Importance of NIST Laboratory Research Programs to Support Smart Grid Standards

Visiting Committee on Advanced Technology (VCAT)

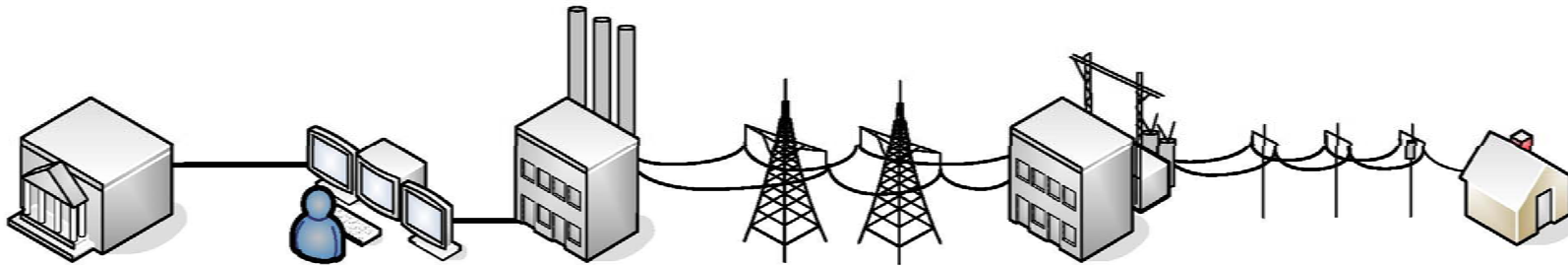David Wollman

NIST Smart Grid Team

June 9, 2009

The "smart grid" combines the electrical and "intelligence" infrastructures …
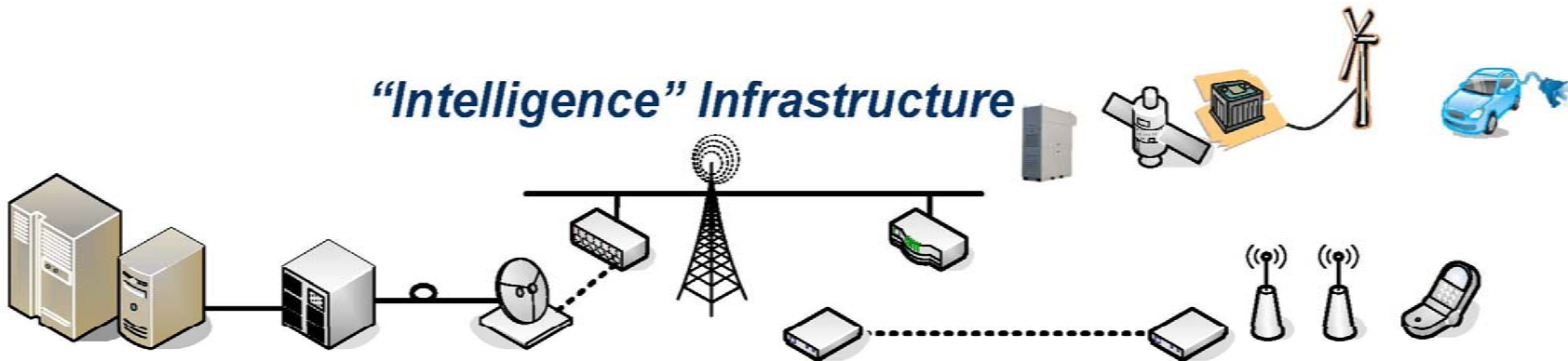
Electrical Infrastructure

Fusing electrical and information infrastructure requires interoperability…

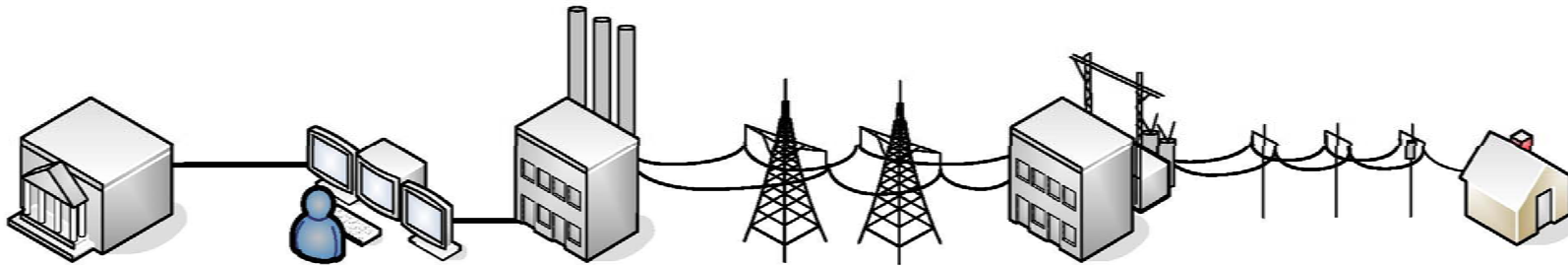Interoperability requires reliable standards and validated performance – **a clear role for NIST**

"Intelligence" Infrastructure

Graphics courtesy of EPRI

The "smart grid" combines the electrical and "intelligence" infrastructures …
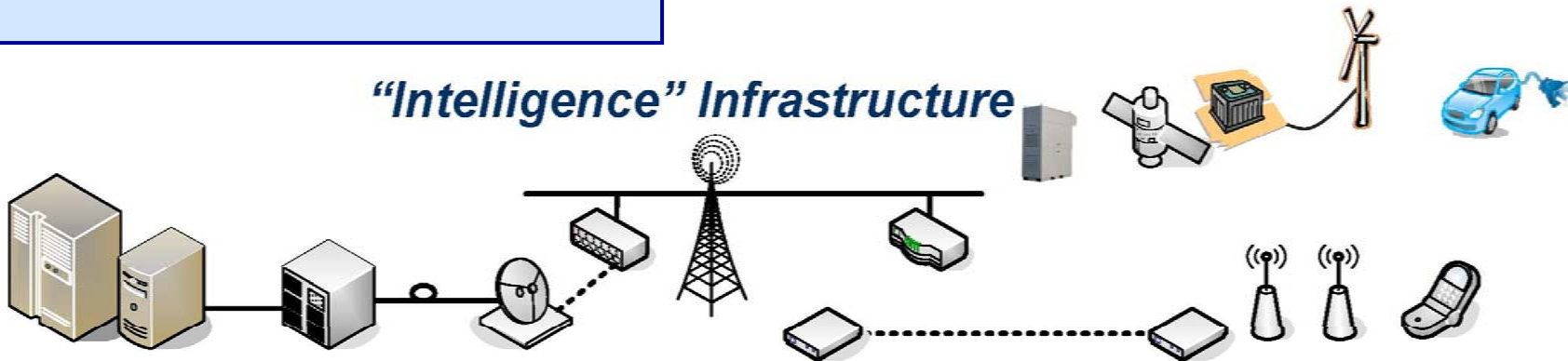
Electrical Infrastructure

NIST research/measurements support technically accurate standards – **a clear, traditional role for NIST**

Interoperability requires reliable standards and validated performance – **a clear role for NIST**
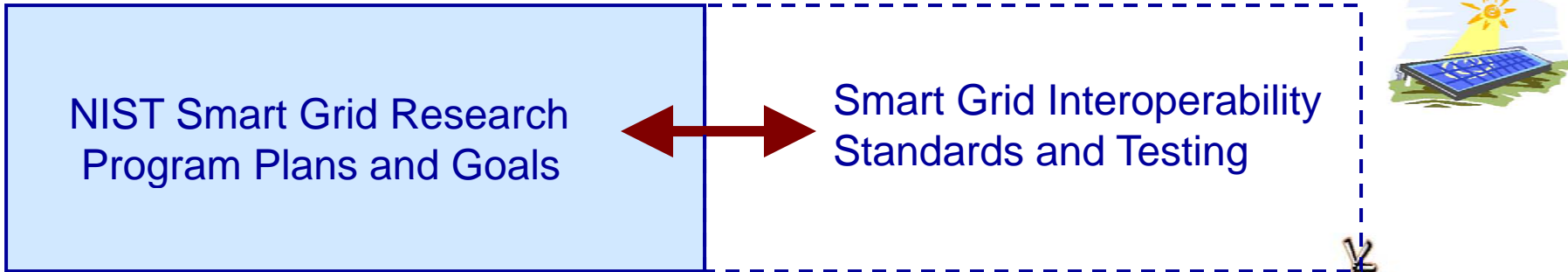
"Intelligence" Infrastructure

Graphics courtesy of EPRI

The "smart grid" combines the electrical and "intelligence" infrastructures …

Electrical Infrastructure

NIST Smart Grid Research Program Plans and Goals ⟷ Smart Grid Interoperability Standards and Testing
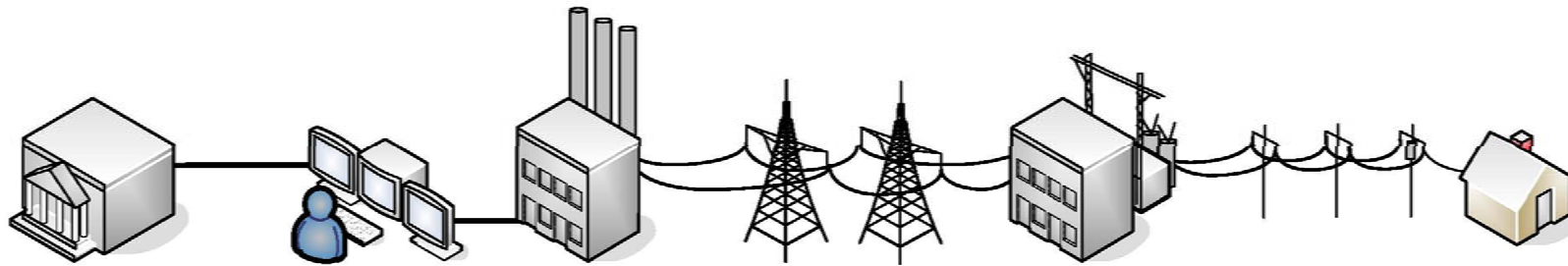
"Intelligence" Infrastructure
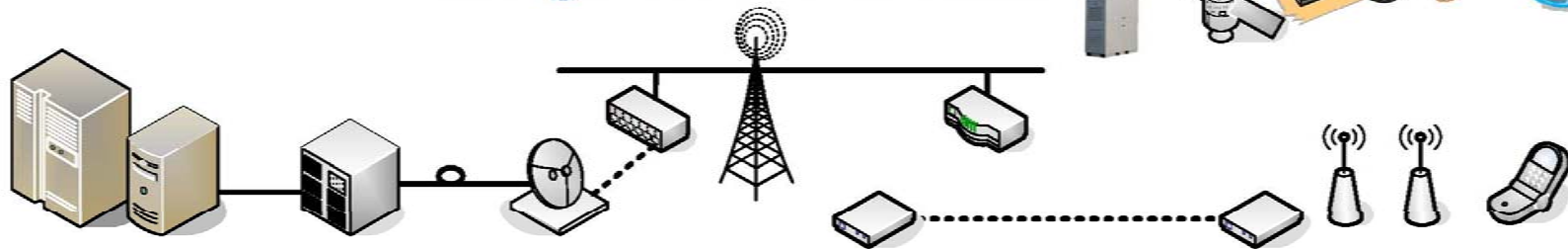
Graphics courtesy of EPRI

NIST smart grid vision:

1. **NIST accelerates smart grid interoperability standards**
   - Delivers "Interoperability Framework" including "Release 1.0"
   - Three phase accelerated NIST plan:
     - Interim Roadmap, Standards Panel, Conformity Testing
   - NIST drives standards process by organizing Standards Development Organizations (SDOs) and accelerating standards development in private sector

   Speed is absolutely critical for this!

2. **NIST builds up smart grid research program**
   - Increases measurement capability related to SG/power industry
   - Solves interoperability technical issues
   - Creates testbeds/measurements to support conformity testing
   - Anticipates new smart grid technologies and measurement standards; develops key measurements

NIST smart grid research:

- **NIST smart grid research spans many Laboratories**
  - Electronics and Electrical Engineering:
    - Electric Power Metrology and Power Electronics

  - Building and Fire Research:
    - Building Systems

  - Information Technology:
    - Cybersecurity and Networking

  - Manufacturing Engineering:
    - Industrial Control and Security

NIST Research Maps onto Smart Grid Functions
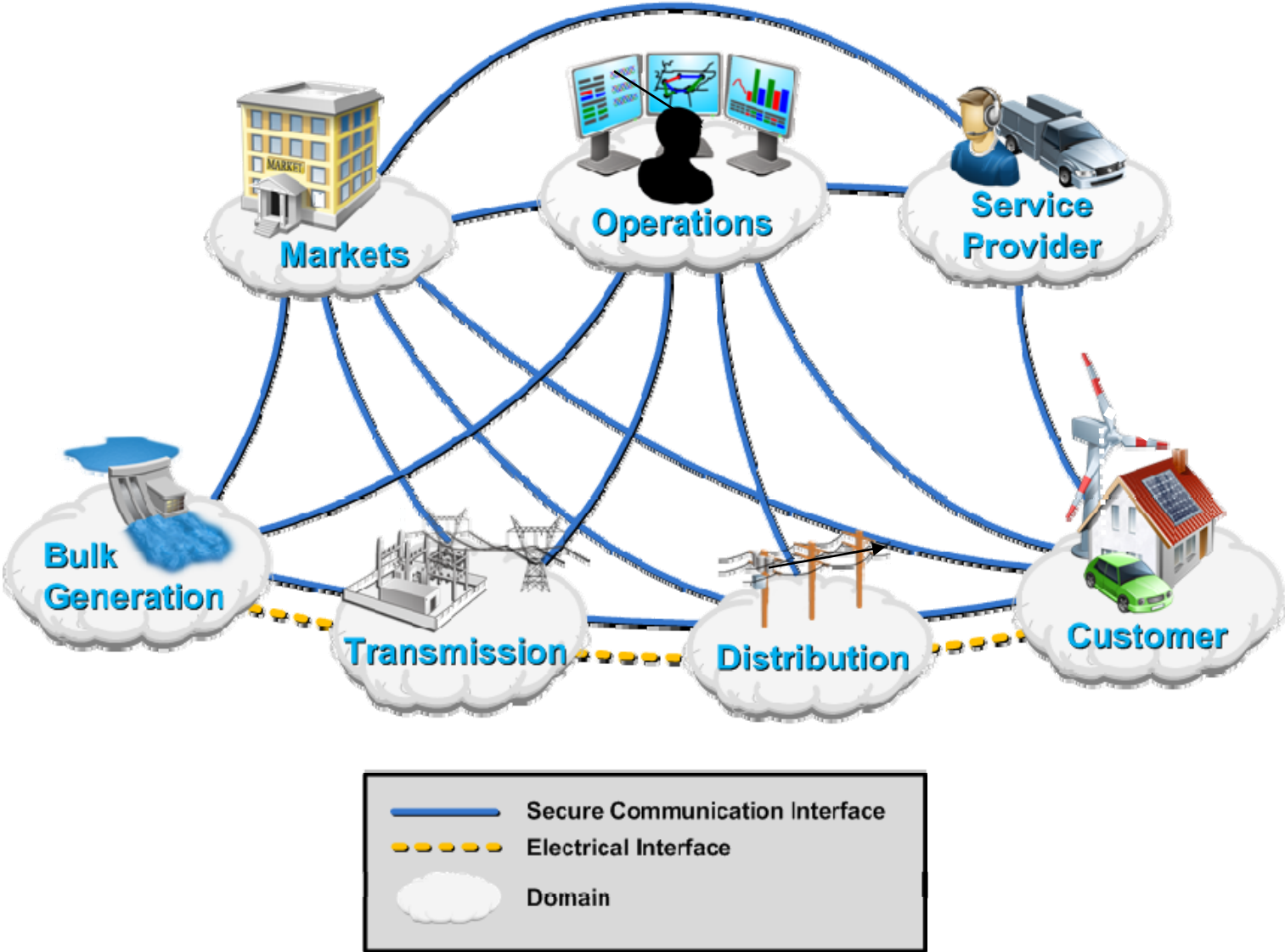
Markets

Operations

Service Provider

Bulk Generation

Transmission

Distribution

Customer

Secure Communication Interface
Electrical Interface
Domain

NIST Research Maps onto Smart Grid Functions

Cybersecurity (everywhere)

Markets

Operations

Service Provider

Wide Area Situational Awareness (WASA)

Networks

Building Automation

Intelligent sensors

Bulk Generation

Transmission

Distribution

Customer

Industrial Control Systems

Power Electronics

Electric Power Metering

Secure Communication Interface
Electrical Interface
Domain
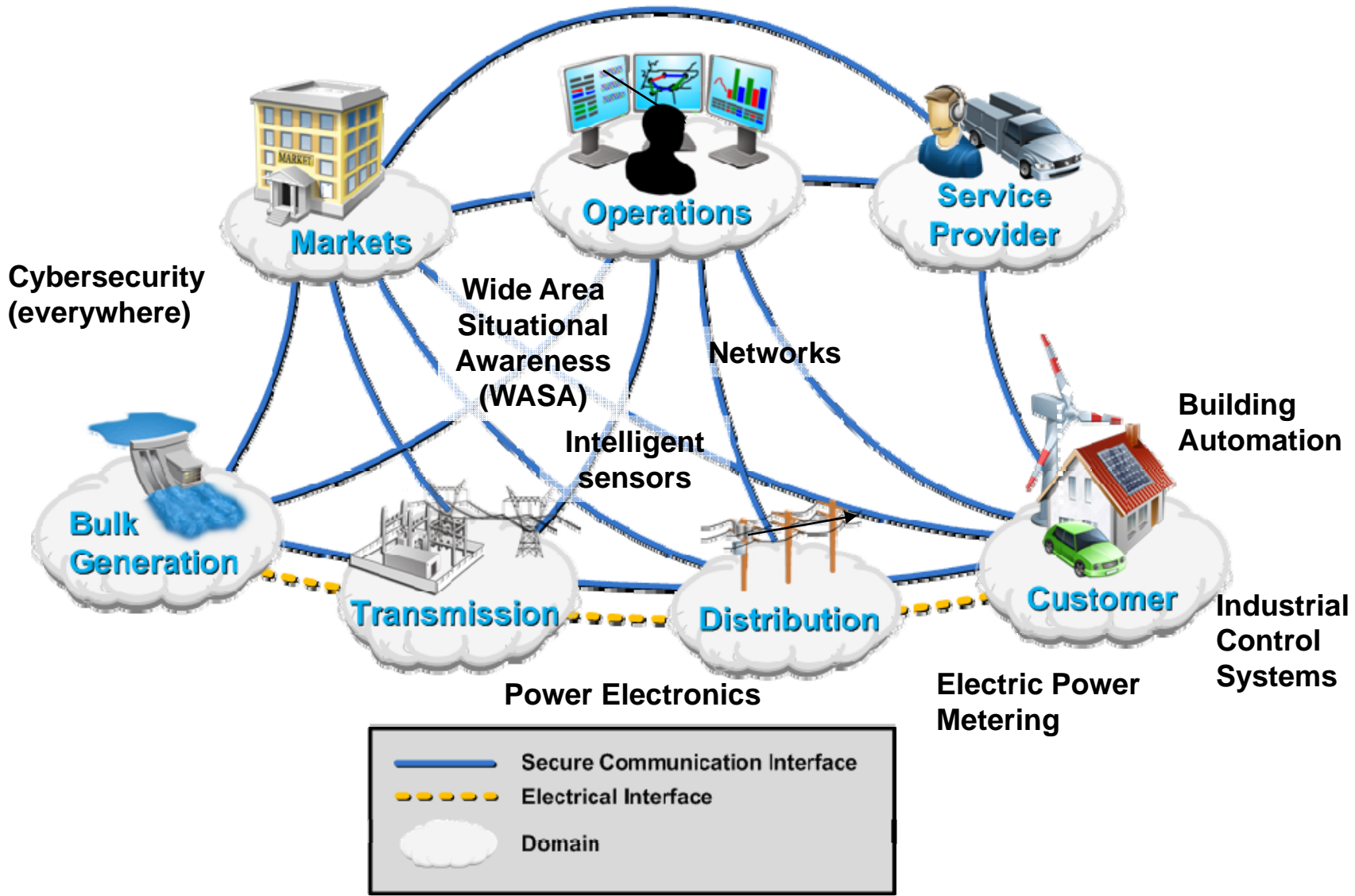
NIST research supports smart grid standards through different mechanisms

- Calibration and testing of smart grid equipment based on standards
- Leadership of standards committee by NIST staff

- Interagency coordination and leadership based on technical expertise; roadmapping
- Information models and standards leadership

- Specific federal roles and responsibilities

- Measurement science and research

NIST research supports smart grid standards through different mechanisms

- Calibration and testing of smart grid equipment based on standards (phasor measurement unit testing)
- Leadership of standards committee by NIST staff (electric power metering)
- Interagency coordination and leadership based on technical expertise; roadmapping (power electronics)
- Information models and standards leadership (building automation control)
- Specific federal roles and responsibilities (cybersecurity)
- Measurement science and research (network, electromagnetic compatibility, …)

Wide Area Situational Awareness (WASA) is key part of the smart grid operational vision

- **Monitors the health of the electric power grid**
- **Will reduce blackouts and interruptions**
- **Make operation of the grid more efficient**
- **Priority in recent FERC policy statement, roadmap workshop**
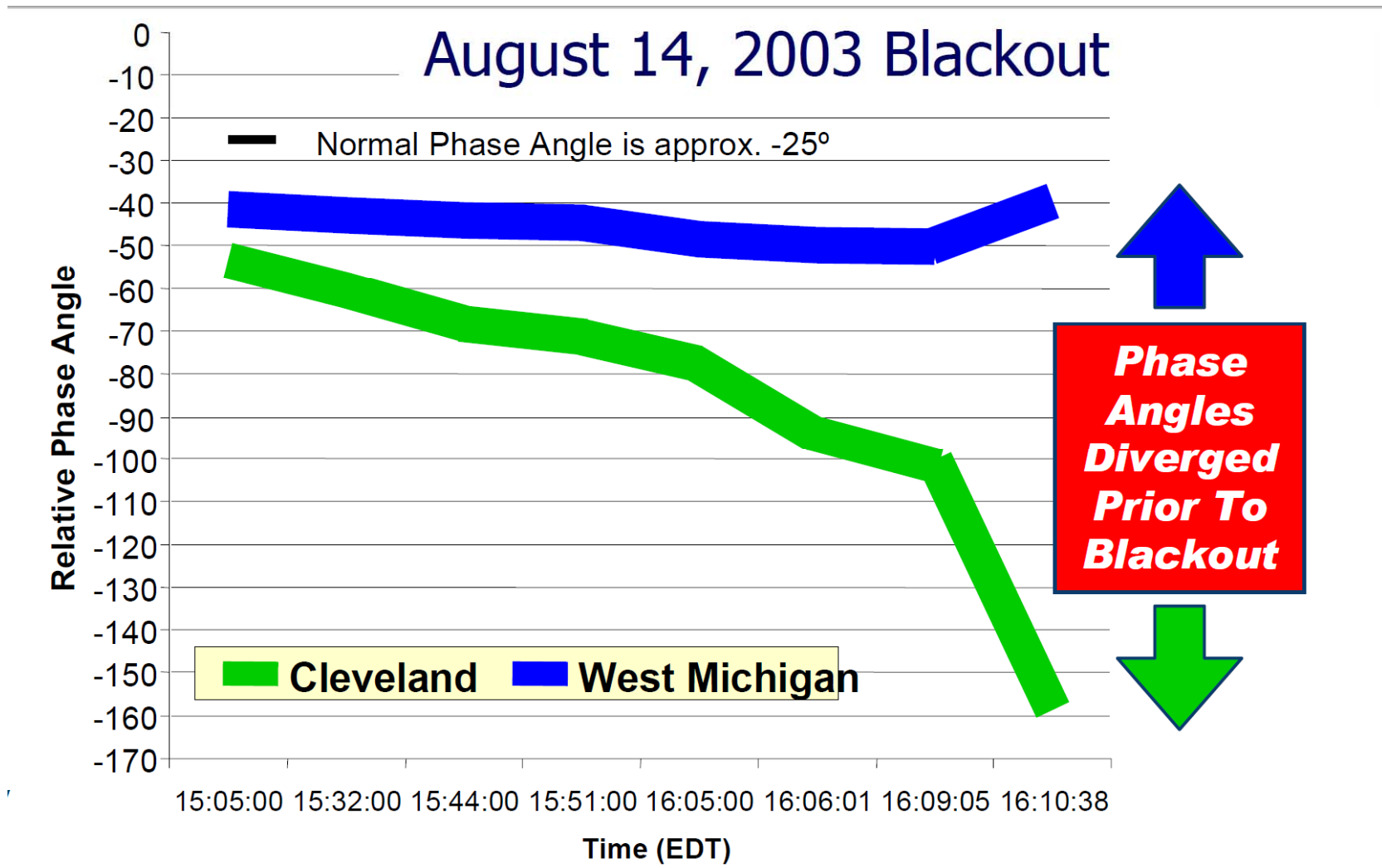
- NIST/EEEL testing of Phasor Measurement Units (PMUs) for WASA

- What is a Phasor?
  Amplitude and Phase Angle

1 PPS (UTC Ref.)

$\sqrt{2}$ A

A ϕ

ϕ

t
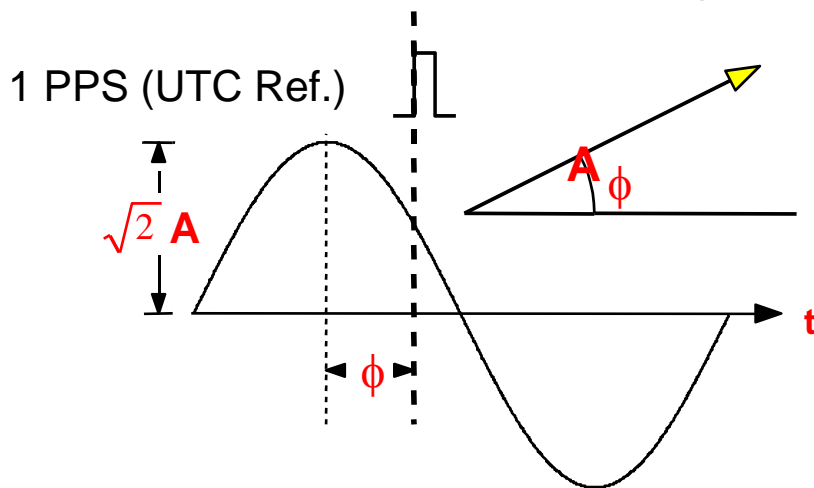
- Phasor Measurement Units (PMUs)
  - **Voltage and current phasors**
  - **Frequency; rate of change**
  - **Timestamps measurements**
  - **Transmits data immediately**
  - **IEEE C37.118 standard**

Northeast Blackout 2003 – PMUs would have provided advance warning to be able to respond

August 14, 2003 Blackout

Normal Phase Angle is approx. -25°

Relative Phase Angle

Cleveland   West Michigan

Phase Angles Diverged Prior To Blackout

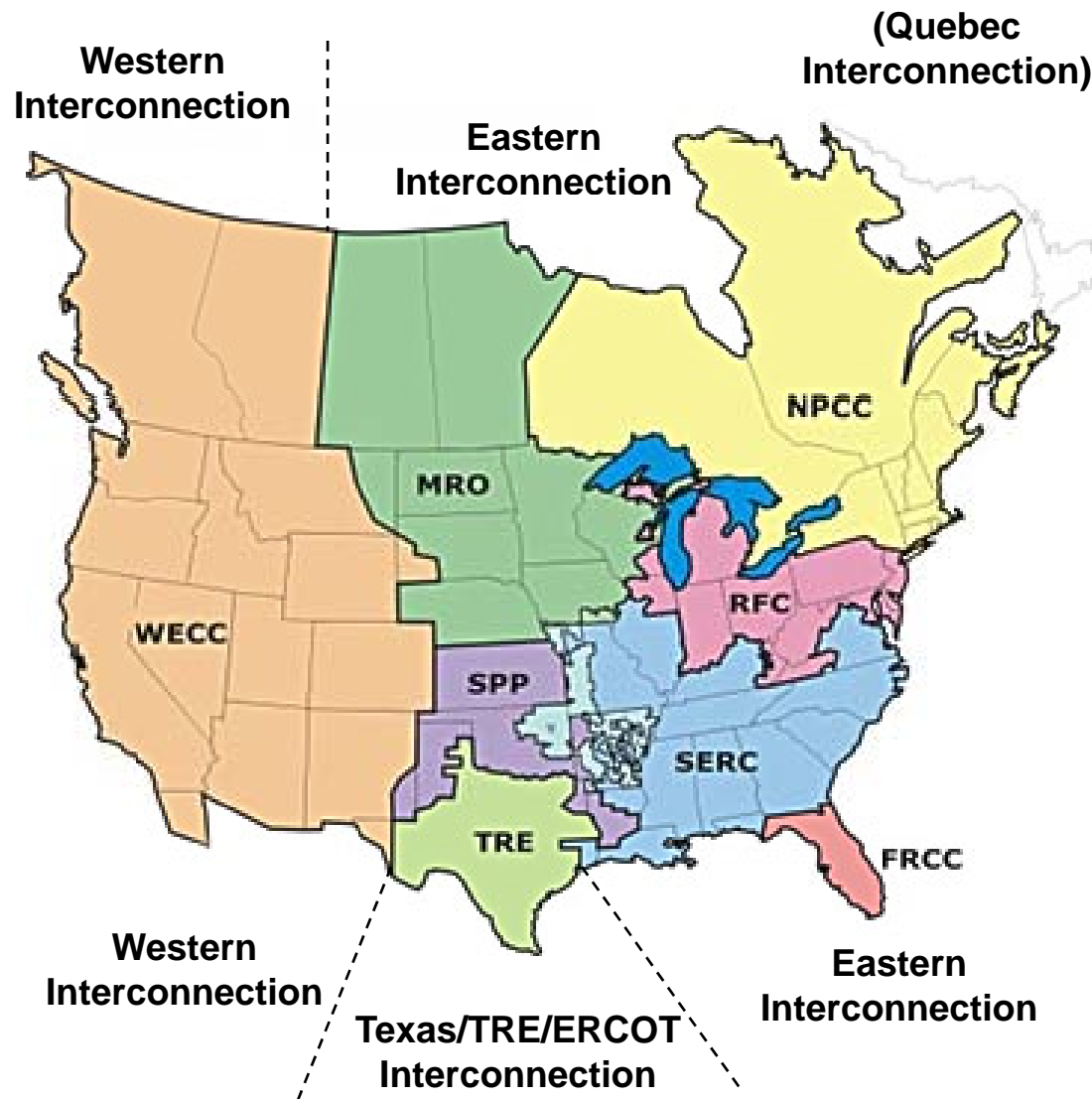15:05:00 15:32:00 15:44:00 15:51:00 16:05:00 16:06:01 16:09:05 16:10:38

Time (EDT)

Simulated data

NIST SynchroMetrology Laboratory tests PMUs

- Supported by NIST/EEEL and DOE
  - **Initiated FY05; FY06/07 received EEEL Dir. Res. seed funding**

- NIST only NMI to offer PMU calibration special test service
  - **Example: testing 8 PMUs from manufacturers around the world for Brazil National System Operators**

- NIST has provided assistance to manufacturers and utilities on design, testing and use of PMUs. Testing PMUs important; only 1 of 8 tested meets full IEEE standard C37.118.

- Future:
  - **Dynamic state measurements**
  - **Support calibration of PMU testers**
  - **Support DoE and utilities for upgrades to meet new testing needs**
  - **Other intelligent sensors**
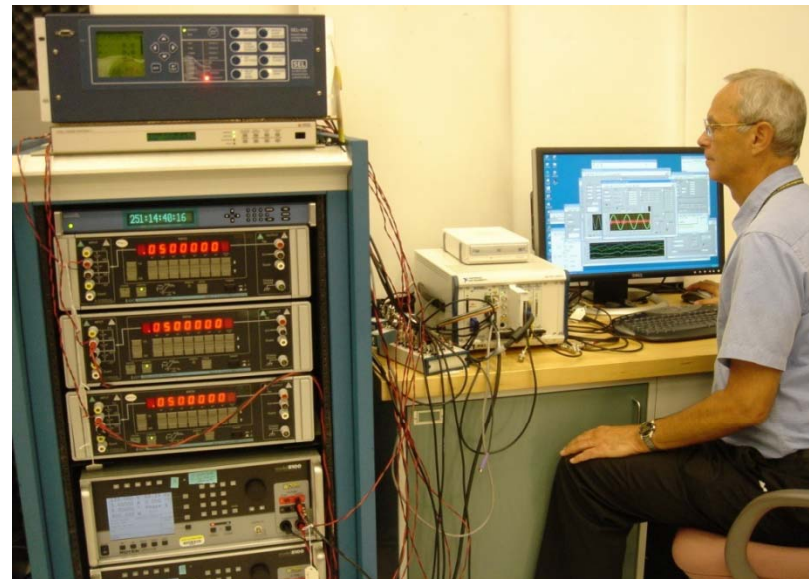
North American Synchrophasor Initiative (NASPI)

(Quebec Interconnection)

Western Interconnection

Eastern Interconnection

NPCC

MRO

RFC

WECC

SPP

SERC

TRE

FRCC

Western Interconnection

Eastern Interconnection

Texas/TRE/ERCOT Interconnection

NERC Reliability Regions

- Project sponsored by DOE and the North American Electric Reliability Corporation (NERC)

- Promoting "better use of measurements and information to improve system performance"

- NIST/EEEL important contributor, lead of performance requirements team (Jerry Stenbakken)

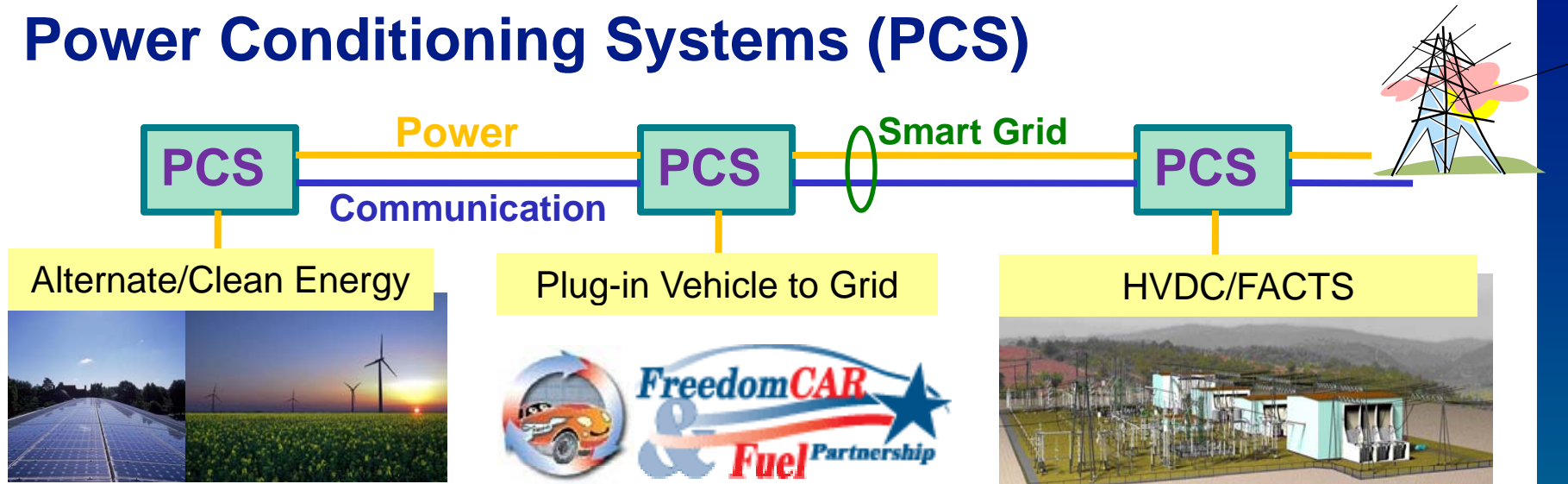- NASPI provides input to standards process (IEEE)

Electric Power Metering

- All electric energy (kilowatt-hours) sold in the U.S. (over $300 Billion/year) is traceable to NIST Electric Power Laboratory
- ANSI C12 standards for electricity metering, typically mandated in the U.S. by state Public Utility Commissions (PUCs)
  - **NIST/EEEL chair of ANSI C12 main committee (NEMA)**
    - Project leader of Power&Energy research/calibration service

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- Quantum watt: successfully tied electric power to quantum standards (major development effort: DSP-based waveform generator, world's best voltage amplifier, AC Programmable Josephson Voltage Standard) - uncertainties decreased from 15 to 2 ppm
- Future: three phase power, distorted power

Power Conditioning Systems (PCS)

PCS — **Power** — PCS — **Smart Grid** — PCS
Communication

Alternate/Clean Energy — Plug-in Vehicle to Grid — HVDC/FACTS

- PCS required to adapt unsynchronized AC and unregulated DC power of Alternate/Clean energy systems to/from 60 Hz AC grid and enable Smart Grid with enhanced features:
    - **Connectivity of solar, wind, fuel cell, plug-in vehicle, storage**
    - **A power network with controlled flows (cf. free-flow today)**
    - **Dispatchable real and reactive power → high efficiency, low loss**
    - **Controllable harmonic cancellation, phase balancing, inertia**
    - **Accommodate faults faster with controllable trip points**
    - **Permits utility controlled islanding**
- High megawatt PCS required for enhanced grid capacity/stability
   - **HVDC, FACTS, Microgrids, SS Circuit Breaker, SS Transformer**

EEEL Power Electronics and PCS Leadership

- PCS advancement enabled by new power electronics components
  - **NIST is leading expert on preferred high power modules: IGBT**
  - **NIST plans and leads multi-agency power electronics programs**
- NIST/DOE initiated "*High Megawatt PCS Industry R&D Roadmap*" process to guide development of technologies needed for future alternate/clean energy and the Smart Grid
- Interagency Advanced Power Group (IAPG)
  - **1958 statute created federal membership organization for coordination of federal programs in power technologies**
  - **NIST chairs IAPG Electrical Systems Working Group to coordinate federal PCS programs for future energy and grid**
- IEEE 1547 is a key standard defining grid connectivity requirements
  - **Evolving rapidly with new energy systems and grid architectures**
  - **Clear need for NIST metrology to validate PCS conformity**

Building Automation Control Research

Addressing the role of the building in the smart grid:

- **72% of all electricity is consumed by building system loads.**
- **BFRL smart grid research is focused on improved energy management in complex facilities.**
- **BFRL research leads to information models that enable communication standards for the Smart Grid**
  - Includes extensions to BACnet for energy management, and demand response protocols
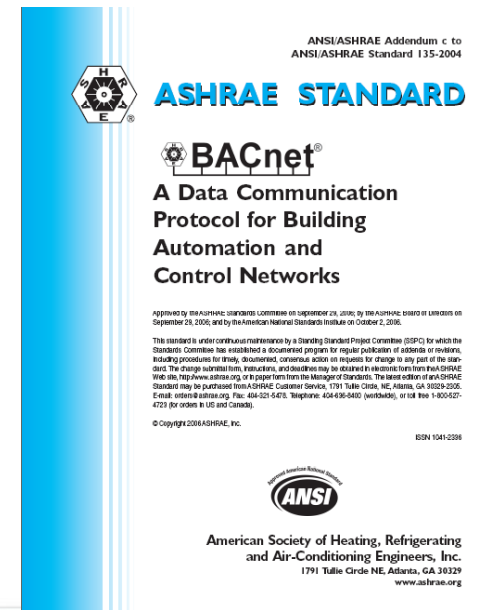
NIST BFRL Virtual Cybernetic Building Testbed

BFRL research and standards impact for SG

- ANSI/ASHRAE 135 BACnet (ISO 16484-5) is the dominant international standard for commercial building automation and control including energy management.

- BFRL has lead in the development of BACnet to meet the interoperability challenges of Smart Grid at the gateway to the consumer facility.

- The BACnet Utility Interaction WG has developed a Load Control Object and is now addressing control of distributed energy resources (generation and storage)

- BFRL has actively served in addressing standards for demand response and has helped initiate, through the NIST Smart Grid Program collaboration activities, a new Energy Interoperation TC under a standards organization to continue to advance a national standard for demand response communications.

- On-going research will serve to strengthen these standards efforts and test the protocols.

NIST cybersecurity important for smart grid

- High visibility of potential security and privacy issues
- Specific federal roles and responsibilities for NIST:
  - **Federal Information Security Management Act (FISMA)**
  - **Cyber Security Research and Development Act**
  - **Homeland Security Presidential Directive (HSPD) 7**

- For smart grid effort, NIST's Computer Security Division established a Cyber Security Coordination Task Group (CSCTG)
  - **Consists of individuals from the private sector, academia, federal agencies, and regulatory bodies**
  - **Implementing a cyber security strategy for the Smart Grid**
    - Using a risk management approach to define threats, vulnerabilities and impacts
    - Developing a set of cyber security requirements for the Smart Grid
    - Identifying gaps and making recommendations

Advanced Networking Technologies – Standard Activities

- NIST research in networking expedites development of standards to improve trust in networked IT systems – modeling, simulation, analysis to assess the completeness, performance, and emergent behavior of proposed standards.

- NIST worked with industry and standards organizations such as:

    - **Internet Engineering Task Force (IETF),**

    - **IEEE 802 LAN/MAN Committee,**

    - **Telecommunications Industry Association (TIA) on telecommunications and networking standards.**

- Many of these standards are applicable to the Smart Grid information network infrastructure.
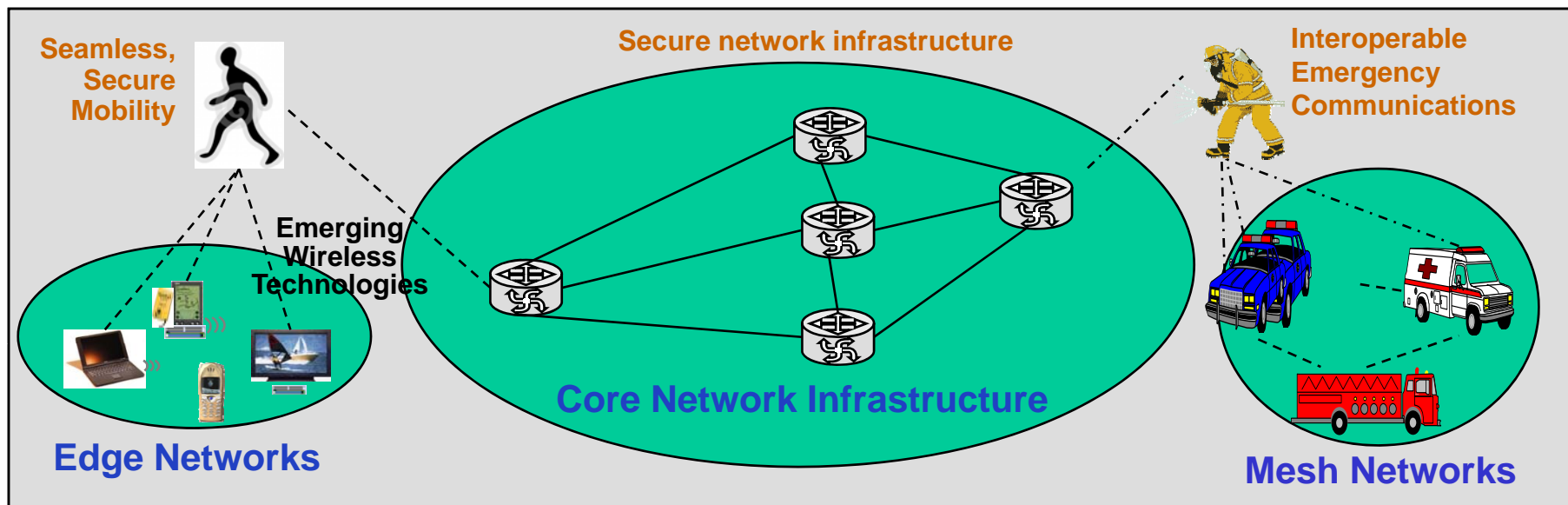
Impact of NIST Work on Networking Standards

For protocols that could be used for Smart Grid information infrastructure

- *Internet Protocol Version 6:* IPv6 will be needed in order to address a large number of smart meters. NIST's IPv6 profile selects features from the IPv6 protocol suite for the U.S. Government networks, but is also applicable to Smart Grid; NIST's IPv6 testing and certification procedures will simplify procurement of IPv6 complaint equipment.

- *Domain Name Service:* DNS is a phonebook look up service that maps Internet names (e.g. www.nist.gov) to IP addresses. It is well known that an attacker can easily hijack the mapping and redirect traffic to hijacker's site. NIST's work on DNSSEC standards and its world wide deployment will close this major risk.

- *IEEE 802 Protocols:*

  - NIST provided the Specification and Description Language (SDL) description for the ZigBee protocol in the IEEE 802.15.4 specification, ensuring the proper design of the protocol.

  - NIST developed a simulation tool for 802.11 (WiFi) and 802.16 (WiMAX) enabling developers to test applications using these network technologies.

Future area: electromagnetic interference in SG

Electromagnetic interference (such as wireless communications associated with metering) is identified as a potential issue for smart grid

- **Electromagnetic compatibility allows electronics to function near one another (i.e. non-interference)**
- **FCC regulates the emission and immunity levels based on radiated and conducted measurements**
- **Both intentional and unintentional RF radiators**

EEEL Electromagnetics Division has measurement expertise and leadership of relevant standards efforts

- **ASC C63 provides EMC standards for electronic equipment**
- **NIST/EEEL chair of ASC C63 techniques committee; IEEE secretariat**
- **These standards cover methods of testing, facilities for testing and guides for applications; metrology standards are also covered.**

Summary

- NIST ramping up smart grid interoperability standards efforts, providing strong federal coordination role

- NIST research supports smart grid standards and testing through different mechanisms

- More closely coupled bidirectional interactions between NIST research and standards/testing is possible in the future