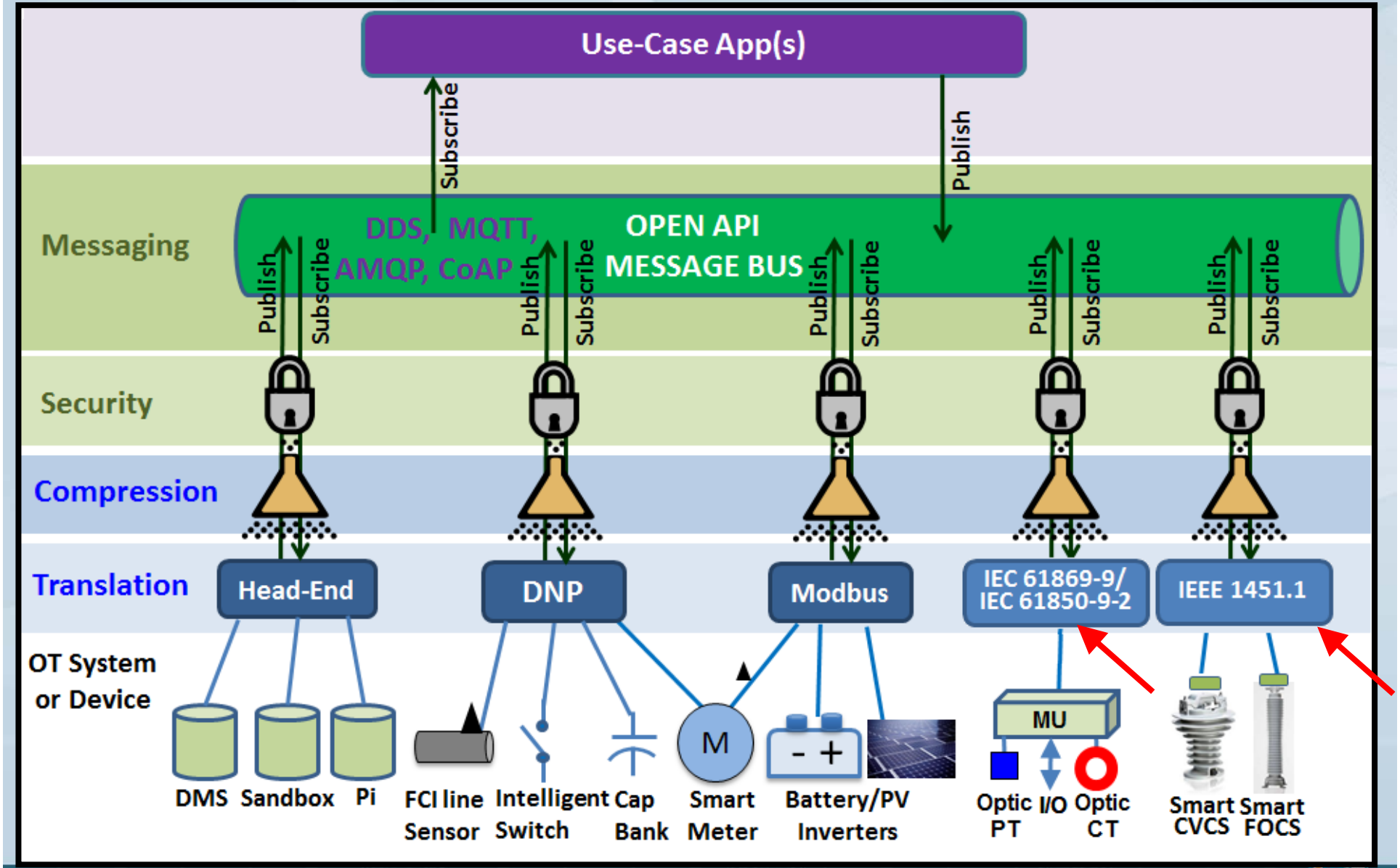
IT Networks, Cyber Security, EMC, Sensors & Smart Meters

Power Electronic Interconnection Equipment

Grid-Interactive Microgrid, DER & Smart Appliances



IEC 61869/61850, IEEE 1451 and PAP26



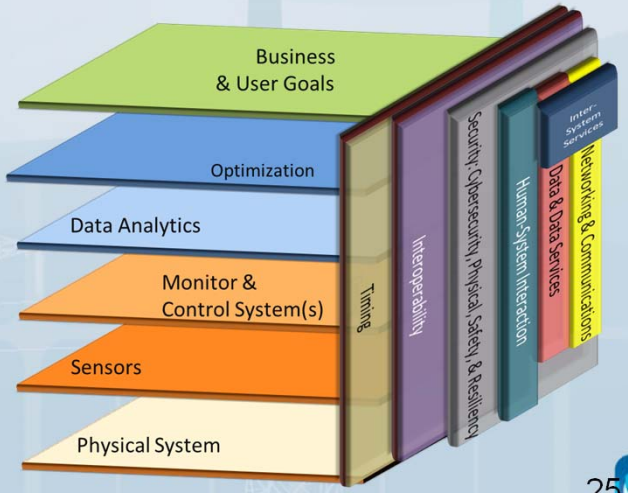
CPS Testbed

NIST is developing an advanced experimental facility for cyber-physical systems – the Cyber Physical Systems Lab.

The Lab will probe basic functions underpinning the Internet of Things, with applications ranging from a smart grid to intelligent transportation, advanced manufacturing, patient-centric health care, disaster resilience, and smart cities.

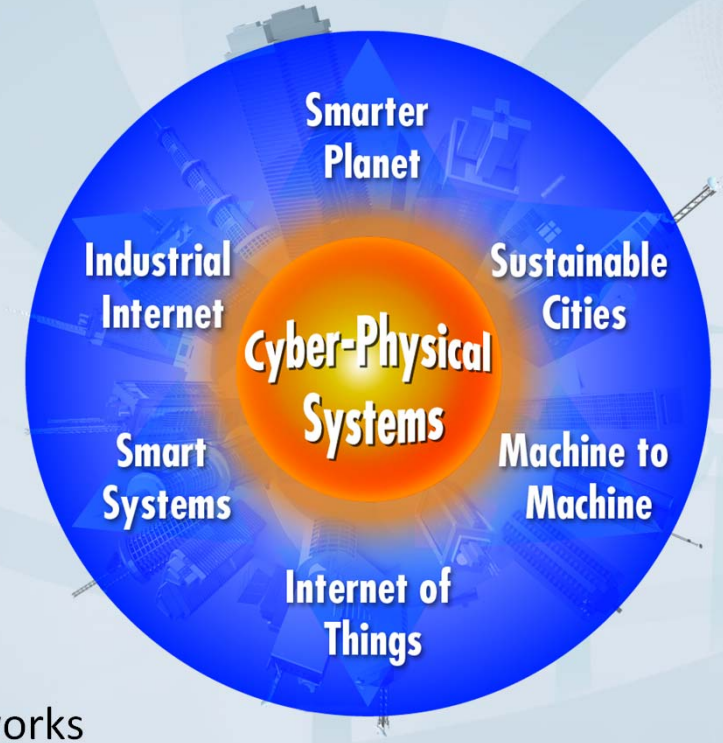
Critical Characteristics of the Lab:

- CPS reference architecture is the design driver
- Modular and composable
- Hybrid of physical and virtual modules
- Reconfigurable
- Remotely operable
- Applicable within and across CPS domains



Cyber-Physical Systems (CPS)

- Integrated, hybrid networks of cyber and engineered physical elements
- Co-designed and co-engineered to create adaptive and predictive systems
- Respond in real time to enhance performance



Examples:

- Internet of Things (IoT)
- Emergency Response Networks
- Smart Robots/UAVs
- Autonomous Vehicles & Traffic Management Networks
- Smart Grid
- Network-enabled Healthcare Solutions
- Advanced Manufacturing Plants

Thank You!